Water Science and Technology Library

Basant Maheshwari
Ramesh Purohit
Hector Malano
Vijay P. Singh
Priyanie Amerasinghe *Editors*

The Security of Water, Food, Energy and Liveability of Cities

Challenges and Opportunities for Peri-Urban Futures

Springer

The Security of Water, Food, Energy and Liveability of Cities

Water Science and Technology Library

VOLUME 71

For further volumes:
http://www.springer.com/series/6689

Basant Maheshwari · Ramesh Purohit
Hector Malano · Vijay P. Singh
Priyanie Amerasinghe
Editors

The Security of Water, Food, Energy and Liveability of Cities

Challenges and Opportunities for Peri-Urban Futures

Springer

Editors
Basant Maheshwari
School of Science and Health
University of Western Sydney
Penrith
Australia

Ramesh Purohit
Colleges of Technology and Agricultural Engineering
Maharana Pratap University of Agriculture and Technology
Udaipur
India

Hector Malano
Department of Infrastructure Engineering
University of Melbourne
Parkville, VIC
Australia

Vijay P. Singh
Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering
Texas A&M University
College Station, TX
USA

Priyanie Amerasinghe
International Water Management Institute
Hyderabad, Andhra Pradesh
India

ISSN 0921-092X
ISBN 978-94-017-8877-9 ISBN 978-94-017-8878-6 (eBook)
DOI 10.1007/978-94-017-8878-6
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2014939064

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

The population of cities around the world is growing at an alarming pace, and as a result the landscapes of most cities are undergoing phenomenal changes. Consequently, fertile agricultural lands on the periphery of cities are being converted into non-agricultural use without consideration of holistic planning. Peri-urban areas, zones of transition from rural to urban land uses located between the outer limits of the urban and the rural environment, are experiencing significant losses of agricultural land, increased runoff and degradation of water quality. Concurrently, demands for water, food and energy are increasing within cities, and unless a balance is struck the liveability of these cities will soon be compromised.

The current water and land-use changes have serious consequences for lifestyle, environment, health and the overall well-being of urban communities. It is therefore important for policy makers, urban and peri-urban planners and municipal council managers to understand the current issues and challenges in order to develop suitable strategies and practices to cope with current and future pressures of urbanisation and peri-urban land-use changes. This constituted the motivation for the book which examines a number of critical aspects in relation to the future of cities and peri-urban regions, including the suitability of policies and institutions to sustain cities into the future; impact of current trends on land-use change, population increase and water demand; long-term planning needs and approaches to ensure the secured future for generations ahead; and strategies to adapt the cities and land uses so that they remain viable and liveable.

The subject matter of the book is divided into six parts. Part I comprising two chapters is introductory. Discussing the challenges and opportunities for the future of peri-urban areas, Chaps. 1 and 2 argue that sustainable planning strategies are fundamental to the development of a sound urban transformation policy, and the modelling of the whole water cycle is critical to the policy for integrated urban water management.

Part II contains five chapters that deal with different aspects of urbanisation. Chapter 3 discusses the geo-social dynamics of the assimilation of rural–urban spatial fringe and the geo-social buffer zones forming the basis for the development of peri-urban areas and the strategies for their betterment. Chapter 4 discusses the liveability of future cities, Chap. 5 the impact of expanding urban fringe on peri-urban areas, Chap. 6 challenges in urban and peri-urban transition zones and strategies for sustainable cities and Chap. 7 management of threats and opportunities of urbanisation for urban and peri-urban agriculture.

Water and energy constitute the subject matter of Part III containing five chapters. Chapter 8 examines how urbanisation impacts on water demand, food security and energy need, while Chap. 9 deals with urban water footprint and peri-urban interface. Chapter 10 is about the analysis of water use, demand and availability; Chap. 11 stormwater reuse for sustainable cities; and Chap. 12 the role of solar energy in urban and peri-urban areas for improving the liveability of cities.

Wastewater is the topic of Part IV comprising three chapters. Chapter 13 renewable energy policies for reducing the carbon footprint; Chap. 14 deals with perspectives on urban sanitation, liveability and peri-urban futures; and Chap. 15 decentralised wastewater management for improving sanitation.

Part V is on urban agriculture. It has nine chapters. Chapter 16 the construction of wastewater treatment capacities for relief for peri-urban farmers; Chap. 17 treats the response to food supply crisis; Chap. 18 the assessment of the importance of the city's peri-urban farms; Chap. 19 comparison of urban, peri-urban and rural food flows; and Chap. 20 examines the sustenance of agriculture around cities. Chapter 21 is about the protection of horticulture in peri-urban areas, while Chap. 22 urban and peri-urban dairy production. Chapter 23 examines recycling excreta form peri-urban agriculture; and Chapt. 24 the nutrient recycling from organic wastes in peri-urban areas through viable business models.

Part VI deals with several aspects of peri-urban development, including global warming and climate change, landscape and ecosystems and governance. Chapter 25 the effects of labour migration and land-use changes on food production. Chapter 26 discusses the assessment of knowledge of climate change and urban and peri-urban agriculture, Chap. 27 greenhouse gas emissions of decentralised water supply strategies in peri-urban areas, and Chap. 28 coping with the effect of climate change on urban and peri-urban agriculture.

The next three chapters deal with landscape transformation and impact on the ecosystem. Chapter 29 examines system harmonisation approach for landscape changes and water planning, while Chap. 30 discusses the maintenance of landscape functionality under land-use change. The importance of urban biodiversity is discussed in Chap. 31 and water and biodiversity issues are in Chap. 32.

The aspects of governance in peri-urban landscape are covered in the next three chapters. Chapter 33 discusses the development of law and governance strategies for peri-urban sustainability, Chap. 34 the governance for extreme events in peri-urban areas and Chap. 35 the valuing of water for use in peri-urban areas. Finally, the key points of all the chapters are summarised in Chap. 36.

It is hoped that the book will be useful to policy makers, urban and peri-urban planners and municipal council managers as well as researchers, consultants and postgraduate students of water and land use-planning, environmental management and sustainability aspects.

Basant Maheshwari
Ramesh Purohit
Hector Malano
Vijay P. Singh
Priyanie Amerasinghe

Acknowledgments

This book is a result of the international workshop titled 'Urbanisation of Peri-urban Regions: Challenges and Opportunities for Security of Water, Food and Liveability of Future Cities' held in February 2012 at Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India. We gratefully acknowledge the financial support of the Australia India Institute for the organisation of the workshop. We would also like to acknowledge the sponsorship of the Singhal Foundation and the support of Adj. Assoc. Professor Roger Packham, Dr. N. S. Rathore, Dr. Hakimuddin and a number of staff from Maharana Pratap University of Agriculture and Technology and Vidya Bhawan Krishi Vigyan Kendra for the workshop. Assistance of Dr. Uthapla Pinto and Ms. Joycelyn Applebee in preparing the chapters is gratefully acknowledged. We take this opportunity to thank all the chapter authors for their contribution in the book.

Contents

Part V Urban Agriculture

Part VI Future of Peri-Urban Landscapes

Contributors

Priyanie Amerasinghe International Water Management Institute, Hyderabad, Andhra Pradesh, India

K. D. Ameta Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Shah Mohammad Ashraful Amin UN World Food Programme-Bangladesh, Dhaka, Bangladesh

Philip Amoah International Water Management Institute, Accra, Ghana

Arti Arha Department of Agricultural Economics and Management, RCA, Udaipur, India

Meenakshi Arora Department of Infrastructure Engineering, University of Melbourne, Parkville, VIC, Australia

Ranjana Audichya Department of Agricultural Economics and Management, RCA, Udaipur, India

Lu Aye Department of Infrastructure Engineering, Melbourne School of Engineering, The University of Melbourne, Melbourne, VIC, Australia

Zahra Barzegar Department of Art and Architecture, Science and Research Branch, Islamic Azad University, Tehran, I.R. Iran

Govind Singh Bhardwaj College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, India

Rohatash Kumar Bhardwaj UNDP, MOHE, Mekelle University, Mekelle, Ethiopia

Trent Biggs San Diego State University, San Diego, USA

Michael Buxton RMIT University, Melbourne, Australia

Olufunke O. Cofie Challenge Program for Water and Food, Ouagadougou, Burkina Faso

Donna Craig School of Law, University of Western Sydney, Sydney, Australia

G. Danso International Water Management Institute, Colombo, Sri Lanka

Brian Davidson Melbourne School of Land and Environment, University of Melbourne, Parkville, VIC, Australia

Mohamed O. Diagne Dakar, Senegal

Mouhamadou Dial UCAD, Dakar, Senegal

Pay Drechsel International Water Management Institute, Colombo, Sri Lanka

Mansour Esfandiari-Baiat Department of Agriculture, Firouzabad Branch Islamic Azad University, Firouzabad, I.R. Iran

Jean Pierre Yvon Fall IDEV-ic, Dakar, Senegal

Mathias Fosu Savanna Agricultural Research Institute, Tamale, Ghana

Issahaka Fuseini Department of Geography and Resource Development, University of Ghana, Legon, Ghana

S. K. Gangwar UNDP, MOHE, Mekelle University, Mekelle, Ethiopia

Tesfaye Gebrekidane UNDP, MOHE, Mekelle University, Mekelle, Ethiopia

Biju George Department of Infrastructure Engineering, Melbourne School of Engineering, The University of Melbourne, Melbourne, VIC, Australia

Edwin Akonno Gyasi Department of Geography and Resource Development, University of Ghana, Legon, Ghana

Petra Hellegers Environmental Economics and Natural Resources Group, Wageningen, The Netherlands

Sarah James Australian National University, Canberra, Australia

Michael Jeffery School of Law, University of Western Sydney, Sydney, Australia

C. B. Katongole School of Agricultural Sciences, Makerere University, Kampala, Uganda

R. A. Kaushik Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Ganesh Keremane Centre for Comparative Water Policies and Laws, School of Law, National Centre for Groundwater Research and Training, University of South Australia, Adelaide, SA, Australia

Mamadou Khouma IDEV-ic, Dakar, Senegal

Gordana Kranjac-Berisavljevic University for Development Studies, Tamale, Ghana

A. K. Kurchania College of Technology and Engineering, MPUAT, Udaipur, India

Basant Maheshwari School of Science and Health, University of Western Sydney, Penrith, NSW, Australia

Hector Malano Melbourne School of Engineering, University of Melbourne, Melbourne, VIC, Australia; Parkville, VIC, Australia

Paul Martin University of New England, Armidale, Australia

David Mason NSW Department of Primary Industries, Richmond, NSW, Australia

Jennifer McKay Centre for Comparative Water Policies and Laws, School of Law, National Centre for Groundwater Research and Training, University of South Australia, Adelaide, SA, Australia

Sarita Mehra Rajputana Society of Natural History, Udaipur, Rajasthan, India

Satya Prakash Mehra Rajputana Society of Natural History, Udaipur, Rajasthan, India

Adelina Maria Mensah Department of Geography and Resource Development, University of Ghana, Legon, Ghana

Sudeep Nair Department of Infrastructure Engineering, Melbourne School of Engineering, The University of Melbourne, Melbourne, VIC, Australia

Bandara Nawarathna Department of Infrastructure Engineering, Melbourne School of Engineering, The University of Melbourne, Melbourne, VIC, Australia; Bureau of Meteorology, Melbourne, VIC, Australia

Marie Sophie Ndong IAGU, Dakar, Senegal

Yacine Ndour ISRA, Dakar, Senegal

Idy Niang Environment Department, Dakar, Senegal

Youga Niang UNDP, Dakar, Senegal

Josiane Nikiema International Water Management Institute, Accra, Ghana

Phillip O'Neill Urban Research Centre, University of Western Sydney, Sydney, NSW, Australia

Santosh Ojha Department of Agricultural Engineering, NIET, NIMS University, Jaipur, India

Jon Padgham START, Washington D.C., USA

D. C. Pant Department of Agriculture Economics and Management, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, India

G. Purohit School of Engineering, Sir Padampat Singhania University, Bhatewar, Udaipur, India

Ramesh Purohit College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Atiq Rahman Bangladesh Centre for Advanced Studies, Dhaka, Bangladesh

Rajiv Raman Senior Consultant Water and Sanitation Program—South Asia, Himachal Pradesh, India

P. S. Rao Department of Soil and Water Conservation, Maharana Pratap University of Agriculture and Technology, Udaipur, India

K. Rathnayaka Department of Infrastructure Engineering, University of Melbourne, Parkville, VIC, Australia

N. S. Rathore College of Technology and Engineering, MPUAT, Udaipur, India

E. N. Sabiiti School of Agricultural Sciences, Makerere University, Kampala, Uganda

D. K. Sharma School of Engineering, Sir Padampat Singhania University, Bhatewar, Udaipur, India

Krishan Kumar Sharma Biodiversity Research Laboratory, Department of Zoology, Maharshi Dayanand Saraswati University, Ajmer, Rajasthan, India

S. K. Shrimali College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

B. Simmons University of Western Sydney, Penrith, NSW, Australia

Ranvir Singh Institute of Agriculture and Environment, Massey University, Palmerston North, New Zealand

Vijay P. Singh Department of Biological and Agricultural Engineering, Zachry Department of Civil Engineering, Texas A&M University, College Station, TX, USA

Ian Smout Water Engineering and Development Centre, Loughborough University, Loughborough, UK

Daniel Van Rooijen UNICEF, Addis Ababa, Ethiopia; Nairobi, Kenya

R. W. Vervoort Hydrology and Geo-Information Sciences Laboratory, Faculty of Agriculture and Environment, The University of Sydney, Sydney, NSW, Australia

Jacqueline Williams University of New England, Armidale, Australia

Zhifang Wu Centre for Comparative Water Policies and Laws, School of Law, National Centre for Groundwater Research and Training, University of South Australia, Adelaide, SA, Australia

Gerald Yiran Department of Geography and Resource Development, University of Ghana, Legon, Ghana

Lotfollah Yousefi Khanesazan Bunyan Marcos Co., Shiraz, I.R. Iran

Part I
Introduction

Chapter 1
Challenges and Opportunities for Peri-urban Futures

Hector Malano, B. Maheshwari, Vijay P. Singh, Ramesh Purohit and P. Amerasinghe

Abstract Rapidly increasing population and urban migration across different regions of the world are creating new and complex challenges. It is now increasingly realised that we need to restructure and rebalance the way that land use planning addresses these problems. Achieving and maintaining sustainability, liveability and productivity of these regions must address several key goals which include provision of adequate infrastructure, adaptation to new environments created by climate change, reduction energy consumption and greenhouse gas emissions, provision of adequate water supply and disposal of wastewater streams and maintaining biodiversity. This complex and 'wicked' problem manifests itself more dramatically in peri-urban areas, as these undergo faster land use changes. As such, this problem must be approached in a new integrated and interdisciplinary manner.

Keywords Urbanisation · Complexity · Landuse changes · Water resources · Liveability

---

H. Malano (✉)
Department of Infrastructure Engineering, University of Melbourne, Parkville, VIC, Australia
e-mail: h.malano@unimelb.edu.au

B. Maheshwari
School of Science and Health, University of Western Sydney, Penrith, Australia
e-mail: b.maheshwari@uws.edu.au

V. P. Singh
Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering, Texas A&M University, College Station, USA
e-mail: vsingh@tamu.edu

R. Purohit
College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, India
e-mail: purohitrc@yahoo.co.in

P. Amerasinghe
International Water Management Institute, Hyderabad, Andhra Pradesh, India
e-mail: p.amerasinghe@cgiar.org

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_1,

1.1 Introduction

Significant challenges are being imposed by rapidly increasing population and urban migration across different regions of the world. Coupled with climate change, food security concerns and the need to improve environmental sustainability, it is now increasingly realised that we need to restructure and rebalance the way land use planning addresses these problems. We need balanced urban growth which may involve integrated planning of cities and towns and their surrounding areas to ensure that the structure and layout of new or high density residential areas are making the best possible use of public assets such as transport and other infrastructure, while providing ecosystems services of the highest order in the longer-term. Furthermore, the competition for land and water resources in peri-urban areas is becoming intense and the question of maintaining some level of agricultural production is critical from social, economic and environmental viewpoints. A dilemma often policy makers and planners are increasingly facing is whether it is worthwhile to protect traditional industries, such agriculture, or we assist the urbanisation process to be more orderly, productive and sustainable.

The population of cities around the world are growing at an alarming rate, and as a result the landscapes of most cities are going through enormous changes. In 2008 for the first time the population living in cities surpassed 50 % (United Nations 2012). It is estimated that this number will reach 60 % by 2030 and 70 % by 2050. The total world population is projected to reach 9.3 billion by 2050 while the world urban population to 7.4 billion, an increase of 2.3 billion on today's figures. There are large differences in the rate of urbanisation between developed and developing countries, with most of the urban growth occurring in developing regions. Only a small increase in urban growth is expected in the developed world (Fig. 1.1).

1.2 Urbanisation Process and Impacts

The rapid urbanisation process occurs in response to rapid economic and social changes in countries with large population, such as India, China and Indonesia. There are, however, certain pull and push factors that have a significant impact in the intensity and form of changes in land use, including public transport, roads, institutional and legal factors and planning policies. These factors operate at different stages of the suburbanisation process. One direct and visible impact of urbanisation is that fertile agricultural lands at the periphery of the cities are being developed without consideration of holistic planning. As such, peri-urban areas, zones of transition from rural to urban land uses located between the outer limits of the urban and the rural environment are experiencing significant losses of agricultural land, increased runoff, and water quality degradation. Concurrently, the demands for water, food and energy are increasing within cities, and unless a balance is struck the liveability of these cities will soon be compromised.

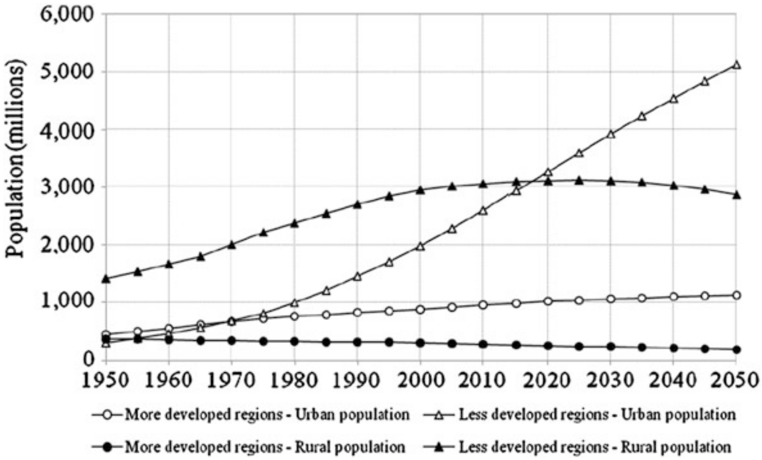


Fig. 1.1 Change in urban and rural population by development group between 1950 and 2050 (after world urbanization prospects—the 2011 revision)

The current water and land use changes have serious consequences for lifestyle, environment, health and the overall well-being of urban communities.

Urbanisation and urban growth is a dynamic process which affects the urban core and peri-urban fringes where the process is actually more dramatic due to the large scale transformation in land use. Urbanisation creates opportunities and challenges. The main attractors for migration to urban areas are better job opportunities, education and higher incomes. It also creates challenges due to increased need for new infrastructure, housing, education and social services and urban encroachment into agricultural areas and consequent reduction in arable land and reduction in biodiversity. These challenges are further exacerbated by the potential impacts of climate change, additional demand for water resources and imperatives to reduce energy consumption and carbon emissions.

1.3 The Complex Nature of Peri-urban Areas

There is no standard definition of peri-urban areas, however, they can often be described as those areas located at the fringes of consolidated urban centres. As such, they share some features of urban and rural lands. Typically, they consist of a mix of residential, industrial and agricultural land uses and may contain important natural resources, biodiversity (Fig. 1.2). Above all, they are often characterised by a rapid degree of transition from rural to urban landscapes. In many of the world megacities, peri-urban areas also have poorer urban infrastructure and lower demographic density. Peri-urban urban can also show very dissimilar characteristics depending to whether they are located in developing or industrialised countries. Peri-urban spaces in industrialised countries are more often areas for expansion of

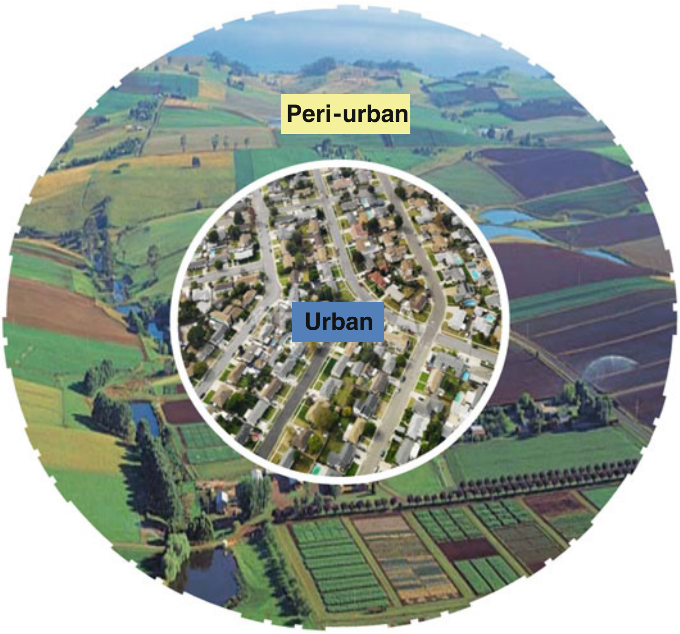


Fig. 1.2 Geographic schematic of peri-urban area

low-density development into rural lands. This type of urban sprawl is usually poorly served by transport infrastructure and highly automobile dependent. Conversely, peri-urban spaces in developing countries typically exhibit a greater degree of poverty, lower services and prevailing slum conditions.

Like urban systems, peri-urban spaces are highly complex systems that contain a number of subsystems. These complex systems are multi-layered, non-linear and interacting subsystems, including infrastructure, water supply and wastewater, energy supply and consumption and waste systems (Vermont Complex Systems Centre 2013). In this book, we have taken an explicit reductionist approach to dealing with peri-urban systems by inviting a number of experts from around the world to share their experience built on specific geographical locations and focus on specific aspects of the peri-urban environment.

1.4 Sustainable Urbanisation and Future Challenges

Cities, like organisms, consume water, energy and nutrients and dispose of wastes and other by-products. This idea is often referred to as "urban metabolism". These processes are driven by socio-economic activities and interact with regional and global bio-physical processes. Understanding the behaviour and all these interactions is the realm of trans-disciplinary research (Fernandez 2009).

Cities also constitute major engines of innovation, regional and national growth, productivity and job creation, and urbanisation through increased rural migration to urban forms an intrinsic part of this process. Peri-urban areas that lie on the fringes of major megacities, particularly in the developing world, form the transition between rural and densely populated urban areas.

With increasing movement of population to urban centres, the future success and sustainability of these centres rest on our ability to face a number of critical challenges. These challenges are more severe for peri urban areas. Foremost among these are our abilities to:

- Supply potable water and remove and treat the resulting wastewater stream.
- Adapt to the increasing threat of climate change and the need to reduce, energy consumption and GHG emissions.
- Provide sustainable infrastructure and to minimise risks to food security, and
- Maintain biodiversity.

1.5 Water Resources

Urbanisation has massive impacts on the hydrologic water cycle ranging from increased runoff generation from increasing impervious areas that causes degradation of waterways to increased demand for water to satisfy the needs of the growing population (Grimm et al. 2008). These changes are accompanied by increased wastewater generation, which can often contribute to the degradation of waterways and receiving waters due to the lack of effluent standards.

It is widely recognised that the provision of good access to clean water and sanitation facilities is a key factor in improving the health and development of a country or region. The health and productivity of a society is a direct result of the general health of the population. There are, however, large disparities between access to water supply and sanitation in the industrialised world and the developing world. These are particularly acute in the peri-urban fringes of large cities in the developing world. The WHO estimates that 780 million people still lack access to safe drinking water. The state of affairs in sanitation is far gloomier with 2.5 billion people lacking access to improved access to sanitation (WHO 2013).

Increasing development of water resources in catchments that contain significant urban and peri-urban agglomerations have created acute competition for water due to increasing urban and industrial demand. At the same time, increasing sewage effluent remains untreated and is often used to irrigate adjacent agricultural land. The city of Hyderabad, India, is experiencing a high rate of population growth largely as a result of increased rural and interstate migration. This process has been accompanied by a steady reduction of catchment runoff that supplies water to the city of between 12 and 20 % due to increased irrigation development in the upper catchment. As a result, the city has increasingly relied of water imported through various inter-basin transfer infrastructures (George et al. 2009).

Untreated and partially treated sewage generated by the city is now used to irrigate up to 20000 ha of land in adjacent peri-urban and rural areas, causing a range of environmental and health impacts on the population.

Increasing inter-sectoral demand and competition for water due to demographic changes, economic growth and climate change call for new and innovative approaches to meet demand (Novotny et al. 2010; Leeuwen et al. 2012). Compounding this picture in the developing world is an acute infrastructure deficit. The vast majority of water supply and wastewater treatment infrastructure worldwide is of a centralised nature.

Integrated urban water management (IUWM) is an approach that takes a holistic approach to urban water management that considers water supply, stormwater and wastewater as elements of an integrated physical system. Such an approach is based on a systemic approach that takes into account all the interactions between all the elements of the water system (Maheepala et al. 2010). IUWM is a vital approach to underpin the application of a fit-for-purpose approach to water supply under conditions of scarcity that utilises all water sources, including roof runoff, stormwater, grey water, and wastewater (Mitchell 2006).

Younos (2011) presents a model of water infrastructure based on decentralised, small to medium scale systems that utilise locally available sources of water for various in-building and outdoor uses, and facilitate use and reuse of generated wastewater and stormwater runoff locally. A greater use of decentralised systems can also assist in reducing the volume of freshwater that must increasingly be imported to cities and reduce the volume of wastewater and stormwater discharge into the environment.

1.6 Infrastructure Development

Rapidly developing urban areas that receive a large population influx from rural migration and from other urban centres face a significant challenge to meet their infrastructure needs. This is typically a twofold problem: insufficient investment in new infrastructure and poor performance of existing infrastructure. Infrastructure bottlenecks are the key hindrance to achieving economic potential, environmental quality and social wellbeing. These impacts are particularly severe in the developing world and on the disadvantaged segments of the population.

The provision and operation of infrastructure is very expensive, with the value of existing infrastructure stocks in most countries representing about 80 % of GDP. McKingsey (2013) has estimated that at present there is an infrastructure backlog worldwide of $57 trillion while it has identified large inefficiencies in the delivery of current infrastructure investments. Meeting this challenge is made doubly more difficult in developing countries to procure the necessary capital to meet this type of investment. The World Bank estimates that based on past investment trends, it will take more than 50 years for African countries to achieve universal access to clean water and improved sanitation.

The future provision of infrastructure will require a departure from the current "business-as-usual" approach to planning, delivering and operating infrastructure. There are large potential gains from applying better selection criteria and delivery of new projects, such as scale adaptation to suit demand by local communities, adoption of new technology to improve the operation of existing infrastructure such as the use of intelligent networks, improved monitoring to reduce water distribution losses among others. These improvements typically fall into the so called "soft improvement" category.

1.7 Urbanisation and Biodiversity

Urbanisation is one of the significant threats to biodiversity globally, and the threat could be through direct impacts on habitats conversion or through the various indirect effects through resource use and degradation, disturbance of water and nutrient cycle and habitat fragmentation (Ricketts and Imhoff 2003). The distribution of biodiversity varies with locations and so the severity of impacts of urbanisation can also vary. For cities and towns to be liveable into the future, urbanisation needs to be managed in a way that richness of species and the overall biodiversity sustained in longer-term.

To understand how urbanisation is impacting biodiversity, we need to understand the interactions among the various aspects of physical changes in landscape, and to create better cities and towns we need to examine the options that will protect biodiversity. There has been limited attention given to biodiversity aspect while building new urban areas by developers and government policies and has put future liveability of cities in a difficult position. Therefore, there is a need to identify opportunities that will help reconcile communities and biodiversity by creating future urban areas that are ecologically sustainable, economically productive, socially just, politically participatory, and culturally vibrant (Elmqvist et al. 2013).

References

Elmqvist T, Fragkias M, Goodness J, Güneralp B, Marcotullio PJ, McDonald RI, Parnell S, Schewenius M, Sendstad M, Seto KC, Wilkinson C (eds) (2013) Urbanization, biodiversity and ecosystem services: challenges and opportunities. Springer, New York, p 755

Fernandez J (2009) Urban metabolism. Notes on urban resources. Department of Architecture, Yale University. Available via http://www.urbanmetabolism.org/. Accessed 18 June 2013

George B, Malano H, Khan A, Gaur A, Davidson B (2009) Urban water supply strategies for Hyderabad, India—future scenarios. Environ Model Assess 14(6):691–704

Grimm N, Faeth S, Golubiewski N, Redman C, Wu J, Bai X, Briggs J (2008) Global change and the ecology of cities. Science 319:756–760

Leeuwen CJV, Frijns J, Wezel AV, Ven FHMVD (2012) City blueprints: 24 indicators to assess the sustainability of the urban water cycle. Water Resour Manage 26:2177–2197

Maheepala S, Blackmore J, Diaper C, Moglia M, Sharma A, Kenway S (2010) Towards the adoption of integrated urban water management approach for planning. Water Environment Federation WEFTEC 20120: session 91 through session 100, pp 6734–6753

McKinsey Global Institute (2013) Infrastructure productivity: how to save $1 trillion a year. McKinsey and Company, New York 88 pages

Mitchell VG (2006) Applying integrated urban water management concepts: a review of Australian experience. J Environ Manage 37:589–605

Novotny V, Ahern J, Brown P (2010) Water centric sustainable communities: planning, retrofitting, and building the next urban environment. Wiley, New York

Ricketts T, Imhoff M (2003) Biodiversity, urban areas, and agriculture: locating priority ecoregions for conservation. Conserv Ecol 8(2):1 (online)

United Nations (2012) World urbanisation prospects. The 2011 revision. Available via http://esa.un.org/unup/pdf/WUP2011_Highlights.pdf. Accessed 17 June 2013

Vermont Complex Systems Centre (2013) Why study Complex Systems? Available via http://www.uvm.edu/~cmplxsys/?Page=visionmission/definition.php&SM=visionmission/_vismismenu.html. Accessed 14 June 2013

WHO (2013) Millennium development goal drinking water target met. Sanitation still lagging far behind. Available via http://www.who.int/mediacentre/news/releases/2012/drinking_water_20120306/en/. Accessed 4 July 2013

Younos T (2011) Paradigm shift: holistic approach for water management in urban environments. Front Earth Sci 5:421–427

Chapter 2
Integrated Water Cycle Modelling of the Urban/Peri-urban Continuum

Hector Malano, Meenakshi Arora and K. Rathnayaka

Abstract The world is undergoing an intensive process of urbanisation. In 2008, for the first time in history, over half of the world's population was living in urban and peri-urban areas. It is estimated that this number will increase to 5 billion by 2030 with most of this growth occurring on the edges of mega-cities. Smaller cities are also undergoing large transformations. Urbanisation can bring opportunities for people to improve their standard of living and access to education and other services but it can also bring and concentrate poverty in developing countries where most of this urban growth is occurring. Increased urbanisation presents planners and policy makers with many challenges, foremost among them, competition for land and water resources with other sectors such as agriculture. Critical to our capacity to develop a sound urban transformation policy is our ability to integrate science to support the formulation of sustainable planning strategies. Increasing competition for water in many regions of the world provides an impetus for increasing use of water saving and replacement techniques, such as water reuse and recycling and urban runoff harvest. This new paradigm requires an improved capability for integrated modelling approaches to analyse the whole-of-water-cycle. Such an approach involves the integration of the various sub-systems—Catchment (surface-groundwater), water supply systems, wastewater, water allocation, internal recycling, decentralised treatment and storm water harvesting. Adding to this system complexity is the need to consider water quality as a constraining factor when using a fit-for-purpose approach to integrated urban water management (IUWM). This paper focuses on the challenges and opportunities involved in modelling the urban/peri-urban water cycle for planning of urban and peri-urban systems, including spatial and temporal scale and integration of hydrologic, water allocation with differential water quality across catchment and political divisions. Case studies are used to illustrate the use of integrated water modelling to inform a scenario planning approach to integrated water resource

H. Malano (✉) · M. Arora · K. Rathnayaka
Department of Infrastructure Engineering, University of Melbourne,
Parkville, VIC, Australia
e-mail: h.malano@unimelb.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_2,

management in an urban/peri-urban context. In this analysis, two main constraints to effective modelling are identified—Lack of model integration and lack of data in the appropriate time and spatial scale often stemming from the lack of a robust data monitoring program of the entire water cycle. A framework for integration of water system modelling with economic modelling is presented.

Keywords Urban water cycle · Modelling · Water supply · Water demand · Decentralized systems

2.1 Introduction

The world is undergoing an intensive process of urbanisation. In 2008, for the first time in history, over half of the world's population was living in urban and peri-urban areas. It's estimated that this number will increase to 5 billion by 2030 with most of this growth occurring on the edges of mega-cities, although smaller cities are also undergoing large transformations (Worldwatch Institute 2008).

Urbanisation can bring opportunities for people to improve their standard of living and access to education and other services but it can also bring and concentrate poverty in developing countries where most of this urban growth is occurring. Increased urbanisation presents planners and policy makers with many challenges, foremost among them, competition for land and water resources with other sectors, such as agriculture.

Achieving these goals in a sustainable manner represents an additional challenge as new economic activities in the urban environment face increasing pressure to reduce their carbon emissions. Management of the water cycle in its entirety must be carried out in a way that minimises resource demand, Green House Gas (GHG) emissions and other environmental impacts.

2.2 Urban/Peri-urban Land Use Continuum

Peri-urbanisation is a complex process that occurs across a range of metropolitan and non-metropolitan landscape settings which often straddle a continuum of land uses ranging from urban residential centres to agricultural land. Chow et al. (2008) identifies several combinations of land uses that include peri-urbanisation associated with urban metropolitan centres, regional centres and discrete urban centres in rural and regional areas. Figure 2.1 provides a pictorial example of these scenarios for the Melbourne Metropolitan area and surrounding green wedges (Buxton and Goodman, 2002).

Fig. 2.1 Melbourne metropolitan area and surrounding peri-urban areas. *Source* Buxton and Goodman 2002

Peri-urban areas undergo a continuous and dynamic process of land use change as a result of economic and demographic forces including changes in the agriculture and cropping profile, conversion of agricultural land into residential, commercial or industrial development. From a hydrological point of view, these changes in land use have a direct impact on the water cycle, in particular, the behaviour of runoff generation and the pattern of water demand.

2.3 Urban/Peri-urban Water Cycle

Multiple and changing land uses in peri-urban areas lead to continuous changes in the hydrologic and water supply-demand configuration of the water cycle. The consideration of alternative planning and development scenarios demands modelling capability that describes these critical processes involved.

Modelling of the water cycle must be designed with a view to assessing the various responses to the changing landscape and the resulting water security and sustainability performance. There is ample literature related to the use of environmental sustainability indicators (ESI) for urban water systems (Lundin and Morrison 2002). It is important to note that there is a proliferation of articles proposing different ESIs but not many refer to the need to develop a set of criteria to select these ESIs. An approach increasingly used by industry is based on life cycle assessment (LCA). When applied to the urban water cycle, this approach entails defining the geographical boundaries of the system (upstream and downstream cut offs). The LCA of an urban system begins with the diversion of water from surface or groundwater and ends with the discharge of treated/untreated storm water and wastewater, and must include a time series analysis that reflects the life of the physical infrastructure. These processes are linked to other resources, such as energy and other linked processes such as GHG emissions resulting from moving water and wastewater, incineration of sewage sludge and disposal as waste.

Various authors have described the key elements of the urban/peri-urban water cycle to include the following:

- Catchment (surface/groundwater)
- Water Supply system
- Sewerage and wastewater treatment systems
- Water sharing and allocation (matching multiple supplies and demands)
- Receiving water system.

At a sub-system level, complexity may vary to include internal processes and interactions between subsystems which could include internal recycling processes such as:

- Use of water tanks
- Decentralised water treatment
- Storm water harvesting.

An increase in number of subsystems, and in particular the degree of interaction between these subsystems, will determine the complexity of the system.

2.4 Water Cycle Modelling

Systems models are designed to represent an abstraction of the processes involved in the systems and sub-systems outlined above. Often, modellers have a proclivity to isolate individual systems to reduce complexity. Water cycle modelling can be described by a hierarchy of sub-systems that encompass the whole-of-water cycle through a progressive disaggregation of the various subsystems (Khan et al. 2008; Malano 2010).

Importantly, it is necessary to recognise the many interactions that occur across the individual subsystems boundaries that are represented in the Integrated Urban Water Management modelling framework.

2.5 Resource Assessment and Allocation

Surface and groundwater modelling is used to determine changes in water generation arising from alternative and changing land uses in the catchment. Land use changes are the result of the dynamic changes resulting from the continuous evolution of urbanisation of peri-urban areas, usually conversion of rural land to urban use and consequent alteration of pervious and impervious surface areas.

The main objective of a hydrologic study is to assess the source and quantity and quality of available water resources. This is best accomplished through rainfall/runoff modelling that is capable of representing a mosaic of land uses in the catchment, usually by applying a distributed or semi-distributed rainfall/runoff modelling approach. In order to properly model a hydrologic system, consideration should not only be given to surface water, but also to groundwater, land use, soil type, existing land and water use practice, including any conservation measures, nutrient cycles, as well as historical data concerning rainfall patterns.

Figure 2.2 depicts the land use in the South Creek catchment, Western Sydney, a typical peri-urban catchment with multiple forms of land use. South Creek catchment covers approximately 620 km^2 and contains portions of eight LGAs, five of these political entities account for a significant proportion of the catchment. In addition, all five LGAs extend well beyond the boundaries of the catchment. In this study a semi-distributed model (BTOPMC) was employed to describe the land use configuration of the catchment. It is a physically-based distributed hydrological model based on block-wise use of TOPMODEL, with the Muskingum-Cunge flow routing method that has been used for simulating runoff in different sized watersheds. Nawarathna and Kazama (2006) extended this model by introducing distributed parameters and applying it to a part of the Mekong River basin. In a semi-distributed model, like BTOPMC, identified processes are simulated in daily time steps. This provides the required detail for the spatial and temporal modelling of water allocation.

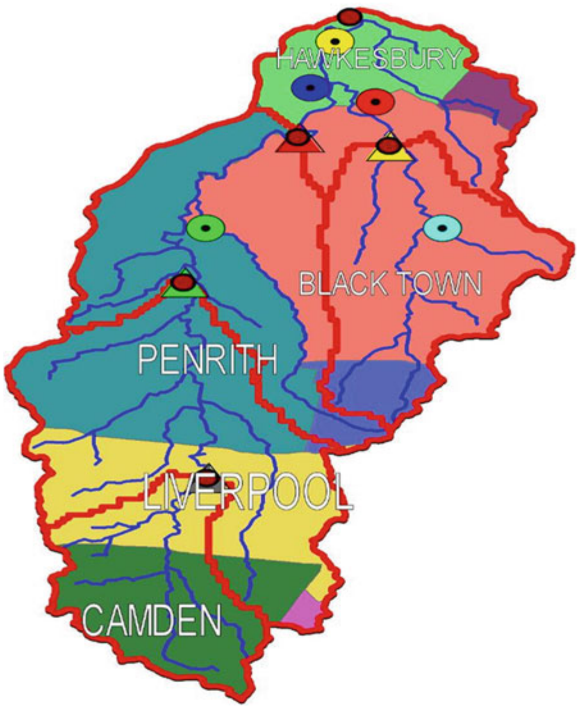


Fig. 2.2 South Creek catchment

The existing supply sources in the South Creek catchment include potable water, surface water, and groundwater. It is envisaged, however, that future increases in water demand will require a comprehensive portfolio of alternative water sources, including storm water harvesting and effluent recycling which will be used on a fit-for-purpose basis to meet multiple demands, such as domestic indoor use, domestic outdoor use, commercial/indoor use, irrigation and environmental flows (Fig. 2.3). The schematic of the water allocation and substitution model is shown in Fig. 2.4. A salient feature of the South Creek modelling system is the discrepancy between the hydrologic landscape and the political divisions represented by the Local Government Areas (LGAs).

A modelling framework consisting of the BTOPMC model coupled with the Resource Allocation Model (REALM) (Perera et al. 2005) was applied to analyse a set of scenarios formulated by a partnership between researchers, stakeholders and decision makers. These scenarios reflect a combination of land use changes—natural growth and concentrated growth centres—and use of storm water harvesting, effluent reuse to supplement environmental flows and improved on-farm irrigation efficiency.

Following the assessment of available resources, we must focus our attention on the allocation of resources to meet various water end-use demands. Water allocation and substitution refers to the approach used to match water resources quantity and quality with alternative demands subject to water quality constraints.

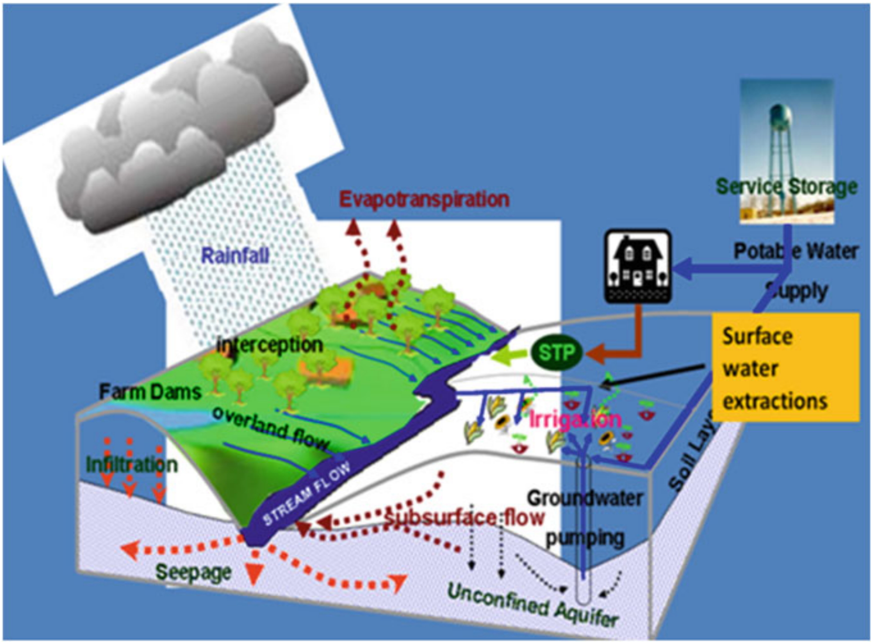


Fig. 2.3 The South Creek catchment water system. *Source* Singh et al. 2009a, b

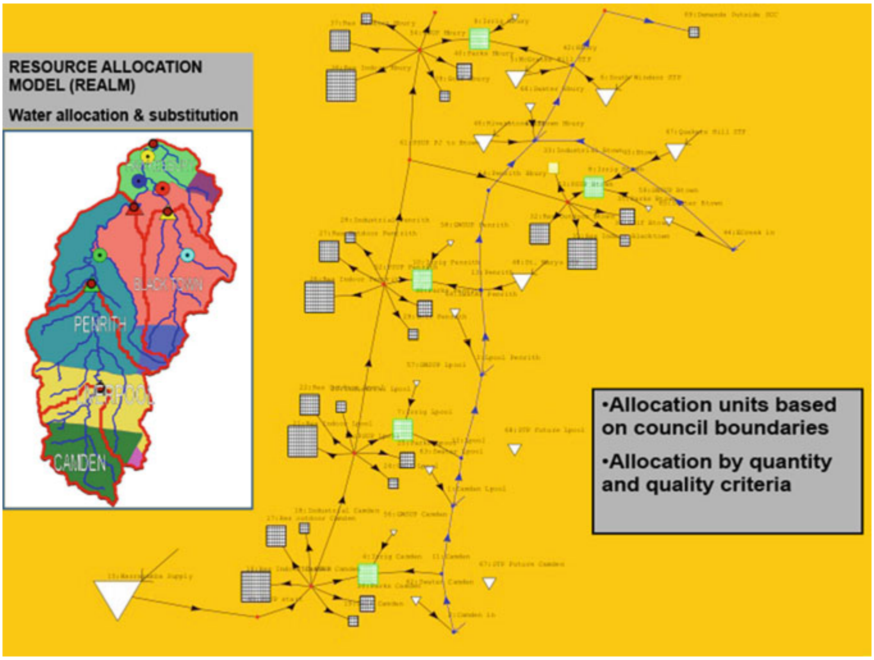


Fig. 2.4 Schematics of water allocation-substitution model. *Source* Davidson et al. 2013

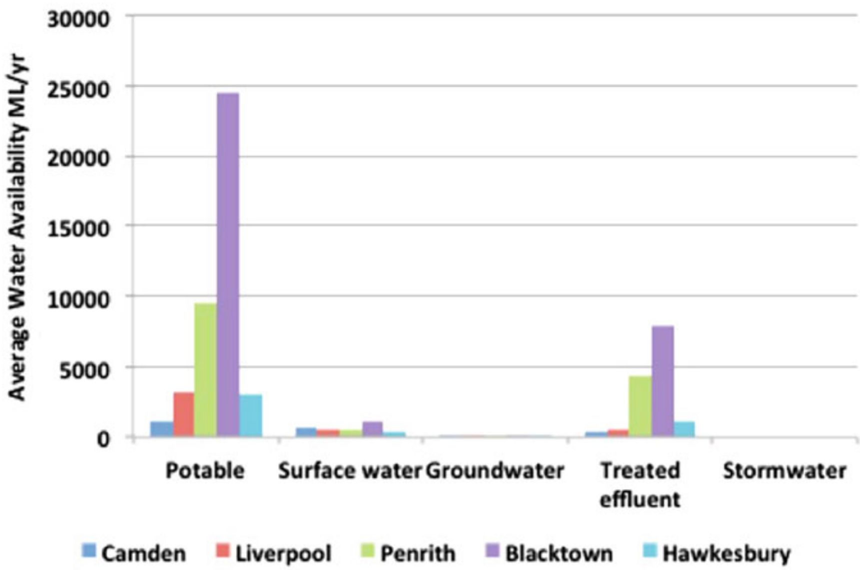


Fig. 2.5 Allocation substitution results for each LGA in South Creek, Western Sydney. *Source* Singh et al. 2009a, b

Usually, a fit-for-purpose criterion is used to allocate the resource. This objective is usually achieved through the application of the REALM water allocation model (Perera et al. 2005) which can accommodate various priorities of allocation and quality constraints for the alternative pathways between water availability and water demand.

Figures 2.3 and 2.4 provide a schematic representation of the water resource system in South Creek catchment, Western Sydney. The supply sources in the South Creek catchment include potable water, surface water and groundwater, treated effluent and treated storm water. Water demand was segregated into residential indoor and outdoor, industrial, primary production, open space irrigation and environmental flow. Demand in each of the LGAs was split between four categories based on use and anticipated differing value of resources—residential, industrial and commercial, agriculture and recreation.

Figure 2.5 presents a sample of modelling results for the effluent reuse option. The allocation-substitution modelling shows the average water available to each LGA segregated by water class. These are average water allocation amounts for the period 2008–2030, assuming a medium impact of climate change.

The system's security of supply is of critical importance to planners and decision makers. Security of supply is represented by the combination quantity of water available at a specified probability of assurance. The derivation of this metric requires a sufficiently long time series of data input and modelling outputs. A more detailed discussion about security of supply can be found in George et al. (2011).

2.6 Urban/Peri-urban Subsystems Modelling

An urban water supply and wastewater system consists of a number of individual but connected subsystems. Modelling of each individual subsystem is often necessary to analyse the individual subsystem's performance and the interactions with and impacts on other subsystems and on various components of the water cycle. In the following, we discuss the main sub-systems that are present in the urban/peri-urban water cycle and key modelling considerations related to the main subsystems.

Water supply subsystem: This may include a number of options and configurations such as centralised and decentralised systems, and various forms of alternative water sources including stormwater, rain water tanks and recycled effluent. Traditionally, centralised systems have been the predominant type of infrastructure for water supply and wastewater collection systems combined with a single-use of water modality. But high population growth in urban and peri-urban areas, intensive agricultural development, urbanisation and industrial growth are all leading to an increased demand for water and are forcing many cities to reconsider their present water management strategies and practices. Many countries around the globe are now looking for alternative water supply options to ensure future water security via a mix of centralised and decentralised systems.

The IUWM approach to water management is increasingly embedded in the planning process of many urban and peri-urban areas to provide sustainable water services to communities and to the environment (Maheepala et al. 2010). This approach seeks to utilise diverse water sources, including grey water, roof water, recycled water, stormwater, surface water, groundwater and desalinated water at different spatial scales on a fit-for-purpose basis. Some of these sources, such as recycled water, can be available at larger spatial scales, such as whole-of-city scale. Other alternative supplies, such as roof water, grey water and stormwater, can be available for individual households. In addition to considerations of spatial, temporal scales are important for both availability and demand, since these vary at the sub-daily scale. Thus, these are important considerations when developing a modelling strategy for optimal use of the multiple sources of water to satisfy multiple fit-for-purposes which must be based on a detailed understanding of the multiple end-uses at different spatial scales (household, precinct, suburb and city scales) and temporal scales (sub-daily to annual scale).

Water demand subsystem: Water demand and its various components is one of the main forcings of the water supply subsystem. There are a number of end-use components that determine the overall water demand, including indoor uses (cooking, washing, bathroom) and outdoor use (gardening, car washing). These individual components of demand are often determined from household surveys or actual meter readings and then extrapolated at different spatial scales (precinct, development, city) and various economic sectors (residential, commercial, amenities). This is a deterministic approach which does not account for the behavioural drivers that affect the pattern of demand. Typically, this type of demand

Table 2.1 Water supply and demand drivers in urban and peri-urban areas

	Residential	Non residential	Open spaces	Roads and pavements
Building typology	Single houses Attached houses Apartments	Office buildings Schools/Colleges Industrial/commercial	Parks Golf courses	Roads
Water supply sources	Imported water Rainwater Stormwater Grey Water Sewer mining Groundwater	Imported water Rainwater Stormwater Grey Water Sewer mining Groundwater	Rainwater Stormwater	Rainwater Stormwater
End use water demand	Kitchen Toilet Showers Dishwasher Laundry Taps Leaks Heating/Cooling Irrigation Evapotranspiration	Kitchen Toilet Showers Dishwasher Laundry Taps Leaks Heating/Cooling Irrigation Evapotranspiration	Leaks Irrigation Evapotranspiration	Evapotranspiration

assessment is conducted on a monthly or annual time scale and is used for aggregate modelling at the initial feasibility assessment stage for a new urban development. These methods of water demand forecasting are dependent on none or few variables and produce water demand outputs that have been used in early simple econometric and time series models.

With the increasing importance of IUWM, modelling must take a more holistic approach to characterising water demand. Consequently, the role of water demand forecasting and simulation has also changed substantially. The degree of complexity of urban water systems modelling arises from the need to incorporate better predictive capability of the constant changes due to demographics, urban renewal, technology take-up rates and changing water policies (Mitchell et al. 2001).

Identifying how urban residential water demand varies over space and time and its underlying factors is considered critical to our ability to extrapolate future predictions. In a recent study, Roberts (2005) and Willis et al. (2009) identified the significance of spatial variability of urban residential water demand at household scale by conducting an intensive data collection of end-use water use.

Decentralised water supply systems are beginning to play an increasing role in the provision of urban water. There is limited research to date focusing on predicting water demand of differential quality and constrained uses to enable planning of this type of system. This is a critical limitation in the current ability to represent these processes in IUWM models.

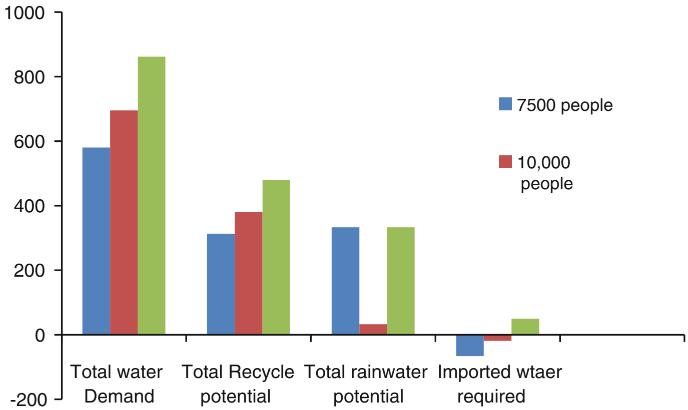


Fig. 2.6 Water demand and supply options for three different density scenarios for a new development. *Source* Arora et al 2013

A more sophisticated approach named 'end-use modelling' can be used to elucidate the complex interactions between forcing variables that drive end-use demand dynamics at different spatial scales. This modelling approach allows the representation of all objects and typologies, such as residential (detached houses, multi dwelling and apartments), non-residential (commercial and industrial), open spaces (parks, golf courses etc.) and roads, that populate the urban landscape. A summary of water supply and demand drivers is shown in Table 2.1 which describes the various sources of water at various scales and water demand at end-use level. End-use water demand depends on various building attributes like occupancy, land size (area), roof area, paved area and unpaved (green) area.

Modelling of water availability must simulate the water available from various sources like roof rain water, stormwater, grey water reuse, wastewater recycling, groundwater and desalination. This modelling approach aims to model availability at different time scales ranging from diurnal to annual time steps and spatial scales ranging from individual dwellings to whole precincts. Rathnayaka et al. (2011) presents a comprehensive review of the existing modelling capability to describe end-use demand and the current gaps and opportunities that still need to be addressed in this domain. Their review found that the existing end-use models have limited capacity to describe water demand at various spatial and temporal scales. This is due to these models describing water demand based on average values and lack of capacity to describe the complex relationships between variables and the limited availability of data to validate these relationships.

Figure 2.6 presents an example of the total water demand for a new residential development site in metropolitan Melbourne with three different scenarios of development density. There are three main sources of water supply available locally in addition to imported water—roof rain water, storm water and recycled wastewater—Water demand increases with increasing density which in turns leads to an increase in the amount of recycled water available on the site. It is important to note that roof rain water and storm water available on site is finite as these are determined by climate. In this case study, the population density must be maintained below the maximum capacity of 10,000 residents to achieve self-sufficiency of water provision and avoid resorting to additional freshwater water imports. The current site will provide water for a population of up to 10,000 residents in an average rainfall year, but it will require additional imported water for a population density of 13,000 residents.

Wastewater treatment subsystem: This may include several options such as classical centralised systems and increasingly the use of decentralised treatment systems. Wastewater systems may also incorporate downstream recycling of wastewater and waste into various kinds of agricultural products such as fertilisers and energy generation. Health and risk management are the most important factors in decentralised wastewater treatment systems. The performance of the wastewater system can be affected by the physical configuration of the system and unintended connections with the urban runoff system which may significantly increase the waste water stream.

Decentralised wastewater treatment systems can be used to reduce the need for new water supply to satisfy an increasing demand. The introduction of decentralised systems, such as sewer mining, however, can create changes in the composition and concentration of wastewater which may compromise the operation of the receiving centralised system.

A key aspect that must be considered in integrating wastewater into the water cycle modelling is the description of all water and solutes fluxes across the entire wastewater system. This is of particular importance if wastewater disposal becomes an important consideration in determining impacts on the receiving water subsystem and meeting effluent quality standards.

A similar degree of detail required to model water supply processes that involve multiple fit-for-purpose sources is needed for wastewater, as there is a direct relationship between wastewater generation and water use. Identifying end-use water demands at multiple scales also enables the prediction of wastewater outputs with different quality levels at different scales. This understanding is particularly necessary to incorporate decentralised reuse of wastewater within an IUWM framework.

Receiving waters subsystem: In systems where there is an outfall to a receiving body of water, the impact on the quantity and quality of water is an important consideration. This refers to a broad range of physical, chemical and biological variables and is aimed at describing the cause-effect relationships and pollutants pathways from points of origin to removal. These are dynamic processes that require considering modelling time scales that vary from small time steps (fractions of a second) to describe for example the impact of a rainfall event on pollutant fluxes to much longer time steps to describe groundwater pollution processes.

Table 2.2 Modelling time scales, spatial scales and dimensionality in urban/peri-urban water cycle

Subsystem	Time scale	Spatial scale
Bulk assessment and allocation	Monthly to annual	Catchment Political division
Water supply subsystems	*End-use models*: seconds to daily *Feasibility studies*: monthly-annual average	*End-use models*: single to multiple dwellings *Feasibility studies*: aggregate-stratified clustering
Wastewater subsystems	*Dynamic models (quantity-quality sewer flow)*: fractions of seconds to hours for short term dynamic processes and continuous simulation	*Treatment plant*: whole of plant system
	Performance assessment: monthly to annual	*Sewer subsystem modelling*: individual sewer subsystem component *Drainage pollution loads*: catchment/sub-catchments
Receiving waters subsystem	*Surface water dynamic modelling*: seconds to hours *Groundwater*: daily to monthly	*Surface water bodies*: partial or whole water body *Groundwater*: partial or whole aquifer depending on objective and affected area

2.6.1 Integrated Modelling Challenges

There are a number of models available that are used to represent and describe individual subsystems (water supply, wastewater and receiving waters) that run largely independently with exogenous data transfer between models (Rathnayaka et al. 2011). The main constraint imposed by this approach is that data and model processing can only occur sequentially in the downstream direction, thus precluding feedback between subsystem models. Simultaneous processing will allow these feedbacks to be taken into consideration. Integration of all water quantity and quality modelling processes still remains a challenge, highlighting the need to harmonise the interfaces between models.

The two main obstacles that must be addressed to achieve better integration of models are incompatibility of spatial scales and time scales (Schmitt and Huber 2006).

A summary of the time and spatial scales for the more important subsystems in an urban and peri-urban water cycle are described in Table 2.2.

Data availability: Water cycle modelling relies on sufficient quality data to enable adequate calibration and evaluation of models performance. Lack of adequate data can be a major constraint in water cycle modelling due to lack of consistency in data collection across subsystem boundaries and within subsystems.

These inconsistencies typically occur in the temporal and spatial scales at which data are collected. Often, data are collected by different agencies responsible for operating these systems, which collect data according to their individual protocols and requirements.

A water cycle monitoring program needs to be designed to collect data on different components of the water cycle in such a way that the data collected can be verified for quality and at the same time can support the assessment of the key sustainability parameters of the system. The design of the monitoring network refers to the selection of sampling sites and temporal sampling frequency to determine quantity and quality properties of water. These features must be selected based on the objectives set for the monitoring network. There are a variety of objectives that can be pursued in monitoring the water cycle such as environmental monitoring, detection, compliance, or research. Environmental monitoring is aimed to understand the characteristics of the water cycle and its variations over time. Detection has the primary objective of identifying specific contaminants and when their concentration exceeds a certain level. The compliance objective is similar to detection except that it is designed to enforce water quality standards and/or progress with water quality remediation works. The research objective requires a more detailed monitoring network of spatial and temporal water quality specifically designed to satisfy a specific research objective.

2.7 Conclusions

With over half of the world's population now living in urban and peri-urban areas and further future growth predictions that it is expected to reach 70 % by 2050, competition for land and water resources is expected to increase rapidly. It is posited in this paper that the urban/peri-urban water cycle consists of a continuum of spatial scales ranging from largely agricultural land to urban areas. This continuum can contain a broad typology of land uses distributed over a catchment landscape as illustrated by the Melbourne Metropolitan and Green Wedges area and the South Creek catchment in Western Sydney.

Water cycle modelling forms a critical part of the decision support systems process for planning future peri-urban and urban developments. As such, water cycle modelling must be designed to meet specific objectives ranging from bulk resource assessment and allocation to description and analysis of individual subsystems. Integrated Urban/Peri-urban Water Cycle modelling involves a range of hierarchical processes associated with individual subsystems including whole-of-water-cycle, water supply subsystem, water demand subsystem, wastewater subsystem and receiving waters subsystem.

Most of the existing models to date operate at a subsystem level and model integration must occur via exogenous data transfer. While it is desirable to integrate these models under a common shell to enable simultaneous modelling and feedback capability, this goal is made more challenging by heterogeneity of temporal and spatial scales across the subsystems boundaries and a similar lack of consistency in data collection and availability. A robust data monitoring program of the entire water cycle is of critical importance to support the modelling effort and provide the data needed for managing the water cycle in a sustainable manner.

Acknowledgments We are indebted to the CRC for Irrigation Futures that funded a large component of the research leading to these findings and to the Australia India Institute, University of Melbourne for their support to the international workshop that brought many of us together in Udaipur, India, where these concepts were first presented.

References

Arora M, Aye L, Malano H, Ngo T (2013) Water-Energy-GHG emissions accounting for urban water supply: a case study on an urban redevelopment in Melbourne. Water Util J 6:9–18

Buxton M, Goodman R (2002) Maintaining Melbourne's green wedges: planning policy and the future of Melbourne's green belt. RMIT University, Melbourn, 84 p

Chow D, Sutherland C, Glesson B, Dodson J, Sipe N (2008) Change and continuity in peri-urban Australia. Griffith University, Periurban Futures and Sustainable Development, p 111

Davidson B, Malano H, Nawarathna B, Maheshwari (2013) The hydrological and economic impacts of changing water in political regions within the peri-urban south creek catchment in Western Sydney II: scenarios. J Hydrol 499:349–359

George B, Malano H, Davidson B, Hellegers P, Bharati L, Sylvain M (2011) An integrated hydro-economic modelling framework to evaluate water allocation strategies I: model development. Agric Water Manag 98(5):747–758

Khan S, Malano H, Davidson B (2008) System harmonisation a framework for applied regional irrigation business planning. Irrig Drain 57(5):493–506

Lundin M, Morrison G (2002) A life cycle assessment based procedure for development of environmental sustainability indicators for urban water systems. Urban Water 4:145–152

Malano H (2010) Modelling and decision making in water resource management. In: Khan S, Savenije H, Demuth S, Hubert P (eds) IAHS Publication 338. Hydrocomplexity: new tools for solving wicked water problems. UNESCO, Paris, pp 111–126

Maheepala S, Blackmore J, Diaper C, Moglia M, Sharma A, Kenway S (2010) Integrated urban water management planning manual. Commonwealth Scientific Industrial and Research Organization (CSIRO), Australia

Mitchell VG, Mein RG, McMahon TA (2001) Modelling the urban water cycle. Environ Model Softw 16:615–629

Nawarathna NB, Kazama AO (2006) Influence of human activities on the BTOPMC model runoff simulations in large-scale watersheds. In: IAHR Congress Proceedings Theme A, pp 93–99

Perera BC, James B, Kularatna M (2005) Computer software tool REALM for sustainable water allocation and management. J Environ Manage 77:291–300

Rathnayaka K, Malano H, George B, Nawarathna B, Mahipala S, Arora M (2011) Review of residential urban water end-use modelling. International Congress on Modelling and Simulation, Australia, pp 3321–3327

Roberts P (2005) 2004 Residential end-use measurement study. Yarra Valley Water, Melbourne, 493 p

Schmitt TB, Huber WC (2006) The scope of integrated modelling: system coundaris, sub-systems, scales and disciplines. Water Sci Technol 54:405–413

Singh R, Nawarathna B, Simmons B, Maheshwari B, Malano HM (2009a) Understanding the water cycle of the South Creek Catchment in Western Sydney. part I: catchment description and preliminary water balance. CRC for Irrigation Futures Technical Report No 05/09, 48 p

Singh R, Maheshwari B, Malano HM (2009b) Understanding the water cycle of the South Creek Catchment in Western Sydney. part II: catchment water balance modelling. CRC for Irrigation Futures Technical Report No 05-2/09, 98 p

Willis R, Stewart RA, Panuwatwanich K, Capati B, Giurco D (2009) Gold coast domestic water end-use study. J Aust Water Assoc 36(6):79–85

Worldwatch Institute (2008) http://www.worldwatch.org/node/5455. Accessed 23 May 2013

Part II
Urbanisation

Chapter 3
Geo-Social Aspects of Developments in Peri-urban Regions

Govind Singh Bhardwaj

Abstract The peripheral fringe area of cities comes under the peri-urban category, where rural areas are forced to assimilate with urban areas. Sustainable development of fast growing peri-urban regions is a big challenge for the various agencies and authorities concerned throughout the world. The geo-social dynamics of assimilation of the rural-urban spatial fringe are a new concept to understand; its significance in planning and management of the sustainability of environment, ecology of the area in particular the socio-economic facet of sanitation and health. The quantification of the sustainability of the development establishes by geo-social degradation. There are several geo-social buffer zones, which have been specified to understand the existing peri-urban regions state of development and evolve the strategies for betterment. Geo-social aspect of peri-urban regions development is an interdisciplinary approach.

Keywords Geo-social · Rural-urban transformation

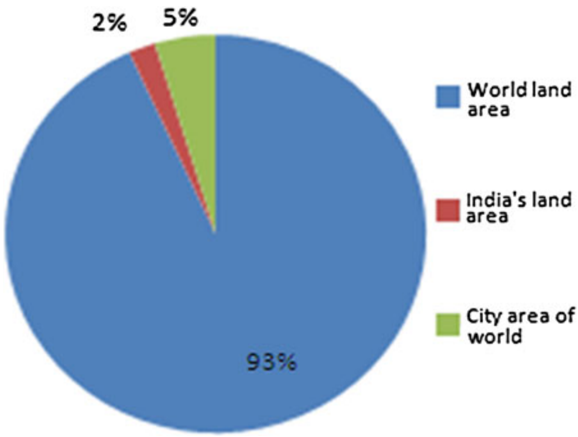
3.1 Introduction

The rapid rate of expansion of peri-urban regions has caused problems of engulfing of periphery land, forest, vegetative cover, rural life and culture, water resources, agricultural fields, topography, drainage patterns. The cities are located in zones of physiographic diversities and these diversities are mere reflections of spatial distributions of the subsurface rock formations and their structural features like joint, fold, and fault and rock strata attitude. Peri-urban fringe expansions type and direction of expansions are variable in space and time and city specific. It is due to

G. S. Bhardwaj (✉)
College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur 313001, India
e-mail: bhardwaj_gs@rediffmail.com

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_3,

Fig. 3.1 Showing world urban area and India's land area



several reasons, which can be explained by the cause and effect relationship. One of the very important causes is population growth, rising trends of nuclear families, modern amenities development, sports complexes, and stadiums, road by-passes construction and land acquisition and holdings for investments purposes, hotels and resort construction, and airports expansion.

The urban area of the world is 7,447,000 km^2 out of the world total area of 148,940,000 km^2 and India's land area is 3,287,263 km^2 (Anonymous 2013). In rapidly urbanizing regions, resources to implement sustainable urban planning are often lacking. The global urban expansion will draw heavily on water, among other natural resources, and consume prime agricultural land. The present status of the world's percentage share of the urban area is given in Fig. 3.1. According to Thomas Elmqvist, cities need to learn how to better protect and enhance biodiversity as this is extremely critical to the well-being of people (Anonymous 2012). He asserts that urbanization has an impact far beyond the city limits. Over the next couple of decades, urban expansion will claim an area of land the size of South Africa, much of this being prime agricultural land, which will be sorely missed as population rises and demand for food increases.

In the last 10 years the average rate of expansion of peri-urban regions in India is 30 % with the highest rate observed in Delhi at 48 % (Shaw 2005). Expansions of Indian cities in respect to land coverage are now more than 50 million ha of which more than 10 million ha is peri-urban region (McKinsey Global Institute 2010).

The Indian economy is a split between urban and rural, where technological advancement in the urban sector has forced the rural land into urbanisation (Nath V. and Aggarwal 2007). This is another aspect whereby the real estate industry is forcing the rural periphery area to transform into the peri-urban (Revi 2012). Present scenario shows that in India 30 % of the population is residing in urban areas and that figure is expected to become 50 % by 2044 (Thomas 2012a, b). Three of the ten largest cities in India and three of the world's ten fastest growing

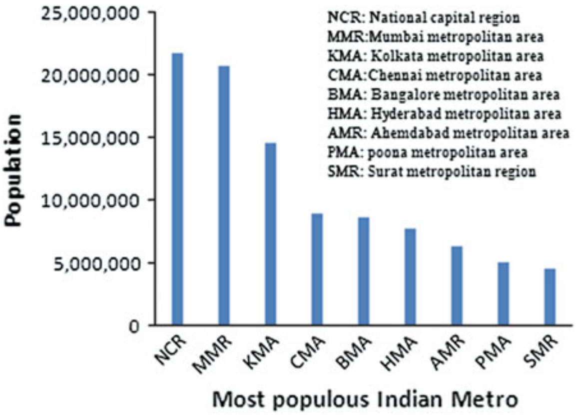


Fig. 3.2 Population statuses of most populous Indian metropolises

cities are Ghaziabad, Surat and Faridabad. As per the 2001 census, 72.2 % of the population lives in about 638,000 villages and the remaining 27.8 % lives in more than 5,100 towns and over 380 urban agglomerations (Anonymous 2011, Census of India 2011 and India stats 2011). The population status of the most populous Indian metropolises is given in Fig. 3.2.

The urbanisation rises on the periphery of the large developing cities results in the formation of mixed land use settlements halfway between urban and rural zones, transitory spaces undergo rapid and multiple transformations from physical, morphological, social and demographic as well as cultural, economic and functional aspects. Facets of the peri-urban dynamics are multiple and rely on a multidisciplinary working group. The objective is to put together a series of studies and fieldwork in order to promote reflection on the complex equation between population, habitat and environment in these suburban spaces defined as peri-urban (http://www.csh-delhi.com downloaded on 17.11.2012).

Peri-urban regions are the interface between the dynamic, interactive and transformative rural-urban spectrum. On the basis of the transformative spectrum the peri-urban regions can be divided into several types but most of the peri-urban regions belong to high complexity zones, where spatial and landuse/cover structure and temporal variability of land use forms are displayed. Due to a rapid urbanisation process pressure is imposed on peri-urban soil resources. The first symptom of significance observed is fast transformation of farming lands into non-agricultural uses, resulting in a sharp decrease in agricultural soil area. This decrease directly threatens the local agricultural production and food security. Another serious concern is the accumulation and disposal of wastes originating from urban, industrial and agricultural sources in peri-urban areas. The resultant soil degradation and pollution, leads to adverse influences on the quality of agricultural products and local ecosystems. Studies focusing on landuse changes and soil resource dynamics in the peri-urban areas are now in demand (LI et al. 2005).

The geo-social land suitability analysis, geo-social planning and management of disaster mitigation and management, geo-social land use planning, special provision for environmentally sensitive/fragile areas protection, are all areas needing care while planning activities/land uses, planning for environmentally relevant land uses including sites for industries and other developmental projects (Rao S.K. 2010, Bhardwaj 2012).

3.1.1 Peri-urban Development in India

Peri-urban developments in India are progressing on a single track system although a well-defined physiographic division of disparity has been gifted by nature. The construction of buildings throughout the peri-urban areas is similar and results in the same type of houses in most of the cities (Narain and Nischal 2007).

Whatever civil construction we see in particular town/city/peri-urban area, it is not in accordance with or fine tuned to the nature of the landscape, physiographic division of the area or the subsurface rock types available in the area viz. different properties, behaviour, geo-mechanical properties, porosity, permeability etc. are responsible for the growth of luxuriant forests as well as moisture content of the area or surface of the earth (BIA 2007). In the country a negative type of real estate industry response is observed which is not acceptable to the mother earth. If the health and hygiene of the earth is good then society will survive. The geo-societal aspect must be looked in a scientific way to overcome the peri-urban problems of sanitation and water supply.

The master plan prepared for the development of peri-urban regions should include various types of land use categories including residential, commercial and trade, industrial, office, communities' facilities, parks, open spaces, recreation including green belt, undefined areas, railways, roads, bus depots, college and schools and hospitals. This exercise is strictly on the basis of availability of the area. The category of land distribution patterns is changing all the time and no clear cut road map is available.

3.2 Geo-Social Land Suitability

Geo-social land suitability for development in the fringe areas has to be carried out for fast growing towns and cities. Preparation of base maps need to be eco-friendly and nature friendly to peri-urban regions. Following base maps are required:

- Contour map at various scales
- Drainage map
- Surface water bodies and submergence area map
- Rainfall precipitation distribution map
- Wind direction map by month
- Wind velocity map by month

- Natural gradient map
- Soil distribution map
- Soil profile depth map
- Soil fertility map
- Rock formation distribution map
- Rock structure and lineament map
- Rock strata porosity and permeability map
- Seismic intensity map
- Seismic micro-zonation map
- Landslide sensitivity map
- Historical buildings location map
- Heritage buildings location map
- Geological monument map.

Along with the above maps a base line database of peri-urban areas with the background information of the area is required (Maller et al. 2007). The above maps are to be made available to the administrator or the government authority and ideally should be made available to all. The preparation of all maps requires the involvement of experts available from different fields and multidisciplinary team task feasibility should evolve. This exercise is desirable to overcome the problems raised due to unplanned or imperfect plans. This approach may be viable for developmental activities of peri-urban regions universally (Jacquin et al. 2008).

3.3 Challenges of Urban Development

The world is increasingly urban, interconnected, and changing. If current trends continue, by 2050 the global urban population is estimated to double and be approximately around 6.5 billion. Most of future urban growth is expected to happen in small and medium-sized cities, not in megacities, and approximately 60 % of the projected total urban area in 2030 has yet to be built (United Nations 2006). This represents unprecedented challenges for both halting biodiversity loss and creating sustainable global development, but also unprecedented opportunities. Many of the opportunities can be found in nature based solutions, using biodiversity and ecosystems in novel ways to address some of the most pressing challenges, such as climate change, water and food security. In particular, the way forward for cities involves reimagining cities as places of biodiversity, and as sources for unique ecosystem services that have value to society, rather than only sinks that create large ecological footprints (Thomas 2012a, b).

Urbanisation is spreading across the face of the planet at an unprecedented rate. In the Indian perspective most of it is opportunistic ad-hoc development and shanty towns rather than master plans. Virtually none of it is planned or otherwise, incorporates the elements of natural capital that are needed to create sustainable cities. Every time a new piece of urban fabric is created, or an existing piece is

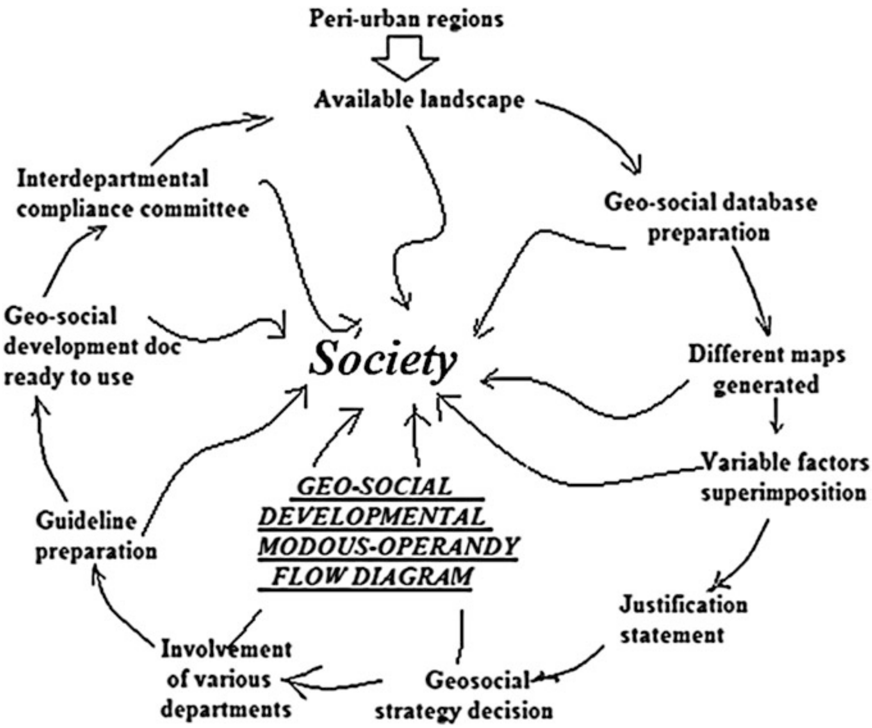


Fig. 3.3 Geo-social development flow diagram

patched up and reworked, it may add to the value of the real estate but subtracts from the ecological health of the urban area. As each conurbation grows it diminishes the biological wealth of its region. Globally, the entire urban system trends towards becoming increasingly dysfunctional. An "urban fractal" is a network that contains the essential characteristics of the larger network of the city. Each fractal will possess nodes, or centres, and patterns of connectivity that define its structure and organisation, and it will exhibit characteristics of community associated with living processes. It is a particular type of cultural fractal. Each neighbourhood scale piece of the city should be called an "urban fractal", containing the essential characteristics that is in the whole urban system, including nature, ecosystem services, and urban agriculture. The dimensions of an urban fractal are defined in terms of performance, rather than its spatial dimensions. Thus, a required dimension for an urban fractal that supports nature in the city might be a set of Design Guidelines for Non-Human Species that required it to provide support for wildlife indigenous to the place and be able to provide, for example, sufficient viable habitat that it can support at least one key indicator species of fauna and a majority of the indigenous birds species (Downtown 2012).

The geo-social development of peri-urban regions fulfils the mandate of a nature friendly aspect, since every aspect about the nature and earth is incorporated

Fig. 3.4 Photograph showing scenic beauty of lakes and tons of waste dumped near Bhuwana bypass, Udaipur. *Source* http://www.udaipurtimes.com/villagers-reacts-over-waste-dumping/

in the concept. It is in the initial stage of birth of the concept where there is scope for improvement. There are various stages of geo-social planning of the peri-urban regions and the preliminary geo-social action oriented developmental aspect is given in Fig. 3.3.

3.4 Case Study of Udaipur

According to Travel and Treasure magazines the city of lakes and fountains named as Udaipur a city in Rajasthan, India is the seventh most beautiful city of the world (2009). The weather and climatic conditions attracts tourists from all over the world. The panoramic beauty of one of the lakes just after the rains is given in the photograph (Fig. 3.4).

Nowadays it is growing as an education and medical hub. This has attracted the real estate industry and the peri-urban area is expanding rapidly. The expanding peri-urban is not systematic with private land and government land arranged by the real estate industry, private parties and civil construction performed as per their desire and requirement. This has caused a mixed zone of residential colonies, hospitals, government offices, educational institutions, hotels, industries and waste

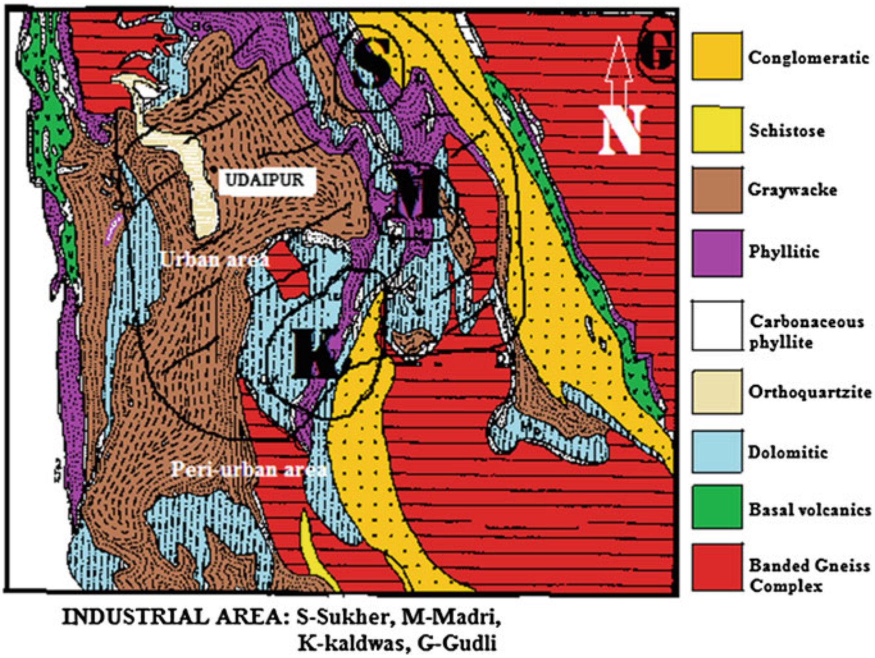


Fig. 3.5 Geological map of the Udaipur city modified after Heron 1953

dump yards at the urban and peri-urban contact area all along the irregular peripheral line. The new developing area, truly speaking, is not developing but it is merely a spoiling exercise of the entire area. The marble waste slurry yard of 5 km^2 areal span and average depth of 20 m are located in the north-eastern part of the urban/peri-urban contact, which has severely affected the north east area of the urban Udaipur. The marble dust particles are spreading in the air and eventually leaching into the groundwater system in the catchment area and causing serious threat to the Roopsagar dam. The municipal waste dump yard of about 1 km^2 area with a depth of 5 m is located in the south urban portion of the city, from where a microorganism in the air spread disease. The industrial waste dump yard of Gudli is located in the peri-urban area and is causing a threat to the nearby agricultural land by the spread of toxic seepage from the yard.

Surprisingly educational institutions are mushrooming without any concrete scientific citing. The various infrastructure and establishment of cities are not located geo-socially and future generations have to face the serious consequences. For example Hindustan Agro Ltd located nearby downstream of the Udaisagar Lake has deteriorated the downstream surface water bodies and groundwater aquifer. Fresh water availability becomes a dream in the Bichhri area. Properties of rock formations and their in-depth characters plays a significant role in deciding geo-social suitability of the land for specific purposes. The city is located in a geologically complex area; a geological map showing spatial distribution of rock formations are given in Fig. 3.5.

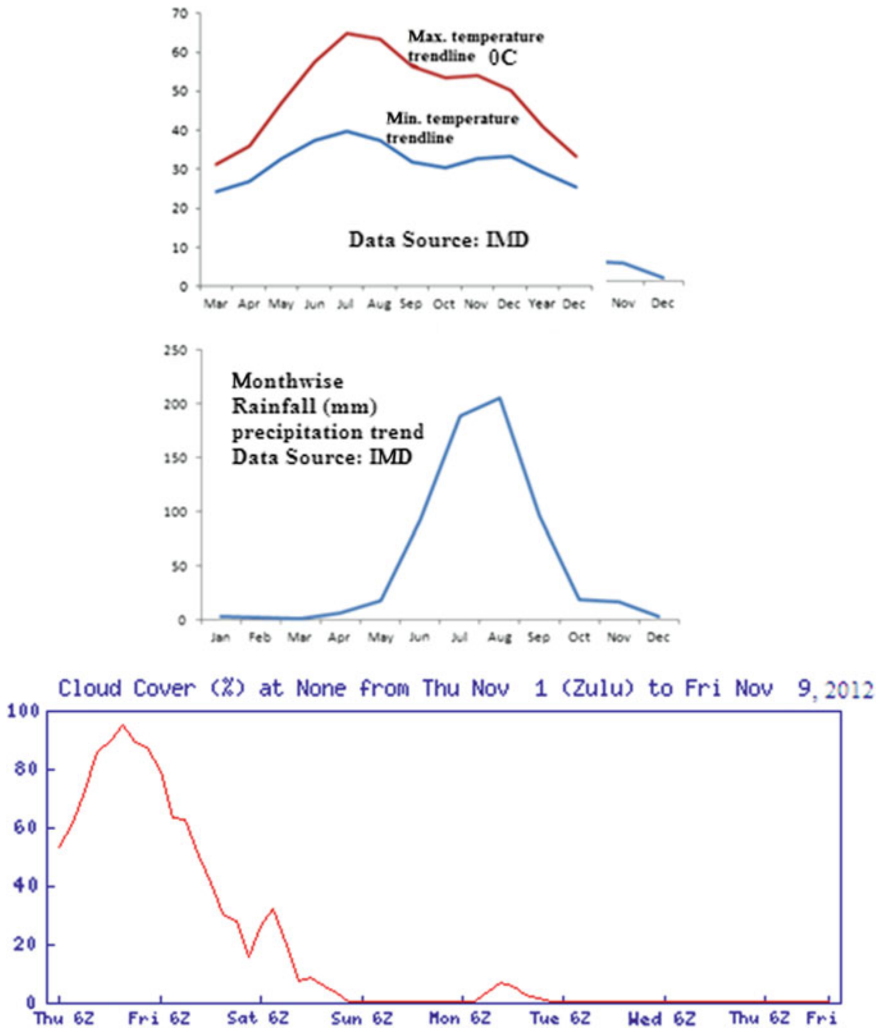


Fig. 3.6 Monthly temperature, rainfall and weekly cloud percentage trends

Pleasant local weather conditions are evident by the maximum temperature rises in the month of June with the lowest in December. The cloud cover percentage of Udaipur city including urban and peri-urban areas of seven days from November 1 to 9, 2012, showing the typicality and uniqueness of weather conditions of Udaipur city are shown in Fig. 3.6.

The Ahar River has become a wastewater drain and is heavily polluted as a result of raw sewage inflow and dumping of solid wastes; has increasing levels of water and air pollution due to inefficient drainage/sanitation and increasing traffic respectively; and has competing investment in tourism infrastructure in other cities

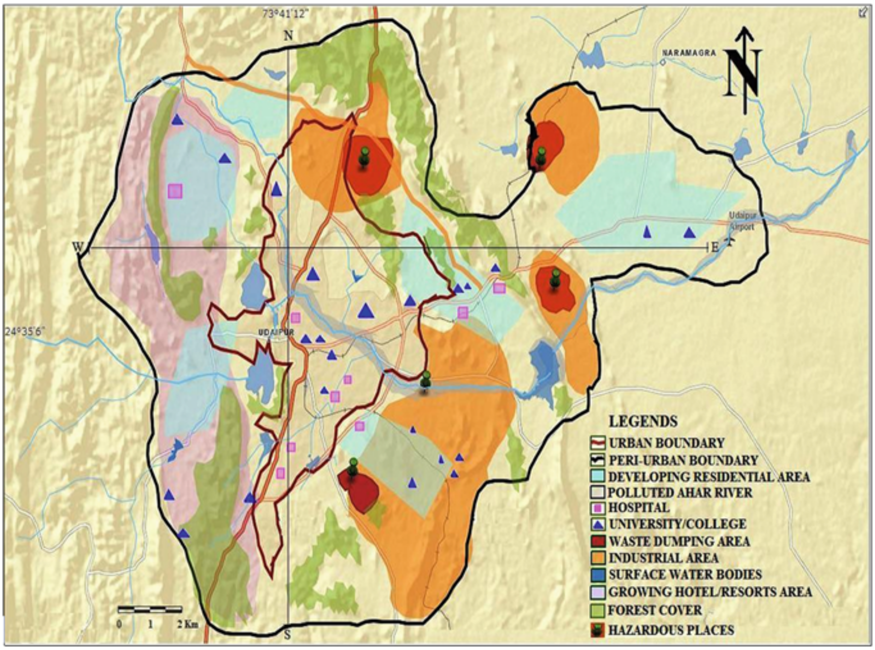


Fig. 3.7 Map showing peri-urban expansion of Udaipur city

both in Rajasthan and other states (Sancheti 2006). With zero recycling and poor waste management, city outskirts have now become dumping grounds at a number of places.

3.4.1 Recent Trends of City Developments

Status of the peri-urban expansion of Udaipur city has been analysed by Arc GIS software and an explanatory map has been prepared. Various features are plotted in the map showing that the spatial distributions of different land-use are lacking in geo-social planning (Fig. 3.7). Waste disposal dump sites viz. marble slurry in the northern centre portion of the city are causing hazards in the Chitrakootnagar area; industrial waste in Gudli is causing threats to the surrounding area; and municipal waste in the southern central area is causing environmental problems. The severity of the deteriorating environmental status is aggravated by the buffer zone produced by the overlapping of various land types. The Ahar River becomes polluted by the mixing of city waste water and ultimately pollutes Lake Udaisagar. Developing new residential areas are engulfing peri-urban agricultural lands. The bio-waste produced from hospitals is not being treated by a proper disposal system in the township. Most of the private academic institutions located in the peri-urban area are not sited geo-socially.

3.5 Conclusions

The cause and effect phenomenon of expansion of the peri-urban regions of Indian cities in particular and the world over in general has been acknowledged and it is realised that there is a big challenge in managing the developmental activities in these regions. It is an enormous task to fulfil the day-to-day needs of the civilian society while maintaining bio-diversity as well as ecology of the area. A coordinated approach has to be followed considering the society and land area. The sustainable planning, management and development of existing peri-urban regions as well as future peri-urban development and expansions are directly linked with the geo-social spirit of the land area. Geo-social strategy for the peri-urban regions of India is a demand of the times to achieve nature-friendly city development.

References

Anonymous (2011) Census of India 2011, provisional population totals India data sheet. http://pib.nic.in/prs/2011/latest31mar.pdf. Accessed 21 Dec 2012

Anonymous (2012) Responding to climate change. http://www.rtcc.org/climate-change-tv/cbd-cop11-area-size-of-south-africa-may-be-lost-to-urban-expansion/. Accessed 21 Dec 2012

Anonymous (2013) Demographia world urban areas: 9th annual edition. http://www.demographia.com/db-worldua.pdf. Accessed 12 Dec 2013

Bhardwaj GS (2012) Geo-social aspect of peri-urban regions. Int J Res Eng IT Soc Sci IJREISS 2(6):35–56. ISSN: 2250-0588

BIA (2007) Bureau of Indian affairs, office of facilities management and construction, School facilities design handbook, March 30, 2007. http://www.bia.gov/cs/groups/xraca/documents/text/idc008030.pdf. Accessed 22 Dec 2012

Census India (2011) http://www.censusindia.gov.in. Accessed 22 Dec 2012

Downtown P (2012) Neighbourhoods and urban fractals—the building blocks of sustainable cities. http://www.thenatureofcities.com/2012/10/17/neighborhoods-and-urban-fractals-the-building-blocks-of-sustainable-cities/. Accessed 17 Oct 2012

India Stats (2011) Million plus cities in India as per Census 2011. Press Information Bureau, 31 Oct 2011. Accessed 6 Aug 2012

Jacquin A, Misakova L, Gay M (2008) A hybrid object-based classification approach for mapping urban sprawl in peri-urban environment. Landscape Urban Plann 84:152–165. Available online at http://www.sciencedirect.com; http://www.dpi.inpe.br/sil/CST310/AULAs/Aula7_DadosSR/apoio/disciplina_introdu%C3%A7ao%20ao%20sensores_LU/216-3_Introd.Sensores/Monografia/Epiph_article.pdf. Accessed 22 Dec 2012

LI G, Chen J (2005) Landuse and pressure on social resources in periurban areas. Res Environ in Yantze Basin, 14(5):579–583. ISSN 1004-8227 CN42-1320/X

Maller C, Kancans R, Carr A (2007) Biosecurity and small landholders in peri-urban Australia. Australian Government, Bureau of Rural Sciences, Australia, p 191. http://adl.brs.gov.au/brsShop/data/biosecurity_and_small_landholders.pdf. Accessed 22 Dec 2012

McKinsey Global Institute (2010) India's urban awakening: building inclusive cities and sustaining economic growth. http://www.urbanindia.nic.in/programme/uwss/MGI_india_urbanization_fullreport.pdf. Accessed 12 Dec 2013

Narain V, Nischal S (2007) The peri-urban interface in Shahpur Khurd and Karnera India, Environment and Urbanization 2007, 19:261. Published by: SAGE, Environment & Urbanization Copyright © 2007 International Institute for Environment and Development (IIED). 261 vol, 19(1):261–273. doi: 10.1177/0956247807076905. http://www.sagepublications.com. Accessed 22 Dec 2012

Nath V, Agrawal SK (2007) Urbanization, urban development, and metropolitan cities in India. Concept Publishing Company. ISBN 978-81-8069-412-7, Accessed 3 Aug 2012

Rao SK (2010) EIA guidance manual building, construction, townships and area developmental projects. Ministry of Environment and Forests Government of India, pp 1–200. http://environmentclearance.nic.in/writereaddata/Form-1A/HomeLinks/building-construction_May-10.pdf. Accessed 22 Dec 2012

Revi A (2012) The urban engine. Expansion of cities remains unaffected by worsening Indian economy October 26, 2012, Updated 12:15 IST, India Today, in Business India. Accessed 5 Nov 2012

Sancheti HS (2006) City development plan of Udaipur. ITPI J 3(4):36–41

Shaw A (2005) Periurban interface of Indian cities, growth, governance and local initiatives, economic and political weekly, Jan 8 2005, pp 129–136

Thomas E (2012a) The cities and biodiversity outlook. India's urban expansion to impact environment: United Nations report. The Economic Times, Oct 15 2012, 06.45 PM IST. http://articles.economictimes.indiatimes.com/2012-10-15/news/34473366_1_urban-population-urbanisation-level. Accessed 15 Oct 2012

Thomas E. (2012b) Cities and biodiversity outlook—unprecedented opportunities lie ahead in greening urban expansion. Posted on Oct 3 2012. The nature of cities. http://www.thenatureofcities.com/category/thomas-elmqvist/. Accessed 17 Oct 2012

United Nations (2006) World urbanization prospects: The 2005 revision. Working paper No. ESA/P/WP/200

Chapter 4
Urbanisation of Peri-urban Regions: Is It a Boon or Threat to the Liveability of Future Cities in India?

Ramesh Purohit and S. K. Shrimali

Abstract Populations of cities are increasing rapidly and people from nearby rural areas have been migrating to cities at unprecedented rates during the last 15–20 years. Is it a problem? Why is there so much hue and cry regarding this issue? Are we really going to face the problem of water supplies, food shortages and liveability of cities in the future? To reflect on these issues we will have to think of the Liveability Index. Are our cities lagging behind on liveability standards? What is the understanding of policy makers? Do policy makers have a generic grasp into the state of cities? What roadmaps are being evolved to excel global standards? This paper addresses the issues of sustainable development in landscapes around our cities, particularly in light of utilizing present resources, while keeping in mind the future needs of society, so as not to exhaust resources. Further, it should not disturb the ecological cycle and hence preserve the environment and liveability of future cities. Using City of Lakes, Udaipur, as an example the paper will also discuss what options we have to meet the future demands of housing around our cities while meeting water needs and production of local fresh food and vegetables for the community.

Keywords Water shortage · Food shortage · Liveability · Environment · Peri-urban areas

4.1 Introduction

Urbanisation of peri-urban regions is a ground reality not only in India, but in almost all developing and developed nations. The growth rate may vary from country to country. This phenomenon of urbanisation of peri-urban regions calls

R. Purohit (✉) · S. K. Shrimali
College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India
e-mail: purohitrc@yahoo.co.in

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_4,

for the attention of planners to solve the problem of unplanned and haphazard city growth in the light of changing land use, loss of agricultural land and liability conditions of cities in future.

Urbanisation of a peri-urban region is a continuous process experienced by all nations from agrarian to industrial societies. Employment is one of the important factors which has a positive impact on the growth of peri-urban areas. Economic pressure or “pulls” in the country side which “pushes” people into the cities in search of employment and livelihood. The rural urban migration that leads to urbanisation is more a consequence of this push from the country side, rather than a pull.

The growth of economic activities on the city has its impact on growth as well as structure. Activities tend to cluster in urban areas at various locations, because these locations provide the necessary market, communication, transportation and other infrastructure. Due to these extra facilities at different locations in urban areas labour moves to these locations. This leads to spatial expansion which also causes an increase in population due to immigration and this spatial expansion causes a rise in services and infrastructure. Industrial activities are the basis of all economic development in a city.

The urban population of Rajasthan is increasing at an enormous rate and it is higher than the rural population growth and total population growth. All the towns of Rajasthan are not growing at same rate, as some are growing at an increasing rate and some at a slow rate (Table 4.1). To achieve planned rural development, the Panchayati Raj Department has issued guide lines as below:

- Village plans should be prepared for 20 years and preparation of a village plan exercise is to be done at the level of gram panchayat.
- Study of existing facilities available in the village and identification of short camp.
- Identification of available resources in and around villages.
- Conservation of water bodies, rivers, nallas, step wells, etc.
- Rights of way on the important roads should be as per the norm of the Public Works Department (PWD) and distance from railway lines should be kept as per the norm.
- Conservation and improvement of the environment of villages should also be considered.
- Extension should be as per the size of the villages.
- Pasture land should be conserved and protected.
- Forest land and plantation should be conserved and afforestation activities should be enhanced.
- Soil conservation measures should be taken and conservation of water resources should also be undertaken, while preparing village plans.
- Planning of the village should be carried out properly, with provision for various facilities made for future markets in a planned manner.

Table 4.1 Population growth of major cities in Rajasthan

S. No.	Name of town	Year				Growth rate		
		1981	1991	2001	2011	1981–1991	1991–2001	2001–2011
1	Jaipur	1015160	1518235	2324319	3073350	49.56	53.09	26.91
2	Jodhpur	506345	666279	856034	1043916	31.59	28.48	27.69
3	Kota	358241	537371	704731	1001365	50.00	31.14	24.35
4	Bikaner	287712	416289	529007	647804	44.69	27.08	41.42
5	Ajmer	375593	402700	490138	542580	7.22	21.71	18.48
6	Udaipur	232588	308571	389317	451735	32.67	26.17	23.66
7	Bhilwara	122625	183965	280185	360009	50.02	52.30	16.09
8	Alwar	145795	210146	265850	315310	44.14	26.51	22.70
9	Ganganagar	123692	161482	222833	224773	30.55	37.99	10.06
10	Bharatpur	105274	150042	205104	252109	42.53	36.70	21.32
11	Pali	91568	136842	187571	229956	49.44	37.07	11.99
12	Sikar	102970	148272	185506	237579	44.00	25.11	17.04
13	Tonk	77653	100235	135663	165363	29.08	35.34	17.33
14	Hanumangarh	60071	82733	129654	151104	37.73	56.71	17.24
15	Beawar	89998	106721	125923	145809	18.58	17.99	18.20
16	Kishangarh	62032	81948	116156	155019	32.11	41.74	18.31
17	Gangapur city	46026	68886	105336	119045	49.67	52.91	15.9
18	Sawai Madhopur	59083	77690	101994	120998	31.49	31.28	19.79
19	Churu	62070	82852	101853	119846	33.48	22.93	6.10
20	Jhunjhunu	47177	72187	100476	118966	53.01	39.19	11.81

4.2 Land Mafia and Land Use Change

Land within urban fringes is an attractive area for private developers, who consider that topography of the surrounding countryside is not an impediment to the expansion of the city. Property prices rise, as the real estate market gets active and shelter affordability of the people in urban areas start to get challenged. Saini and Kaushik (2011) reported a case study of the Chandigarh peripheral area for a period of 36 years (1972–2009) and found that the area devoted to agricultural purposes, which was 43 % in 1971, has decreased to 30 % in year 2000; whereas built up land which was barely 1 % in year 1972 has grown to 18 % in year 2008. Gupta (2011), using multi resolution, multi temporal satellite data, found that in Jaipur the crop area has shrunk by 1.6 km^2 per year, fallow land by 2.94 km^2 per year and waste land by 0.59 km^2 per year in last 34 years (1975–2009). The built up area has increased at the rate of 4.46 km^2 per year or 1.02 % per year.

4.3 Good Practice Urban Agriculture

What is meant by 'good practice urban agriculture'? Good practice urban agriculture is effectively regulating agriculture to provide 'safe food' to city dwellers' (Smit et al. 1996). Good practice urban agriculture includes farming, fishery, horticulture, forestry, poultry and livestock development. It has the potential to provide much higher benefits in nutrition improvement, income generation, enterprise development and land and waste management. Moreover, with good practice urban agriculture, the urban environment can improve. A system of sanctions and rewards may be necessary to promote optimum results. In this regard, much focused study is needed to identify and quantify.

There are different views on this. One view of regulation is the cost savings from using waste to generate food rather than its sanitary disposal under strict regulations. From city to city there may be variations of extensions of health programs, environmental programs, etc. with China being a very good example of 'Good Practice Urban Agriculture'. In 1900, eight of the sixteen cities in the world with a population over 500,000 were in China. All of these cities have effectively regulated agriculture for over 100 years and today's China is highly dependent on urban agriculture. Now the question is what is meant by a healthy sustainable built environment and where are the open spaces within a built environment?

4.4 Open Spaces Within Built Environment

Utilizing parks, rivers and canal banks, etc. is becoming a well-known way to improve the environment in a city. To do so through an economically viable way is of great interest to cities with income and land constraints. It is less popular as most of our Indian cities, due to high population densities, have both the above disadvantages, i.e., land constraints and income constraints.

Production of fruit and vegetables within cities is a greening application that can operate on a large scale with low operating costs compared to equivalent ornamental green spaces. Planting trees on road sides, plants on roof tops and available bare compact soil are a kind of greening application which can transform any cityscape. This statement may require substantial research and documentation to be made for convincing many bankers and recreational open space planners in India but it is already being proven in many developed countries.

Converting wastes to food and greenery is important but where? Land unsuitable for use as 'built up' spaces, such as steep slopes, wetlands, land cover and aquifers can be utilized for urban agriculture. Further ancillary spaces along highways, river banks, costal zones, under electric power lines, airports and prisons, land around institutional buildings, and peripheral areas around schools and parks are the areas where fruit trees and vegetables can be grown. This greening application will transform the city into a green city. Moreover, the above land under strict regulatory measures can be rented out to farmers who pay land rent to the owners. Also backyard home gardens should be encouraged.

Perhaps, the most underrated role of urban agriculture is revitalizing the city soil. City land tends to be starved as its life is leached away and replaced due to pollution. Even leaves on the streets are collected in plastic bags and hauled away, whereas this practice can be easily replaced by the production of vermicomposting. Vermicomposting, thus produced, can be utilized as organic manure for growing useful trees in the city.

Hence, urban agriculture in the city can decrease pollution. It can help in reducing fuel costs by bringing food from afar. It can decrease hunger, poverty and help in waste management. Further, it can support the economy and employment in the city. There is a significant decrease in the secondary sector of the labour force due to upgradation of technology and extensive use of computers and machinery in India. This labour force can be gainfully employed using their indigenous skills in agricultural production. It is worth noting that women are especially skilled in this area.

4.5 Benefits to Slums and Peri-urban Zones

Biological transformation of urban wastes to assist food production and green space development is essential for sustainable cities. In Indian cities the areas, which will benefit the most by 'Good Practice Urban Agriculture' are low income residential and mixed use areas and urban fringes.

Low income areas typically have the worst environmental conditions with the presence of garbage, sewage, dust packed earth, and unstable soils. Farming in these areas is particularly feasible because the availability of low cost labour benefits could accrue and not only serve the immediate community but also to a lesser degree the entire city and periphery.

Urban fringes in Indian cities are mostly used as dumping sites for city waste. If appropriate agricultural practices were practiced by squatter settlers living there, it would be beneficial to all. Urban agriculture, with good practice, introduced to the fringes has several environmental benefits, namely reduced pollution, beneficial reuse of wastes, increased tree cover and better living conditions for the urban poor living in the urban fringe areas.

4.6 Urban Forestry

Lately, Urban Forestry in the urban fringes is being encouraged in India. As it serves a dual purpose, i.e., urban agro-forestry can reduce air pollution and add oxygen to the city air while providing food, fuel and inputs to industry and delimiting the size of the city.

However, in a marked difference to the city greening programs of the 1970s and 1980s, urban agro-forestry is presently becoming more popular. Urban agriculture greening programs are expected to pay back in their own way by producing products with market demand. This includes food, fuel, insecticides, medicines, building materials and compost. These projects can involve active participation of the poor who can perceive both short and long term family and community benefits. The illiterate poor are not devoid of indigenous skills of producing vegetables and fruits and they are innovative enough in survival techniques. They need a little financial help and guidance from the government to improve their own economic condition and quality of life.

The other very important function of urban agro-forestry is to delimit the size of cities which is presently being overlooked. In ancient Indian cities moats were built for different purposes, one of them being to delimit the size of a city, which can be replaced by urban agro-forestry in the present day scenario.

4.7 Closing Ecological Loops

In India, urban agriculture is just witnessing its beginning with piecemeal efforts made in a few cities. However in the perspective of a growing population and growing food scarcity in the near future, it can be developed in every city as a 'resource conserving industry'. It takes away a city's wastes and converts them into resources. It creates a diverse ecology where fruit trees, vegetable plantations and fish could coexist with the built environment—a wholly ecologically sustainable scenario. Surveys suggest that almost 50 % of vegetables waste can be composted as organic manure to help produce vegetables and fruit trees. Similarly 50 % of urban waste water can be biologically treated to be used for irrigation of food products or as a medium for aquaculture.

4.8 Liveability

Liveability refers to an urban system that contributes to the physical, social, mental and personal development of all its inhabitants. It is about delightful and desirable urban spaces that offer and reflect cultural and sacred enrichment. Key principles that give substance to this theme are equity, dignity, accessibility, conviviality, participation and empowerment.

A liveable city is one that directly benefits the people who live and work in it along with those who visit it. It refers to the environmental and social quality of an area, which includes local environment conditions, presence of quality education and health institutions, infrastructure, spending power administered by its consumers, safety of the population and recreational avenues. Likewise, businesses are on a persistent search for locations that complement the production process. To cite one case, an area with a regular supply of power and well-connected roads provides a favourable environment for a commercial activity. At this stage it is mandatory to draw a couple of distinctions between a few intertwining terminologies. First, it is important to understand that liveability is not the same as quality of life or quality of living enjoyed by the residents of a place. The quality of life is a subjective notion and a limited concept that weighs the extent to which the 'desires' of people are met. These desires may not be the same across the different sections of society and thus are sensitive to individual choices.

On the other hand, liveability traverses an extra mile to include every member in the society and is defined as the creation of that utopian environment in which all people achieve a high standard of living by having access to basic human needs along with city infrastructure and a safe living environment. Liveability, although inclusive of the 'desires' of the citizens, gives more weight to human needs than human wants. The second important difference is between the definitions of development and liveability. While development is a measure of the economic prosperity of a region, liveability is an instrument measuring the welfare pulse of the people and the region. At the same time, it has to be borne in mind that urbanization, although a significant component is not an absolute parameter for gauging the degree of liveability of a city.

To find the liveability index of a particular urban area we need to look at eight pillars (Fig. 4.1). These are the: Demographic pillar, Education pillar, Health and medical standard pillar, Safety pillar, Housing option pillar, Socio-cultural/natural environment pillar, Economic environment pillar and Planned environment pillar.

Demographic pillar includes population, its migration and labour participation. Education pillar includes education level and its occupation level. Health and medical standard pillar includes health parameters and health support infrastructure. Safety pillar includes crime and road accidents. Housing option pillar includes housing cost and its availability and urban household crowding. Socio-cultural/natural environment pillar includes supporting infrastructure, natural

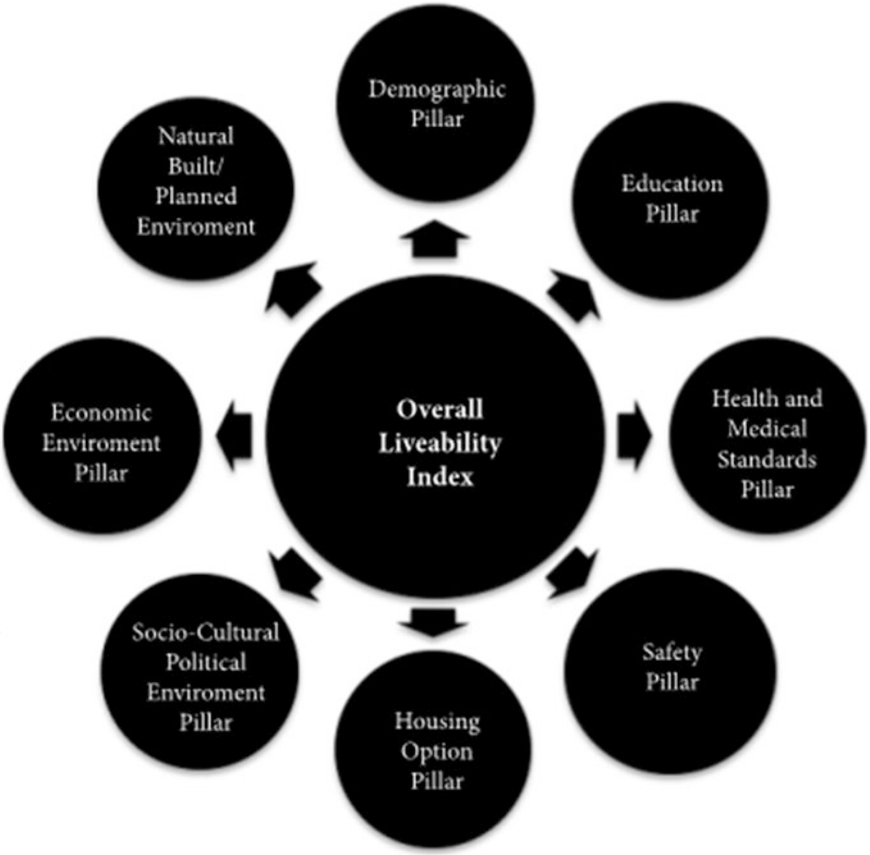


Fig. 4.1 Pillars of liveability index

environment and cultural environment. Economic environment pillar includes income and environment, economic infrastructure, business environment, purchasing power. Planned environment pillar includes communication and transport.

4.9 Migration in Indian Cities

Internal migration is on the rise in India. Lack of opportunities, unequal distribution of resources, violence and natural calamities are the main reasons that lead to the heavy influx of people from rural areas and smaller cities into bigger urban cities. The estimated net migration rate in India for 2011 has been calculated at 0.05 migrant(s)/1,000 population. Rural–Urban migration rates for intrastate migration flows are higher when compared to the interstate flows. While the metropolitan cities of Delhi, Mumbai, Bengaluru, Chennai, Kolkata and Pune experience heavy inflows of migrant population, the cities of Srinagar, Coimbatore, Agra, Varanasi and Amritsar see their respective populations leaving.

4.10 Stimulating the Role of Governance

4.10.1 Decentralized Government at the City-Level

India has a 3-tier system of Government, with the power decentralized between the national, state and local (district) governments. Considering the expansive nature of operations in the cities (along with sprawling cities themselves), there is a need for an actively involved and responsive government mechanism at the city-level. Such form of government will have the efficiency to combat all challenges posed by the eight pillars (covered under our study) and make the lives of citizens more prosperous. City-level government should start by setting a vision for its city, "To make the city the best in the country". Thereby, it should take actions that aid in realizing this vision. A few measures include:

- Improved public administrative machinery; a goal that can be accomplished by establishing employment exchanges, public distribution systems, population control departments, protection of women and empowerment cells, public grievances department and consumer protection forums.
- Increased public investment on public infrastructure (hospitals, dispensaries, educational institutes, banks, roads, highways, mass transit facilities, telecommunications, rail, electricity and water supply, sewage control, public housing and energy).
- Public safety through security surveillance and enforcement of stringent laws in all spaces.
- Environment conservation measures. Apart from controlling traffic (which contributes to air and noise pollution), the government should encourage Greener Projects (business initiatives that aim to contribute to society but with a minimum carbon footprint). For instance, eco-tourism projects have the dual objective of adding to the economic base (through creation of employment opportunities) and preserving the environment by adopting energy conservation measures (wind mills/watershed). In addition to this, the government should adopt a policy of penalty and subsidy, conditioned upon the type of impact a project has on the environment.
- Establishment of consumer markets and banks in close proximity to residential colonies that cater to the needs of the consumers in that particular area.
- Increased recreational facilities for citizens (maintained and protected heritage sites such as monuments, parks, clubs, restaurants, libraries, art galleries, theatres, auditoriums and museums).
- Strong involvement in city level planning programs and strategic public/private and city level partnerships.

4.10.2 Policy Initiatives and Funding to Cities

The Central/State Government should come up with policies that ensure both economic and social sustainability of cities. A slew of reforms which were announced as part of the 11th Five Year Plan are being implemented across the nation. Many model laws intending to initiate reforms in areas, like real estate, higher education, agriculture and others, have been initiated in Parliament and several, like the ones pertaining to medical education, right to education and industrial disputes have been passed at the Central Government level. However, the implementation of these bills by the States with the adoption of State level reforms has been an area of concern. At the same time the government should allocate funds to projects and programs that carry a promise to enhance citizen welfare and city liveability.

To cite a case, the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) is a reforms-linked funding initiative of the Government to empower cities to focus on urban renewal, upgrade their infrastructure, address the issue of slums as well as increase their capability to raise funds through credit ratings, among many other areas of reform. JNNURM has met with varying results in cities across the nation, depending on the capability and clarity of the city to envision, implement and sustain these changes.

In addition to this, funding and assistance (in the form of advisory services) from international bodies, like the World Bank, International Monetary Fund and the Asian Development Bank, for local level developments can also prove beneficial.

4.10.3 Effective Land Use and City Planning

The planning of Indian cities lags behind in time, while the cities grow explosively. From the overall vision to the land use planning of each city block, clarity in the urban strategy is a key step in achieving any goals a city might have. In fact, goals, such as attracting investment or increasing employment, have a distinct relationship with city planning and translate directly into physical and tangible requirements, like office complexes, improved infrastructure or more transport facilities, all of which need to be factored in by urban planners.

The ad-hoc approach that plagues most cities only sounds their death knell. It is imperative for city authorities to wake up to the impending disaster that could be a result of poor (or lack of) planning. Learning from previous schemes, the government is also emphasizing the importance of planning. Rajiv Awas Yojana (RAY), another recently launched central Government scheme, which focuses on making India slum free, is mandating that cities prepare detailed plans or upgrade their existing ones before they can avail themselves of the scheme.

Each city has got its own set of strengths. It might have a large pool of human resources or natural endowments; the strategy is to identify such advantages and plan an urban paradigm based on these strengths that helps in achieving the twin goal of economic growth along with sustainable development. However, it should also focus on growing along the pillars where it does not fare well. This is a competitive advantage that each city has to discover for itself and remember that it has to be created and not inherited. For example, Jaipur is endowed with heritage sites, so it should translate this tourist attraction into monetary gain by adopting eco-friendly measures. At the same time, it should also uproot the social evils of high infant mortality rate that plague the city. Based on these distinctive traits the cities should try to attract adequate foreign direct investment inflows.

4.10.4 Role of Civil Society Groups/NGOs

A city, apart from being an economic centre, is a society representing groups. Civil society is one such group that strives to ensure the wellbeing of all people and functions as a separate entity from the state. By adopting people-centric policies, the civil society actors maintain stability, equality, prosperity and peace in society. These groups take the form of Non-Government Organisations (NGO), self-help groups, business associations, advocacy groups, faith-based groups, charities and trade unions and ensure transparency in the system. For instance, an NGO propagating equal human rights prevents the outbreak of a riot or any other form of communal violence by working for the welfare of minority groups and thus assisting in establishing a peaceful society. Governments should encourage, aid and extend beyond the public sector to include such bodies in its mandate, as they are devoted to the needs of the weaker members of the society.

4.10.5 Role of Private Players and Technology

Inadequate public infrastructure is one of the greatest bottlenecks that impede production and hence prosperity. Investment by private players on roads, highways and public transit not only reduces the woes of daily commuters but also aids in avoiding the continuous degradation of present resources and infrastructure. There could be private transportation management associations (shuttle service) that provide transportation in a particular area. At the same time, another option, like car-sharing, should be exercised as this helps in reducing traffic congestion and reducing the carbon footprint.

Use of advanced technology in infrastructure can also lead to increased standards and productivity. Technology of the developed cities of the world can be adopted or replicated in the Indian cities.

4.10.6 Role of the Public

All the initiatives, policies, plans and models of the government or other actors of the society are aimed at one common goal of public welfare. To attain the intended results, the beneficiaries should themselves be involved in the whole process. There should be direct interaction between the public and the government (or other players) so that the desired objectives can be instantly met. The needs and problems of the public through various forums should be directly addressed so that an immediate solution is granted. For capacity building and a prosperous society, collaborative actions between national, state and local governments and within the city, between government, private business players and civil society members are needed. Only when all these bodies work in an environment of partnership, under a common vision, can the far-fetched dream of a perfect city be realized. Although baby steps have been taken, the road ahead is far too long.

Good Practice Urban Agriculture has to be linked with food system planning and land use pattern of a city and surroundings. As urban planners we should realize that every activity on Earth has some spatial implications. Hence, good practice urban agriculture, food system and land use patterns are closely linked and are to be brought under the purview of regulatory framework. In consonance with this realization, the following actions are suggested:

- Identification of land for urban development with agriculture;
- Prohibition of filling in major water bodies and marshy lands;
- Specific land uses for waste land, including useful tree plantation and city farming;
- Agricultural land within the metropolitan area to be protected under the provisions of Town and Country Planning Acts;
- Underutilized areas on long banks of rivers or canals can be developed for urban-agro forestry, including parks and gardens;
- Planting fruit trees in the periphery of existing city parks, which can generate employment and municipal income for maintenance of parks and other such areas;
- New townships and housing estates should incorporate city farming, horticulture etc. from the planning stage;
- Derelict land, abandoned brick fields and other areas near industries should have an ecological restoration program making it part of the planning condition while granting permission;
- Revitalization of canals which will encourage aquaculture and fish production;
- Garbage dumping sites and sewage fed fisheries in east Kolkata are already producing substantial vegetables and fish through pisciculture, and the concept could be extended to other areas; and
- In rural fringes and non-municipal urban areas of the metropolitan areas, there is the potential for poultry, diaries and livestock development, which could be linked with both rural and urban areas in the surrounding region.

4.11 Conclusions

There must be a long term regional perspective to make cities sustainable through urban agriculture. The rivers, canals, agricultural lands and forests in metropolitan areas are connected with those in the surrounding region. Urban agriculture and associated developments can be a link between urban and rural areas. In the present context 'Good Practice Urban Agriculture' should be incorporated as a type of new land use amongst all other land uses.

References

Gupta RK (2011) Change detection techniques for monitoring spatial urban growth of Jaipur city. Inst Town Planners India J 8(3):88–104

Saini SS, Kaushik SP (2011) Land use changes in Haryana sub region of Chandigarh periphery controlled area: a spatio-temporal study. ITPI J 8(4):96–106

Smit J, Ratta A, Bernstein J (1996) Urban agriculture: an opportunity for environmentally sustainable development in Sub-Saharan Africa. Post-UNCED series, paper no. 11, the World Bank

Chapter 5
The Expanding Urban Fringe: Impacts on Peri-urban Areas, Melbourne, Australia

Michael Buxton

Abstract The resources of peripheral urban areas are under unprecedented threat because of the rapid conversion of rural land for urban purposes. Yet these resources offer significant long-term advantages to cities by increasing their resilience in times of rapid change. Cities which retain the values of their hinterlands may be those which survive best this century. The fate of the peri-urban area of Melbourne, Australia, and associated decision making processes, provide a case study of the pressures on peri-urban regions and the common inadequacy of government responses. Australian cities are characterised by two co-existing city types. Dense, nineteenth century mixed use inner urban areas characteristic of European cities are becoming denser. Yet new outer urban development continues the detached housing model and separated land uses typical of North America and adopted in Australia early in the twentieth century at some of the world's lowest housing and population densities. Spatial difference is matched to social inequity. Higher income, tertiary educated, professionally employed households are concentrated in service rich inner and middle ring suburbs and selected outer urban areas, while lower income households without tertiary qualifications are concentrated primarily in service poor outer urban areas. Australian cities consume land at one of the world's highest per capita rates, continually transforming nearby rural areas with high natural resource values to urban uses. These cities also affect broader non-urban areas. People are attracted to semi-rural lifestyles within commuting distance of metropolitan areas. Unless governments intervene, land is subdivided into rural-residential lots and agricultural pursuits relocate further from cities. Tourism and recreational developments are constructed on rural land and a range of other urban related land uses gradually emerge until the rural nature of these areas is irrevocably altered. Every Australian capital city adopted a metropolitan strategic spatial plan after 2000 which attempted to limit further outer growth into urban hinterlands through a range of urban containment policies.

M. Buxton (✉)
RMIT University, Melbourne, Australia
e-mail: michael.buxton@rmit.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_5,

However, none of these plans succeeded in containing the urban sprawl or in radically changing the dominant model of outer urban development from detached housing with little variation in lot size or house types, large average lot sizes and separated land uses. Every State strategic plan has been substantially modified or abandoned. This chapter describes the impacts of metropolitan centres on peripheral urban areas, examines development pressures on these areas, why they are important to cities and why Australian cities continue to spread despite stated policies to the contrary. The city of Melbourne, Australia, is used as a case study, but broader conclusions are drawn for other cities.

Keywords Urban fringe · Peri-urban planning · Development pressures · Lot size · Australian cities

5.1 Introduction

Peri-urban (peripheral urban) regions are those areas into which cities expand (Burnley and Murphy 1995; Budds and Minaya 1999) or which cities influence (Houston 2005). Their extent is changing constantly as the influence of cities on their hinterlands increases. The belt of peri-urban land is either diminished if it is finite, or its inner and outer boundaries move constantly outward as cities expand. All outer urban land development thus occurs initially on peri-urban land. Melbourne's outer urban growth illustrates this process of continual expansion, consuming large areas of agriculturally productive and environmentally significant land (see Fig. 5.1).

Metropolitan areas exert a range of pressures on peri-urban land. Land on the urban periphery becomes regarded as an urban land bank awaiting use, a "zone of impermanence" or the "residual zone" (Pryor 1968, p. 205). Rural land in this peripheral zone becomes regarded as "an area of transition, where land, as well as occupational and social structure, await transformation into suburbia" (Friedberger 2000, p. 503). This suggests a distinct settlement pattern, neither urban nor rural but an interface (Audirac 1999). Peri-urban areas are commonly regarded as neither urban nor rural but a new and distinct form of settlement (Ford 1999; Nelson and Dueker 1990). Their dynamic nature identifies them as a "middle landscape" between the boundary of an urban area and rural pursuits (Davis et al. 1994, p. 46), in contrast to truly rural areas situated well beyond commuting range of urban areas and isolated from urban markets (Nelson 1999, p. 138).

Peri-urban regions can be defined structurally by their physical structure and form or functionally or by a combination of spatial and functional factors (Buxton et al. 2006). Structural characteristics include lower population and building densities compared to urban regions, heterogeneous land uses and rapid rates of change; while a functional analysis of social and economic roles is both interactionist and system based. The influence of Australian metropolitan areas is heightened by the unusual concentration of population, with three quarters of

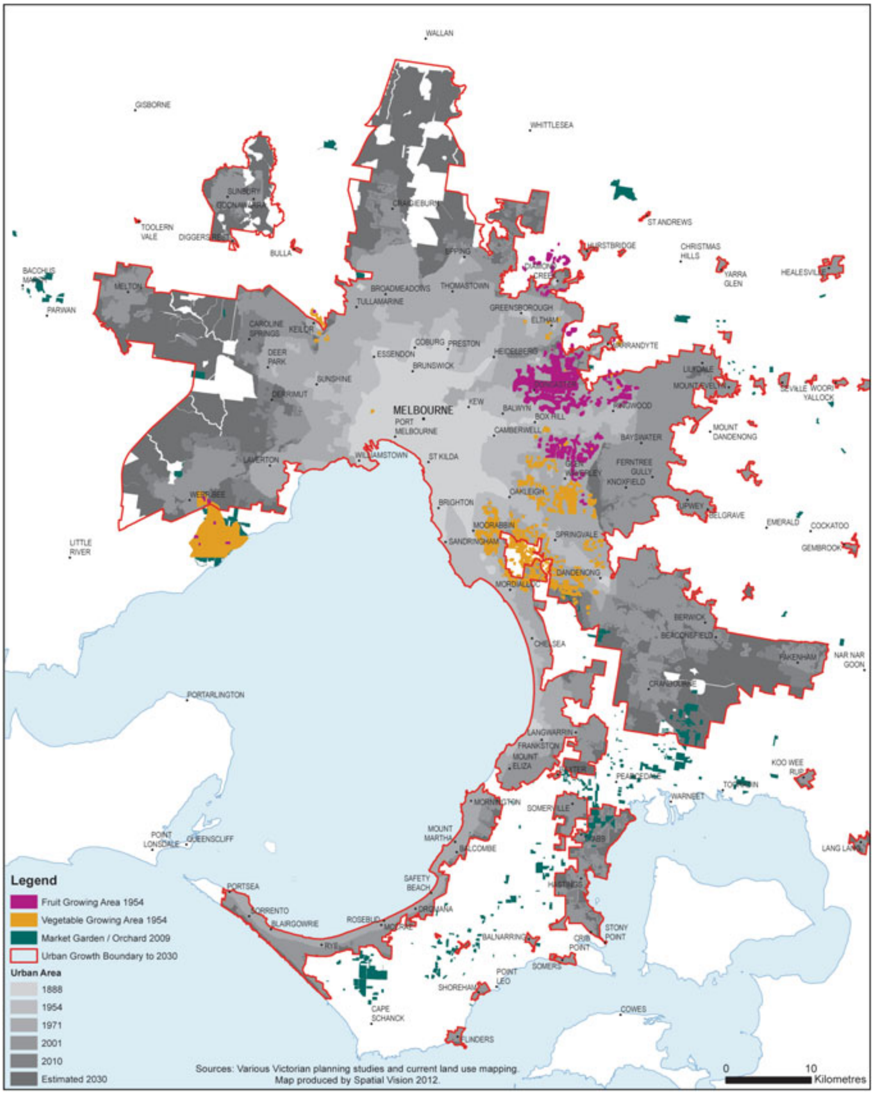


Fig. 5.1 Melbourne urban growth impact on agriculture (1888–2030). *Source* Compiled by RMIT University and Spatial Vision (2012)

Australians living in 17 cities of 100,000 people or more, and 60 % in the five largest cities (Commonwealth of Australia 2010). This concentration increases pressures on surrounding peri-urban areas as cities expand and peri-urban areas themselves attract increasing populations and provide resources to nearby cities. New peri-urban residents are able to easily use metropolitan resources such as employment opportunities and entertainment facilities. The attractiveness of peri-urban areas is further increased by their high natural amenity (Barr 2005).

Peri-urban areas in many countries can be relatively stable, such as green belts in the United Kingdom (UK), Europe and many other countries, often protected over long periods of time. Such green belts are not areas in transition, but are highly rural, and are the location of productive agricultural and other rural activities, and often significant environmental values. But generally, peri-urban areas are subject to constant and often rapid change from powerful nearby urban influences. They are the fastest growing regions in many countries and hold high strategic, spatial, social, economic and environmental significance. The processes of peri-urban development are disputed. Change is sometimes regarded as orderly (Burnley and Murphy 1995) generally in the form of concentric rings, or alternatively as disorderly (Daniels 1990), even chaotic. The structure of peri-urban areas under change often takes the form of a mosaic characterised by heterogeneous land uses, "a polyglot of landscapes" (Nelson 1999, p. 137). Audirac (1999, p. 13) describes the United States (US) peri-urban areas as "a jumble of rural, urban and suburban, light industrial and high-tech landscapes … mixed-use-developments featuring hotels, office and recreation space, convenience retail, shopping malls and cultural centres, and undeveloped farmland", along with warehouses, motels, franchised outlets, hobby farms, gated communities and mobile home parks. Audirac (1999) and Anderson et al. (1996) also identify a range of other urban related uses, such as service facilities including airfields, landfills, utilities, transport infrastructure and transitional open space used for agriculture or land speculation.

Dispersed cities developed quickly from the 1950s in Australia, modelled on American cities. Urban fringes in the US developed complex structural and functional relationships with metropolitan areas through a process of defined stages from monocentric to polycentric (Leinburger 1996; Audirac 1999). Gillham (2002) shows that during the 1970s and 1980s over 95 % of population growth in the US took place in suburban centres. Most of this land was expropriated from exurban areas. Melbourne's development particularly since 1945 illustrates this trend.

5.2 Melbourne's Peri-urban Zones

Melbourne's peri-urban area consists of inner and outer peri-urban zones (see Fig. 5.2). The inner zone is a conventional green belt of 8,829 km^2 extending between a legislated Urban Growth Boundary (UGB) at the metropolitan edge and the rural boundaries of 17 fringe area municipalities. This zone corresponds to Melbourne's official green belt. The outer zone consists of the next belt of eight rural councils and their regional cities and townships extending in an arc. McKenzie (1996) defined the peri-urban area functionally as the area within daily commuting distance of a city extending to a distance of over 100 km from that city's CBD.

Melbourne's green belt, was officially established in the 1971 Melbourne strategic plan, *Planning Policies for the Melbourne Metropolitan Region* (MMBW

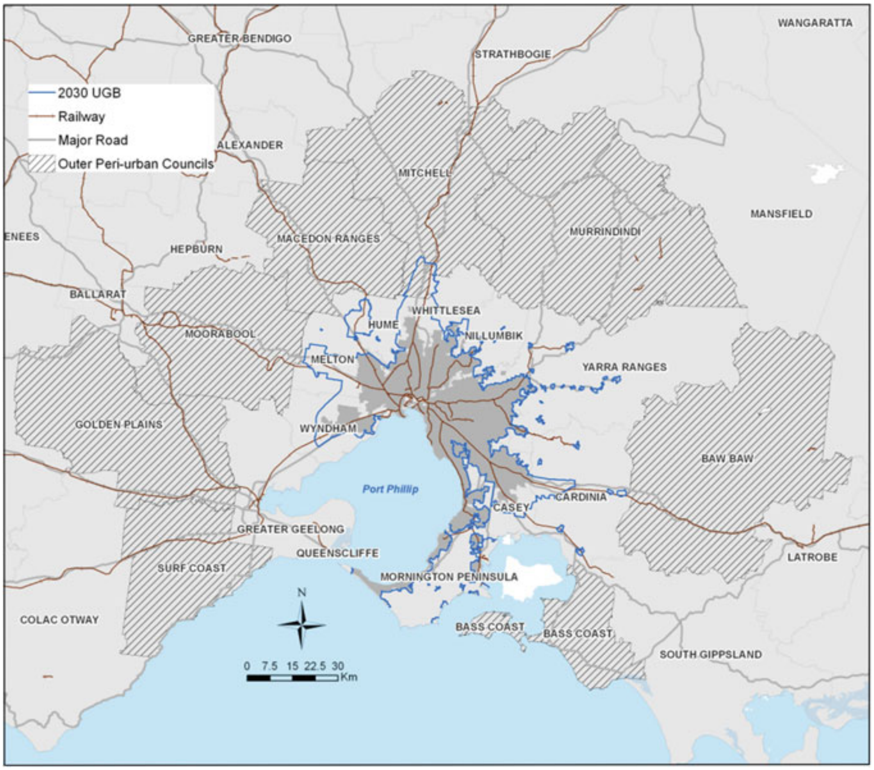


Fig. 5.2 Inner and outer peri-urban Melbourne. *Source* Buxton et al. (2011)

1971). The 1971 plan was developed by the metropolitan planning authority, the Melbourne Metropolitan Board of Works (MMBW) and was Melbourne's first regional plan. The area affected was revised from 1,800 to 5,029 km^2 and extended to Westernport Bay, the Dandenong Ranges, and far to the north, south and west of Melbourne. The non-urban zones, including nine green wedges, covered 2,400 km^2 or about half the MMBW planning area.

The non-urban countryside would define the outer limits of urban development between the urban corridors and was intended to "provide relief from continuous building development. The preservation of countryside near to established population is a most important consideration" (MMBW 1967, pp. 14–16). Its other functions were to protect areas of high natural amenity including landscapes and other environmental features such as native vegetation, primary production, deposits of minerals and other resources, to maintain rural activities and to provide locations for major public utility installations and large institutions. More recently, the health benefits of retaining rural peri-urban values, and their potential as healthy food sources have been recognised (Giles Corti 2011), principles consistent with the original objectives.

The Minister for Local Government, Hamer, reinforced the British green belt tradition and the importance given to a green belt by theorists such as Lewis Mumford (1961) as an end in itself. Hamer stated as early as 1966 that a widely dispersed metropolis, unless carefully planned, raised a threat to the surrounding countryside, and "nobody could happily contemplate a future metropolis of seemingly endless suburbia spreading outwards indefinitely. It must be strongly emphasised that future planning should take full account of the surrounding countryside as a vital part of the metropolitan environment" (MMBW 1967, p. 29).

Wale (2003) argues that the 1971 plan tried for the first time in Victoria to change landowner expectations and eliminate land speculation in rural areas. It did this by confining urban growth to growth corridors separated by permanent green wedges, or non-urban areas, in a plan which has defined the direction of urban growth and the shape of Melbourne over the last 40 years. All future urban development was to be confined to the growth corridors which would not be wider than 4–6 miles. Physical and economic constraints on development were identified and these helped to define the features to be protected in the green wedges. Over 4,000 objections were received to the exhibited plan (MMBW 1974, p. 12) but unlike the situation in Sydney, the MMBW and the Government held firm and rejected the great majority of objections to green wedge zonings.

The MMBW and the government of the day regarded the protection of the natural resources of the green wedges as a central element of long term metropolitan planning. An urban growth boundary, drawn around the limits of urban corridors and the rest of the metropolis was protected under planning legislation. Two major studies were undertaken by the MMBW into non-urban zones in the mid 1970s. The first was the *Review of Planning Policies for the Non-Urban Zones* (MMBW 1977, p. 12) and the second was the *Metropolitan Farming Study* (Aberdeen Hogg and Associates 1977). Both studies made strong recommendations aimed at ensuring the continuation of farming, removal of urban expectations and achieving certainty through permanent non-urban zones. The non-urban zones review outlined the importance of non-urban zones in terms of State production of agricultural products and showed that in many cases almost the whole of the State's supply was produced in the Melbourne Planning Region. It reaffirmed the importance of retaining corridor-green wedge policy.

The farming study argued for high minimum sub-division sizes up to 80 ha, strong use controls, the preservation of large metropolitan farms and the introduction of more restrictive uses in environmental zones. The study stated that "when a farm is sold it tends to be subdivided to the minimum lot size allowable. This reduces the capacity of the non-urban zones to achieve the desired planning objectives of retaining agricultural production and rural landscape" and concluded that "it is important to realise that any production that is lost through sub-division or urban incursion may not be capable of being produced elsewhere, or, of it is, it would involve higher prices to the consumer" (Aberdeen Hogg and Associates 1977, p. 8, 1).

This early planning has continued to influence the shape of Melbourne, with the growth corridor and green wedge model of urban form still recognisable, though much altered. The processes of both outer urban growth into peri-urban areas, and of the development of peri-urban land, will now be examined.

5.3 Urban Encroachment into Peri-urban Areas

Governments failed to limit the spread of Melbourne in two ways. Firstly, most notably in the metropolitan plans of 1954 and 1971, governments could have limited the consumption of outer urban land by adopting higher urban densities for new suburbs. The land savings from higher outer urban densities have been disputed (McLoughlin 1991) but have been shown to be considerable (Buxton and Scheurer 2007) and were recognised by planners as early as the 1954 plan (MMBW 1953). In 1990, the Victorian State Government finally adopted a minimum average density requirement of 15 lots per hectare for new urban corridors, an increase of 50 %, but this was repealed by the Kennett State government 3 years later. This was a lost opportunity to limit the spread of Melbourne into valuable agricultural and environmentally significant land.

Secondly, successive governments failed to adhere to the corridor-wedge principle. Governments were unable to resist rezoning ever more outer urban land to cater for forecasts of population increase. This path dependent approach has defined Melbourne's planning and led to increasing impacts on the inner peri-urban zone. Governments have proved to be unable to even implement their own plans, most noticeably, the Labor government after 2002. Its proposal to shift up to 45 % of planned growth from the urban fringe was never implemented and abandoned in 2008.

Initially, the Cain Labor government in 1990 added 7,600 ha of green wedge land to the Werribee urban corridor, and 3,300 ha to the south-eastern urban corridor. A general move away from State Government strategic planning occurred during the 1990s and this also led to the loss of land from green wedges. Between 1996 and 2002, over 4,000 ha of non-urban land in green wedges was approved for residential subdivision or related urban uses (Buxton and Goodman 2002). In addition, the former Kennett Government created 1,369 residential and rural residential lots in the environmentally significant Upper Yarra and Dandenong Ranges region with about 800 ha of land being excised from the green wedge in this region (Buxton and Staindl 1999).

The Victorian Government passed the *Planning and Environment (Metropolitan Green Wedge Protection) Act* in May, 2003. This defined an Urban Growth Boundary (UGB) and green wedges, required prior ministerial approval before councils could initiate planning scheme amendments, and parliamentary ratification for any change to the UGB and subdivision controls in a total of 17 fringe area planning schemes. However, powerful parliamentary regulatory control proved to be no obstacle to breaches of this Act as both major political parties acted together to constantly expand the boundary, in December 2003 by 1,610 ha; in November 2005 by 11,132 ha, increasing the size of urban corridors by 34 %; and in 2010 by 43,000 ha. These expansions removed all incentives to transfer metropolitan growth and for the more efficient use of urban land. Instead of reducing new corridor housing from 39 to 31 % in accordance with the strategy *Melbourne 2030*, these UGB expansions led to a corridor growth of 47 %. Planned new corridor dwellings therefore rose from 180,000 in 2004, 225,000 in 2005 at a net residential density of 11 dwellings per hectare, to 284,000 in 2008 at 12.5 net dwellings per hectare.

The Baillieu Coalition government in 2012 announced an expanded UGB of another 6,000 ha. This represented a 30 year land supply at a low 12.5 lots per hectare, a supply probably unmatched anywhere in the world. A comparison with the Portland UGB illustrates the waste and lost opportunity of this continual expansion. Whereas the 2010 Melbourne UGB expansion of 43,600 ha will accommodate just 134,000 new houses, the Portland Metro Council in 2010 recommended an expansion of the Portland boundary by between 6,000 and 12,000 ha to accommodate another 900,000 to 1.2 million people and accompanying jobs.

5.4 Development Impacts on Inner Peri-urban Resources

Strong regulatory land use controls were used until the early 1990s to protect the resources of Melbourne's inner and outer peri-urban regions. Governance arrangements were critical to this protection. Until 1985, the Melbourne Metropolitan Board of Works (MMBW) was responsible for developing and administering a metropolitan planning scheme for the urban and non-urban areas of Melbourne. The MMBW introduced a number of rural zones with minimum subdivision controls up to 80 ha in the general farming zone. Strong land use controls prevented the use of rural land for urban related purposes. During the 1970s, the government also introduced regional planning for the inner green belt, establishing regional planning authorities for the Mornington Peninsula and the Upper Yarra Valley and Dandenong Ranges. Legislation and strong directive policies protected these regions from urban and rural-residential subdivision in order to encourage the continuation of agriculture and other rural uses.

Forms of land tenure were identified as the key factor with the capacity to alter these areas from a resource intensive to an urban condition. Land subdivision was the fundamental influence on forms of development, progressively enabling a wide range of land uses. Existing lots posed a significant threat. In the Upper Yarra Valley and Dandenong Ranges region, for example, about 62 % of 17,273 rural lots did not contain dwellings and 42 % of the 43,334 urban lots were vacant with the potential to double through subdivision (Loder and Bayly 1980). The regional planning authority concluded that housing development on existing lots would permanently change the region's productive value and landscapes. Their development would introduce incompatible urban related uses to rural areas and decrease the comparative rate of return from agriculture by raising the price of rural land, leading to a cycle of land speculation and increased rural subdivision. The authority also identified potential impacts on habitat through the potential loss of vegetation; reduced water yield from logging; and on increased fire risk to houses constructed in some of the world's most fire prone areas. Reduced economic returns to the region from recreation and tourism, and high infrastructure costs through outer urban road construction and service provision were also assessed (UYVDRA 1980).

In response to these perceived threats, the authority, government and local councils introduced or maintained regulatory limits to rural subdivision through minimum subdivision sizes of between 25 and 60 ha, and prevented the further subdivision of extensive urban areas in environmentally significant locations. They amalgamated thousands of existing titles in restructured lot patterns and the State government purchased thousands more lots and added these to existing parks. This remains Australia's most radical policy response to the potential of peri-urban development to alter a region's functioning characteristics.

The results of this planning are evident today. Melbourne's inner peri-urban (green belt) area is the second highest producer of agricultural products in the State of Victoria with a gross production in 2001 of $890 million from 4,010 farms, although the true value may be closer to double this figure (Langworthy and Hackett 2000). The agricultural output per hectare of this area is the highest in Victoria, at least three times greater than any other region in the state and four times the state average. Agricultural activities in 2004 occurred on 64 % of land in Melbourne's green wedges (PPWCMA 2004).

In the Upper Yarra Valley region, the removal of urban expectations controlled land speculation and prices, and increased the capacity for agriculture to persist by maintaining comparative rates of return and the potential to innovate. This region is well known internationally for its attractiveness and diversity of resources. It extends from the eastern edge of metropolitan Melbourne and includes a population of 137,000 people in an area of about 2,500 km^2. It is the most important economic and environmentally significant part of Melbourne's inner peri-urban area, containing major water resources, food production, forest products, landscapes, recreation and tourism, and natural, historical and archaeological features. Government action to protect the resources of this region has maintained options and made possible significant local innovation which development would have prevented. Innovative agriculture has made particular contributions to adaptive capacity and regional resilience, illustrated by the history of the Upper Yarra Valley wine industry. From 35 ha under vineyards in 1973/1974, by 1998 there were an estimated 114 vineyards and 50 wineries on about 2,500 ha with an estimated turnover of $100 million annually attracting over 600,000 visitors a year. Between 1986 and 2001, farms engaged in viticulture increased by 998 % and the area in grapes by 777 % while farms devoted to flowers and nurseries increased by 31 % and in area by 29 % (Parbery et al. 2008). The protection of agriculture and environmental values, in turn, facilitated a major increase in tourism and recreation. Today, this region is Victoria's second most visited tourist area with over 2.5 million visitors a year.

The fate of these inner peri-urban areas demonstrates that closer forms of land tenure, particularly residential and rural residential subdivision, lead to a range of reciprocal impacts, such as threats to continued agricultural production and biodiversity, which decrease resilience and ultimately shift peri-urban regions to urban or quasi-urban states. Forms of governance are critical elements in maintaining, increasing or decreasing peri-urban resilience.

5.5 Melbourne's Outer Peri-urban Region

The State's total peri-urban region accounts for about one quarter of the State's land area but half of the agricultural production value (Houston 2004). Five municipalities in Melbourne's outer peri-urban belt contributed over 5 %, or $390 million, of the State's $7.5 billion farm business turnover in 2006, an increase from 4.1 % in 1997. These municipalities contain almost 2,500 farm businesses, or 7.6 % of the total farm businesses in the state, an increasing proportion, largely a product of growth in small farm numbers. The number of small peri-urban farm businesses has remained stable since 1997 while declining across the state (Buxton et al. 2011).

A study of two scenarios for Melbourne's outer peri-urban region has also demonstrated that land use and development posed the greatest threat to resilience. Land tenure was the key factor in a complex network of interacting variables and reciprocal relationships. Across the study area of eight outer peri-urban municipalities, 53,629 rural lots currently exist, 80 % less than 10 ha in size, of which 28,802 are estimated to contain occupied dwellings. This existing rural development capacity of 24,827 additional dwellings plus the potential total subdivision capacity of 6,881 parcels provides a potential development capacity of 31,708 dwellings. Population growth rates of about 1.8 per cent per annum are expected to increase (Buxton et al. 2011). Under a business-as-usual scenario, dwellings will be constructed on most of these lots by 2025 with development pressure greatest in areas closest to Melbourne and on major transport corridors (see Fig. 5.3).

The study concluded that a range of reciprocal impacts would be exerted across sectors reinforcing the stress experienced by socio-ecological systems. It assessed development impacts as detrimentally affecting agriculture, biodiversity and water resources, leading to high costs in the provision and maintenance of social and physical infrastructure. The values of the outer peri-urban area would be degraded to the detriment of the region's inhabitants and its potential future value to Melbourne and large regional urban centres. Residents would be further exposed to risks from climate change and extreme weather events. A cycle of land speculation, small lot subdivision and higher land prices would progressively lower farm viability and eliminate agriculture.

Other reciprocal impacts also would arise from more intensive rural development. Construction of a further 16,252 dwellings on rural lots in 14 peri-urban catchments would increase stock and domestic dam capacity by 68,262 ML or

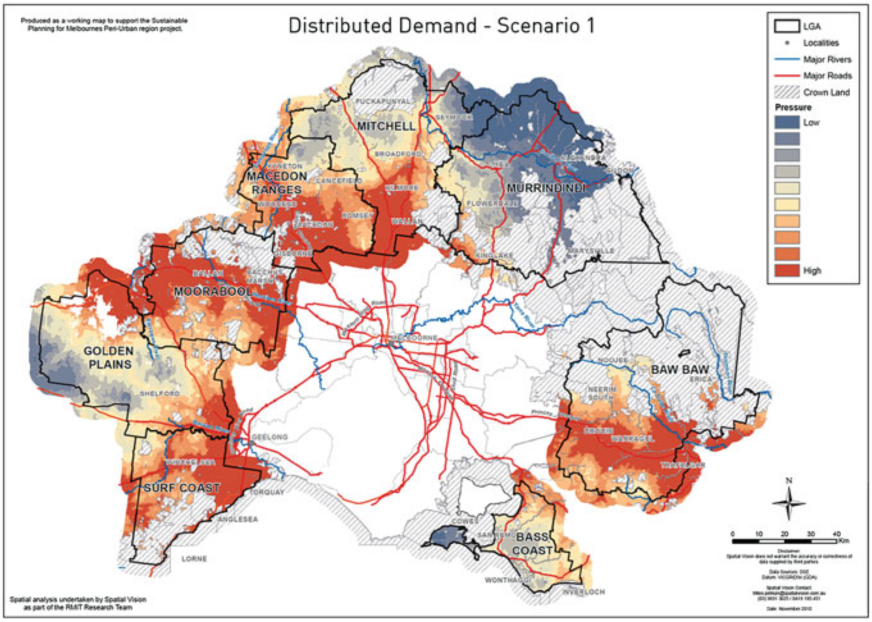


Fig. 5.3 Peri-urban attractiveness. *Source* Buxton et al. (2011)

35 % leading to major reductions in stream flows. Most remnant native vegetation is located on large lots of 40 ha or more comprising 28 % of the rural peri-urban area while 71 % of vegetation with a bioregional conservation status is situated on these lots. The retention of larger lots is an example of precautionary planning maintaining a region's resilience by retaining future options for agriculture and protecting landscapes and biodiversity at least until future global and environmental conditions are clarified (Buxton et al. 2011). In this sense, they represent a significant component of the region's future.

Nevertheless, regulatory land use planning tools had been commonly mismatched to land characteristics and conditions in the outer peri-urban region with the strongest zones and other tools such as overlay controls used rarely. For example, relatively high proportions of the remaining native vegetation on private land have relatively little protection, with 81 % placed within the weakest rural zone, the Farming Zone (225,800 ha), and only 13 % (35,140 ha) in the strongest zone, the Rural Conservation Zone (Buxton et al. 2011).

An alternative development scenario to path dependent development of Melbourne's outer peri-urban region was also modeled by Buxton et al. (2011). This scenario assumed a future to 2040 where agriculture would continue, native vegetation would remain, and water resources and existing landscapes were largely retained. This scenario required policy intervention to achieve the alternative scenario, in contrast to the business-as-usual scenario which under existing policy settings would lead to the development of most vacant lots along transport corridors and near the Melbourne boundary by 2025. New policy measures examined included the transfer of development rights on rural lots to townships, the maintenance of strong rural subdivision controls, rural lot restructure and amalgamation, and limitations on rural housing construction. A number of options for transferring demand from rural to township locations were modeled. The transfer of rural development capacity of 16,250 dwellings to townships would require about 464 additional ha of land, and the transfer of an excess demand by 2040 for 9,458 rural lots would require 270.2 ha of township land, at a density of 35 dwellings/ha. The land required for township expansions under these projections is a small proportion of the land required for rural residential development of existing or newly subdivided lots in rural locations and would allow the continuation of rural activities. Modelling was also carried out on the impacts of restricting development on rural lots in proclaimed water supply catchments to a minimum developable density of one dwelling per 40 ha. This density would reduce the maximum number of future rural dwellings from the potential 7,178 to 343. This in turn would substantially reduce the number of future farm dams and diversion of stream flow. Regulating to prevent dwelling construction on multiple lots in single ownership would also substantially reduce the number of rural dwellings.

5.6 Cross-Sectoral Policy and Neoliberal Governance

Land development has always been a political activity in Victoria. Sandercock (1979, p. xi) comments that "land speculation and land scandals…have been so widespread in Australian society since the early nineteenth century that they deserve to be dubbed 'The National Hobby'". Until the early 1990s, the balance exerted by responsibilities shared between a State government, metropolitan and country planning authorities, regional planning authorities and local councils, along with a tradition of regulatory planning, ensured consistent protection of much of Melbourne's broad peri-urban area. However, neo-liberal planning arrived in Melbourne in 1992 with the election of the Kennett coalition government. This government acted quickly to deregulate Melbourne's planning, adopting a facilitative, discretionary model (Maclellan 1993). Policies which had operated to protect the green belt since 1971 fell into disuse, and rural zones were deregulated, largely eliminating prohibited uses (Buxton et al. 2005).

The Labor government, after 2002, re-regulated rural zones for Melbourne's inner and outer peri-urban areas, largely preventing the location of urban related uses in these areas. However, in 2012, a new conservative coalition government announced the deregulation of the Victorian planning system in the most radical system alteration in the State's history. These changes include the liberalisation of some rural planning zones and other controls to allow substantial urban related uses and developments in rural areas.

Progressive alterations to strategic plans for Melbourne and the lack of long term bipartisan political support for peri-urban planning after the early 1990s consistently rewarded land speculation by development companies. A 2003 government decision to provide a constant 15-year supply of land for development by extending the UGB (Delahunty 2003, p. 1) provided a signal to developers where to purchase land immediately outside urban growth corridors in the expectation of windfall gains when the UGB was extended, bidding up the land price. Most of the land adjoining the four urban growth corridors was purchased or optioned by development companies (DPCD 2008). These companies then pressured the government to amend their rural land zonings to an urban designation (Millar et.al. 2007). The State government accepted a neoliberal and developer narrative that the UGB had led to land scarcity and therefore higher land price. This narrative was false (Buxton and Taylor 2011; DPCD 2007; AEG 2008) but led to an increase in the supply of outer urban land from 15 years to a 30 year supply at some of the world's lowest densities at the same time demand for outer urban land in Melbourne fell substantially.

Anticipating the reciprocal impacts of a range of drivers of system change implies an active management process through the identification of functional elements and ways they interact. Anticipatory policy is more likely if it is cross-sectoral and developed from integrated institutional arrangements. However, the demise of integrated governance arrangements, such as through metropolitan and regional planning authorities, has led to more fragmented and sectoral decision making. Cross-sectoral policy is rare for Australia's peri-urban areas. Fragmented institutional arrangements characterised by horizontal agency fragmentation and by vertical fragmentation between state, local and regional governments have been coupled with deregulated governance arrangements which substitute the facilitation of ad-hoc, incremental decision making by individuals and companies for government planning. The inevitable result is the lack of effective anticipatory government policy to deal with threats to peri-urban resilience. A recent Australian government report into public decision making applies equally to governance in Victoria's peri-urban regions. It concluded that interagency and intergovernmental collaboration is hindered by a single agency approach to policy development instead of a cross portfolio approach. Most officials were primarily agency focused with an insufficient culture of engagement and an inability to deal with contemporary policy challenges, such as climate change, which span multiple agencies. Departments also displayed a short term focus and poor strategic policy capability (Commonwealth of Australia 2009).

5.7 Conclusions

Peri-urban areas internationally are important sources of food, resources and environmental services to cities and are important also in their own right. However, they are under unprecedented threat and are rapidly being reduced or eliminated by urban and rural residential development. Deregulated, uncoordinated and weak government institutions lead to fragmented, sectoral policy and perhaps the greatest threat to peri-urban resources, the spatial fragmentation of land. World population will rise by 50 % at the same time food production in many established areas is likely to fall, water resources be over taxed and biodiversity be severely reduced. Maintaining as many options as possible, for the longest time possible, may be the best adaptation measure to fundamental change. Important peri-urban resources may prove to be vital in maintaining urban resilience through the capacity to innovate and adapt. However, these resources will be rapidly lost to humanity without anticipatory policy developed through a strong government role.

References

Aberdeen Hogg and Associates (1977) Metropolitan farming study. MMBW, Melbourne

Anderson W, Kanaroglou P, Miller E (1996) Urban form energy and the environment: a review of issues, evidence and policy. Urban studies 33(1):7–35

Audirac I (1999) Unsettled views about the fringe: rural-urban or urban-rural frontiers? In: Furuseth O, Lapping M (eds) Contested countryside: the rural urban fringe in North America. Ashgate, Aldershot

Audit Expert Group (AEG) (2008) Melbourne 2030 audit expert group report. Department of Planning and Community Development, Melbourne, p 53

Barr N (2005) The changing social landscape of rural Victoria. Department of Primary Industries, Victoria

Budds J, Minaya A (1999) Overview of initiatives regarding the management of the peri-urban interface. Strategic environmental planning and management for the peri-urban interface research project, Development Planning Unit, University College London, London. http://www.ucl.ac.uk/dpu/pui

Burnley I, Murphy P (1995) Exurban development in Australia and the United States: through a glass darkly. J Plann Educ Res 14:245–254

Buxton M, Alvarez A, Butt A, Densley L, Farrell S, O'Neill D, Pelikan M (2011) Scenario planning for Melbourne's peri-urban region. RMIT University, Melbourne

Buxton M, Goodman R (2002) Maintaining Melbourne's Green Wedges: planning policy and the future of Melbourne's Green Belt. School of Social Science and Planning, RMIT University, Melbourne

Buxton M, Goodman R, Budge T (2005) Planning and deregulation: the failure of the new Victorian planning system. Aust Planner 42(3):52–58

Buxton M, Scheurer J (2007) Density and outer urban development in Melbourne. Urban Policy Res 25(1):91–111

Buxton M, Staindl P (1999) Planning on the run. Report to the Upper Yarra and Dandenongs Environmental Council, Lilydale

Buxton M, Taylor E (2011) Urban land supply, governance and the pricing of land. Urban Policy Res 29(1):1–17

Buxton M, Tieman G, Bekessy S, Budge T, Coote M, Mercer D, Morcombe, J (2006) Change and continuity in peri-urban Australia, state of the regions. School of Global Studies, Social Science and Planning, Melbourne

Commonwealth of Australia (2009) Commonwealth Advisory Group on the Reform of Australian Government Administration, Canberra: Australian government

Commonwealth of Australia (2010) State of Australian Cities 2010. Commonwealth of Australia, Canberra
Daniels T (1990) Policies to preserve prime farmland in the USA: a comment. J Rural Stud 6(3):331–336
Davis J, Nelson A, Dueker K (1994) The new burbs. The exburbs and their implications for planning policy. J Am Plann Assoc 60(1):45–59
Delahunty M (2003) Melbourne's urban growth boundary settled. Ministerial Press Release, Melbourne, pp 439–443
Department of Planning and Community Development (DPCD) (2007) Melbourne 2030 audit analysis of progress and findings from the 2006 Census. DPCD, Melbourne
Department of Planning and Community Development (DPCD) (2008) Urban development program 2007 annual report. DPCD, Melbourne
Ford T (1999) Understanding population growth in the peri-urban region. Int J Popul Geogr 5:297–311
Friedberger M (2000) The rural-urban fringe in the late twentieth century. Agric Hist 74(2):502–514
Giles-Corti B (2011) Urban intensification, state of Australian cities conference. University of Melbourne, Australia
Gillham O (2002) The limitless city: a primer on the urban sprawl debate. Island Press, Washington
Houston P (2004) National audit of peri-urban agriculture, project No. SAR-40A. Rural Industries Research and Development Corporation, Canberra
Houston P (2005) Revaluing the fringe: some findings on the value of agricultural production in Australia's peri-urban regions. Geogr Res 43(2):209–223
Langworthy A, Hackett T (2000) Farming real estate? Challenges and opportunities for agribusiness in the urban fringe—Yarra Valley region. Swinburne University of Technology, Melbourne
Leinberger C (1996) Metropolitan development trends of the late 1990s: social and environmental implications. In: Diamond LH, Noonan PF (eds) Land use in America. Island Press, Washington
Loder and Bayly (1980) Inventory of subdivision and development. Upper Yarra Valley and Dandenong Ranges Authority, Lilydale
Maclellan R (1993) Planning better future for Victorians: new directions for development and economic growth. Department of Planning and Development, Victoria
McKenzie F (1996) Beyond the suburbs: population change in the major exurban regions of Australia, bureau of immigration multicultural and population research. Australian Government Publishing Service, Canberra
McLoughlin J (1991) Urban consolidation and urban sprawl: a question of density? Urban Policy Res 9(3):148–156
Melbourne and Metropolitan Board of Works (MMBW) (1953) Melbourne Metropolitan Planning Scheme 1954—Report. MMBW, Melbourne
Melbourne and Metropolitan Board of Works (MMBW) (1967) The future growth of Melbourne: a report to the minister for local government on Melbourne's future growth and its planning administration. MMBW, Melbourne
Melbourne and Metropolitan Board of Works (MMBW) (1971) Planning policies for the Melbourne metropolitan region. MMBW, Melbourne
Melbourne and Metropolitan Board of Works (MMBW) (1974) Report on general concept objections, 1974. MMBW, Melbourne
Melbourne and Metropolitan Board of Works (MMBW) (1977) Review of planning policies for the non-urban zones. MMBW, Melbourne
Millar R, Schneiders B, Lucas C (2007) The price of a piece of dirt. The Age. 22 September, p 5
Mumford L (1961) The city in history: its origins, its transformations and its prospects. Secker and Warburg, London

Nelson A (1999) The exurban battleground. In: Furuseth O, Lapping M (eds) Contested countryside: the rural urban fringe in North America. Ashgate, Aldershot
Nelson A, Dueker K (1990) The exurbanization of America and its planning policy implications. J Plann Educ Res 9(2):91–100
Parbery P, Wilkinson R, Karunaratne K (2008) Square pegs in Green Wedges?. Department of Primary Industries, Melbourne
PPWCMA (2004) Port Phillip and Western Port regional catchment strategy 2004–2009. Port Phillip and Westernport Catchment Management Authority, Melbourne
Pryor R (1968) Defining the rural-urban fringe. Soc Forces 47(2):202–215
Sandercock L (1979) The land racket. Silverfish Press, Melbourne
Upper Yarra Valley and Dandenong Ranges Authority (UYVDRA) (1980) Regional strategy plan. UYVDRA, Lilydale
Wale N (2003) Green wedges and metropolitan strategies. Plann News 29(3):17–18

Chapter 6
Challenges in the Urban and Peri-urban Transition Zones and Strategies for Sustainable Cities: Experiences from Selected Cities

Arti Arha, Ranjana Audichya and D. C. Pant

Abstract Like many other countries, India has experienced rapid urban growth in recent decades. This paper focuses on the changes taking place in the peri-urban area of India where urban development is occurring both within and around the indigenous villages. In India, most people move to the urban areas due to factors such as poverty, environmental degradation, food insecurity and lack of basic infrastructure and services in the rural areas. The number of towns has increased by 2,774 since the last census in 2001 and the level of urbanisation has increased from 28 % in the 2001 census to 31 % in the 2011 census while the proportion of rural population declined from 72 to 69 %. The urban–rural ratio for India in 2011 is around 45 meaning that for every 100 ruralites there are 45 urbanites in India. This increased level of urbanisation has changed the environment of the peri-urban areas of India. Urbanisation poses challenges in relation to the water, agriculture and energy in peri–urban areas of the cities of India. In the post-liberalisation period a process of change has been induced by the growth of the information technology (IT) sector leading to tremendous expansion of cities. With the expansion of these cities, changes have occurred that the surrounding villages witnessed; massive real estate development, a decrease in agricultural land and a year round shortage of water. Villages being absorbed into the cities has led to increasing competition over scarce water through industry, domestic use, farm houses and recreation parks. Urbanisation brings major changes in demand for agricultural products both from increases in urban populations and from changes in their diets and demands.

Keywords Urbanisation trends · Indian cities · Water and sanitation · Urban agriculture

A. Arha · R. Audichya · D. C. Pant (✉)
Department of Agricultural Economics and Management, RCA, Udaipur, India
e-mail: pantnodal.mpuat@gmail.com

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_6,

6.1 Introduction

Today's world is rapidly urbanising, with a particularly radical urban expansion predicted in developing countries. Increasing urbanisation impacts on the peri-urban areas in terms of; changes in land use, changing forms of household composition and the increased pressure on common natural resources. Urbanisation brings the creation of new opportunities, but also a dramatic increase in the concentration of poverty and environmental degradation in peri-urban zones. Despite offering immense opportunities, the peri-urban interface is little understood, often disregarded and characterized by increasing marginalisation and environmental degradation. In this uncertain and highly dynamic context, improved understanding of the peri-urban situation is an essential prerequisite to address the current and emerging challenges. In this paper sustainability challenges in relation to water, agriculture and energy in the peri-urban context are reviewed with particular reference to India.

In both the developed and developing countries, rapid urbanisation is associated with problems of unemployment, poverty, inadequate health, poor sanitation, urban slums and environmental degradation which pose a formidable challenge in many developing countries. More than half of the world's 6.6 billion people live in urban areas, crowded into 3 % of the earth's land area. The proportion of the world's population living in urban areas, which was less than 5 % in 1800 increased to 47 % in 2000 and is expected to reach 65 % in 2030. However, more than 90 % of future population growth will be concentrated in cities in developing countries and a large percentage of this population will be poor. Asia, where urbanisation is still considerably lower (40 %), is expected to be 54 % urban by 2025. Urbanisation, simply defined, is the shift from a rural to an urban society and involves an increase in the number of people in urban areas during a particular year. Urbanisation is the outcome of social, economic and political developments that lead to urban concentration and growth of large cities, changes in land use and transformation from rural to a metropolitan pattern of organisation and governance.

Increasing urbanisation impacts on the peri-urban areas in terms of changes in land use, new forms of household composition, differential access to urban benefits (such as health infrastructure and employment) and increased pressure on common natural resources. Urbanisation brings the creation of new opportunities, but also a dramatic increase in the concentration of poverty and environmental degradation in peri-urban zones. When urban areas grow in a disorderedly manner and sprawl into the peri-urban areas, this process can be referred as peri-urbanisation. Peri-urbanisation can be regarded both as a driver and an effecter of global environmental changes. Observing land use and land cover change over time the effects and impacts of urbanisation on peri-urban areas can be perceived. A peri-urban area refers to a transition or interaction zone, where urban and rural activities are juxtaposed and landscape features are subject to rapid modifications, induced by human activities. Peri-urban areas, which might include valuable protected areas, forested hills, preserved woodlands, prime agricultural lands and important wetlands can provide essential life support services for urban residents. Peri-urban zones are often far more environmentally unstable than either urban or rural settings. From the ecosystem's point of view, physical, chemical and biological factors generally interact among themselves and are interrelated with socio-economic forces. These factors have their own functions, which can be enhanced or reduced depending on the conditions of other factors in the same system.

A gradual increasing trend of urbanisation is the result of increasing population and this urbanisation is responsible for the peri-urban growth. This paper discusses the causes of urbanisation, arising challenges and policies to face the challenges, focusing on the issues of food security and water supply in the peri-urban region.

6.2 Urbanisation in India

6.2.1 Type of Towns

In the census of India, 2011 two types of town were identified:

i. Statutory towns: All places with a municipality, corporation, cantonment, board or notified town area committee so declared by state law.
ii. Census towns: Places which satisfy following criteria—a minimum population of 5,000; at least 75 % of male working population is engaged in non-agricultural pursuits; and a density of population of at least 400 persons per km^2.

In the 2011 census, 475 places with 981 out growths (OGs) have been identified as Urban Agglomerations (UA) as against 384 UAs with 962 OGs in the 2001 Census (Table 6.1). The census in 2011 showed that there are 7,935 towns in the country. The number of towns has increased by 2,774 since previous census. Many of these towns are part of UAs and the rest are independent towns. The total number of UAs/Towns, which constitutes the urban frame, is 6,166.

6.2.2 Volume and Trend of Urbanisation in India

India shares most of the characteristic features of urbanisation with other developing countries:

- Numbers of UAs/towns have grown from 1,827 in 1901 to 6,166 in 2011 (Table 6.1).
- The total population has increased from 23.84 crores in 1901 to 121 crores in 2011 whereas the population residing in urban areas has increased from 2.58 crores in 1901 to 37.71 crores in 2011 (Table 6.2). This reflects a gradual

Table 6.1 Number of urban agglomerations and out growths

Type of towns/UAs/OGs	Census	
	2001	2011
Statutory towns	3799	4041
Census towns	1362	3894
Urban agglomerations	384	475
Out growths	962	981

Table 6.2 Population of India by residence (1901–2011)

Census years	Number of urban agglomerate ions/towns	Total population	Urban population	Rural population
1901	1827	238396327	25851873	212544454
1911	1825	252093390	25941633	226151757
1921	1949	251321213	28086167	223235046
1931	2072	278977238	33455989	245521249
1941	2250	318660580	44153297	274507283
1951	2843	361088090	62443709	298644381
1961	2363	439234771	78936603	360298168
1971	2590	598159652	109113977	489045675
1981	3378	83329097	159462547	523866550
1991	3768	844324222	217177625	627146597
2001	5161	1027015247	285354954	741660293
2011	6166	1210193422	377105760	833087662

increasing trend of urbanisation and that India is at the acceleration stage of the process of urbanisation.

6.2.3 Trends in Rural and Urban Population

It is observed in Table 6.3 that the level of urbanisation increased from 27.78 % in the 2001 Census to 31.16 % in the 2011 Census while the proportion of rural population declined from 72.22 to 68.84 %.

Table 6.4 shows that the increase in the number of towns from 2001 to 2011 is 2,774, so the increase in population parallels the increase in the number of towns. The increasing trend can be viewed in urban distribution of the population from 1901 to 2011. In the year 1901 only 10.8 % of the population was living in urban areas but in 1951 the percentage had grown to 17.3 and by the year 2011 it is up to 31.2, with the increasing trend in the urban population observed in Fig. 6.1.

Table 6.3 Population of India 2001–2011 (in crore)

	2001		2011		Difference
	No.	Percent	No.	Percent	
India	102.9		121.0		18.1
Rural	74.3	72.22	83.3	68.84	9.0
Urban	28.6	27.78	37.7	31.16	9.1

Table 6.4 Number of urban units of India (2001–2011)

Type of towns	2001	2011	Difference
Towns	5161	7935	+2774
Statutory towns	3799	4041	+242
Census towns	1362	3894	+2532

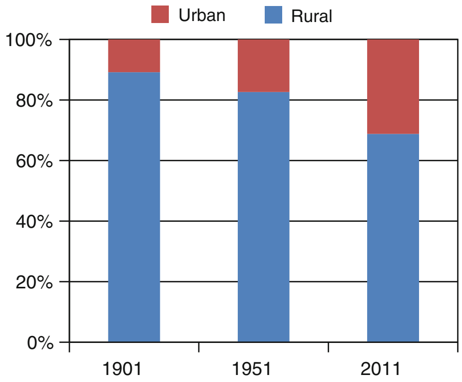


Fig. 6.1 Trends in rural-urban distribution of population—India (in %) (1901, 1951, 2011)

6.2.4 Causal Factors Behind Urbanization in India

Rural–Urban Migration: Primary driving forces of rural–urban migration include the opportunities and services offered in urban areas especially jobs and education, while in some cases, conflict, land degradation and exhaustion of natural resources in rural areas are also important.

Links to Globalization: The steady increase in the level of urbanisation reflects the fact that the size of the world's economy has grown many times. Technology has increased the already dominant economic role and importance of urban areas worldwide, indicating the growing importance of cities in the global economy.

Mismanagement: It is often highlighted that many urban environmental problems are the result of poor management, poor planning and an absence of coherent urban policies rather than of urbanisation itself. In order to attract investment, industrial promotion policies are designed to offer privileges and incentive packages, including low-taxes regulations and subsidised infrastructure, targeting urban areas. Industrial growth, combined with inadequate infrastructure, inappropriate pricing of resources and services and inadequate institutional mechanism to ensure environmental protection, further accelerates environmental degradation in urban areas.

6.3 Peri-urban

The peri-urban, 'suburbs', 'urban fringe', 'city edge', 'metropolitan shadow' or 'urban sprawl' zone is considered to be a transition zone and is conceptualised as a space in 'continuum' with the urban area, characterised by mixed land use with agricultural land predominating the landscape within which there is other rural land that is converted into permanently built-up areas and covered with infrastructure.

Village Peri-urban (Rural)

- Not proximate to city
- High agricultural and farming activities
- Strong rural migrant, cultural influences and traditional structures.

In-place Peri-urban (Peri-urban)

- Located on city fringes
- Combined framing and market retail activities
- Traditional oriented structures incorporating some urban influences.

Absorbed Peri-urban (Urban)

- Geographically absorbed with the city
- Mainly retailing of agricultural products
- Strong interface with urban formal structures.

6.3.1 Major Challenges for Peri-urban Futures

The process of rapid urbanisation has thinned down the distinction between what is purely 'rural' and 'urban' with the intermediary 'peri-urban' zone becoming more prominent and visible in the future. Since peri-urban regions have specific social, economic and institutional characteristics, there is a need to understand these unique characteristics in order to develop new innovative ways of addressing peri-urban challenges and cutting across the frontiers of rural and urban governance. This is a process emerging out of development activities, manifested in changing social and economic interactions and increasing mobility of production factors, such as capital, labour, technology, and information to the urban fringe near mega cities.

This section reviews the challenges in relation to water, agriculture and energy in a peri-urban context of the four most populated cities of India viz. Mumbai, Delhi, Bangalore and Hyderabad. For these cities, the post-liberalisation period has seen a form of development, where the process of change has been induced by growth of the information technology (IT) sector leading to tremendous expansion. With the expansion of these cities, some of the changes that surrounding villages have experienced are massive real estate development, decrease in agricultural land and shortage of water year round.

6.3.2 Peri-urban Water Security

Water is the 'lifeblood of ecosystems' and 'essential for many eco-hydrological functions'. Water, and its accompaniment sanitation, is also fundamental for people's livelihoods, well-being and production. Water is often conceptualised in terms of a 'natural water cycle', 'ecosystem', 'watershed' or 'river basin' in which agriculture, rain water, groundwater sources, river systems and so forth are all interconnected and act in predictable ways.

Supplying water and sanitation services to a city and its peri-urban fringe is characterized by uncertain dynamics i.e. interlocking social, technological and ecological/hydrological dimensions of water and sanitation in peri-urban areas. The expansion of the city and villages being absorbed into the city have led to increasing competition over water through industry, domestic use, farm houses and recreation parks. Water is thus subject to severe pressure from agricultural, local non-farm and urban demands. This arises due to massive changes in land use, competitive demands for water and pollution from industry. People in the peri-urban fringe are at risk of exposure to liquid waste such as effluents; groundwater contamination; water pollution. Furthermore, inadequate sewerage disposal often leads to cholera, typhoid and health implications.

Water availability per capita in India has fallen from 5 million litres in the 1950's to 1.3 million litres in 2010. This is a significant drop in water availability that India has witnessed in the last 50 years, primarily due to an increasing population. For much of India's 'water history', the focus has been on large scale surface water projects to provide access, neglecting sources within the city and in the peri-urban areas.

In terms of quality, the water sources face increasing stress from sewerage and industrial effluent pollution, dumping of solid waste and agricultural runoff. Overall the situation is dire with very few urban areas having successfully managed their water resources in order to provide adequate and safe water to all the residents. The unplanned and unsustainable development process in these cities has proved to be quite unsustainable and has turned out to be a serious threat to the cities and their environs.

Hyderabad, being located in an area with hard-rock aquifer, has very limited percolation while water drawn from the aquifer far exceeds the amount that is actually recharged. The groundwater depth during the dry season and monsoons, when correlated to rainfall over the last 10 years, reveals the gravity of the problem. There has been a progressive decline in the percentage of rainfall converted into inflows due to the increased use of surface and groundwater in the catchment areas surrounding Hyderabad. Historical data shows that there were 932 tanks in and around Hyderabad in 1973, which had come down to 834 in 1996. Consequently, the area under water bodies was reduced from 118 to 110 km^2. Approximately 18 water bodies of over 10 ha size and 80 tanks of below 10-ha size were lost during this period in the Hyderabad metropolitan area. Besides the large water bodies, numerous small water bodies in the peri-urban zones also shrank, when the city underwent a wave of real estate growth. However, systems for water and sanitation have often been specifically planned and constructed for either urban or rural situations, resulting in the peri-urban interfaces being neglected or forgotten, leaving large numbers without sufficient clean drinking water or adequate sanitation.

This makes planning for sustainable water and sanitation systems in peri-urban areas an important and challenging issue, since sources are limited and often diminish over time due to land acquisition for residential and commercial purposes. A survey done in 2003 in Hyderabad revealed the plight of low income households in accessing water, which was supplied either on alternate days for a few hours or once in three or four days. This was in sharp contrast to the large quantity of water supplied to the IT companies and other institutions like the Indian School of Business (ISB) and the National Academy of Construction (NAC). Drinking water was supplied in tankers (which made about five trips a day) by the local municipality. The plan to lay pipelines so that domestic connections can be given to those who have the ability to pay clearly points to the concept of ‘user pays’, which brings in inequality and water equity issues. The area around the Rajiv Gandhi International Airport is a semi-arid zone, dotted with numerous lakes and kuntas. There are 140 lakes and kuntas in this area, one of the largest being the Himayatsagar on the north–west. Kunta is a local term in Telugu used when referring to a small lake. Changing Waterscapes in the Periphery 167 is an area where recent developments have started in full swing. Seventy percent of this lake has already shrunk due to the drying up of the smaller lakes in the surrounding areas accentuated by low rainfall and low groundwater recharge along with construction of the international airport (Ramachandraiah and Prasad 2004). The area also consists of fertile agricultural land, especially at Ravirala, Kongara, Chowdarypalli, Narkhoda, Adibhatla, and Dosawada.

6.3.3 *Water and Sanitation Issues*

Traditional water and sanitation engineering in most parts of the global South (especially in countries like India) have allowed for a kind of control and govern mentality which makes some citizens enjoy abundant access to water whereas others are denied access. In Delhi's National Capital Territory, the affluent areas of Jorbagh and Chanakyapuri receive more than 500 L per capita per day and slum dwellers comprising, 40 % of Delhi's population, receive only 30 L per capita per day against the norm of 350 per capita per day. Almost half the populations in slums and peri-urban areas do not use toilet facilities. Toilet blocks from the Municipal Corporation of Delhi, Sulabh International and other Non-Government Agencies (NGOs) may not be used because they are too expensive as one has to pay INR 2.00–3.00 in order to use these toilets.

Peri-urban sites often lack water mains and sewer lines. This is, in part, related to the low value of the land which, as a consequence, is occupied by poor people who cannot meet the high service installation costs. Informal or illegal access to water is linked to insecure tenure of land and housing rights. Similarly, it is very difficult to build sustainable sanitation systems due to tenure insecurity and dense housing. Thus, the lack of proper disposal of waste can lead to the faecal contamination of groundwater.

Housing settlements often follow village traditions and not conventional urban patterns of settlement layout with no formal streets and no provision for services. Therefore it is difficult to install conventional sanitation and engineering systems. Also due to competing administrative jurisdictions these areas may be overlooked. Due to lack of secure tenure, financial institutions may not make loans and collect payments for water fees.

6.3.4 Water Supply and Access

Often the infrastructure costs of extending a water line and sinking new pipes are much more expensive than installing a new system all together. While piped water is made out to be very expensive in reality water provision from vendor trucks and buckets costs far more than water from piped systems.

Water privatisation has often been advocated as a 'solution' to former inefficient public water systems and as a way to enhance access to water. However, it is well known that privatisation (be it a long-term concession contract as in Latin American cities or the more benign management or service contract) largely leaves peri-urban areas, slums and so called 'illegal' colonies unserviced. In peri-urban areas both the poor and rich access water through a host of unconventional means. These include vendors, privately operated wells, gifts and clandestine connections. Families often hook up illegally to water systems because the initial connection fee is prohibitively high (the combination of the cost of house connection plus the meter fee). Thus, local people draw on individual and collective solutions to access water.

In India, while large-scale privatisation such as in Buenos Aires and other Latin American cities does not exist, there are numerous private players in peri-urban settings. They provide water through tankers, by selling bottled water and by recycling waste water in urban regions. The private sector also over-exploits groundwater sources causing environmental hazards and negative externalities. These hybrid private players are not subject to any regulatory framework which can, in principle, be pro-poor and provide for basic environmental standards.

In peri-urban areas, there are competing claims over water. Water-scarce Mumbai is a good case in point of competition over the allocation of water (e.g. between irrigation, domestic supply and industry as well as different users across the city and its fringes). In 2001, the Water Board entered into an agreement with the Maharashtra Electricity Board and farmers who supply 20 million litres a day to the Board whereby farmers are paid INR 26 per hour and run their boreholes for about 20 h to supply water to the city. This saves money for the Board because it has no investment costs for wells. This is a good income for the farmers, who also sell water to private water tankers and is supposed to be compensation for not undertaking agriculture.

6.3.5 Coping Strategies

Wastewater reuse has huge potential and rainwater that is harvested and stored in tanks is also being seen as an alternative source to help bridge the water supply gap. Other solutions like reviving surface water bodies and desalination are also being attempted.

Provision of water is a State responsibility, with the State Government having the primary care of the management and deployment of this resource to meet critical lifeline needs as well as for livelihoods, agriculture and industry. Research in biotechnology for improving development of food grains strains that would tolerate salinity and those which would require less water gets high priority. A movement towards making water harvesting, storage and its need based use part of every citizens life should be taken up. Sustainable water resource management will require a holistic approach by examining surface, ground, rain and recycled waste water in conjunction with conservation and other measures.

6.3.6 Mainstreaming Peri-urban Issues in Policy and Planning

As urbanisation proceeds, the distinction between ‘rural’ and ‘urban’ will get blurred and more of the intermediary peri-urban zone will become visible. Peri-urban issues need better reflection in policy and planning. There is a need for rigorous studies on the carrying capacity of cities and urban expansion plans should be based on this. Otherwise, the ecological footprint of cities will continue to expand through to the peripheral areas, engulfing the land and water resources of peripheral villages, depriving locals of access to land, water and other natural resources.

Lack of suitable urban development policy instruments breeds a pattern of urbanisation that is inequitable, conflict-ridden and unsustainable. Current urban development policies also need to revisit and revise the existing building by-laws in peri-urban areas, which often ignore the negative consequences of urban expansion for the socially and economically marginalised communities. Often, these communities are affected by the development enclaves leading to reduced access to clean and safe water sources as well as other natural resources.

There is a need to devise ways of breaking the rural and urban dichotomy in planning. The focus of urban authorities on urban expansion and rural authorities on rural areas often implies that the relationships across 'rural' and 'urban' go unaddressed. Even if the peri-urban areas fall within a development zone, the focus tends to be largely urban-centric with little efforts to integrate rural development with the activities undertaken. The 74th amendment to the Constitution of India provides for the creation of District Planning Committees (DPCs) to integrate planning at a district level. There is a need for such committees to better integrate planning across rural and urban areas. In general, there is a need to better recognise flows of water across rural and urban areas. The dichotomy between 'rural' and 'urban' water supply is superficial and overlooks the flow of water between rural and urban areas, which will become more visible with ongoing processes of urbanisation. Often the expansion of urban water supply is at the expense of rural water supply, as peri-urban residents give away their land and water to allow canals to pass through to quench urban thirst, or allow water to be transported from their villages to the city in tankers. A strong policy for conserving natural resources, especially water and forests in peri-urban areas should be formulated. They are often a source of livelihood for the landless as well as for resource-poor farmers.

6.3.7 Loss of Agricultural Land and the Issue of Food Security

Urbanisation brings major changes in the demand for agricultural products both from increases in urban populations and from changes in their diets and demands. This has brought and continues to bring major changes in how demands are met and in the farmers, companies, corporations, and local and national economies that benefit and lose. It can also bring major challenges for urban and rural food security. It would be expected that in nations with successful economies and rapid urbanisation, there will be rising demands for meat, dairy products, vegetable oils and 'luxury' foods and this implies more energy-intensive production and, for many nations, more imports. Urbanisation is also associated with dietary shifts towards more processed and pre-prepared foods, in part in response to long working hours and, for a proportion of the urban population, with reduced physical activity.

6.4 Issues in Urban and Peri-urban Agriculture

6.4.1 Safe and Nutritionally Adequate Food for Consumers

Poor urban dwellers often lack the purchasing capacity to acquire adequate amounts of food. Urban agriculture appears to reduce food insecurity by providing direct access to home-produced food to households and to the informal market. Even for people who have little or no land part-time farming of vegetables can provide food and income. Simple, popular hydroponics or substrate culture in beds can produce high value and nutritious vegetables on surfaces as small as one metre.

Urban agriculture also appears to enhance food security during times of crisis and severe scarcity. Whether caused by national crises (civil war, widespread drought, currency devaluations, inability to import, etc.) or household crises (illness, health, sudden unemployment, etc.).

Urban and peri-urban agriculture enhances the freshness of perishable foods reaching urban consumers, increasing overall variety and the nutritional value of food available. An important reason appears to be that food produced by consumers, or in close proximity to them, is often fresher than food that travels long distance to markets.

6.4.2 Agricultural Efficiency of Producers

There are mixed implications from urban and peri-urban agriculture on the efficiency of agricultural and forestry production for various reasons. Cost savings can be achieved because of proximity to consumers and less need for extensive and expensive infrastructure for transportation and preservation of perishable products. Moreover, quality increases because of greater responsiveness to consumer preferences as well as availability of products that cannot be obtained from rural producers such as wood energy. But in spite of such potential efficiencies there is a strong perception of the unsuitability of agriculture in the urban and peri-urban areas. Concerns arise over competition for resources (land, water, labour, and energy) and incompatible uses (smells, noises, pollution). Though many of the same concerns can and do arise in rural agricultural production, two important differences make the concerns more acute in the urban environment: proximity to greater numbers of people and already high stresses on the natural resource base. Without appropriate management and monitoring of resources, negative environmental and health effects of urban and peri-urban agriculture can be imposed on society.

6.4.3 Sustainability of Urban Environment for Society

Doubts have been raised about the contribution of urban and peri-urban agriculture to a city's environmental sustainability in the sense of the quantity and quality of urban natural resources being maintained. Indeed, basic resources (water, soil) needed for agricultural production is in competition with other priority urban needs (drinking and industrial water use, infrastructure construction). There is real risk involved in food production in and near cities, just as there is also the possibility of improving the urban environment if food production and forestry are managed appropriately. The long-term viability of urban and peri-urban agriculture itself depends on how successful farmers and urban officials are at exploiting the potential environmental benefits, minimising the problems and finding ways to secure growers access to land. A comprehensive assessment of the impacts is urgently needed before policies and guidelines are implemented.

Optimal management of urban and peri-urban resources requires land use planning which views agriculture as an integral component of the urban natural resources system and balances the competitive and synergistic interactions among the users of the natural resources (water, land, air, wastes). Benefits of appropriate management include improved hydrological functioning through soil and water conservation, micro-climate improvements, avoided costs of disposal of the recycled urban wastes (wastewater and solid waste), improved biodiversity and greater recreational and aesthetic values of green space.

6.5 Concluding Remarks

There is a need for rigorous studies on the carrying capacity of cities with urban expansion plans needing to be based on this. Otherwise, the ecological footprint of cities will continue to spill-over to the peripheral areas, engulfing the land and water resources of peripheral villages, depriving locals of access to land, water, and other natural resources.

This breeds a pattern of urbanisation that is inequitable, conflict-ridden, and unsustainable. Urban development policies also need to revisit and revise the existing building by-laws in peri-urban areas. More and more of the world's population are becoming concentrated in and around large cities. Ensuring the right to have access to safe and nutritious food and water to the billions of people living in cities represents a global development challenge of the highest order. Despite all the policy responses to better manage urbanisation, the opportunity to prevent the urbanisation transition would be less effort from a practical point of view.

The increasing trend in urban population is a major issue of concern for food production, marketing and transportation. The sustainable management of natural resources in and around cities will play an important role in addressing this concern. Traditionally, India has been well endowed with large freshwater reserves, but growth of the Indian economy is driving increased water usage across sectors. Wastewater is increasing significantly and in the absence of proper measures for treatment and management, the existing freshwater reserves are being polluted. Increased urbanisation is driving an increase in per capita water consumption in towns and cities. Urbanisation is also driving a change in consumption patterns and increased demand for water-intensive agriculture. It is urgent to integrate food security and water security into the agenda of city planners and local urban authorities. This is possible through high-tech urban agriculture and planning for adequate water bodies in urban and peri-urban areas.

Many developing countries have established extensive regulations on pollution, most of which are not applied effectively because of the lack of proper institutions, legal systems, political will and competent governance. Specific attention needs to be given to the links that connect urban and rural communities, shape the economic relationships between them and determine how water and other natural resources are shared. It is imperative to think in terms of territorial planning that incorporates rural, peri-urban and urban areas. Participation of all stakeholders who are benefiting from relevant decisions and actions should be ensured at all levels of planning activities in combination with greater access to relevant information and enhancement of public awareness of urbanisation issues.

The doubling of the population in Indian cities within the next two decades poses distinct questions on how city functions are planned and executed. Globally the world is facing a convergence of a number of interdependent and mutually reinforcing sustainability oriented crises. The energy/food nexus is a core component of these crises. Addressing these two dominant, but mutually beneficial, urban challenges requires fundamentally different urban governance strategies.

Suggested Readings

Adesina A (2007) Socio-spatial transformations and the urban fringe landscape in developing countries. Paper presented at the United Nation University Institute for Environment and Human Security

Allen A (2003) Environmental planning and management of peri-urban interface: perspective on an emerging field. Environ Urbanization 15(1):135–148

Allen A, Dávila JD, Hofmann P (2006) Governance of water and sanitation services for the peri-urban poor: a framework for understanding and action in metropolitan regions. Development Planning Unit, University College, London

Banerjee-Guha S (2002) Shifting cities: urban restructuring in Mumbai. Econ Polit Wkly 12:121–127

Birley M, Lock K (1998) Health and peri-urban natural resource production. Environ Urbanization 10(1):89–106

Brockerhoff M, Brennam E (1998) The poverty of cities in developing regions. Populations Dev Rev 24(1):75–114

Breese G (1969) Newly developing countries. Prentice Hall, New Delhi

Datta P (2006) Urbanisation in India. Population Studies Unit, Indian Statistical Institute

Davis K, Golden HH (1954) Urbanisation and development in pre-industrial areas. Econ Dev Cult Change 3(1)

Davis K (1962) Urbanisation in India: past and future. In: Turner R (ed) India's urban future. University of California Press, Berkley

Davis K (1965) The urbanization of the human population. Sci Am 213(3):41–53

Despande S, Despande L (1998) Impact of liberalisation of labour market in India: what do facts from NSSO's 50th round show. Econ Polit Wkly 33(22):L21–L31

FAO (1999) Urban and peri-urban food production: a new challenge for the Food and Agriculture Organization (FAO) of the United Nations.In: Drescher AW, Iaquinta DL (eds) Internal report, Rome

Hardoy JE, Mitlin D, Stterthwaite D (2001) Environmental problems in an urbanizing world. Earthscan publishing, London

Hasse JE, Lathrop RG (2003) Land resource impact indicators of urban sprawl. Appl Geog 23(2–3):159–175

Kundu A (1983) Theories of city size distribution and Indian urban structure: a reappraisal. Econ Polit Wkly 18(3)

Lo F-C and Marcotullio PJ (eds) (2001) Globalization and the sustainability of cities in the Asia Pacific region. United Nations University Press, Tokyo

MGI (2010) India's urban awakening: building inclusive cities, sustaining economic growth. McKinsey Global Institute, Mumbai

Moonis R, Kundu A (1978) Some aspects of disfunctional characteristics of urbanisation. In: Socio-economic development problems in South and South East Asia. Popular Prakashan, Bombay

Mukherji S (1993) Poverty induced migration and urban involution in India: cause and consequences. International Institute for Population Sciences, Bombay, pp 1–91

Nayak PR (1962) The challenge of urban growth to Indian local government. In: Turner (ed) India's urban future. University of California Press, Berkley

OECD (1979) Agriculture in the planning and management of peri-urban areas, vol 1. Synthesis, Paris

Pathak P, Mehta D (1995) Recent trend in urbanisation and rural-urban migration in India: some explanations and projections. Urban India 15(1):1–17

Premi MK (1991) India's urban scene and its future implications. Demography India 20(1):41–52

Ramachandraiah C, Prasad S (2004) Impact of urban growth on water bodies. The case of Hyderabad. Working Paper no. 60. Centre for Economic and Social Studies, Begumpet, Hyderabad

Registrar General (1991) Census of India. Emerging Trends of Urbanisation in India. Occasional Paper no. 1 of 1993, Registrar General, New Delhi

Registrar General (2001) Census of India, India, 2A, Mansingh Road, New Delhi 110011, 25 July 2001

Resources census concept. J Hum Ecol 23(3):243–252 (Consultants Mart Report)

Sen A, Ghosh J (1993) Trends in rural employment and poverty employment linkage. ILO-ARTEP Working Paper, New Delhi

Sovani NV (1966) Urbanisation and urban India. Asia Publishing House, Bombay

Chapter 7
Managing Threats and Opportunities of Urbanisation for Urban and Peri-urban Agriculture in Tamale, Ghana

Edwin Akonno Gyasi, Gordana Kranjac-Berisavljevic, Mathias Fosu, Adelina Maria Mensah, Gerald Yiran and Issahaka Fuseini

Abstract Urbanisation involves growth and transformation of settlements into increasingly large spatially sprawling cities. By encroaching upon agricultural land, taxing water resources and enticing rural people away from farming, urbanisation poses a threat to agriculture within both the built-up and peri-urban areas. Growing climate variability, an apparent sign of climate change, exacerbates the threat. At the same time, through an increased demand for food, the potential for affordable organic manure from urban waste and a need for efficient intensive land use urbanisation may encourage agricultural production and, thereby, enhance urban food security. Preliminary findings of an on-going inter-institutional, inter-disciplinary assessment focused on Tamale, a rapidly growing city in Ghana, show that farmers seek to manage the agricultural threats and opportunities by various ingenuous survival strategies, notably livelihoods diversification, new cultivars, and land use intensification. This paper highlights the strategies and argues that if they are nurtured and integrated into policy they would positively inform sustainable urban development planning.

Keywords Agriculture · Food-security · Opportunities · Threats · Urbanisation

---

E. A. Gyasi (✉) · A. M. Mensah · G. Yiran · I. Fuseini
Department of Geography and Resource Development, University of Ghana, Legon, Ghana
e-mail: edwin.gyasi@gmail.com

G. Kranjac-Berisavljevic
University for Development Studies, Tamale, Ghana

M. Fosu
Savanna Agricultural Research Institute, Tamale, Ghana

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_7,

7.1 Introduction

Urbanisation involves growth and transformation of settlements into increasingly densely populated multi-functional spatially sprawling cities. It is associated with natural population growth within the settlements and with influx of people from outside them.

Urbanisation is accelerating rapidly. Reportedly, globally, the proportion of urban population (as opposed to rural population) increased from 13 % in 1900 to about 50 % today. It is projected to increase to 60 % by 2030, with the highest growth rates in Africa and Asia (United Nations 2009; Getis et al. 2006; Satterthwaite 2007).

In Ghana, where an urban area is officially defined as any settlement or built-up area having a population of 5,000 or more, 44 % of the total population is reported to be urban (National Population Council 2006), and the rate of urbanisation to be over 4 % per annum (Braimoh and Vlek 2004; Ghana Statistical Service 2005).

By encroaching upon agricultural land, exerting pressure on water resources and enticing rural people away from farming, urbanisation poses a threat to agriculture, both within the built-up core area and its immediate periphery, often called the peri-urban zone, the transitional between the built-up area and the outlying rural area. Growing climate variability, an apparent sign of climate change, exacerbates the threat. However, at the same time, by increased demand for agricultural produce, potential generation of affordable organic manures from huge quantities of urban waste and a need for efficient land use intensification, urbanisation may encourage agricultural growth and development thereby enhancing urban food security. How farmers manage these threats and opportunities are examined in this paper with reference to Tamale, a city in Ghana. The discussion draws mainly from the preliminary findings of an interdisciplinary assessment of knowledge on 'Climate change and urban and peri-urban agriculture (UPA) in Sub-Saharan Africa and South Asia', which is being carried out mainly on the basis of secondary information (Fuseini 2013) by international institutional partners led by Global Change System for Analysis Research and Training—START Secretariat, Washington DC. Various theoretical ideas of agricultural change, mostly change attributable to land use competition and intensification driven by pressures of population (Boserup 1965), inform the discussion of the empirical information. It is expected that lessons learnt would feedback positively into knowledge of sustainable ways of designing agriculture for food security in the wake of urbanisation.

This paper reviews existing knowledge of the role of urban agriculture in the urban economy and then starts the discussion followed by a profile of Tamale, the focal city. The paper continues with a discussion of the expansion of Tamale and the associated agricultural threats and opportunities and concludes with farmer reactions to the threats and opportunities. The conclusion distils the discussions and their implications for policy.

7.2 Economic Role of Urban and Peri-urban Agriculture

Urban and peri-urban agriculture is an important component of the urban and peri-urban life-support system. Simply defined, it is an industry dedicated to raising, processing, and marketing of plants and animals within and outside cities (Brown and Carter 2003). It has become a vital activity in urban economies partly because of people's attempts to improve their food security and well-being through self-reliant production. A desire for income generation through production aimed at cashing in on the high price of food sold in urban areas also motivates urban and peri-urban agriculture (Mubvami and Mushamba 2006; Cofie et al. 2010). Furthermore, the growth of urban agriculture reflects a migration of poverty, food insecurity and malnutrition from rural to urban areas. Thus, urban agriculture may be interpreted to be a survival strategy for the urban poor, since it provides food and job opportunities for unemployed or underemployed city dwellers including youthful rural migrants (Van Veenhuizen and Danso 2007; Urban Agriculture Network 2008). As Marshall et al. (2009) notes "For poor peri-urban communities, agriculture forms a key part of often diverse livelihood strategies—meeting basic food requirements for some or all family members through home production, or as a source of income through the sale of produce or employment opportunities as farm labourers" (Marshall et al. 2009). In an account of peri-urban agriculture in Dar Es Salaam, Nelson (2007) notes that during the 1980s, when economic conditions worsened, the peri-urban areas of Dar Es Salaam became known as 'zones of survival' as people from a number of socio-economic backgrounds used the peri-urban zones to produce their own food for survival.

Urban and peri-urban agriculture is increasing in importance throughout the world. It contributes to food availability, particularly of fresh produce in cities (Brown and Carter 2003). The United Nations Development Programme (UNDP) estimated that 800 million people were engaged in urban agriculture worldwide in 1996 (Urban Agriculture Network 2008).

An equally significant consideration is the high productivity of urban agriculture. Australia exemplifies this with 20–25 % of gross value of agricultural output accounted by peri-urban areas from less than 3 % of land used for agriculture in the five mainland states (Land and Water Australian 2008).

However peri-urban agriculture is not without difficulties. Perhaps the most serious one is the constraint imposed by scarcity of land. This results from competition with other land uses, including residential, industrial and commercial ones, in accordance with von Thunen's notion of economic rent (Chisholm 1962). This situation is compounded by the often unregulated land markets in peri-urban areas into which cities expand. The market involves speculative land sales in the wake of rising land values which, as a rule, do not favour agriculture especially by the poorer farmers who are marginalised by urbanisation (Ubink 2006; Yaro 2010). Another constraint arises from insecurity of land tenure. Often, urban farmers do not own the land they cultivate but only hold it in the form of short lease holding or rental unit, which does not promote long-term investments. Moreover, as tenants, they operate at the mercy of landlords who, at very short notice or none at all, may eject a tenant-farmer (Brown and Carter 2003).

7.3 Profile of Tamale, the Focal City

Tamale, the focal city of this paper, is located in the guinea savannah zone in the northern sector of Ghana, a 240,000 km^2 middle income basically agricultural country of some 24 million people in the West Africa (Fig. 7.1). It epitomizes the universal trend towards urbanisation. Tamale is among the fastest growing cities in West Africa. It expanded from a small, thinly inhabited village of some 1,500 inhabitants in 1907 to its present status of a metropolis containing an estimated population of 300,000.

The climate may be described as sub-humid. It is hot (28 °C mean temperature), relatively dry and characterized by a single rainy season, which ranges in volume from 900 to 1100 mm and fluctuates greatly over time. The natural vegetation comprises guinea savannah marked by grass and shrubs interspersed by trees. Trees have become less in density because of land clearance to make room for farming, housing and other urban activities. Soils are fairly rich in minerals, but deficient in organic matter because of the relatively thin vegetative cover. Historically, farming which presently engages 30 % of the economically active population (Fig. 7.2), is the dominant occupation. It involves raising of both crops and livestock. The principal crops are cereals, especially maize and sorghum/guinea corn, yam (a tuber), nuts and pulses. Their cultivation occurs around each of a set of circularly arranged houses interconnected by walls in a system of intensive agricultural land use called compound farming that is sustained by refuse of the compound houses. Additional cropping takes place at locations farther away through bush fallow or land rotation, whereby soil fertility of the patches of cropped land are regenerated by periodically leaving the cropped patch fallow for some time. Free-range livestock farming features prominently and focuses principally upon cattle production. An important supplementary primary economic activity by farmers is harvesting of the fruits of naturally occurring shea and *dawadawa* trees in farms, fallow areas and uncultivated bush, especially by women and children.

In the tradition of the Dagbon people, the predominant natives, the land for farming and other purposes is owned in common by communities and extended families, as are cattle and naturally occurring economic trees. Another historically important economic activity is trading, both retailing and wholesaling. Presently this engages approximately 25 % of those employed. The substantial numbers of people engaged in other secondary and tertiary sectors including manufacturing and various services, notably western-type administration and education (Fig. 7.2), suggests a trend towards economic modernisation. Tamale has assumed importance as an education and research centre that boasts a Government owned

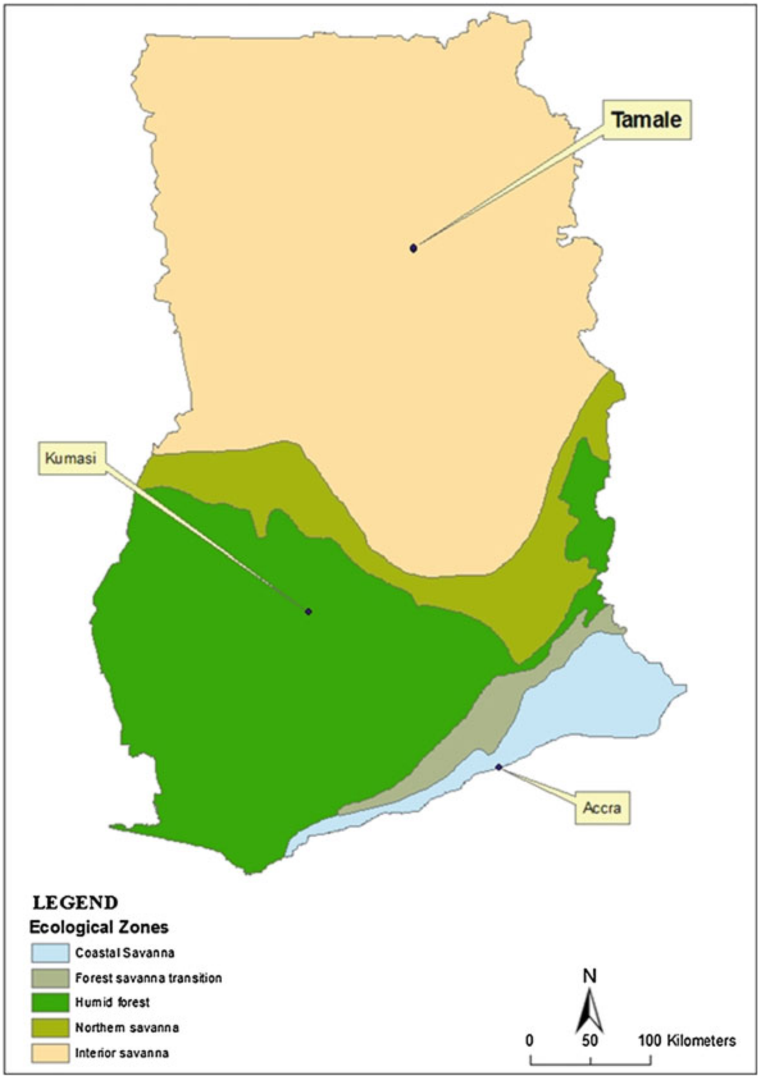


Fig. 7.1 Location of Tamale in Ghana

university and an agricultural research institute which, together with the many mainly public colleges and secondary and primary schools, employ large numbers of people, as do other Government organisations and a growing number of NGOs. Most of the workers (68 %) are self-employed in the private informal sector, 12 % in the public formal sector and the rest in the private formal and other unspecified sectors (Ghana Statistical Service 2005).

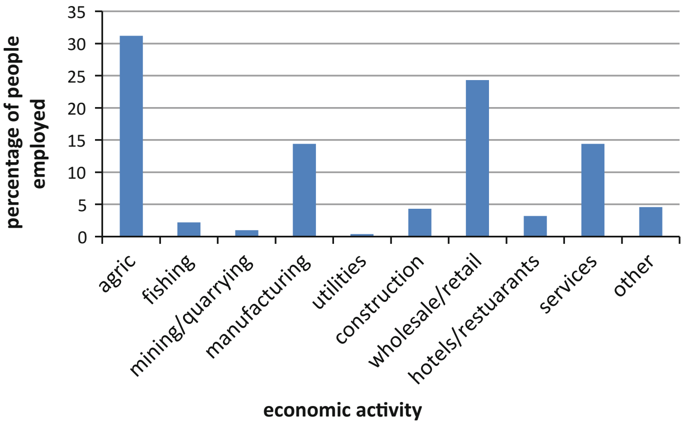


Fig. 7.2 Distribution of population by occupation. *Source* Fuseini (2013)

7.4 The Expansion of Tamale and Associated Agricultural Threats and Opportunities

Tamale's area barely extended to 1 km^2 around 1945, two years before its declaration as the administrative capital of the then Northern Territories of the Gold Coast (now Ghana) due to its central location. Using the official spatial demarcation as the reference, Tamale has expanded into the third largest city in Ghana (after Accra and Kumasi) and covers an area of over 900 km^2. Approximately 70 % of the 300,000 inhabitants occupy the core built-up area, with the rest occupying the periphery intervening between the core and the rural outlying areas (Staniland 1975; Braimoh and Vlek 2004; Ghana Statistical Service 2005; Unpublished records of the Town and Country Planning Department; Fig. 7.3). Because of the relative flatness of the terrain, the spatial expansion has been approximately radial or concentric. Remotely sensed imageries provide further insights into the spatial expansion or urban sprawl of Tamale (Fig. 7.4). Between 1989 and 2005, the built-up area expanded substantially to absorb a significant number of village communities.

The population has shown a similar expansion. It was estimated at about 1,500 in 1907. By 1931, the population had increased to nearly 13,000 and to approximately 300,000 in 2000. Between 1984 and 2000, it grew at an annual rate of 3.3 % Boserup and, at this rate, the population will most likely double by the year 2021. The growth results from the high fertility rate and influx of people from outside (Staniland 1975; Ghana Statistical Service 2002). Accompanying the population increase is an expansion of housing, schools, markets and other infrastructure, such as roads, in response to the increased demand for these facilities.

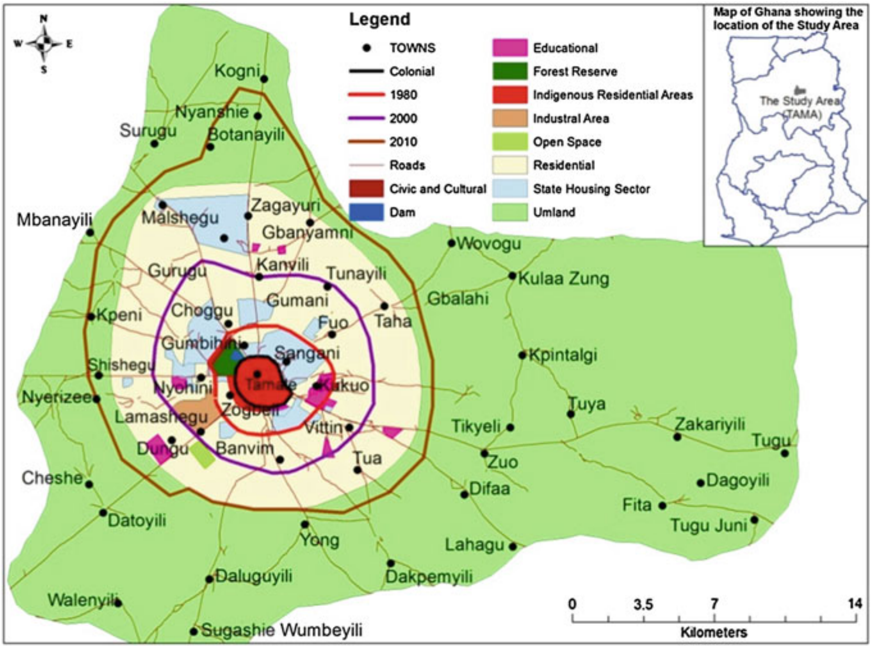


Fig. 7.3 Map of Tamale metropolitan area. *Source* Town and Country Planning Department (2000)

In relation to agriculture, the major adverse effect of the urban sprawl is the loss of agricultural land, since the process has inevitably involved incursion into actual or potential farming areas. The loss is due to other competing land use forms, notably modern housing and industries, which attract higher economic rent. This trend accords with classical theories of land use competition (Chisholm 1962). Several factors underscore the gravity of the growing scarcity of agricultural land including decreased agricultural holdings, shortened fallow times, increased farming distance, conversion of independent farmers into tenants or even landless and abandonment of farming by the youth. Traditionally, besides the home-centred compound farming, agriculture has involved cropping and grazing among trees occurring naturally in the grassy savannah landscape. Now, this environmentally low impact and, therefore, ecologically desirable agroforestry system, is under threat by the loss of trees to the urbanisation.

Water availability poses a further threat. Housing, office space, manufacturing, traffic, motor vehicle parks, markets and other pressures of urban growth have so encroached upon natural surficial water bodies causing them to disappear, or there is hardly any space around the surviving ones to support arable farming and the watering of livestock, especially cattle. The modern public pipe-borne system cannot make up for the shortfall even where there is sufficient agricultural land because it cannot meet domestic water demands, let alone the demand for

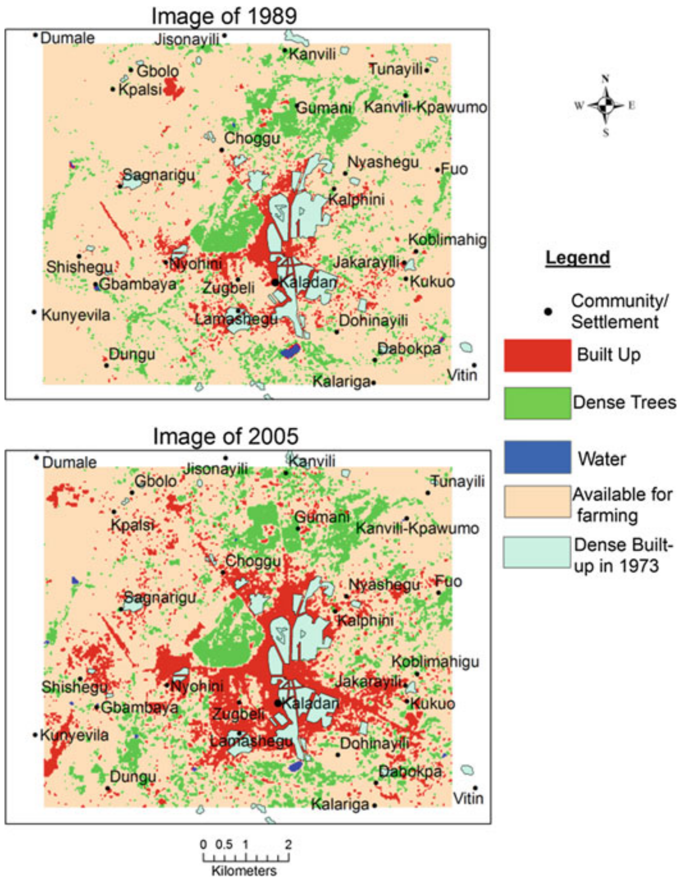


Fig. 7.4 The expansion of Tamale between 1989 and 2005. *Source* Satellite imagery downloaded in May 2011 from University of Maryland website (http://www.glcf.org) modified by the authors

agriculture. Public pipe-borne water meets only 54 % of the domestic water requirement of the city (Giweta 2011). Compounding the situation is the apparent climate change marked by rising temperatures and increasingly erratic rainfall which, in turn, is characterised by annually occurring intra-seasonal dry spells that are getting more frequent and longer, sometimes exceeding three weeks and resulting in crop failure. A possible further symptom of the apparent climate change is highly concentrated rainfall, which causes flooding, especially in the built-up localities (Kasei 1988; Lizcano and McSweeney 2008).

However, amidst the threats, there are opportunities for agricultural development which, if well managed, would enhance food security and livelihoods in Tamale. Perhaps the most fundamental one is the exploding spatially concentrated population now numbering 300,000 and growing at a rate exceeding 3 % per annum. Following the hypothesis by Boserup (1965) and the empirical findings of others (Gyasi 1976; Gyasi et al. 1995), population growth has the propensity to stimulate agricultural production by the increased demand or market prospects for food.

The prospect of meeting the increased demand is reinforced by a compelling need for farmers to survive by innovative ways of intensifying use of the increasingly limited agricultural land. Tamale generates huge quantities of urban and municipal waste including faecal matter, sludge, garbage and discarded water. They offer a basis for innovative organic farming. A further opportunity for enhanced agriculture by farmers within the Tamale urban and peri-urban areas is their easier access to the Tamale market than farmers living and operating in rural areas beyond the Tamale Metropolitan Area.A question, then, is how are farmers attempting to manage the threats and opportunities? We address these issues briefly below on the basis of available information.

7.5 Farmer Reactions to Threats and Opportunities

The responses are varied. They include the following:

- Livelihood diversification
- Switch to different cultivars
- Shift in planting dates
- Land use intensification.

They are discussed in turn. There is a definite trend towards livelihoods diversification. Farmers and potential farmers are migrating into the secondary and tertiary sectors of the economy. There is increased emphasis upon horticulture, especially the raising of vegetables facilitated by wastewater use. Beekeeping is gaining in importance, especially among women, in the peri-urban areas together with the intensive battery-type poultry production, all geared towards meeting the urban demand.

There is evidence of the growing use of new cultivars which require shorter growing periods and are resistant to drought. For example, farmers in Kanshegu and Savelugu are de-emphasising the cultivation of the *mankariga* (5 months), and *kukohibua* varieties of sorghum that mature over a longer period (3–5 months) to the *kadaga* variety having a much shorter gestation period (less than 3 months). There also is a reported change from cultivation of the late maturing Dagomba cowpea to early maturing ones (Bediako et al. 2005).

Timing of planting and fertilizer application shows significant shifts. For example, normally cereals are planted in July instead of June in response to the observed persistent delayed onset of the rains. In the wake of the growing scarcity of agricultural land, farmers are intensifying agricultural land use by:

- Chemical fertiliser and pesticides.
- Use of municipal liquid and solid waste (including human excrement) for watering and organic manure with the latter boosted by a privately owned composting facility.
- Greater exploitation of water by tapping groundwater with wells and boreholes and harvesting rainwater by dugouts.

Farmers actively encourage cesspit emptiers to dump human waste on farms to fertilise the soil (Owusu-Bennoah and Visker 1994). Other responses under investigation include the use of valley bottoms and out-migration.

7.6 Conclusions

As is commonly the case universally, the urbanisation of Tamale poses threats to agriculture, while at the same time opens up opportunities for this traditional economic activity and other forms of livelihood in the urban and peri-urban areas. The foremost threat is land shortage, which results from increased land use competition. Others include increased tenancy, landlessness, water shortage and ecologically high impact harmful farming practices. Opportunities include spatially concentrated demand, which favours the marketing of agricultural produce. People react variously to these threats and opportunities, especially by way of land use intensification involving the use of increased municipal waste for horticulture. The key challenge will be to enhance the capacity for managing the threats and opportunities for a sustainable urban future through food security.

References

Bediako J, Fosu M, Kasei CN (2005) Report on drought mitigation ground truthing survey in Northern Ghana. CPWF PN06 Report, SARI

Braimoh AK, Vlek PLG (2004) Land cover dynamics in urban areas of Ghana. Earth Interact 8(1):1–15

Boserup E (1965) The conditions of agricultural growth. Aldine, Chicago

Brown KH, Carter A (2003) Urban agriculture and community food security in the United States: farming from the city centre to the urban fringe. Community Food Security Coalition’s North American Urban Agriculture Committee, Venice

Chisholm M (1962) Rural settlement and land use: an essay in location. Hutchinson University Library, London

Cofie O, van Veenhuizen R, de Vreede V, Maessen S (2010) The role of urban agriculture in sustainable urban nutrient management: analysing the nexus of sanitation and agriculture nutrient cycles in three African cities. Urban Agriculture Magazine, no. 23

Fuseini I (2013) Land use competition: its implications for food security in peri-urban Tamale. Dissertation, University of Ghana, Legon

Getis A, Getis J, Fellman JD (2006) Introduction to geography. McGraw Hill, New York

Ghana Statistical Service (2002) 2000 Population and housing census. Ghana Statistical Service, Accra
Ghana Statistical Service (2005) 2000 Population and housing census: analysis of district data and implication for planning for Northern Region. Ghana Statistical Service, Accra
Giweta M (2011) Mainstreaming wastewater management issues into urban planning: the case study of Tamale Metropolis, Ghana. Dissertation, Wageningen University
Gyasi EA (1976) Population pressure and changes in traditional agriculture: case study of farming in Sekesua-Agbelitsom, Ghana. Bull Ghana Geog Assoc 18:68–87
Gyasi E, Agyepong GT, Ardayfio-Schandorf E, Enu-Kwesi L, Nabila JS, Owusu-Bennoah E (1995) Production pressure and environmental change in the forest-savannah zone of Southern Ghana. Glob Environ Change 5(4):355–366
Kasei CN (1988) The physical environment of semi-arid Ghana. In: Unger PW, Sneed TV, Jordan WR, Jensen R (eds) Challenges in dryland agriculture: a global perspective. Proceedings of the international conference on dryland farming. FAO, Amarillo
Land and Water Australia (2008) Change and continuity in peri-urban Australia. Australian Government Social and Institutional Research Programme, Canberra
Lizcano C, McSweeney M (2008) UNDP climate change country profile: Ghana—Oxford climate data, Oxford Report, UNDP, Accra
Marshall F, Waldman L, MacGregor H, Mehta L, Randhawa P (2009).On the edge of sustainability: perspectives on peri-urban dynamics. STEPS Working Paper 35. STEPS Centre, Brighton
Mubvami T, Mushamba S (2006). Integration of agriculture in urban land use planning and adaptation of city regulations. http://www.idrc.ca/en/ev-103759-201-1-DO_TOPIC.html. Accessed 20 Sept 2010
National Population Council (2006) Ghana's development agenda and population growth: the unmet need for family planning. National Population Council, Accra
Nelson SC (2007) Farming on the fringes: changes in agriculture, land use and livelihoods in peri-urban Dar es Salaam, Tanzania. Honours projects, Paper 10. http://digitalcommons.macalester.edu/geography_honors/10
Owusu-Bennoah E, Visker C (1994) Organic wastes hijacked. ILEIA 5(2):12–13
Satterthwaite D (2007) The transition to a predominantly urban world and its underpinnings. International Institute for Environment and Development; Human Settlement Discussion Paper Series, Urban change-4
Staniland M (1975) The lions of Dagbon: political change in Northern Ghana. Cambridge University Press, London
Town and Country Planning Department (2000) Tamale outline plan. Town and Country Planning Department, Tamale, Ghana
Ubink J (2006) Land, chiefs and custom in peri-urban Ghana. Paper presented at workshop on indigenous peoples' and local communities' rights and tenure arrangements, as part of the international conference on land, poverty and development, the Hague
United Nations (2009) World population monitoring: focusing on population distribution, urbanisation, internal migration and development. United Nations, New York
Urban Agriculture Network (2008) Promoting urban agriculture: the role of UrbANet in Northern Ghana. UrbANet, Tamale
Van Veenhuizen R, Danso G (2007) Profitability and sustainability of urban and peri-urban agriculture. FAO, Rome
Yaro JA (2010) Customary land tenure under siege: contemporary access to land in Northern Ghana. GeoJournal 75:199–214

Part III
Water and Energy

Chapter 8
Urbanisation and Its Effects on Water, Food Security and Energy Needs in Iran: A Case Study of City of Shiraz

Mansour Esfandiari-Baiat, Zahra Barzegar, Lotfollah Yousefi and Basant Maheshwari

Abstract Urbanisation is threatening the sustainability of water, food and energy security in Iran. The primary reason for urbanisation is the migration of people from rural areas to cities. The city of Shiraz is located in the Shiraz Plain (380 Km^2) in southern Iran. Its population in 1956 was 170,659 and grew to 1,351,181 in 2006. The population of Shiraz grew about 8 fold during this period while that of Iran during the same period only grew about 4 fold, indicating that the rate of migration was very high and urbanisation around Shiraz happened very fast in the same period. In 1956, Shiraz had a beautiful landscape, its size was 894 ha and it was surrounded by 1,565 ha of beautiful gardens and 35,714 ha of good agricultural land, fertile arable land and rangeland. In 1989, Shiraz had 5,962 ha of gardens. In 2006, Shiraz's size grew to 19,074 ha (21 fold growth) and this rapid urbanisation has replaced not only 2,987 ha of valuable gardens but also caused the disappearance of some 18,000 ha of agricultural land, fertile arable land, and rangeland. Changes in land use in the Shiraz Plain, because of rapid urbanisation, were very high and have seriously reduced agricultural and horticultural production and also created significant problems for the people in the city. Due to rapid urbanisation, the demand for water has increased 15 times in the city during the period of 1956–2006. The consumption of energy in the Iranian residential sector is high and it was 2.5 fold of the world's average consumption.

M. Esfandiari-Baiat (✉)
Department of Agriculture, Firouzabad Branch Islamic Azad University, Firouzabad, I.R. Iran
e-mail: esfandiari.b@gmail.com

Z. Barzegar
Department of Art and Architecture, Science and Research Branch, Islamic Azad University, Tehran, I.R. Iran

L. Yousefi
Khanesazan Bunyan Marcos Co, Shiraz, I.R. Iran

B. Maheshwari
University of Western Sydney, Penrith NSW 2751, Australia
e-mail: b.maheshwari@uws.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_8,

According to the power consumption records from the Shiraz electricity company between 1968 and 2006 consumption grew 70 fold. The preliminary analysis in this study through the case study of Shiraz suggests that we need an in-depth study to understand how urbanisation has impacted on the availability of water supplies, the security of food production around our cities and the energy needs at the national level and what policy and planning changes are required to achieve sustainable and liveable cities in the future.

Keywords Urbanisation · Shiraz · Iran · Food security · Water · Energy

8.1 Introduction

Urbanisation can be defined as the expansion of a city, the increase of total population or area in urban localities (cities and towns) over time (Antharvedi 2013). The prime reason for urbanisation is migration of people from rural areas to cities. Two centuries ago there were only two cities with a million inhabitants, London and Beijing (Desai and Potter 2002). But now there are 293 cities with a million inhabitants and most of these are in the developing world. The growth rate of these cities was 10 fold between 1950 and 1990. Some of these cities, such as Abidjan, Amman, Dhaka, and Harare, are now defined as mega cities with 10 million inhabitants (Desai and Potter 2002). Urbanisation is considered part of the development process in developing countries in the present world. It has been seen through history that cities are the driving force of a country's economic and social development. Higher income, improved healthcare, better living standards and other better opportunities lead towards rapid urbanisation but all these benefits have an environmental and social cost (South Asia: State of the Environment 2001). Rapid urbanisation is threatening sustainable life in the world through its negative effects on the environment (biosphere, pedosphere and hydrosphere). Damage to soil, water and forests, air pollution and greenhouse gas emissions are the major environmental costs to socio-economic activities (Todaro and Smith 2006).

Air, noise, water, and soil pollution are consequences of urbanisation and threaten not only the health of people but their food and water security. Urbanisation is also destroying farm fields, gardens and rangelands around the cities and this seriously decreases agricultural and horticultural production leading to food shortages in the world. As cities become bigger, agricultural land around cities is converted into residential areas. In Conception, a Chilean city, 1,734 ha of wetlands and 1,417 ha of agricultural land and forests were converted into residential areas over the period 1975–2000 (Pauchard et al. 2006). In Accra, Ghana, 2,600 ha of agricultural land are converted each year into residential areas (Maxwell et al. 2000). Similar actions are seen in China and Indonesia (Verburg et al. 1999; Weng 2002).

As cities expand, the demand for water increases which causes the share of water for agricultural activities to decrease and consequently decreases agricultural products. Migration of rural people to cities reduces the number of active people in the agricultural sector and probably leads to the decrease of agricultural production.

The current trends of urban dynamics in the Third World regarding climate change are alarming, because they are giving an increasing importance to cars, buildings and industries (Benoit 2009). By growing urban areas and energy consumer sectors (residential, commercial and industrial), the energy consumption in all sectors increases. This leads to greater greenhouse emissions and air pollutants with negative impacts on the health of urban residents. Urbanisation affects household travel and energy consumption through other channels (Chao and Qing 2011). Big cities all need more types of transportation vehicles and instruments which all consume fossil fuels or converted energy. Therefore, the role of world transportation in energy consumption (69.7 % in 2010) and urban emission accounted for 28.3 % of all sectors' emission in 2009. Population and building growth over the last decades has caused the energy consumption in this sector to increase and its emission is now 37.63 % (EIA 2008). As a result, adopting energy controlling policies in urban areas is inevitable. In this paper, we discuss the Shiraz urbanization processes during the period of 1956–2006 and its effects on water and food security and energy needs are discussed.

8.2 Shiraz and Its Population Growth

Shiraz is located in the Shiraz Plain (380 Km^2), centre of Fars Province in southern Iran (29° 33′–29° 41′ N, 52° 29′–52° 36′ E), 1,488 m above mean sea level) (Fig. 8.1). Shiraz, with a mean annual precipitation of 320 mm, is located in an arid and semi-arid region. The Shiraz Plain is surrounded by limestone mountains in the north, northeast, south, and southwest and by Maharloo Lake (closed salty lake) in the east and southeast. The Shiraz Plain is a sedimentary plain and its soil is rich and deep. Shiraz is the largest city in southern Iran. The population of Shiraz grew from 170,659 in 1956 to 1,351,181 in 2006. It has grown about 8 fold during the period 1956–2006 (Iran Statistical Centre 2006). The population of Iran in the above period (1956–2006) grew by about 4 fold (Table 8.1). Shiraz's population growth trends from 1956 to 2006 are shown in Table 8.2. Up until 1986 the growth ratio has been high, because of natural population growth and also migration to the city. War, drought, adoption and implementation of urban land law were the causes of immigration to Shiraz (Karimi et al. 2009). The growth ratio decreased from 1986 to 1996 and there is again an increasing trend from 1996 to 2006 (Table 8.2).

Fig. 8.1 Fars Province and Shiraz location

Table 8.1 Population of Shiraz and Iran in 1956 and 2006

Year	1956	2006
Population of Shiraz	170,659	1,351,181
Population of Iran	18,954,704	70,495,782

Data source General Population and Housing Census in 1956 and 2006

Table 8.2 Shiraz population growth trend from 1956 to 2006

Year	Population	Growth ratio	Source
1956	170,659	2.18	General census 1956
1967	262,396	3.99	Faculty of Fine Art, Tehran University
1974	394,360	5.99	Recognition of the comprehensive plan
1984	728,245	6.32	Peygeran Engineering Consultant
1986	836,055	7.15	General census 1986
1991	973,161	3.08	Current population survey 1991
1996	1,053,025	1.59	General census 1996
2006	1,351,181	2.52	General census 2006

Data source General Population and Housing Census in 1956–2006

8.3 Land Use Changes in the Shiraz Plain

Changes in different land uses, such as urban, horticulture, agriculture, arable land, and rangeland in the Shiraz plain, were surveyed during the period of 1956–2006 using aerial photos (Fig. 8.2). Results are shown on Table 8.3. As shown in Table 8.1, the population of Shiraz grew about 8 fold during the period of 1956–2006, while the urban occupied land grew 21 fold during the same period (Table 8.3). As shown in Table 8.3, the urban land size of Shiraz in 1956 and 2006 were 894 and 19,074 ha, respectively. This rapid urbanisation has replaced not only 2,987 ha of fantastic gardens, but has also caused the disappearance of about 18,000 ha of good agricultural land, fertile arable land and rangeland. As shown in Table 8.3, the amount of horticultural land increased from 1,565 ha in 1956 to 5,962 ha in 1989 but subsequently decreased to 2,975 ha by 2006.

8.4 Urbanisation and Its Effect on Water Resources

Groundwater is a valuable and vital source of water supply in arid and semi-arid regions. In 1956 the Shiraz plain was rich in groundwater in the alluvial and karst aquifers. Alluvial aquifers are in sedimentary formations in the Shiraz plain and the karst aquifer is in the limestone mountains which are located in north, northeast, south and southwest of the Shiraz Plain.

In 1956, the quality of water in the alluvial aquifer was good and was used for drinking, sanitation and irrigation of farm fields and gardens around the city. As shown in Table 8.4, 6,229,053 m^3 of water was used for drinking, sanitation, and irrigation of gardens in the backyards of the City in 1956. Due to urbanisation and entering of the wastewater through absorbed wells into the aquifer, it has been contaminated and has become unsuitable for drinking. As a result, authorities in the city decided to supply water from other resources such as the karst aquifer and surface water from Doorodzan storage dam (100 km far from Shiraz). Table 8.4 shows the amount of water used in the city for drinking, sanitation, and irrigation of gardens in the backyards in different years: 91,037,396 m^3 in 2010. The volume of water that is used annually increased 15 times in the period of 1956–2006. This means a big reduction in agricultural water and as a consequence a decrease in agricultural production around the city.

The proportion of different sources of water supply for selected months in 2011 is shown in Table 8.5. This shows that the karst aquifer provides 65 % of the water supply to the city. Discharge from the karst aquifer started from 2005 with a total discharge rate of 3,280 L/s. The karst aquifer has good quality water and its maximum and minimum Electrical Conductivity (EC) is 1475 and 271 micromohs/cm, respectively. The EC of water in some wells, with a total discharge rate of 750 L/s, is less than 700 micromohs/cm (Water and Wastewater Organization of Fars Province, unpublished data). Karst groundwater is a valuable and strategic

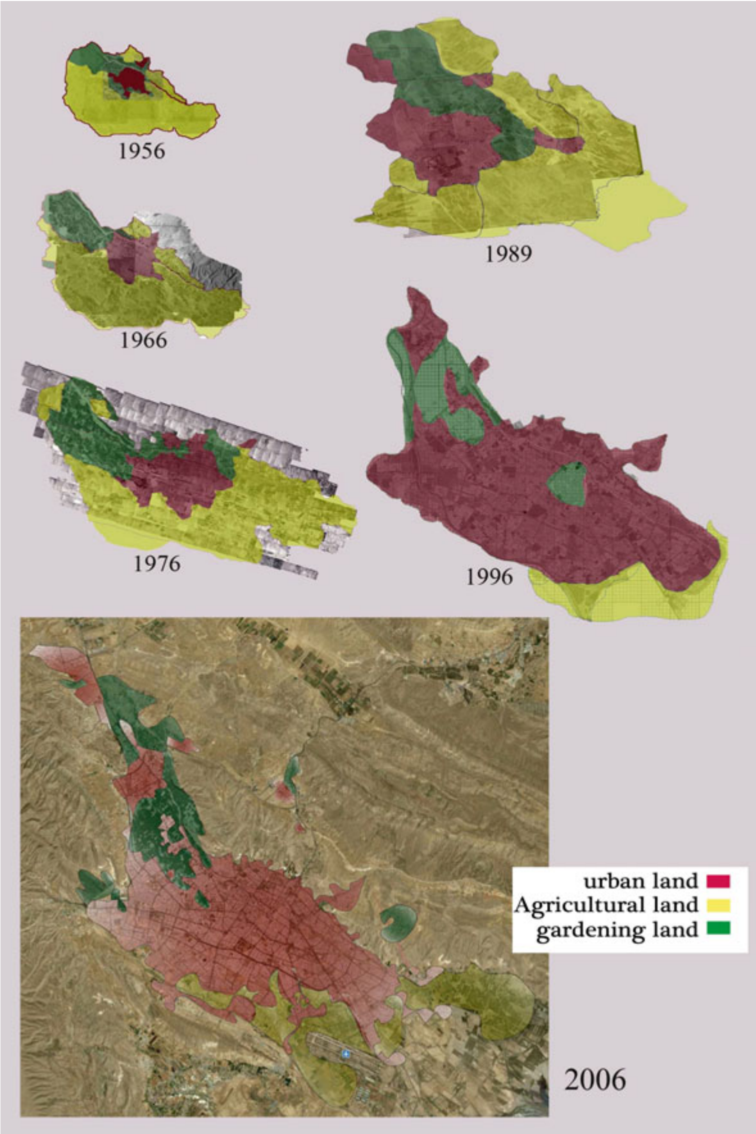


Fig. 8.2 Aerial photos of the Shiraz Plain from 1956 to 2006. *Source* National Cartographic Centre (2011)

water resource and it must only be used for drinking and preserved for the future. Unfortunately, the karst water has been used for sanitation and irrigation of gardens in houses. As mentioned previously, the EC of some wells, with a total discharge rate of 750 L/s, is less than 700 micromohs/cm and this can be classified as very good quality water. Therefore, this amount of water 23,328,000 m^3 can be

Table 8.3 Changes in land uses in the Shiraz plain during the period of 1956–2006

Year (ha)	1956	1966	1976	1989	1996	2001	2006
Urban land	894	1,609	3,540	9,098	13,880	1,6574	1,9074
Horticultural land	1,565	3,547	5,042	5,962	5,023	4,530	2,975
Agricultural land, fertile arable land, and rangeland	35,714	33,420	30,603	22,366	21,463	19,023	17,726

Data source National Cartographic Centre (2011), Shiraz Municipality (2006)

Table 8.4 Volume of water was used in the Shiraz city during different years

Year	The volume of water (m^3)
1956	6,226,053
2005	79,208,024
2006	80,846,467
2007	83,713,892
2008	87,328,783
2009	89,593,175
2010	91,037,396

Data source Water and Wastewater Organization of Fars Province (unpublished data)

Table 8.5 Shares of different sources of water in supplying of needed water for some months in 2011

Month	Surface water from Doorodzan dam (1,000 m^3)	Karst groundwater (1,000 m^3)	Alluvial groundwater (1,000 m^3)	Total volume of produced water (1,000 m^3)
April	2,853	5,389	397	8,639
May	3,046	6,309	407	9,762
June	2,959	7,440	766	11,165
July	2,909	7,707	868	11,484
August	2,782	7,321	993	11,096
Sep.	2,759	6,587	813	10,159
Oct.	2,635	6,329	747	9,711
Total	19,943 (27.7 %)	47,082 (65.4 %)	4,991 (6.9 %)	72,016 (100 %)

Data source Water and Wastewater Organization of Fars Province (unpublished data)

considered as mineral water that could be exported overseas. At an estimated price of 1 USD/L, the value would be USD 23,328,000,000. This large income can improve the quality of life of people in the city. Also, as shown in Table 8.5, 27.7 % of needed water in Shiraz is supplied from Doorodzan dam (100 km far from Shiraz), meaning a big reduction of agricultural water in the Doorodzan region that has a negative effect on the amount of agricultural produce in the region apart from the environmental impact.

8.5 Urbanisation and Its Effect on Food Security

Gardens in cities have a vital role in the sustainable management of the cities, as they reduce air pollution and air temperature by absorbing CO_2 and releasing O_2 in the air. This provides a healthier atmosphere for city dwellers. Gardens can attract many tourists and this means more money coming into a city and an improved lifestyle for people in the cities. Gardens are also pleasant places for resting and relaxing which can reduce people's daily stresses. The famous gardens of Shiraz are in the Ghasrodasht and Chamran regions in the northwest of city that produce different kinds of fruits such as walnut, apricot, cherry, black cherry, grape, plum, persimmon, and pomegranate for the consumption of inhabitants. Unfortunately, in the past 25 years, by increasing the price of land for the construction of buildings, many gardens have been destroyed.

As shown in Table 8.3, the garden area increased from 1,565 ha in 1956 to 5,962 ha in 1989, but subsequently it decreased to 2,975 ha in 2006. This means a significant reduction in the size of gardens (2,987 ha) in the city. Agricultural land, fertile arable land, and rangeland were 35,714 ha in 1956 but later it decreased to 17,726 ha by 2006. This means a significant reduction in the size of the agricultural land, fertile arable land, and rangeland (18,000 ha). This is a significant threat for the food security. Table 8.4 shows that the volume of water used annually in the city for different purposes increased 15 times in the period of 1956–2006. This was a considerable reduction in agricultural water and may impact on agricultural production and food security in general.

8.6 Urbanisation and Its Effect on Energy Consumption and Air Pollution

Due to urban land expansion and population growth the consumption of energy and air pollution increased in Shiraz during the period of 1956–2006. This caused an energy crisis in production, distribution and consumption sectors. Furthermore, the use of fossil fuels affects people as they contribute to air pollution, climate change, ozone depletion and greenhouse gas emission (GHG). The average annual Iranian residential sector consumed 310 $KWh/m^2$of energy in 2006, while, in similar climate regions of the world it was 120 KWh/m^2. Therefore, the Iranian residential sector energy consumption is 2.5 fold of the world's average (Toloeyan 2006). Figure 8.3 shows the Iranian residential sector energy consumption trend from 1974 to 2003.

Shiraz's energy portfolio consists of oil, gas, and electricity. Table 8.6 shows the consumption of different kinds of energy sources in 2001. By converting all energy sources to primary energy (EPA 2011; EIA 2011) the average energy

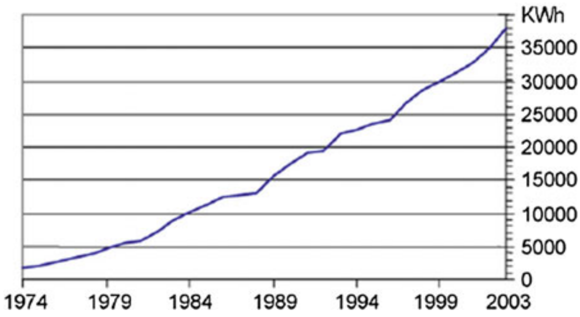


Fig. 8.3 The Iranian residential sector energy consumption uptrend from 1974 to 2003. *Source* Azadeh and Faiz (2011)

Table 8.6 Amount of consumption of different kind of energy in Shiraz in 2001

Source of energy	Unit	Consumption	Source-site ratio (EPA 2011)	Source
Natural gas	M M^3	1,990	1.047	Fars Province National Gas Company (NGC)
Electricity power	M KWH	2,416	3.34	Shiraz Power Distribution Company (2013)
Gasoline engine	M^3	377,008	1.01	Fars Province National Oil Products Distribution Company (NIOPDC) (2013)
Liquid gas	Tonne	51,278	1.01	
Kerosene	M^3	148,518	1.01	
Fuel oil	M^3	151,045	1.01	
Oil gas	M^3	528,296	1.01	
Total consumption	Primary energy	1,278,859	–	

consumption of urban land for each square meter was 77.16 MWh primary energy out of the total energy consumption of 1,278,859 MWh primary energy in Shiraz in 2001 which represents a large component. By growing the population and urban area this consumption will be increased each year without a well-considered controlling plan. The urban land growth impacts directly on energy consumption. For example, the energy consumption in 2006 was at least 115 % of 2001. According to Shiraz's electricity consumption records from 1968 to 2006, the consumption growth was about 70 fold (Table 8.7). Moreover, the growth rate of Shiraz's electricity consumption per capita from 1968 to 2006 was 15 fold. Electricity consumption per capita is displayed in Tables 8.2 and 8.7. Therefore, there is an urgent need to develop an econometric model for energy intensity and GHG emission intensity in view of the poor energy supplies and environmental situation in Shiraz.

Table 8.7 Shiraz electricity consumption in MWh from 1968 to 2006

Year	Residential	General	Agricultural	Industry	Commercial and etc.	Street lightening	Total	Consumption growth based on 1968	Per capita GHG emission (tonnes of CO_2)
1968	–	–	–	–	–	–	52,299	–	0.194
1976	81,774	107,052	12,598	133,143	1,904	12,260	348,831	6.67	0.819
1989	345,682	297,721	–	171,361	654	34,632	850,842	16.27	1.018
1996	546,001	47,398	142,423	429,073	188,060	48,588	1,501,543	28.71	1.456
2006	1239,721	591,822	773,594	656,492	251,855	126,580	3,640,064	69.60	2.966

Source Shiraz Power Distribution Company 2013

8.7 Strategies for Sustainable Cities in Iran

The preliminary analysis in this study, through the case study of Shiraz, shows that unplanned and rapid urbanisation of cities in Iran in the past has threatened not only water, food, and energy security but also created significant problems for the people who live in cities. We suggest that an in-depth study is needed to understand how urbanisation has impacted the availability of water supplies, the security of food production around our cities and the energy needs at the national level and what policy and planning changes are required for sustainable and liveable cities in the future.

Two types of strategies are needed to be considered at the national level for sustainable and liveable cities into the future. Firstly, a strategy for improving the living conditions for the people who live in cities, such as increasing green spaces, parks, and sport facilities within the cities and improving transport systems. Secondly, there is need for strategy for more orderly and planned migration from rural areas into cites and encouraging people to stay in rural area by providing enough water for agricultural production through implementing rain water harvesting and water saving programs, decreasing poverty through introducing alternative income generating programs, and improving living conditions by providing good educational and health system in rural areas.

8.8 Conclusions

Shiraz has been faced with rapid urbanisation in the period of 1956–2006. In 2006, Shiraz's size became 19,074 ha (21 fold) and this rapid urbanisation has replaced not only 2,987 ha of valuable gardens but also has been responsible for the disappearance of some 18,000 ha of good agricultural land, fertile arable land and rangeland. Changes in land use in the Shiraz Plain due to rapid urbanisation were very high and this not only seriously reduced agricultural and horticultural production but has also created serious issues for the people in the city. In particular, the volume of water used annually increased 15 times in the period of 1956–2006. This means a significant reduction in water for agricultural irrigation and consequently a decrease in the agricultural production from the region. The consumption of energy in the Iranian residential sector is very high and was 2.5 fold of the world's average. More research is needed to know how urbanisation has impacted on water resources, food, and energy security around Iranian cities and what policy and planning changes are required for sustainable and liveable cities in the future.

Acknowledgments We wish to express our sincere appreciation to Khanesazan Bonyan Marsoos Co. for its special cooperation in collecting data and also we would like to thank Islamic Azad University, Science and Research Branch and Islamic Azad University Firouzabad Branch for their financial support.

References

Antharvedi U (2013) Urban environment—sustainable development (8 Jan 2007). Available at SSRN: http://ssrn.com/abstract=955789 or http://dx.doi.org/10.2139/ssrn.955789. Accessed 24 Oct 2013

Azadeh A, Faiz ZS (2011) A meta-heuristic framework for forecasting household electricity consumption. Appl Soft Comput 11:614–620

Benoit L (2009) Long-term energy consumptions of urban transportation: a prospective simulation of transport–land uses policies in Bangalore. Energy Policy 37(3):940–953

Chao L, Qing S (2011) An empirical analysis of the influence of urban form on household travel and energy consumption. Comput Environ Urban Syst 35(5):347–357

Desai V, Potter BR (2002) The companion to development studies. Oxford University Press Inc., New York

EPA (2011) United nation environmental protection agency, energy star performance ratings methodology for incorporating source energy use, pp 3

Fars Province National Oil Products Distribution Company (NIOPDC) (2013) http://www.niopdc.ir/HomePage.aspx?TabID=5374&Site=fars.niopdc&Lang=en-US

Iran Statistical Centre (2006). General population and housing census 2006 and 1996. Shiraz, Iran

Karimi A, Karimi B, Roshani A (2009) Evaluation of Shiraz physical development with emphasis on natural factors. J Geogr Zagros Landscape 1(1):5–18

Maxwell D, Levin C, Armar-Klemesu M, Ruel M, Morris S, Ahiadeke C (2000) Urban livelihoods and food and nutrition security in Greater Accra, Ghana. IFPRI, Research Report 112. International Food Policy Research Institute, Washington DC

National Cartographic Centre (2011) Shiraz aerial photograph. National Cartographic Centre, Tehran, Iran

Pauchard A, Aguayo M, Pena E, Urrutia R (2006) Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepcion, Chile). Biol Conserv 127:272–281

Shiraz Municipality (2006) Recognition of the comprehensive plan and Shiraz detailed design. Shiraz, Iran

Shiraz Power Distribution Company (2013) http://www.shirazedc.co.ir/PrintPage.aspx?Page_=form&PageID=603&PageIDF=&lang=1&tempname=mainsite&sub=0. Accessed 24 Oct 2013

South Asia: State of the Environment (2001) United nations environment programme. http://www.rrcap.unep.org/pub/soe/sa_part2_4.pdf. Accessed 24 Oct 2013

Todaro MP, Smith S (2006) Economic development, 9th edn. Prentice Hall, New Jersey

Toloeyan A (2006) Energy management and its relationship to sustainable development and environmental pollution. In: Paper presented at fifth conference on optimization buildings fuel consumption, Tehran, Iran

U.S. Energy Information Administration/Emissions of Greenhouse Gases in the United States (EIA) (2008) Emissions of greenhouse gases, the United States. www.eia.doe.gov/oiaf/1605/ggrpt. Accessed 20 Oct 2013

U.S. Energy Information Administration/Emissions of Greenhouse Gases in the United States (EIA) (2011) ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy Use. http://www.energystar.gov/ia/business/evaluate_performance/site_source.pdf. Accessed 17 Oct 2013

Verburg PH, Veldkamp TH, Bouma J (1999) Land use change under condition of high population pressure: the case of Java. Glob Environ Change 9:302–312

Weng Q (2002) Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modeling. J Environ Manage 64:273–284

Chapter 9
Thirsty Cities: The Urban Water Footprint and the Peri-urban Interface, a Four City Case Study from West Africa

Pay Drechsel, Olufunke O. Cofie and Philip Amoah

Abstract Urbanisation is increasingly affecting inter-sectoral water allocations. This paper looks beyond physical water transfers at the larger urban water footprint and how much it is affecting the urban periphery in the case of four cities in West Africa (Accra, Kumasi, Tamale and Ouagadougou). The results showed a water footprint variation between 892 and 1,280 m^3/capita/year for these four cities based on actual and virtual water flows. The virtual flow through the food chain is outscoring actual domestic water consumption by a factor of 40–60 and using water resources far beyond the peri-urban interphase. However, the picture is changing with consideration of the grey water footprint. Due to limited wastewater treatment, peri-urban areas are the hot spots of water pollution diminishing their fresh water resources. The fresh water affected by the urban return flow easily doubles the overall urban water footprint. Improved on-site sanitation, especially with water saving and urine and excreta separating toilets would have a significant positive impact on the quality and quantity of the urban water footprint given that actual water availability is limiting large scale sewer connections for final wastewater treatment.

Keywords Virtual water · Wastewater · Water footprint · West Africa

P. Drechsel (✉)
International Water Management Institute, Colombo, Sri Lanka
e-mail: p.drechsel@cgiar.org

O. O. Cofie
Challenge Program for Water and Food, Ouagadougou, Burkina Faso
e-mail: o.cofie@cgiar.org

P. Amoah
International Water Management Institute, Accra, Ghana
e-mail: p.amoah@cgiar.org

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_9,

9.1 Introduction

Urban water demand and its possible impact on the peri-urban and rural environment is receiving increasing attention especially in areas of physical water scarcity (Johnson 2001; Van Rooijen et al. 2005; Molle and Berkoff 2009). While most studies focus on domestic water needs, it is also interesting to look at the larger urban water footprint. How much water does a city consume? To answer this question we defined the urban water demand as the water needed to (i) support urban (domestic and industrial) water needs (ii) feed the city, and (iii) dilute the urban return flow (discharged wastewater) to acceptable standards (grey water footprint). The study was carried out in four West African cities: Kumasi, Accra and Tamale (all Ghana) and Ouagadougou (Burkina Faso). The four cities give a cross-section through different agro-ecological zones while advancing from coast and forest belts to drier savannah areas. While Accra and Kumasi are in the West African tuber belt, the agro-zone around Tamale and Ouagadougou is increasingly dominated by cereal based diets. Accra is the capital city of Ghana with an assumed population of 1.66 million for the assessment (Ghana Statistical Services 2002). Representing the semi-humid forest zone of Ghana, Kumasi is the capital town of Ghana's Ashanti Region and the second largest city in the country with a population of about 1.1 million during the study period. Tamale is the capital of Ghana's Northern Region. The Tamale district covers the city itself and some surrounding villages with a total population of 290,000 (Ghana Statistical Services 2002). Ouagadougou is the capital of Burkina Faso. The population estimate used for the city in this study was 1.2 million capita.

9.2 Methodology

The study was based on an assessment of rural–urban food (and related virtual water) flows based on food marketing surveys and household/street surveys to assess consumed amounts and consumption patterns (Table 9.1). The analysis was carried out across 20 commodities looking at water and food sources to understand the contribution of urban, peri-urban and rural supply. Secondary data from local ministries and Food and Agricultural Organisation (FAO) were used for food production, import and export, and urban water supply and consumption.

The markets surveys covered in each city, all major markets as well as larger ones, specialised on certain commodities (Drechsel et al. 2007). The results of the market and consumption surveys were used to compute food entering the city, consumption and food leaving the city and related water and nutrient flows. With 'urban water footprint' we refer to the urban water demand comprising actual and virtual water under consideration of urban water pollution without ambition to fully apply the footprinting concept (Chambers et al. 2000; Hoekstra et al. 2011).

Table 9.1 Sample sizes market and consumption surveys

City	Number of households	Street food consumer survey	Number of markets covered	Number of food traders
Pilot phase (Kumasi)	91	0	3	85
Accra	999	702	5	370
Kumasi	950	220	4	240
Tamale	463	0	2	240
Ouagadougou	180	0	5	130

Source Drechsel et al. (2007)

9.3 Results and Discussion

Domestic water use for drinking and other household needs is shown in Table 9.2. The table shows that the overall domestic demand is about 12–16 times the drinking water only demand.

The flow of virtual water through the food chain is shown in Table 9.3. Compared with the domestic water use, the virtual water demand is about 40–60 times higher.

Table 9.4 shows the sum of actual and virtual water flows including the water actually transported within the food. It is obvious that the actual crop water content is a small fraction of the amount needed to grow the crop. It is also apparent that the water demanding cereal-based diet in Ouagadougou has much lower actual water content than the tuber and plantain based diets in Accra and Kumasi, especially when we convert the data to a per capita basis. In general, fruit and vegetables show the most favorable (low) ratio between virtual water requirement and actual water content. The total water demand as shown in Table 9.4 (2,440–3,500 l/capita/day) reflects a more crop-based vegetarian diet according to UNESCO-IHE (2006).

Despite their lower actual water content, cereals account for most of the crop-related virtual water footprint as six times as much water is needed to produce 1 kg of cereal compared with that required to produce 1 kg of tuber crops. This implies that the water demand within Ghana's tuber belt is likely to increase due to the common shift in urban diets to rice and poultry based fast food.

The "urban water footprint", which combines the domestic and virtual water demand, varies from Kumasi to Ouagadougou from 892 to 1,280 m^3/capita/year, respectively (Table 9.4). Roughly speaking, a city of one million inhabitants consumes one cubic kilometre (km^3) of virtual water annually. As irrigation is not very well developed in Ghana, the large majority of this amount is derived from precipitation. Thus, there is little competition for agricultural water in Ghana and different footprints mostly reflect different diets.

A possible basis for comparison of the 'urban water footprint' is the 'national water footprint' (Chapagain and Hoekstra 2004), which has been estimated for the period as being 1,293 m^3/capita/year for Ghana and 1,529 m^3/capita/year for

Table 9.2 Domestic water use in 1,000 m^3/year in the four cities

	Accra	Kumasi	Tamale	Ouagadougou
Drinking water	1,820	1,200	320	1,310
All domestic water	29,700	19,700	4,000	21,900

Source Drechsel et al. (2007)

Table 9.3 Virtual water content of selected consumed crops

	Water demand	Virtual water flows (in 1,000 m^3)			
Crop	l/kg crop	Accra	Kumasi	Tamale	Ouagadougou
Cassava	407	33,798	33,635	9,598	1,830
Yam	515	45,518	35,529	7,930	6,539
Cocoyam	1,581	30,352	20,393	5,217	0
Rice	3,327	125,414	99,467	23,619	204,921
Maize	2,930	162,349	71,504	41,906	168,796
Millet	3,172	0	0	0	39,726
Sorghum	3,256	0	0	0	19,350
Wheat	1,160	30,332	16,822	2,208	8,442
Cabbage	319	3,632	2,358	350	0
Tomato	758	18,195	23,000	2,200	7,730
Onion	872	11,420	6,452	1,570	6,000
Eggplant	1,163	19,840	23,500	1,345	5,816
Okra	586	0	0	527	0
Fruits, plantain	432	55,470	36,720	5,790	8,950
Total		536,320	369,380	102,260	478,100

Source Drechsel et al. (2007)

Table 9.4 Virtual and domestic water use in the four cities

	Accra	Kumasi	Tamale	Ouagadougou
Water use in 1,000 m^3/year				
Actual water content of crops consumed	310	290	50	70
Virtual water of crops consumed	536,300	369,400	102,300	478,100
Virtual water of animal products consumed, excluding fish	839,000	399,000	140,000	805,000
Drinking water use	1,820	1,200	320	1,310
Domestic water use including drinking water	29,700	19,700	4,000	21,900
Total water use per capita				
Urban water footprint (m^3/capita/year)	950	892	1,010	1,280
Urban water footprint (l/capita/day)	2,600	2,440	2,767	3,500

Source Drechsel et al. (2007)

Burkina Faso. These estimates, which are based on national production statistics compiled by the FAO and World Trade Organisation (WTO), appear high when compared to the survey based data, which is not unusual (Smith et al. 2006). Still, the figures from Burkina Faso and Ghana show a similar difference between both countries as reflected in the urban assessments (Table 9.4). The reason for the difference could be either the additional consideration of other crops, products and services in the national water footprint calculation, an over-estimation of the national production or deviations through post-harvest losses and the import–export balance.

Not considered in Table 9.4 is the grey water footprint. This grey water footprint refers to the particular 'peri-urban' water quality challenge. Although water recycling (domestic return flow into the natural system) reduces the urban water footprint, this amount remains marginal compared to the additional environmental water requirements to dilute its contamination load where wastewater treatment is poorly developed (cf. Hoekstra and Chapagain 2007). In the case of Accra or Kumasi, less than 7 % of the urban wastewater receives some kind of treatment. Most streams passing the cities have faecal coliform loads of at least 10^5/100 ml.

Faecal contamination derives from open defecation, flying toilets, as well as latrines and septic tanks. Erni (2007) analysed water fluxes in Kumasi and estimated that of the approximate 50 l used per capita a day, about 40 l are lost in or outside the yard or in storm water drains, about 8 l enter on-site septic tanks and latrines and 2 l enter a sewer. Of the 8 l entering on-site septic tanks a maximal 0.5 l is eventually withdrawn with faecal sludge for treatment while the rest leaves the tanks through cracks or overflow. In another assessment, Seidl et al. (2005) estimated overall losses, in Yamoussoukro, Côte d'Ivoire, to be about 85 % and a maximum of 8 l that might be withdrawn for faecal sludge treatment. Also, in this case, the majority of the black water (toilet water) entering septic tanks was assumed as lost, with the difference being the local frequency of tank desludging.

Based on the degree of pollution (10^5 faecal coliform counts/100 ml) we can assume that every litre of domestic return flow requires at least 100 l of clean water to dilute its pollution load below the common World Health Organization (WHO 2006) faecal coliform 10^3-threshold for unrestricted irrigation. In this case, the urban water footprint in all four cities would double. In Ouagadougou, for example, the footprint would increase from 1,280 m^3/capita/year to 2,740 m^3/capita/year putting a significant burden on peri-urban water bodies and pollution related environmental costs.

9.3.1 Reducing the Urban Water Footprint

While Accra receives its piped water from two basins, 80 % of the food-related virtual water comes from four sub-regional basins and 20 % (mostly processed and frozen food) comes from 38 basins worldwide, showing Accra's extensive geographical footprint to satisfy urban food demands (Table 9.5).

Although there is no possibility of closing a 'virtual' water loop, like the rural–urban nutrient loop, i.e., no option to recycle virtual water, there are options to reduce the virtual water footprint. A 5 % increase in water productivity in

Table 9.5 Basins as sources of domestic and virtual water in the case of Accra, Ghana

Water type	Number of basins
Drinking water and domestic water	2
Virtual water (unprocessed food)	4
Virtual water (processed food)	38

Source Drechsel et al. (2007)

domestic rice production, for example, could theoretically make available 5 l of water per capita a day for Ghana's population. Hoekstra and Chapagain (2007) suggests, among others, shifting production techniques and areas from low to high water productivity. In the south–western area of Burkina Faso, like near Bobo-Dioulasso, a cubic metre of water allows for the production of about 1.77 kg of dry sorghum; in the Sudano-Sahelian central sites (like Ouagadougou), it allows for the production of 0.90 kg; in north–eastern Sahelian conditions (i.e., Dori), it allows for the production of 0.32 kg (Perret 2006). In such dry conditions, millet naturally competes with sorghum as the staple food crop, as its water productivity remains relatively much higher (at 1.27 kg/m^3) for similar yields (Perret 2006). This reflects a much better adaptation to drought. However, shifting production areas has immense socio-economic implications, and other possible means of improving water productivity in situ like rainwater harvesting or no-tillage appear more realistic. However, water productivity is not the only important consideration. As water productivity is lower in Ghana than in Asia and Northern America, the national and urban water footprint would increase if import restrictions were imposed to boost the local rice sector, while the geographical footprint would shrink. As most rice production in Ghana is rain-fed, water is not the limiting factor and fewer imports would support the livelihoods of many rural people in areas that currently cannot compete with imported rice.

Another possibility to improve water productivity and reduce the urban water footprint is to improve resource recovery in terms of wastewater treatment and its productive reuse, especially where water is scarce in and downstream of the city. In Accra, irrigated urban agriculture does not compete for freshwater but recycles about 10 % of the water that has already been used (Lydecker and Drechsel 2010). However, this water is treated in only a few cases. Centralised or decentralised wastewater treatment is seldom in place, as sewer networks are usually covering only a small percentage of the West African city. This might be appropriate, as piped water is in short supply in all four cities, is often cut off for days and cannot support the volumes of water required to flush and run large sewerage in any of the four cities. A related calculation was presented for Kumasi by Erni et al. (2010). So far, the growth of most cities in Ghana and Burkina Faso has been spread out horizontally, rather than rising vertically and on-site solutions, such as septic tanks, remain the most appropriate and water-wise sanitation option.

To reduce the steep increase in the grey water footprint through water pollution an important step would be to reduce leakage and overflow from septic tanks and latrines and their impact on nearby waterways. Low flush toilets, dry EcoSan toilets and improved septic tanks with more frequent de-sludging and controlled dumping systems would have a quantifiable, positive impact on urban water demand and the quality of urban and peri-urban water resources (Erni et al. 2010, 2011; Montangero and Belevi 2007).

9.4 Conclusions

Avoiding the increasing disparity between the urban and rural sectors in a century of urbanisation is a major challenge ahead which has significant socioeconomic and ecological dimensions. Our analysis of urban water footprints in the context of the rural–urban divide was designed to shed more light on this topic. The present study focused on actual and virtual urban water consumption in selected cities in West Africa as well as the grey water footprint.

Comparing the four case studies, the sources of actual water supply can vary widely between peri-urban and rural areas, while virtual water related to the food chain is mostly supplied from the rural hinterland. However, the consideration of the grey water footprint shows the key role of peri-urban areas in low income countries where wastewater treatment is usually poor. More than 95 % of the water that the city consumes can be considered as lost resources that pollute, as urban return flow, the environment. These negative contributions can easily double the urban water footprint.

There are, however, options to reduce the footprint, ideally through improved wastewater collection, treatment and reuse where water is in short supply in the production areas supplying food to the cities. Given the common urban water shortage as experienced in the study area, comprehensive treatment is not a realistic option, in contrast to land application. Key entry points for better waste management are in this case the urban households where most losses occur. In particular, reduced septic tank overflow and the comprehensive and timely collection and treatment (e.g., co-composting) of excreta would significantly reduce the urban environmental impact.

Acknowledgments The Comprehensive Assessment of Water Management in Agriculture supported our data collection in Burkina Faso, while the International Development Research Centre (IDRC) in Canada supported parts of the fieldwork in Ghana. We are also indebted to Michael Fink and Sophie Graefe who contributed to an earlier version of this paper and the Water, Land & Ecosystems Research Program of the CGIAR.

References

Chambers N, Simmons C, Wackernagel M (2000) Sharing nature's interest: ecological footprints as an indicator of sustainability. Earthscan, London

Chapagain AK, Hoekstra AY (2004) Water footprints of nations. UNESCO-IHE Institute for Water Education, Delft, The Netherlands

Drechsel P, Graefe S, Fink M (2007) Rural–urban food, nutrient and virtual water flows in selected West African cities. International Water Management Institute, Colombo, Sri Lanka, p 35 (IWMI Research Report Series 115)
Erni M (2007) Modelling urban water flows: an insight into current and future water availability and pollution of a fast growing city. Case Study of Kumasi, Ghana. MSc thesis, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland
Erni M, Dreschel P, Bader H-P, Scheidegger R, Zurbrügg C, Kipfer R (2010) Bad for the environment, good for the farmer? Urban sanitation and nutrient flows. Irrig Drain Syst 24(1–2):113–125 (Special issue on wastewater reuse)
Erni M, Bader H-P, Drechsel P, Scheidegger R, Zurbrügg C, Kipfer R (2011) Urban water and nutrient flows in Kumasi. Ghana Urban Water J 8(3):135–153
Ghana Statistical Services (2002) 2000 Population and housing census; summary report of final results, Accra, Ghana
Hoekstra AY, Chapagain AK (2007) Water footprints of nations: water use by people as function of their consumption pattern. Water Resour Manag 21:35–48
Hoekstra AY, Chapagain AK, Aldaya MM, Mekonnen MM (2011) The water footprint assessment manual. Earthscan, London. http://www.waterfootprint.org/downloads/TheWaterFootprintAssessmentManual.pdf. Accessed 31 Aug 2013
Johnson MP (2001) Environmental impacts of urban sprawl—a survey of the literature and proposed research agenda. Environ Plann 33:717–735
Lydecker M, Drechsel P (2010) Urban agriculture and sanitation services in Accra, Ghana: the overlooked contribution. Int J Agric Sustain 8(1):94–103
Molle F, Berkoff J (2009) Cities versus agriculture: a review of intersectoral water re-allocation. Nat Resour Forum 33(1):6–18
Montangero A, Belevi H (2007) Assessing nutrient flows in septic tanks by eliciting expert judgment: a promising method in the context of developing countries. Water Res 41:1052–1064
Perret S (2006) Climate change and African agriculture. Policy note 36, August 2006, CEEPA, University of Pretoria. www.ceepa.co.za/docs/POLICY%20NOTE%2036.pdf. Accessed 31 Aug 2013
Seidl M, Gnaboa Z, Mouchel JM (2005) Socio-cultural aspects of individual sanitation in West African cities. AGUA 2005, Cali, Colombia, 31 Oct–4 Nov 2005. http://bvs.per.paho.org/texcom/cd050704/seidl.pdf. Accessed 31 Sept 2013
Smith LC, Alderman H, Aduayom D (2006) Food insecurity in Sub-Saharan Africa: new estimates from household expenditure surveys. IFPRI research report 146. International Food Policy Research Institute, Washington DC, USA, pp 122
UNESCO-IHE (2006) UNESCO water portal weekly update no 145: water footprints. www.unesco.org/water/news/newsletter/145.shtml. Accessed 31 Sept 2013
Van Rooijen DJ, Turral H, Biggs TW (2005) Sponge city: water balance of mega-city water use and wastewater use in Hyderabad, India. Irrig Drain 54:81–91
WHO (2006) Guidelines for the safe use of wastewater, excreta and grey water: wastewater use in agriculture (vol 2). World Health Organization, Geneva

Chapter 10
Securing Water Supply in Western Sydney: An Analysis of Water Use, Demand and Availability in the South Creek Catchment

Ranvir Singh, Basant Maheshwari and Hector Malano

Abstract Increasing urbanisation and climate change uncertainties are putting pressure on regional authorities to revisit water management strategies in Western Sydney (Australia). This chapter examines water use patterns, demand and supply options in the South Creek catchment—a typical peri-urban catchment in Western Sydney. If present water management practices are continued, the water demand in the catchment is estimated to be more than double, growing from 53 GL/yr under the 'current' scenario, to 107 GL/yr under the 'future' scenario representing the expected conditions around the year 2025. Most of this increase will be due to residential and non-residential water use, followed by increases in irrigation requirements for recreational space (parks and golf courses). The macro water use, demand and availability analysis suggests that nearly 50 % of the 'current' and 47 % of the 'future' potable water demand could be replaced with non-potable water. The potential availability of non-potable water resources is estimated to be more than double of the potential demand for non-potable water in the catchment. This provides an opportunity to meet the region's domestic, industrial, agricultural and environmental water demands provided all water resources are integrated, used and reused in a harmonised fashion. The stormwater and wastewater is to be seen as a 'resource', rather than a 'waste' in this new paradigm of integrated water supply management.

Keywords Urbanisation · Water use · Western Sydney and water demand

R. Singh (✉)
Institute of Agriculture and Environment, Massey University, Private Bag 11 222, Palmerston North 4412, New Zealand
e-mail: r.singh@massey.ac.nz

B. Maheshwari
University of Western Sydney, Penrith South DC, NSW 1797, Australia
e-mail: b.maheshwari@uws.edu.au

H. Malano
Department of Infrastructure Engineering, University of Melbourne, Parkville, VIC, Australia
e-mail: h.malano@unimelb.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_10,

10.1 Introduction

Water use in most urban and peri-urban catchments across Australia has reached or even exceeded water yield capacity. This trend could also be observed in other major cities around the world, for example, Chennai and Delhi in India, cities in Northern China, Cairo in Egypt, Mexico City in Mexico and Las Vegas in Western United States. Indeed, water use is continuously increasing to meet the demands of a growing population, increasing urbanisation and economic growth of the peri-urban regions around the world. Water managers are facing the challenge of balancing the water demands and supplies for a wide range of water users with limited and often diminishing water resources available.

The population in Sydney (Australia) is projected to grow from the current level of 4.34 to 5.16 million by 2026 and 5.93 million by 2051 (Mackintosh and Parr 2004). Multiplying this projected population with the per capita water demand of 400 L per day (without water use restrictions) suggests that Sydney would require an extra annual water supply of 120 GL/yr by the year 2026, and 232 GL/yr by the year 2051. There are further demands for increasing the legitimate share for environmental flows to protect river health, and to sustain freshwater ecosystems and their benefits for human and nature wellbeing. Compounding on this is the impact of climate change on available water resources. The projected changes in rainfall and higher evaporation rates due to climate change are likely to reduce streamflow (CSIRO 2007) and thereby decrease the sustainable yield of the Hawkesbury-Nepean catchment which contributes nearly 80 % to Sydney's water system.

Increasing water demands, limited water supply, the impact of urban development on water quality, calls for the legitimate share of environmental flows and uncertainties arising from climate change are driving regional authorities to revisit water use and management strategies in Sydney, particularly in the fast growing Western Sydney region. Securing more water supplies through dams, described as 'the engineering solution', does not seem to be an option anymore in Sydney as current water extractions have reached the limit. The long-term sustainable catchment yield for Sydney's Water System has been rated at 600 GL/yr while the current water use is estimated about 625 GL/yr (IPART 2003). Given the fact that Western Sydney is witnessing water stress conditions there is a need to assess how current water resources are used and managed and what are the options for meeting future water demands in the region. Indeed, the big questions are 'Will there be enough water?', and 'Where should investment and effort go to secure future water supplies in the region?' To answer these questions, this chapter examines water use patterns, demand and supply options in the South Creek catchment—a typical peri-urban catchment in Western Sydney. The South Creek catchment currently supports a population of around 323,000 in the region. The future population in the catchment is expected to approach one million in next 25–30 years with the proposed development of North West and South West growth centres for residential allotments (NPI 2013).

This chapter combines the recent work by the authors to understand the peri-urban water cycle of South Creek catchment and explore options to meet current and future water demands with available water supplies in the catchment (Singh et al. 2009a, b, c). This analysis intends to inform and help water managers in formulating water management strategies to meet future water demands with less water in this peri-urban region.

10.2 Water and Irrigation Strategy Enhancement Through Regional Partnership

The Cooperative Research Centre for Irrigation Futures (CRC-IF), through its System Harmonisation TM research program, developed the Water and Land Management Innovation & Sustainability Enhancement Partnership in Peri-urban Research (WISER) project to identify opportunities for improved management of water resources and to deliver optimal production and environmental outcomes in Western Sydney. While water scarcity and climate change are the main drivers for water demand management strategies, the current use of water from different sources in urban and peri-urban landscapes is highly fragmented and uncoordinated. As such, this has limited the use of water for both urban and rural irrigation and environmental purposes and made the scarcity of water much worse than it should be.

The traditional approach of using water once and quickly piping it away to drains and creeks seems to be an inefficient use of water particularly when facing water use restrictions. Furthermore, it is not helpful to use potable quality water for irrigation of parks, golf courses, market gardens and residential outdoor and indoor use (for laundry and toilet flushing). The current use of potable water for the above mentioned purposes could be replaced with non-potable water which could be sourced from stream flows, stormwater harvesting from urban areas and treated effluent from sewage treatment plants.

Western Sydney, specifically the South Creek catchment has a number of sources of water (stormwater, effluent, river water and groundwater), none of which are integrated in regards to productive and environmental uses. The WISER project used the South Creek catchment as a hydrological laboratory to understand and analyse the peri-urban water cycle in Western Sydney.

10.3 South Creek Catchment

The South Creek catchment covers an area of around 625 km^2 of gently undulating plains and low hills in Western Sydney. The major waterway in the catchment, South Creek, rises in low hills near Narellan and runs over 64 km north towards Windsor (Fig. 10.1). The climatic conditions are moderate with warm to hot summers, cool to cold winters and reliable rainfall throughout the year. The average

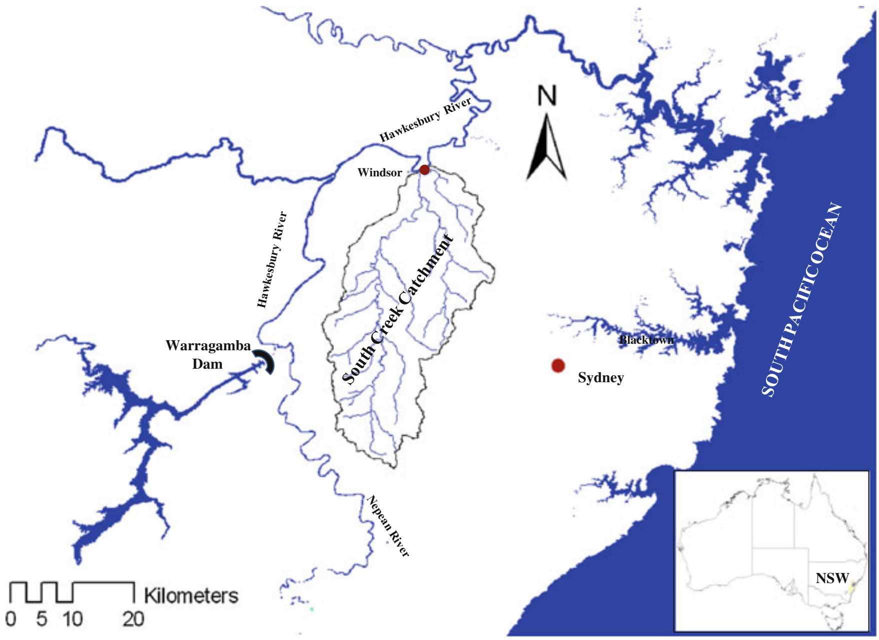


Fig. 10.1 Location of South Creek catchment in Western Sydney

temperature varies from high around 28–30 °C in January to low around 2–5 °C in July. On individual days, the daytime temperature may rise up to 40–43 °C in summer months (January-February) and fall lower than or close to 0 °C in winter months (July-August). The average annual rainfall is less than 800 mm with fairly uniform distribution over the catchment. Future climatic conditions are likely to be warmer and drier with an increase in temperature and changes in rainfall in the region (CSIRO 2007).

10.3.1 Demographics and Land Use

Since the arrival of European settlers in 1788, the South Creek catchment has been subjected to continual land use changes from clearing native vegetation to pastures for grazing and intensive cultivation followed by modern urbanisation. In the year 2000, there was only 22 % of the total land left under natural conditions (Fig. 10.2a) (EPA 2001). The agriculture dominated area has been transformed to a peri-urban agriculture area, where the urban area exceeds the area under agriculture. The urban development occupies nearly 20 % of total land area, which is higher than 17 % of total land occupied by agriculture activities (EPA 2001). Not only has the agricultural area been reduced but the traditional agricultural activities of grazing and farming have been progressively replaced by peri-urban agriculture

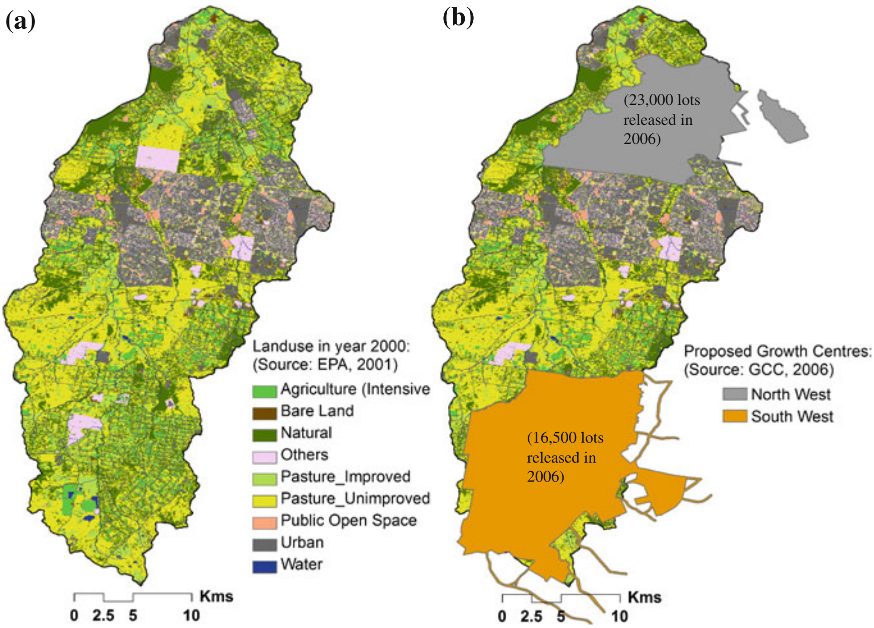


Fig. 10.2 **a** and **b** Contemporary and projected future land use in South Creek catchment (*Source* Singh et al. 2009a)

and horticulture activities such as market gardens, cut flowers, nurseries, greenhouse, hydroponics, etc. The agriculture land use in the region is likely to shrink further where it is competing for land and water resources demanded by the growing population and its associated increasing urbanisation.

The South Creek catchment currently supports a population of around 323,000 with the majority being resident in urban areas established in the central belt between Penrith and Blacktown (Fig. 10.2a). The future population, however, is expected to reach one million over the next two decades with the proposed development of North West and South West growth centres (Fig. 10.2b). In addition there will be significant development for employment land ($\sim$8000 ha) in the catchment. The urban area in South Creek catchment, therefore, is likely to be increased to around 60 % of the total area in the next 25–30 years to accommodate the projected population growth in the region.

10.3.2 Current and Future Scenarios

A scenario approach was taken to examine current and future water use patterns, demand and supply options in the South Creek catchment. The ‘current’ scenario represents the current conditions, with a population of 323,000 living in about

Table 10.1 Different scenarios used for estimation of water use, demand and availability in South Creek catchment

Scenario description	Current	Future_YIA	Future_NIA
Year	~2001–2006	~2025	~2025
Population (×1000)	323	764	764
Households (×1000)	112	264	264
Urban area (ha)	12,536	35,944	35,944
Recreation space (ha)	738	1746	1,746
Irrigated agriculture (ha)	2,204	2,204	0
Climate change (change in annual rainfall)		−7 %	−7 %

Source Singh et al. (2009a)

112,000 private dwellings in the catchment (Table 10.1). These numbers were estimated from the suburb records of the 2006 census of population and housing (ABS 2008). The total urban area, recreation space (parks and golf courses) and irrigated agriculture are based on the land use map of South Creek catchment in the year 2000 (Fig. 10.2a) (EPA 2001).

The 'future' scenario represents the expected conditions around the year 2025, with the proposed North West and South West growth centres (Fig. 10.2b). Under this plan around 66,000 new homes are expected to be built on an approximate area of 10,000 ha in the Northwest and around 115,000 new homes on an approximate area of 17,000 ha in the Southwest (NPI 2013). The North West and South West growth centres fall nearly 90 and 80 %, respectively in the South Creek catchment (Fig. 10.2b). The future developments in South Creek catchment, therefore, are estimated to be about 153,000 new households over an area of 23,408 ha. The ratio of population and recreation space to households under the future scenario is kept unchanged as in the current scenario. This equates to an increase of 441,000 in the population and about 1,000 ha in the recreation space (parks and golf courses). Under the future scenario, two further options are considered: (1) keeping all current irrigated agriculture (Future A), and (2) eliminating all current irrigated agriculture (Future NIA) in the catchment (Table 10.1). These scenarios are designed to explore what impact peri-urban irrigated agriculture may have on overall water use and demand in the South Creek catchment.

The annual rainfall received in the South Creek catchment varied from 485 to 959 mm over the last 15 years from 1992 to 2006. There is about a 40 % chance of receiving the annual rainfall equal to the average annual rainfall of 683 mm. The annual rainfall since year 2002, however, has been lower than the average annual rainfall indicating the recent drought and climate change uncertainties in the region. In a recent climate change report, CSIRO (2007) has projected about ±7 % changes in annual rainfall in the Hawkesbury-Nepean catchment including the South Creek catchment. The report also projected a 0.2–1.6 °C increase in the average temperature, which is expected to increase evaporation rates and thereby a potential reduction in stream flows. Being on the conservative side and keeping it simple, we considered only −7 % changes in annual rainfall to represent climate change conditions under the 'future' scenario (Table 10.1).

10.4 Water Use, Demand and Availability

The peri-urban water cycle of South Creek catchment is quite complex due to a range of water sources and users (Fig. 10.3). The main water users are identified as residential water use, non-residential (commercial/community) water use, peri-urban agricultural irrigation and irrigation of recreation space (parks and golf courses) (Singh et al. 2009b). The main water sources are potable water supply, rainfall-runoff (including surface water extraction from streamflows and stormwater from urban areas), and treated effluents discharges from sewage treatment plants.

Sydney Water supplies potable water from the dams outside of the catchment to residential and non-residential properties and also for irrigation of some parks and golf courses and intensive agriculture and horticulture activities such as market gardens, hydroponics, greenhouses and nurseries in the catchment. Current potable water supply in the catchment is estimated from 31 to 41 GL/yr with an average of 36 GL/yr, of which 71–76 % is supplied to residential properties, followed by 17–19 % to non-residential properties and 6–10 % to primary production activities (Singh et al. 2009b). The properties within the catchment are licensed to extract water of around 8.7 GL/yr from surface water, mainly for irrigation purposes. The use of groundwater in South Creek catchment seems not to be significant due to low yields and high salinity levels in the Hawkesbury Sandstone aquifer underneath the Cumberland Plains in Western Sydney.

The majority of urban areas in the catchment are serviced with the centralised sewer system in the middle and lower parts. However there are some low density urban and rural residences which have onsite wastewater systems and discharge their effluent locally through on-site septic tanks in the upper and lower parts of the catchment. A total of five sewage treatment plants discharged about 27.6 GL/yr of treated effluent into South Creek and its tributaries during 1992 to 2007. Nearly 90 % of the total sewage effluent discharges came from two major sewage treatment plants: the St. Marys Sewage Treatment Plant (STP) discharging an average of 13.5 GL/yr (49 %) into South Creek; and the Quakers Hill STP discharging an average of 11.5 GL/yr (41 %) into Eastern Creek. The rest of the effluent discharge was from the South Windsor STP (5 %), the McGraths Hills STP (2 %) and Riverstone STP (2 %). Flow in South Creek increases significantly from the urban areas in the middle parts of the catchment due to higher surface runoff and sewage effluent discharges. Depending on the rainfall received, the monthly streamflow in South Creek and Eastern Creek could be 5 to 100 % from effluent discharges. The average annual streamflow from South Creek to the Hawkesbury River is estimated to be about 110 GL/yr during the period from 1992 to 2006 (Singh et al. 2009b).

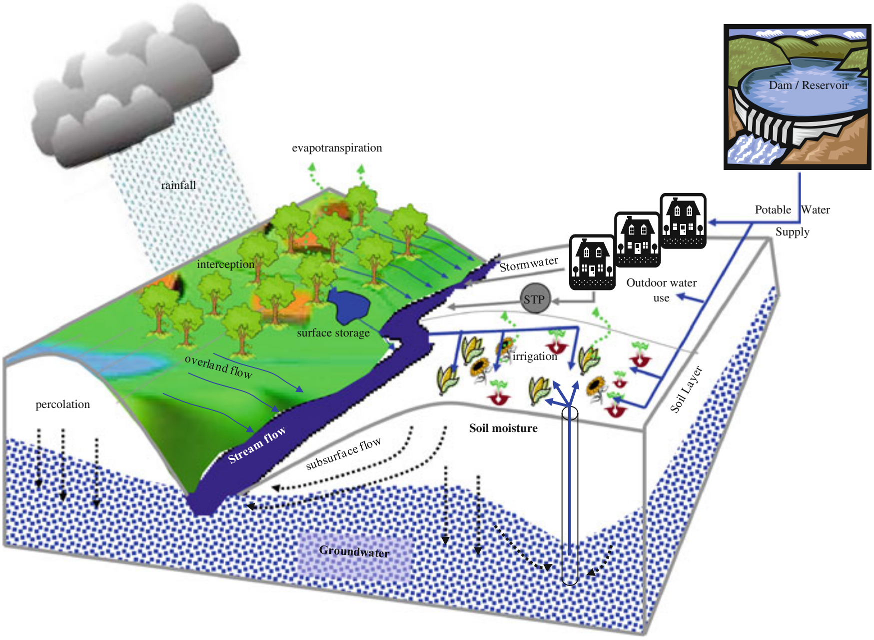


Fig. 10.3 Conceptual representation of peri-urban water cycle in the South Creek catchment (*adapted* after Davis and Cornwell, 1991)

A simple macro analysis approach was used to estimate demands and availability for three different scenarios (Table 10.1) in South Creek catchment (Singh et al. 2009a). The total residential water use was estimated by multiplying the number of households (Table 10.1) with the average residential water use rate of 252 KL/hd/yr in the Sydney region (IPART 2004). Nearly 27 % of the residential water is used for outdoor activities such as garden and lawn irrigation (IPART 2003). This number was used to divide the estimated total residential water use into total residential indoor and outdoor water use in the catchment. In contrast to residential water use, the non-residential water use in commercial and community complexes is highly variable in terms of volume and type in the catchment. As such, it was not possible to estimate non-residential water use by multiplying the average water use rate by the number of non-residential properties. Instead, the non-residential water use was estimated from a simple sewage flow analysis. The sewage flow is mainly from indoor water use in residential and non-residential properties and some possible inflow of stormwater during wet periods. The urban areas of the South Creek catchment are served by five sewage treatment plants, which discharge an average of 27,119 ML/yr of treated effluent into South Creek and its main tributary Eastern Creek. This entails an average rate of effluent generation of 243 KL/hd/yr, from an estimated 111675 ($\sim$112 $\times$ 1000) households in the catchment (Table 10.1). This treated effluent production rate of 243 KL/hd/yr in the South Creek catchment was estimated to be 33 % higher than

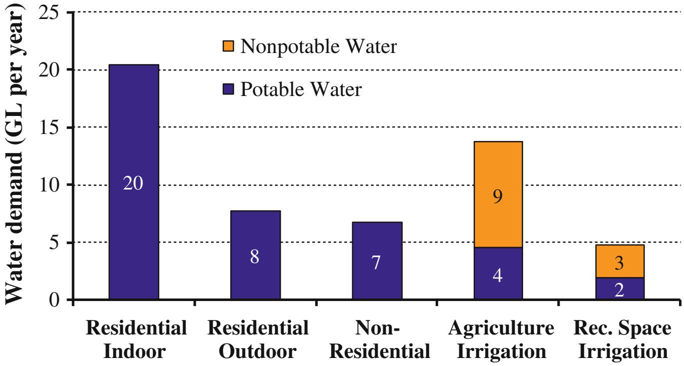


Fig. 10.4 Estimated 'current' water demand for main water users in South Creek catchment (*Source* Singh et al. 2009a)

the average residential indoor water rate of 183 KL/hd/yr (~73 % of total residential water use). It is likely that this extra sewage effluent is mainly discharged from non-residential properties such as schools, hospitals, community services and commercial centres in the catchment. The non-residential water use, therefore, was indirectly estimated by subtracting the residential indoor water use from the treated sewage production in the South Creek catchment.

Peri-urban agriculture uses both potable and non-potable water sources for irrigation of market gardens, dairy pasture, greenhouse crops and hydroponics in the South Creek catchment. Recreation spaces such as parks and golf courses are also irrigated using both potable and non-potable water sources in the catchment. Irrigation water use by peri-urban agriculture activities and recreation space was estimated by multiplying the average annual irrigation rate with irrigation area under different irrigation activities (Singh et al. 2009a, b).

The 'current' water use in the South Creek catchment is estimated to be 41 GL/yr from potable sources and 12 GL/yr from non-potable sources (Fig. 10.4). The majority of potable water use is estimated for residential properties (28 GL/yr) followed by non-residential properties (7 GL/yr). This is in agreement with the potable supply recorded in the South Creek catchment as from 23 to 30 GL/yr with an average of 26 GL/yr for residential properties and from 5 to 8 GL/yr with an average of 7 GL/yr for non-residential properties during the years from 1992 to 2006 (Singh et al. 2009b).

The 'current' irrigation water use is estimated to be 13 GL/yr for agricultural irrigation, and 5 GL/yr for recreation space irrigation (Fig. 10.4). It is estimated that approximately 4 GL/yr of water for agricultural irrigation comes from potable sources. This is higher than the recorded potable water supply for primary production from 1.9 to 3.5 GL/yr with an average of 2.7 GL/yr during the years from 1992 to 2006 (Singh et al. 2009b). The estimated current non-potable water use of 9 GL/yr for agricultural irrigation (Fig. 10.4), however, is in agreement with the surface water extraction entitlements of about 8.4 GL/yr for irrigation purposes in

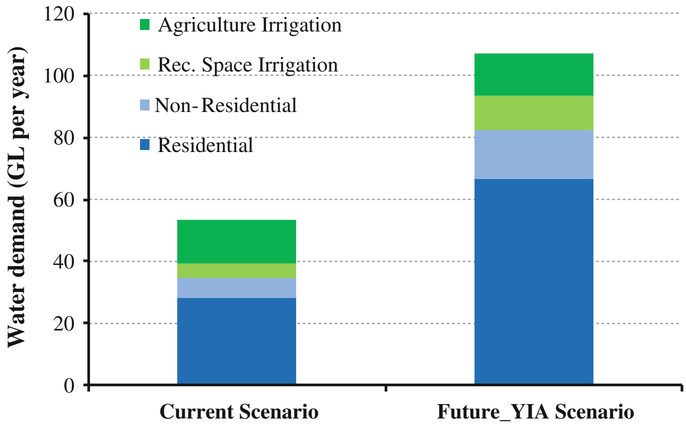


Fig. 10.5 Estimated water demand for different scenarios in South Creek catchment (*Source* Singh et al. 2009b)

the catchment (Singh et al. 2009b). This agreement between the estimated and the recorded 'current' water uses validates the approximate methods and data used in the estimation of 'current' and 'future' water use and demand scenarios in the South Creek catchment (Figs. 10.4 and 10.6).

Water demand in the South Creek catchment is estimated to be more than double, from 53 GL/yr under the 'current' scenario to 107 GL/yr, under the 'future' scenario keeping all current irrigated agriculture (Future_YIA) (Fig. 10.5). Most of this increase in the estimated future water demand is due to an increase in residential and non-residential water use and also irrigation water use for recreation space. The residential water use is estimated to increase from 28 GL/yr under the current scenario to 67 GL/yr under the future scenario. Similarly the non-residential water use is estimated to increase from 7 GL/yr under the current scenario to 16 GL/yr under the future scenario. The analysis reported here is based on a conservative assumption that non-residential water use in commercial and community properties would increase in proportion to the increase in population and households in the catchment.

The potable water demand under the future scenario without agriculture (Future_NIA) was estimated only 5 % lower as compared to the future scenario with agriculture (Future_YIA). This indicates that whether agriculture is kept in place or not there would be no significant impact on future potable water demand in South Creek catchment. However, it could provide the opportunity to use the recycled water from sewage treatment plants.

10.5 Securing Water Supply: Use and Reuse of Water

A range of water management strategies are explored to meet future water demands with available water supplies in the catchment (Table 10.2). These strategies are focused on the potential replacement of potable water use with

Table 10.2 Water management strategies to meet water demand with available supplies in South Creek catchment

Water management strategy	Replace potable water use with non-potable water use for	
RS1		Agriculture irrigation
RS2	RS1 +	Recreation space irrigation (golf courses, parks)
RS3	RS2 +	Residential outdoor in new dwellings
RS4	RS3 +	Residential indoor (for laundry and toilet flushing) in new dwellings
RS5	RS4 +	Residential outdoor in existing dwellings
RS6	RS5 +	Residential indoor (for laundry and toilet flushing) in existing dwellings

Source Singh et al. (2009a)

non-potable water to reduce potable water demand in the catchment. Non-potable water refers to water that has not been treated for human consumption but still could be used for other purposes such as irrigation and residential outdoor and indoor water use including laundries and toilet flushing. It could be extracted from different sources such as streamflows, urban stormwater harvesting in rain tanks and detention basins and pumped from groundwater aquifers. Another major source of non-potable water is recycled water from sewage treatment plants which could be reused safely for different beneficial purposes. Non-potable water may or may not require water treatment, depending on the source and user i.e. 'matching right quality with right user'.

The first and second water management strategies outlined in Table 10.2 assume to replace potable water use with non-potable water in all peri-urban agriculture, horticulture and recreational space irrigation activities in the catchment. The third and fourth strategies assume that all new dwellings in the North West and South West growth centres will have a dual-reticulation system to use non-potable water for residential outdoor water use and for residential indoor water use such as laundry and toilet flushing. The residential laundry and toilet water use is estimated at 17 and 15 % of the total residential water usage, respectively (IPART 2003). In the fifth and sixth strategies, it is assumed that the old suburbs in the South Creek catchment would be retrofitted with a dual-reticulation system to use non-potable water for residential outdoor water use and for residential indoor water uses of laundry and toilet flushing.

Table 10.3 summarises the estimated impact of different water management strategies on potable and non-potable water demands in the South Creek catchment. The "baseline" represents the situation where present water use patterns in the catchment will continue (Fig. 10.5). Under this assumption, potable water demand is estimated to be around 91 GL/yr under the future scenario that includes agriculture in South Creek catchment (Future_YIA). This demand could be lowered by 10 % through water management strategies RS1 and RS2, i.e. replacing potable water use with non-potable water use for all peri-urban agriculture,

Table 10.3 Potable and non-potable water demands under different water management strategies in South Creek catchment

Water management strategy	Water demand (GL/yr)			
	Current scenario		Future scenario (future_YIA)	
	Potable	Non-potable	Potable	Non-potable
Baseline	41	12	91	16
RS1	37	17	87	20
RS2	35	18	82	25
RS3			72	35
RS4			63	44
RS5	27	26	55	52
RS6	21	33	49	58

Source Singh et al. (2009a)

horticulture and recreational space irrigation activities in the catchment (Table 10.2). A major reduction of 21 % in the future potable water demand could be expected through strategies RS3 and RS4 to use non-potable water for residential outdoor and indoor (laundry and toilet flushing) in all new dwellings in the North West and South West growth centres. The future potable water demand could be further reduced by 16 % through strategies RS5 and RS6 of using non-potable water for residential outdoor and indoor (laundry and toilet flushing) in the existing dwellings in the catchment.

The maximum potential use of non-potable water implemented in the water management strategy RS6, i.e. use of non-potable water for all peri-urban agriculture, horticulture and recreational space (parks and golf courses) irrigation activities, residential outdoor and residential indoor (laundry and toilet flushing) in households (Table 10.2), could reduce the estimated potable water demand from 91 to 49 GL/yr under the 'future' scenario in South Creek catchment (Table 10.3). It implies that nearly 47 % of the estimated future potable water demand could be replaced by non-potable water. However, even after implementing the water management strategy RS6, the future potable water demand is estimated to be 18 % higher than the current potable water use of 41 GL/yr in the catchment.

While moving from the 'baseline' situation to implementing the water management strategy RS6 the estimated non-potable water demand would increase from 12 to 33 GL/yr under the 'current' scenario and from 16 to 58 GL/yr under the 'future' scenario (Table 10.3). This non-potable water would need to be sourced from rainfall-runoff (i.e. surface water extractions from stream flows and stormwater harvesting from urban areas) and/or treated effluent from sewage treatment plants in the catchment. Figure 10.6 reproduces the estimated average annual non-potable water availability from urban stormwater and wastewater discharges under 'current' and 'future' scenarios in South Creek catchment.

The wastewater production was estimated by multiplying the average rate of effluent generation (243 KL/hd/yr) with the number of households in the catchment (Table 10.1). The urban stormwater volume was estimated as a proportion of

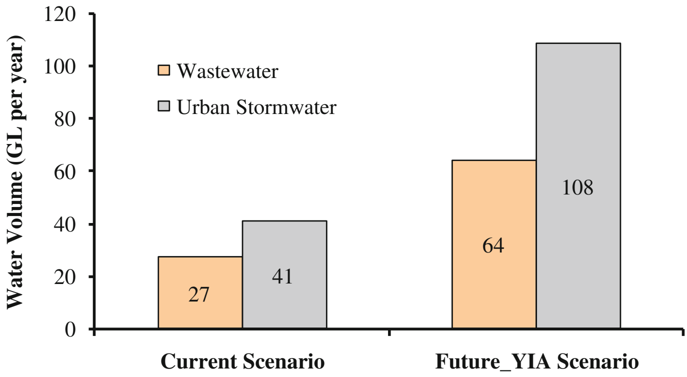


Fig. 10.6 Estimated non-potable water availability for different scenarios in South Creek catchment (*Source* Singh et al. 2009b)

mean annual rainfall of 683 mm per year received in the catchment. An annual volumetric runoff coefficient of 0.47 was used to covert mean annual rainfall over urban areas (Table 10.1) to estimate urban stormwater availability in the catchment. This urban runoff coefficient was based on "Managing Urban Storm Water: Council Handbook" which reported the average annual volumetric runoff coefficients recorded from a number of catchments around Sydney (NSW EPA 1997).

The urban stormwater could be harvested, treated and then used as non-potable water for garden irrigation, laundries and toilet flushing. The infrastructure such as rainwater tanks and detention ponds to harvest stormwater from 30 % of the urban area with a runoff coefficient of 0.47 could potentially provide about 32 GL/yr of stormwater from a rainfall of 635 mm per year under the 'future' scenario in the South Creek catchment. Further, there would be available about 64 GL/yr of treated wastewater from sewage treatment plants (Fig. 10.6). The potential availability of non-potable water from stormwater of urban areas and treated sewage effluent production (Fig. 10.6) is estimated to be more than double of the maximum potential demand of non-potable water under the 'current' and 'future' scenario in South Creek catchment (Fig. 10.5).

This provides an opportunity to develop an integrated water supply system with new facilities such as rainwater tanks and detention ponds to harvest stormwater, and treat and recycle wastewater for peri-urban agriculture, horticulture and recreational space irrigation activities and for residential outdoor and indoor (laundry and toilet flushing) water use in the catchment. With an increase in stormwater volumes due to increased urbanisation, another way of securing water supplies for non-potable water use in peri-urban areas could be to implement managed aquifer recharge and recovery. Depending upon the hydrology and other factors, managed aquifer recharge and recovery may be possible at a number of locations throughout Western Sydney. If planned at the catchment or regional level it may be possible to link different individual managed aquifer recharge and recovery sites through an overarching master plan and provide an alternative regional water supply. Thus, there is potential for managed aquifer recharge and recovery projects to contribute to securing future water supplies by reducing the demand on potable supplies and supplementing non potable usage with other sources, specifically stormwater harvested from the urban areas.

10.6 Concluding Remarks

Increasing urbanisation and climate change uncertainties are putting pressure on regional authorities to revisit water management strategies in Western Sydney. The projected future water demand in the South Creek catchment in Western Sydney is estimated to be more than double, from 53 GL/yr under the 'current' scenario (year 2011) to 107 GL/yr under the 'future' scenario representing the expected conditions around the year 2025 in South Creek catchment. Most of this increase in the future water demand is estimated due to an increase in residential and non-residential water use, and in irrigation water use for recreation space to accommodate about 153,000 new households in the proposed North West and South West growth centres in the catchment. In particular, the residential water use is estimated to increase from 28 GL/yr under 'current' scenario to 67 GL/yr under the 'future' scenario. Whether peri-urban agriculture, in the future, is retained or not there is not much impact on future potable water demand in the catchment. It is interesting to note that nearly 50 and 47 % of the estimated 'current' and 'future' potable water demands could be replaced with non-potable water by implementing a water management strategy RS6, i.e. use of non-potable water for all peri-urban agriculture, horticulture and recreational space (parks and golf courses) irrigation activities, and for residential outdoor and indoor (laundry and toilet flushing) in households in the catchment. It is also noteworthy that even after implementing the maximum potential use of non-potable water through strategy RS6, the future potable water demand is estimated at nearly 18 % higher than the current potable water use of 41 GL/yr in the catchment. This reduction of estimated future potable water demands to the current level of 41 GL/yr would require the reduction of water consumption through the promotion of water saving devices and practices for residential and non-residential indoor water use in the catchment.

The macro analysis estimates the potential availability of non-potable water from urban stormwater and treated wastewater from sewage treatment plants to be more than double the maximum potential demand of non-potable water in South Creek catchment. This gives an opportunity to meet the region's domestic, industrial, agricultural and environmental water requirements provided all water resources are integrated, used and reused in a harmonised fashion. The stormwater and wastewater is to be seen as a 'resource', rather than a 'waste' in this new paradigm of integrated water supply management.

The challenge is to match the 'right water supply (quantity and quality) with the right water user', and to put in place the necessary infrastructure and mechanisms for sustainable water management in the region. This warrants the need of additional studies analysing the feasibility and economic and environmental benefits of an integrated water supply system in Western Sydney which may provide a sustainable solution for reconciling future water demand and future water availability in the region. The WISER project developed a Peri-Urban SIMHYD which integrated rainfall-runoff, urban stormwater and wastewater systems for first time in a single modelling framework to simulate a complete peri-urban water cycle of South Creek catchment (Singh et al. 2009c). The WISER project is also developing an integrated modelling framework to analyse the level of water security and hydrological, economical and social impacts arising from alternative water management strategies under current and future scenarios in the South Creek catchment (Gartley et al. 2009). The development and use of such modelling tools has great potential to aid decision making for integrated management of our complex peri-urban hydrological systems.

Acknowledgments The funding for this study was provided by CRC for Irrigation Futures. The support of WISER project partners and other stakeholder during this study is gratefully acknowledged.

References

ABS (2008) Census of population and housing. Australian Bureau of Statistics (ABS), Australia. Accessed 5 June 2008

CSIRO (2007) Climate change in the Hawkesbury-Nepean catchment. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Davis ML, Cornwell DA (1991) Introduction to environmental engineering. McGraw-Hill, Hightown, NJ, pp 822

EPA (2001) Assessment of diffuse sources of pollution in the South Creek catchment—a GIS approach. Environmental Protection Agency (EPA) (An unpublished report)

Gartley M, Nawarathna B, Davidson B, Malano HM, Singh R, Maheshwari B (2009) System harmonisation framework for water resources planning in peri-urban catchments. In: Anderssen RS, Braddock RD, Newham LTH (eds) 18th world IMACS congress and MODSIM09 international congress on modelling and simulation. Modelling and simulation society of Australia and New Zealand and international association for mathematics and computers in simulation, July 2009, pp 3824–3830. ISBN: 978-0-9758400-7-8

IPART (2003) Investigation into price structures to reduce the demand for water in the Sydney Basin. Discussion Paper DP72, ISBN 1 877049 34 4. Independent Pricing and Regulatory Tribunal (IPART), New South Wales, Australia

IPART (2004) Residential water use in Sydney Blue Mountain and Illawarra. Research Paper PR26, ISBN 1 877049 42 5. Independent Pricing and Regulatory Tribunal (IPART), New South Wales, Australia

Mackintosh M, Parr A (2004) New South Wales state and regional population projections 2001–2051. In: Paper presented at 12th Biennial conference of the Australian population association, Canberra, Australia, 15–17 Sept 2004

NPI (2013) The growth centres. NSW Planning and infrastructure, Sydney, Australia. http://www.gcc.nsw.gov.au/the+growth+centres-5.html. Accessed 13 Dec 2013

NSW EPA (1997) Managing urban stormwater council handbook. NSW Environment Protection Authority, Sydney, Australia 68p

Singh R, Simmons B, Maheshwari B, Nawarathna B and Malano HM (2009a) Reconciliation of future water demand and supply in Western Sydney, Australia. In: Proceedings of the international conference on water, environment, energy and society (WEES-2009), New Delhi, India, 12–16 Jan 2009

Singh R, Nawarathna B, Simmons B, Maheshwari B and Malano HM (2009b) Understanding the water cycle of the South Creek catchment in Western Sydney. Part I: catchment description and preliminary water balance analysis. Technical Report No. 05/09, ISBN: 978 0 9806855 7 2 (print), CRC for Irrigation Futures, Australia, pp 48

Singh R, Maheshwari B, Malano HM (2009c) Understanding the water cycle of South Creek catchment in Western Sydney. Part II: catchment water balance modelling. Technical Report No. 05-2/09, ISBN: 978 0 9808531 9 3 (print), CRC for Irrigation Futures, Australia, pp 98

Chapter 11
Stormwater Reuse for Sustainable Cities: The South Australian Experience

Zhifang Wu, Jennifer McKay and Ganesh Keremane

Abstract Australia has a high level of urbanisation by world standards and the state of South Australia has one of the most concentrated settlement patterns in Australia. Rapid population growth and a drought ending in 2010 have placed increased pressure on urban water resources. Addressing this issue requires that we consider a diverse portfolio of water supply options for non-potable uses. South Australia actually leads the nation in alternative non-potable water sources, with stormwater capture and reuse, wastewater recycling and rainwater tank ownership. However, past studies have identified public health concerns and a lack of public acceptance as major challenges in implementing water reuse strategies. This paper is based on an internet survey of the communities residing in the periphery of the city of Adelaide in South Australia and about their attitudes and intentions to use treated stormwater for various non-potable uses. We found that respondents' emotions and perceptions of health risks regarding the use of treated stormwater were closely related to the proximity of the end use to human contact. In terms of the quality attributes, colour, odour and salt levels were all considered important, but odour was the most important for all potential uses, except washing cars. The quality preferences were also closely related to the proximity of the end use to human contact.

Keywords Managed aquifer recharge · Stormwater use · Health risk concerns · Emotion · Quality attributes

Z. Wu (✉) · J. McKay · G. Keremane
Centre for Comparative Water Policies and Laws, School of Law,
National Centre for Groundwater Research and Training,
University of South Australia, Adelaide, SA, Australia
e-mail: zhifang.wu@unisa.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_11,

11.1 Introduction

In the developed world, population growth in the peri-urban regions of metropolitan centres has been rapid since the population turnaround of the 1970s when a shift in population growth towards non-metropolitan areas occurred (Fisher 2003). However, urbanisation has been contributing to marked environmental damage, depending on the particular urbanisation modalities within each city (Aguilar 2008; Maheshwari et al. 2012). Australia's level of urbanisation is high by world standards and the state of South Australia has one of the most concentrated settlement patterns in Australia, with three quarters of the population residing in the City of Adelaide (Fisher 2003). Due to continued population growth, the water resources of the city need to be shared by an increasing number of people (Qu et al. 2011), which raises the issue of the security of water quality and quantity. However, there is room for environmental improvement in dense areas, depending on how the environmental policies are designed (Zellner and Reeves 2012). Furthermore, it was noted in a recent report, released by the Australian Prime Minister's Science, Engineering and Innovation Council (Australian Prime Minister's Science Engineering and Innovation Council 2007), that Australia needs a diverse portfolio of water supply options. In this regard, South Australia leads the nation in stormwater capture and reuse, wastewater recycling, irrigation practices, and rainwater tank ownership (Department for Water 2010). Given this context, this paper will focus on community attitudes and intentions to use treated stormwater for non-potable purposes.

Along with wastewater and desalinated water, stormwater has been recognised as an alternative source of water to augment the freshwater supply and to address the growing needs of humankind (Stenekes et al. 2006). Australian governments have signed an intergovernmental agreement in 2004, the National Water Initiative (NWI), which aims to encourage water conservation in cities through better use of stormwater and recycled water (COAG 2004). This has seen a strategic policy response from state governments; for example, South Australia's *Local Government Stormwater Management Amendments Act 2007* makes explicit the provision and capability to regulate the capture of stormwater (Ward and Dillon 2011); and the *ASR for Melbourne Metropolitan Water Supply 2008* proposes to solve the water shortage of the city through Managed Aquifer Recharge (MAR) which discharges stormwater flows into the aquifers below Melbourne for storage and future use as a non-potable water supply (Bonacci Water 2008).

MAR systems operate by storing excess treated stormwater flows from urban catchments during wet periods, which are then subsequently extracted for reuse during drier periods. The practice of MAR in Australia has increased in recent years. By 2008, five states and territories in Australia had operational MAR projects and two states had investigations underway (National Water Commission 2009). There are a number of drivers for MAR in urban areas of Australia, one of which is securing and enhancing water supplies to substitute for all, or some, uses of existing mains water supplies (National Water Commission 2009).

While advances in treatment processes have broadened the range of potential uses and sources, the successful implementation of any reuse scheme hinges on public acceptance (Leviston et al. 2006). Without public acceptance, many recycled water projects have been failures (Stenekes et al. 2006; Hurlimann and McKay 2004). Similarly, the technical feasibility of stormwater use projects has been largely proven, but not the social aspects. This makes research into community attitudes of great importance if the stormwater use strategies are to be successfully achieved.

11.2 Method

11.2.1 Study Sites and Survey

The survey was conducted with the residents of two rapidly growing regions located on the boundary of the Adelaide Central Business District. These included the Local Government Areas (LGA) of Salisbury and Charles Sturt (Fig. 11.1). The Salisbury LGA is situated 25 km north of Adelaide and has gained international recognition for the way it harvests urban stormwater and stores it in wetlands, using it for irrigation and industrial use, or storing it in underground aquifers for later use in a process known as aquifer storage and recharge (ASR). Charles Sturt LGA is located within 10 km of the Adelaide CBD and is conducting the Waterproofing the West Project which will harvest, treat, and store stormwater in specific locations and then will distribute the treated stormwater through to areas of demand throughout parts of the Charles Sturt LGA.

The survey tested the attitudes and intentions of the community in the two LGA areas to use treated stormwater through the MAR process for non-potable uses. We presented participants with seven potential options for using the stormwater viz., 1-personal washing, 2-washing dogs, 3-flushing toilets, 4-washing clothes, 5-watering fruit, vegetables and flowers, 6-watering lawns, gardens, and parks, and 7-washing cars. This allowed us to examine that the preferences of residents to using the water for non-potable uses relates to the proximity of the use to human contact (Wu et al. 2012).

Data was collected through an internet survey using email addresses. The email addresses were bought from a permission-based and research-only internet panel. The method has been employed and examined by Dolnicar and Grün (2009). The data collection was conducted in three Australian LGAs; Salisbury LGA and Charles Sturt LGA in South Australia, and Gold Coast LGA in Queensland (Keremane et al. 2011). This paper reports on the results from the Salisbury LGA and Charles Sturt LGA in South Australia only. In total, we sent our survey to 4,000 randomly selected email addresses in the two South Australian LGAs, with 207 valid responses being received. We acknowledge that the response rate (5.18 %) is low and thus the results are likely to be biased. We note this as one of the limitations of this study.

The survey has 39 quantitative questions and the questions satisfied the conditions of validity and reliability (Wu et al. 2013).

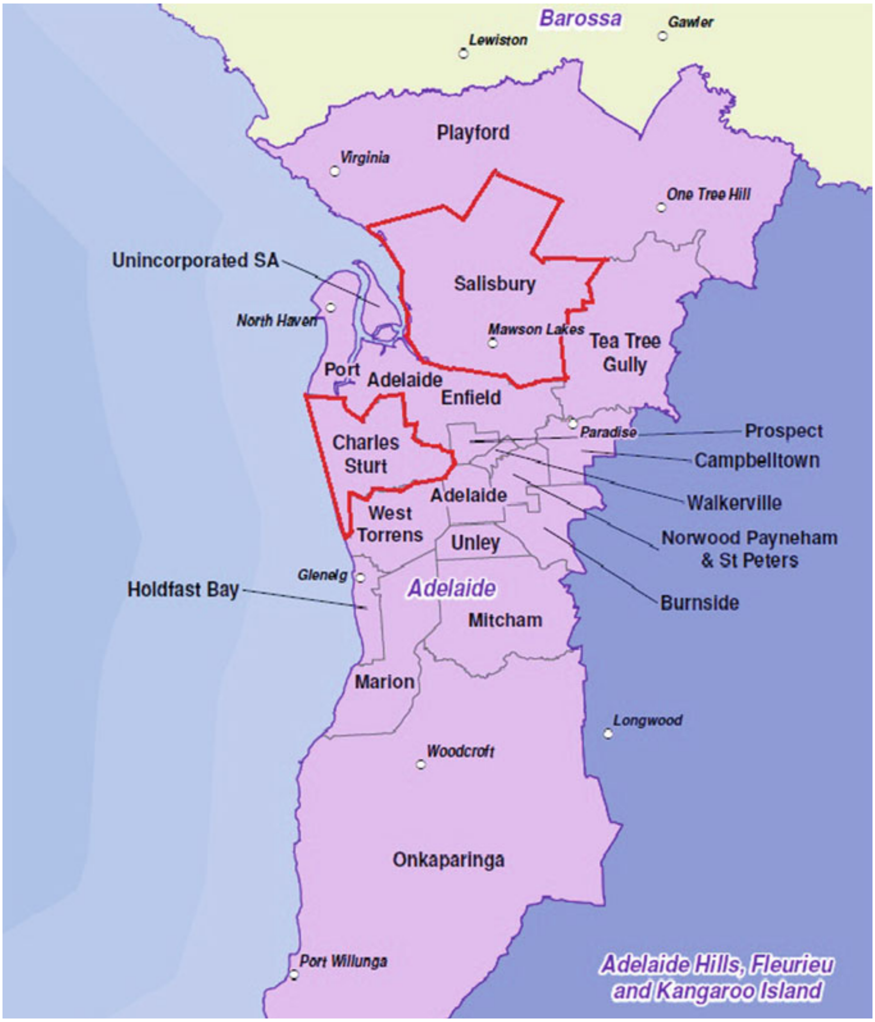


Fig. 11.1 Location of Salisbury LGA and Charles Sturt LGA. *Source* Department of Infrastructure, Transport, Regional Development and Local Government (2010)

11.2.2 Factors Affecting Residents' Attitudes to Using the Treated Stormwater

Given a scarcity of "fit-for-purpose" studies on stormwater use, this study relied on the literature about recycled wastewater use. Studies on public attitudes to water recycling in the United Kingdom (UK), the United States (US) and Australia found that most people are generally supportive of the concept as long as safety can be assured (Jeffrey and Jefferson 2003). However, researchers found that, despite a general acceptance of water recycling, communities have shown reluctance to accept municipal recycling, especially when domestic or personal uses of the water are involved. People's reluctance to support recycled water use increases as the degree of human contact with the recycled water increases (Stenekes et al. 2006; Bruvold et al. 1981; Bruvold 1988; Sydney Water 1999).

This research aimed to understand the preferences of the community in the two LGA areas to use stormwater for non-potable uses and also to investigate how residents perceive the health risks, and their emotions, attitudes, and intentions in relation to using the water for the seven different potential options. The research also investigated how important the participants considered three quality attributes of the water: colour, odour and salt levels, when using the stormwater.

11.2.2.1 Perceptions of Health Risk

Stormwater is defined as 'any rain that falls on the roof of houses or collects on paved areas like driveways, roads and footpaths' (Adelaide and Mount Lofty Range Natural Resources Management Board 2011). Stormwater drains carry stormwater into natural waterways such as rivers, creeks, and the ocean. As it travels over land, stormwater picks up all kinds of pollutants such as oil, grease, fertilisers, litter, and heavy metals not naturally found in our waterways. These pollutants contaminate the water in various ways. After a dry season, the first flush of stormwater can have the same pollutant load as raw sewage (Adelaide and Mount Lofty Range Natural Resources Management Board 2011). Stormwater is therefore perceived as carrying risks to human health. Reducing the risk can be achieved in the treatment process through technical means. However, the risks identified by scientists are often very different from the risks perceived by the community (Daughton 2004). Understanding community perceptions of the health risks of using stormwater will help to increase the feasibility of stormwater projects. Considering the health risks of using the water, the community may determine not to use the water for whatever optional uses, or may determine to use the water for some uses but not others, and in such cases, a careful and clearly targeted and designed strategy will be necessary. The research questions for this study in relation to perceptions are: how does the community perceive the health risks of using stormwater, and does it differ according to different uses?

11.2.2.2 Emotion

Po et al. (2005) investigated the extent to which respondents have negative or positive emotions toward using recycled water and suggested that people's emotional reaction to a recycled water scheme requires further research. The extent to which respondents have negative or positive emotions toward using the stormwater treated through the MAR process has been examined in the current study. The key research questions for this study in relation to emotions are: what does the community feel about using the stormwater emotionally, and do community emotions differ according to different uses?

11.2.2.3 Attitudes and Intentions

A few large scale national studies investigating public attitudes to recycled water have been conducted in Australia over the recent years, such as Marks et al. (2006), Hurlimann (2006, 2007), and Dolnicar and Schafer (2006). These studies have replicated Bruvold's early findings in the USA (Bruvold et al. 1981; Bruvold 1988) that acceptance of recycled water is higher for low personal contact uses, and lower for high personal contact uses. The research questions for this study in relation to attitudes and intentions are: what are the community's attitudes toward using the stormwater? Would the community intend to use the stormwater? Do community attitudes and intentions toward using the stormwater differ according to different uses?

11.2.2.4 Attributes of Stormwater

In a time of climate uncertainty and drought in Australia, improved urban stormwater quality management practices are required not only for protecting waterway health, but also as a fit-for-purpose supply source (Brown and Farrelly 2009). As end users, to what extent individuals accept the quality attributes of the potential treated water plays an important role in implementing a stormwater scheme. Hurlimann and McKay (2007) surveyed 20 residents of New Haven, a small Adelaide suburb where recycled water is used for garden watering and toilet flushing. They reported that every respondent had occasional problems with using the water and found that colour, odour, and salt levels were the most concerning quality attributes of recycled water. Similar problems were reported in a study undertaken in Denmark (Albrechtsen 2002), where rainwater and greywater were used for toilet flushing, resulting in one particular plant being shutdown because of complaints.

One of the purposes of this research is to understand community considerations about the physical attributes of the stormwater treated through the MAR process for different uses. Accordingly, the research questions for this study included the following: what does the community think about the quality attributes such as colour, odour, and salt content of the stormwater? And do colour, odour, and salt levels influence how the community considers using the stormwater for different purposes?

The factors influencing the uptake of stormwater treated through the MAR process that were investigated and explained above are listed in Table 11.1. A five-point Likert scale was used to measure the importance of the various factors (Likert 1932). Respondents were asked to rate each attribute/use combination on a scale of 1, representing strongly disagree/not at all important, to 5, representing strongly agree/very important. SPSS statistical package was then used to calculate the mean and the standard deviation of the importance rating for each combination.

Table 11.1 Factors influencing the uptake of stormwater treated through the MAR process and measurement scales

Measures	Questions	Scale
Perception of health risk	Any treated water through the MAR process must meet the Australian Water Quality Guidelines. Given the quality, if guaranteed, I believe that there is no health risk to me from using treated stormwater through the MAR process for ________	1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree
Emotion	I feel 'yuck' when I think of using the treated stormwater through the MAR process for_________	1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree
Attitudes	I feel no problems in using the treated stormwater through the MAR process for _________	1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree
Intentions	Given that an appropriate quality is guaranteed, I would like to use the treated stormwater through MAR for__________	1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree
Quality attributes		
Colour	How important do you think the colour of the treated stormwater through the MAR process is for__________	1 = not important at all, 2 = unimportant, 3 = neutral, 4 = important, 5 = very important
Odour	How important do you think the odour of the treated stormwater through the MAR process is for__________	1 = not important at all, 2 = unimportant, 3 = neutral, 4 = important, 5 = very important
Salt levels	How important do you think the salt levels of the treated stormwater through the MAR process is for__________	1 = not important at all, 2 = unimportant, 3 = neutral, 4 = important, 5 = very important

11.3 Results and Discussion

11.3.1 Community Attitudes and Intentions in Relation to Fit-for-Use Stormwater Usage

The attitudes of community members were quite positive (67 %) toward fit-for-use stormwater usage given an appropriate quality is guaranteed. Only one respondent from Salisbury and four from Charles Sturt said ‘no’ to fit-for-use stormwater usage.

The frequencies of influencing factors determining the uptake of stormwater according to different potential uses are reported in Table 11.2.

More than half of the respondents considered that using the MAR water would not lead to health problems. Using the water for watering lawns, gardens, parks, flushing toilets, and washing cars were perceived as having less risk than using it for personal washing, washing dogs, washing of clothes, and watering fruit, vegetables and flowers. Respondents’ emotions towards using the treated stormwater through the MAR process were closely related to how close the use was to human contact. Personal washing and washing of clothes were the two uses which respondents felt the most uncomfortable about, while flushing toilets and washing cars were two uses which respondents cared the least about, emotionally.

About 80 % of respondents indicated that they felt there were no problems with the water usage and would like to use the MAR water for flushing toilets, watering lawns, gardens, parks and for washing cars. These preferences are followed in turn by watering fruit, vegetables, and flowers, washing clothes, washing dogs, and personal washing.

Regarding the quality attributes of the MAR water, colour, odour and salt levels were indicated as important, but respondents considered odour as the most important for all uses, except washing cars. How important the attribute of the water was dependent on the particular use. Respondents would prefer to have the least colour, odour, and salt for personal washing and washing clothes, while they have the most tolerance to the water for flushing toilets, watering lawns, gardens, parks, and washing cars. As the use of the water becomes increasingly personal, the importance of the attributes of colour, odour, and salt level increased. The attribute of salt level did not follow the same usage preference pattern. However, salt level was rated as very important for garden watering and more important than colour and odour as salty water is perceived to be harmful to plants and lawn.

11.3.2 Factors Determining the Uptake of Stormwater on Different Potential Uses

The following sections discuss how the community considered the influence of factors discussed below on the seven potential uses. Table 11.3 reports the mean (μ) and standard deviation (σ) of the importance of rating for each combination tested.

Table 11.2 Frequencies (%) of influencing factors determining the uptake of stormwater according to different potential uses

	Perceived risk	Emotion	Attitudes	Intentions	Colour	Odour	Salt level
Personal washing	49	42.4	42.7	39.6	84.1	89.4	75.5
Washing dogs	61.2	24.2	60.5	56.7	56.3	71	64.5
Flushing toilets	77.1	9.8	79.6	80.8	34.1	64.5	38.2
Washing clothes	61	27.6	57	68.1	77.2	85.3	69
Watering fruit, vegetables and flowers	60.3	23	62.8	63.5	48.1	60.2	73
Watering lawns, gardens and parks	71.7	10.6	79.6	80.9	30.1	48.4	63.3
Washing cars	69.7	9.4	77.9	78.3	39.4	51.3	58.4

11.3.2.1 Personal Washing

In case of personal washing, the attributes 'no colour', 'no odour', and 'low salt' were all considered to be very important. 'No odour' was ranked as the most important attribute. Respondents ranked 'perceived health risk' of the water, and their feelings towards using the water for personal washing, to be between 'neutral' and 'agree'. Among seven potential uses, using the water for personal washing was considered as having the highest perceived health risk to them and made them feel the worst. The findings are understandable because personal washing is the closest and most direct contact to human bodies among all the uses tested in the study.

11.3.2.2 Washing Dogs

For washing dogs, 'no colour', 'no odour' and 'low salt' were all considered to be important. When ranking the use of the water for washing dogs, in terms of 'perceived health risk', 'attitudes' and 'intentions' was slightly higher, and in terms of 'emotion', slightly lower, as compared with the rankings of using the water for personal washing. The findings followed the expected pattern, as washing dogs is the second closest activity having direct contact to human bodies, and many households consider 'dogs' as family members in Australia.

Flushing Toilets

For toilet flushing, the most important attribute was considered to be 'no odour', followed by 'low salt' and 'no colour'. The attribute 'no odour' was anticipated to be important as it exists in the bathroom which is inside the home (Dolnicar and Schafer 2006). Using the water for toilet flushing was considered to have the

Table 11.3 Influence of factors determining the uptake of stormwater on different potential uses

	Perceived risk µ (б)	Emotion µ (б)	Attitudes µ (б)	Intentions µ (б)	Colour µ (б)	Odour µ (б)	Salt level µ (б)
Personal washing	3.36 (1.20)	3.17 (1.34)	3.11 (1.37)	3.19 (1.42)	4.39 (.94)	4.59 (0.71)	4.12 (1.01)
Washing dogs	3.63 (1.07)	2.58 (1.19)	3.64 (1.24)	3.65 (1.27)	3.52 (1.27)	3.99 (1.20)	3.83 (1.20)
Flushing toilets	4.08 (0.97)	1.80 (1.11)	4.27 (0.96)	4.33 (0.95)	2.91 (1.33)	3.73 (1.31)	3.01 (1.40)
Washing clothes	3.69 (1.05)	2.63 (1.22)	3.65 (1.19)	3.71 (1.19)	4.17 (1.00)	4.40 (0.86)	3.92 (1.12)
Watering fruit, vege-tables and flowers	3.68 (1.09)	2.49 (1.25)	3.77 (1.21)	3.82 (1.22)	3.26 (1.34)	3.66 (1.41)	4.09 (0.95)
Watering lawns, gar-dens and parks	3.98 (1.02)	1.89 (1.15)	4.22 (0.97)	4.28 (0.99)	2.66 (1.31)	3.29 (1.44)	3.81 (1.06)
Washing cars	3.95 (1.03)	1.87 (1.12)	4.16 (1.00)	4.24 (1.01)	2.99 (1.27)	3.41 (1.37)	3.61 (1.25)

lowest health risk, and to have the least impact on residents' emotions among all potential uses. Respondents showed the highest preference and intention to use the water for toilet flushing among all uses. This could be because using the water for toilet flushing has the least contact with human bodies.

Washing Clothes

In case of using treated stormwater for washing clothes, the attribute 'no odour', followed by 'no colour' and 'low salt' were all considered important. Similar findings were reported by Hurlimann and McKay (2007) who argued that, this may be because respondents were concerned about possible discolouration and odour of clothing washed with water having such attributes. Furthermore, clothes washing is more closely related to human contact which also explains the high importance ranking for the attributes 'no colour' and 'no odour' (Hurlimann and McKay 2007). Respondents would not feel bad about, and moderately agree that using the stormwater treated through the MAR process would not involve any health risks. Accordingly, respondents indicated a moderate preference and intention to use the treated stormwater for clothes washing.

Watering of Fruit, Vegetables and Flowers

The most important attribute for watering of fruit, vegetables and flowers, was considered to be 'low salt' followed by 'no colour' and 'no odour'. This may be due to the respondents having knowledge of the impact that salt levels would have on the fruit, vegetable and flowers they plant or consume. Respondents tended to agree that using the stormwater for watering fruit, vegetables and flowers would not involve health risks and was acceptable. They indicated a moderate attitude and intention to use the stormwater for watering fruit, vegetable and flowers. The conservative attitude of respondents is understandable because fruit, vegetables and flowers have a comparatively close contact with human bodies, although not direct contact.

Watering of Lawns, Gardens and Parks

In case of garden watering, the most important attribute was found to be the salt level of the water. 'Low salt' was ranked as important due to many residents having knowledge of the impact that salt levels would have on the plants in their garden (Hurlimann and McKay 2007). The attribute 'odour' was ranked as somewhat important, as odour would have an impact on peoples' sense of smell. The attribute 'colour' was not considered to be important as anticipated. Respondents considered that using the water for garden watering would not lead to health risks. Respondents also indicated a high level of preference and intention to use the water for garden watering. This could be explained by the fact that using the water for watering of lawns, gardens, and parks does not have close contact with human bodies.

Washing Cars

'Low salt' was considered to be the most important attribute, followed by 'no odour' and 'no colour' in case of washing cars. This could be due to respondents' knowledge of the impacts that salt levels have on the paint used on the cars. Surprisingly respondents did not consider that using the stormwater for car washing would lead to health risks as in reality people do get wet when washing the cars.

11.4 Conclusions and Recommendation

The rapid growth of peri-urban areas has a significant influence on the use of, and demand for, water. Securing a diverse and sustainable water supply in the context of peri-urban areas is one of the greatest challenges for planners (Maheshwari et al. 2012). A clearer understanding of community preferences in peri-urban areas with regards to using non-traditional water resources (e.g. treated stormwater in this study) is critical. However, there is little empirical and/or statistical evidence to back this up. To the authors' knowledge, the current study is the first to comprehensively compare the community's acceptance of stormwater treated through the MAR process for various purposes. Therefore, this study has addressed that knowledge gap, making the following observations.

In general, the community considers that using the stormwater treated through the MAR process does not present a health risk. There was a high degree of support and intention to use the water for non-potables uses. The preferences of the community to using stormwater for non-potables uses were related to the intimacy that the particular use has to human contact. The closer the contact with human bodies (except washing cars as mentioned above), the less preference the community has. Further, depending on the proposed use of the water, the importance of particular attributes varied. The attribute 'no odour' was ranked as the most important for every proposed indoor use, including personal washing, washing dogs, washing clothes, and flushing toilets. For outdoor use, such as watering fruit, vegetables and flowers, and watering lawns, gardens and parks, the attribute 'low salt' was ranked as the most important. The attribute 'colour' was rated as less important.

Water that needs more treatments (e.g. no colour, no odour and low salt) water was desired for certain uses (i.e. personal washing and clothes washing) over others (i.e. watering lawns, gardens and parks, and washing cars).

Based on the observations of the study, we recommend that policy initiatives aiming to promote stormwater use would have to ensure that community expectations and acceptance of the delivered water for particular uses is met. The quality level of delivered stormwater could vary because a higher quality level of water requires a higher level of treatment. Given the variation in attribute importance, depending on indoor or outdoor use, it is considered appropriate for the attributes of the treated stormwater to be established as being 'fit for its purpose'. An implication of this could be the adoption of dual pipes (alongside the mains), delivering a higher quality level of stormwater for indoor use and delivering a lower quality level for outdoor use. Ignoring this point would probably lead to failures of the policy, as well as the projects themselves.

References

Adelaide and Mount Lofty Natural Resources Management Board (2011) Water monitoring. http://www.amlrnrm.sa.gov.au/Water/Stormwater/Aboutstormwater.aspx. Accessed 28 Feb 2011

Aguilar A (2008) Peri-urbanization, illegal settlements and environmental impact in Mexico City. Cities 25:133–145

Albrechtsen H (2002) Microbiological investigations of rainwater and greywater collected for toilet flushing. Water Sci Technol 46(6–7):311–316

Australian Prime Minister's Science Engineering and Innovation Council (PMSEIC) (2007) Water for our cities: building resilience in a climate of uncertainty, a report of the PMSEIC working group for the Australian Government, Canberra

Bonacci Water (2008) Rainwater tank evaluation study for greater Melbourne. Report for Department of Sustainability and Environment

Brown R, Farrelly M (2009) Challenges ahead—social and institutional factors influencing sustainable urban stormwater management in Australia. Water Sci Technol 59(4):653–660

Bruvold W, Olson B, Rigby M (1981) Public policy for the use of reclaimed water. Environ Manage 5(2):95–107

Bruvold W (1988) Public opinion on water reuse options. J Water Pollut Control Fed 60(1):45–49

COAG (Council of Australian Governments) (2004) Intergovernmental agreement on a National Water Initiative, Canberra. http://www.coag.gov.au/meetings/250604/iga_national_water_initiative.pdfS. Accessed 21 Sept 2010

Daughton C (2004) Ground water recharge and chemical contaminants: challenges in communicating the connection and collisions of two disparate worlds. Ground Water Monit Rem 24(2):127–138

Department for Water (DFW) (2010) Water for good annual statement 2010. Department for Water, Adelaide. ISBN 978-1-921528

Department of Infrastructure, Transport, Regional Development and Local Government (2010) Australian, state and territory governments working together to develop Australia's regions. http://www.rda.gov.au. Accessed 3 Sept 2013

Dolnicar S, Grün B (2009) Environmentally friendly behaviour: can heterogeneity among individuals and contexts/environments be harvested for improved sustainable management? Environ Behav 41(5):693–714

Dolnicar S, Schafer A (2006) Public perception of desalinated versus recycled water in Australia. In: CD Proceedings of the AWWA Desalination Symposium

Fisher T (2003) Differentiation of growth processes in the peri-urban region: an Australian case study. Urban Stud 40(3):551–565

Hurlimann A, McKay J (2004) Attitudes to reclaimed water for domestic use: part 2 trust. Water 31(5):40–45

Hurlimann A (2006) Melbourne office worker attitudes to recycled water use. Water 33(7):58–65
Hurlimann A (2007) Is recycled water use risky? An urban Australian community's perspective. Environmentalist 27:83–94
Hurlimann A, McKay J (2007) Urban Australians using recycled water for domestic non-potable use—an evaluation of the attributes price, saltiness, colour and odour using conjoint analysis. J Environ Manage 83:93–104
Jeffrey P, Jefferson B (2003) Public receptivity regarding in-house water recycling: Results from a UK survey. Water Sci Tech: Water Supply 3(3):109–116
Leviston Z, Nancarrow B, Tucker D, Porter N (2006) Predicting community behaviour: Indirect potable reuse of wastewater through managed aquifer recharge. CSIRO Land and Water Science Report 29/2006: Perth
Likert R (1932) A technique for the measurement of attitudes. Arch Psychol 140:1–55
Keremane G, McKay J, Wu Z (2011) No stormwater in my tea cup-an internet survey of residents in three Australian cities. Water 38(2):118–124
Maheshwari B, Simmons B, Singh V (2012) Role and complexity of integrated water-resources management for periurban landscapes in Australia. J Hydrol Eng 17(2):229–236
Marks J, Martin B, Zadoroznyj M (2006) Acceptance of water recycling in Australia: national baseline data. Water 33(2):151–157
National Water Commission (2009) Annual Report 2007–2008. National Water Commission, Canberra. ISBN 978-1-921107-63-4
Po M, Nancarrow B, Leviston Z, Porter N, Syme G (2005) Predicting community behaviour in relation to wastewater reuse: What drives decisions to accept or reject. Water for a healthy country research report. CSIRO Land and Water, Perth
Qu F, Kuyvenhoven A, Shi X, Heerink N (2011) Sustainable natural resource use in rural China: Recent trends and policies. China Econ Rev 22:444–460
Stenekes N, Colebatch H, Waite T, Ashbolt N (2006) Risk and governance in water recycling: 'public acceptance' revisited. Sci Technol Human Values 31(2):107–134
Sydney Water (1999) Community views on re-cycled water. Sydney Water, Sydney
Ward J, Dillon P (2011) Robust policy design for managed aquifer recharge, Waterlines report. National Water Commission, Canberra
Wu Z, Hemphill E, McKay J, Keremane G (2013) Investigating psychological factors of behavioural intention of urban residents in South Australia to use treated stormwater for non-potable purposes. J Water Reuse Desalin 3(1):16–25
Wu Z, McKay J, Keremane G (2012) Issues affecting community attitudes and intended behaviours in stormwater reuse: a case study of Salisbury, South Australia. Water 4(4):835–847
Zellner M, Reeves H (2012) Examining the contradiction in 'sustainable urban growth': an example of groundwater sustainability. J Environ Planning Manage 55(5):545–562

Chapter 12
Improving the Liveability of Cities: The Role of Solar Energy in Urban and Peri-urban Areas

D. K. Sharma and G. Purohit

Abstract Solar energy utilisation is the most important energy resource for bridging the gap between demand and supply of various energy needs in urban and peri-urban areas. The energy consumption is basically in terms of electricity for many appliances and equipment in homes, thermal energy for heating and cooling in homes and passive solar architecture for energy efficient buildings. On the other hand, the conventional energy consumption also induces the ecological imbalance such as the generation of greenhouse gases. Therefore solar energy may be considered an environmentally friendly alternative energy source for sustainable development. In this chapter, different active and passive solar energy harnessing techniques have been discussed, analysed and recommended leading to zero energy buildings (ZEBs) in urban and peri-urban areas. Here the study of solar energy applications for all types of energy needs in a residential building for advanced, ecological and smart liveability is presented. In this Chapter, we suggest some effective ways to harvest solar energy in urban and peri-urban areas using active and passive solar techniques.

Keywords Active solar · PV · Thermal · BiPV · Solar cooker · Passive solar · Heating · Cooling · Sustainability

12.1 Introduction

Solar energy harvesting is one of the most important ways of sustainable living in energy independent buildings which are usually called ZEBs. In urban and peri-urban areas, solar energy can make life more facilitating and luxurious by meeting

D. K. Sharma (✉) · G. Purohit
School of Engineering, Sir Padampat Singhania University,
313601 Bhatewar, Udaipur, India
e-mail: dinesh.sharma@spsu.ac.in

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_12,

almost all energy needs. The biggest features of solar energy usage are that it is firstly abundantly available and free of cost and secondly it is an eco-friendly operation which is a major step towards preventing global warming and climate change. There are two solar methods by which liveability can be improved, i.e., active solar and passive solar (Kroposki et al. 2009; Tinglong et al. 2011; Jakhar et al. 2009; Jin and Zhou 2010; Guiping and Guangcai 2011).

The main types of active solar are SPV (Low et al. 2010; Szymanski et al. 2011) and solar thermal (Stewart and Stewart 1991; Song et al. 2010; Kim et al. 1996; Jardan et al. 2007). In passive solar, the architecture of the house or building is designed for meeting the requirements for space heating in winter and space cooling in summer (Sang Hoon Lim 1997; Jin and Zhou 2010; Twidell and Johnstone 1993; Hong and Zhou 2010; Lim 1997; Stewart and Stewart 1991; Jakhar and Mathur 2009; Guiping and Guangcai 2011; Lim 1997). Solar photovoltaic systems in the form of Building Integrated Photovoltaic (BiPV) can fulfil the electricity needs inside and outside the house (Xiao and Sun 2011; Guan et al. 2010; Tinglong et al. 2011).

Solar thermal systems can meet the thermal energy requirements, i.e. heating and cooling, in homes. Passive solar is simply efficient utilisation of the sun's energy to design and construct energy efficient buildings which are also called green buildings (Muneer et al. 2005, Kroposki et al. 2009; Xu 2011; Jiang and Rahimi-Eichi 2011). By adopting the solar energy utilisation techniques, the economic viability can be enhanced and it would be able to reduce the dependency on fossil fuels (Solanky et al. 1997; Guan et al. 2010).

12.2 Active Solar

Active solar primarily comprises solar photovoltaic (SPV) systems and solar thermal systems. Firstly the SPV systems generate the master energy i.e. electricity. Today, almost all home appliances can be run on electricity and that is why it is the master energy. The electricity produced by solar PV may be used in solar lamps, solar fans, solar powered pumps, solar powered calculators, solar notebooks, solar radios, solar street lights, solar cell phone chargers and solar traffic lights. SPV may also be used as BiPV (Xiao and Sun 2011; Guan et al. 2010). In BiPV, the building is constructed in such a way that some parts of a building, like the roof and windows, are replaced by solar PV modules for generating electricity (Guan et al. 2010) at no extra cost of fixtures and space.

It can be said that solar PV can provide a sufficient supply of energy per household. Another main application of active solar is thermal application in homes (Song et al. 2010). Thermal application of active solar chiefly includes solar water heating systems, solar cooking, solar powered refrigerators and solar powered air-conditioning systems (Kim et al. 1996). In land transport systems, active solar plays a pivotal role by using solar vehicles (Yoshimi et al. 2012). In air transport systems active solar is being used in electric aircraft, solar panels on

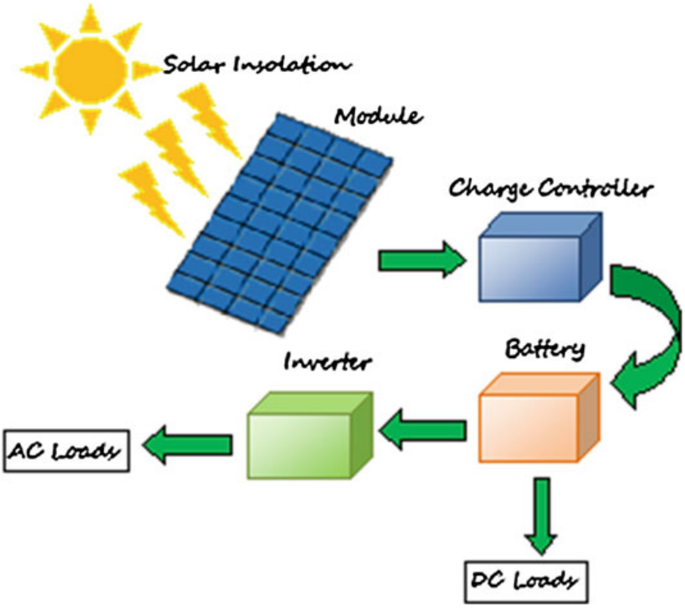


Fig. 12.1 Typical Solar Photovoltaic (SPV) system

aircraft and other solar powered air transport systems like Mauro solar riser and solar challenger. A solar boat can also be utilised as a water transport system. Concentrated Solar Power (CSP) is being used to construct a large solar power plant. Active solar can also be classified and described as follows.

12.2.1 Solar Photovoltaic (SPV) Systems and CSP

Solar PV is a technology by which energy from the sun can be directly converted into electrical energy or electricity (Szymanski et al. 2011). The electricity produced by SPV can provide an adequate power supply for many applications like lighting, fans and water pumping. Solar PV systems (direct coupled and battery coupled) especially standalone systems (Jardan et al. 2007) can meet the requirements of electrical energy consumption in residential buildings and it can act as a small level power generating system. Solar PV is proved to be an economic solution for electrification in urban, rural and peri-urban areas (Khan and Hague 2012). Rural and peri-urban areas can be successfully electrified using solar PV due to the lesser connectivity to the power grid in these areas (Sanneh and Hu 2009). A typical Standalone Solar Photovoltaic system, with various components similar to an inverter for ac loads and batteries for storage of power, has been represented in Fig. 12.1.

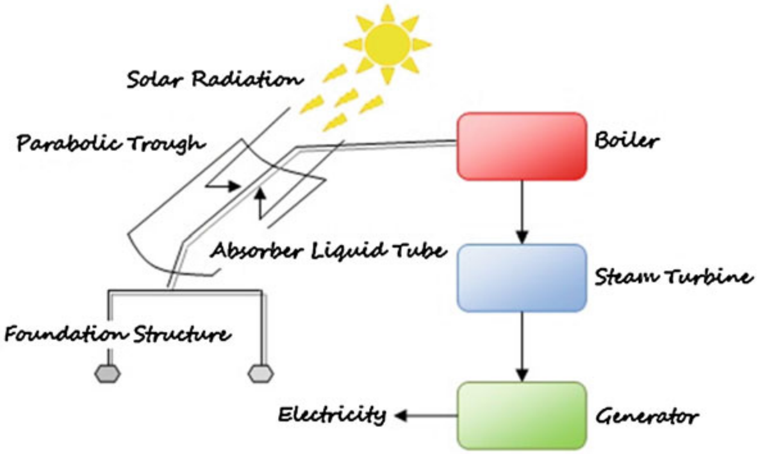


Fig. 12.2 Concentrated solar power: solar thermal to electricity

Alternatively, by using a CSP system, a big scale power plant can be operated. In concentrated solar power system (Moreno 2011), the heat energy from the sun is used to heat the liquid (usually oil) flowing in the glass tube which are placed inside a field of tracking mirrors in the shape of a parabolic trough collector and consequently the liquid heats to a typical temperature of more than 750 °F.

The heated liquid is then circulated through the pipes to a heat exchanger to reheat the heated water using natural gas to create a high pressure stream. Consequently, the stream is used to run the stream turbine which is connected to the generators to generate electricity at a larger scale as in thermal power plants. A CSP system can be viewed as in Fig. 12.2.

There are more than 300 days annually which India gets with a bright sunshine for its significant utilization. The daily average solar energy incident over India varies from 4 to 7 kWh/m^2 with approximately 1800–2200 sunshine hours per year depending upon location which is far more than the current total energy consumption (Solanki et al. 2012). This is equal to over a 5,000 trillion kWh/year, which is far more than the total yearly energy consumption of the country. In the solar energy sector in India, some large projects have been proposed and a 35,000 km^2 area of the Thar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100 GW. SPV systems have found applications in households, agriculture, telecommunications, defense and railways among others. In the last two decades, the cost of PV has gone down by more than 10 times, increasing accessibility for dispersed rural applications.

In July 2009, India unveiled a US$19 billion plan to produce 20 GW of solar power by 2020 (Kaja and Barki 2011). Under the plan, the use of solar-powered equipment and applications would be made compulsory in all government buildings, as well as hospitals and hotels. On 18 November 2009, it was identified that India was ready to launch its Jawaharlal Nehru National Solar Mission (*JNNSM*)

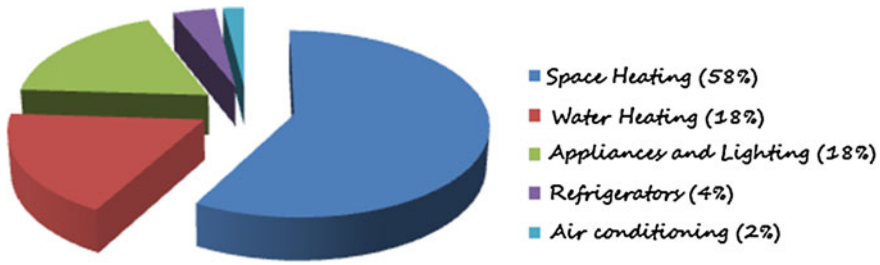


Fig. 12.3 Typical solar thermal contribution in a residential building

under the National Action Plan on Climate Change (NAPCC), with plans to generate 1,000 MW of power by 2013 (Solanki et al. 2012).

The Australian government has awarded the University of New South Wales AU$ 5.2 million to train next-generation solar energy engineers from Asia-Pacific nations, specifically India (Solanki et al. 2012) and China, as part of the Asia-Pacific Partnership on Clean Development and Climate (APP). Land is a scarce resource in India and per capita land availability is low. Dedication of land area for exclusive installation of solar arrays might have to compete with other necessities that require land. The amount of land required for utility-scale solar power plants is currently approximately 1 km^2 for every 20–60 MW generated.

12.2.2 Solar Thermal Systems

Solar thermal systems are basically used to meet the heating and cooling requirements in buildings. Water heating using a solar thermal system is one of the most usual applications. Solar cookers are also used to cook and reheat the food. Due to developments in solar thermal technology, solar thermal based refrigerators and air-conditioners are also in use. A typical solar thermal contribution has been shown in Fig. 12.3.

Solar water heaters are also called solar domestic hot water systems and can be a cost effective method to generate hot water for homes. They can be used in any climate and the fuel used is sunshine which is absolutely free. Solar water heating systems include storage tanks and solar collectors. Residential solar thermal installations fall into two groups: passive sometimes called “compact” and active sometimes called “pumped” systems. Both typically include an auxiliary energy source electric heating element or connection to a gas or fuel oil central heating system) that is activated when the water in the tank falls below a minimum temperature setting such as 55 °C. Hence, hot water is always available. The combination of solar water heating and using the back-up heat from a wood stove chimney to heat water can enable a hot water system to work all year round in cooler climates, without the supplementary heating requirement of a solar water heating system being met with fossil fuels or electricity.

The type, complexity, and size of a solar water heating system are mostly determined by:

- The temperature and amount of the water required from the system.
- Changes in ambient temperature and solar radiation between summer and winter.
- The changes in ambient temperature during the day-night cycle.
- The possibility of the potable water or collector fluid overheating.
- The possibility of the potable water or collector fluid freezing.

The minimum requirements of the system are typically determined by the amount or temperature of hot water required during winter when a system's output and incoming water temperature are typically at their lowest. The maximum output of the system is determined by the need to prevent the water in the system from becoming too hot.

Solar cookers are used to cook or heat food and solar cooking is the simplest, safest and most convenient way to cook food without consuming fuels or heating the kitchen and many people choose to cook with solar for these reasons. Solar water pasteurization is a life-saving skill for hundreds of millions of people around the world who cook over fires fuelled by wood or dung and who walk for miles to collect wood or spend much of their meagre incomes on fuel and for the millions of people who lack access to safe drinking water and become sick or die each year from preventable waterborne illnesses. The World Health Organization reports that in 23 countries, 10 % of deaths are due to just two environmental risk factors: unsafe water, including poor sanitation and hygiene; and indoor air pollution due to solid fuel use for cooking. There are mainly three types of solar cookers i.e. Box type, parabolic type and Panel type.

In urban areas, the active solar techniques viz. solar PV for power sustained supply, solar thermal for water heating and solar cookers for cooking may be useful for minimum possible energy consumption in homes. By using these techniques power grids will be prevented from overloading and also our environment would be pollution free and greener.

12.3 Passive Solar

Passive solar especially concentrates on the environment-friendly and energy efficient buildings which are usually known as Green Buildings. In passive solar, the buildings are designed in such a way that solar energy can be utilised for most of the heating needs in the building. Passive solar design is an aspect of building design in which the solar cycle is exploited in winter to provide free passive building heating. In essence, the heat of the sun is 'captured' in winter to provide building heat—known as designing for solar gain. The passive in passive solar means that there is no active device or machinery required to extract the benefits of solar heating which is being achieved by designing and constructing buildings in a specific manner.

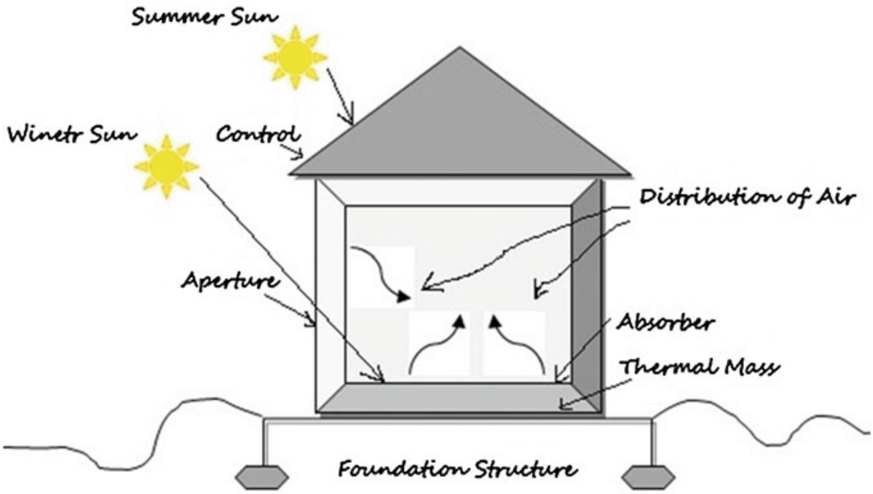


Fig. 12.4 Elements of passive solar design, shown in a direct gain application

Daylight also provides natural light for a building's interior as an open plan design can allow light to reach through a building. Using natural daylight rather than switching on artificial lights can help reduce energy demands and also provide a better quality of light. It has been indicated that such natural daylight conditions also provide improved productivity at work and better health.

12.3.1 Working Principle of Passive Solar Design

There are five separate principals as in Fig. 12.4 that when combined provide a complete passive solar building design as follows:-

(a) *Aperture Collector* is a large glass window area through which sunlight enters the building. Typically, the apertures should face within 30 degrees of true South or North (if in the Southern hemisphere) and should not be shaded by buildings or trees from 9 a.m. to 3 p.m. each day during the heating season.
(b) *Absorber* is a hard, darkened surface of the storage element. This surface; which could be that of a masonry wall, floor, or partition phase change material, or that of a water container; sits in the direct path of sunlight. Sunlight hits the surface and is absorbed as heat.
(c) *Thermal mass* is materials that retain or store the heat produced by sunlight. The difference between the absorber and the thermal mass, although often the same wall or floor is that the absorber is an exposed surface whereas thermal mass is the material below or behind that surface.

(d) *Distribution* is the method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes conduction, convection, and radiation exclusively. In some applications fans, ducts and blowers may help with the distribution of heat throughout the house.
(e) *Control* whereby roof overhangs can be used to shade the aperture area during summer months. Other elements that control under and/or overheating include: electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds; and awnings.

12.3.2 Passive Solar Heating

Two primary elements of passive solar heating are: (a) South facing glass or window, and (b) Thermal mass to absorb, store, retain and distribute heat. There are three techniques to design passive solar systems—*direct gain, indirect gain and isolated gain*. The goal of all passive solar heating systems is to capture the sun's heat within the building's elements and release that heat during periods when the sun is not shining. At the same time that the building's elements are absorbing heat for later use, solar heat is to be available for keeping the space comfortable but not overheated.

In the *Direct Gain* system, the actual living space is a solar collector, heat absorber and distribution system. South facing glass admits solar energy into the house where it strikes directly and indirectly thermal mass materials in the house such as masonry floors and walls. The direct gain system will utilize 60–75 % of the sun's energy striking the windows.

Thermal mass in the interior absorbs the sunlight and radiates heat at night. In a direct gain system, the thermal mass floors and walls are functional parts of the house. It is also possible to use water containers inside the house to store heat. However, it is more difficult to integrate water storage containers into the design of a house. The thermal mass will temper the intensity of the heat during the day by absorbing the heat. At night, the thermal mass radiates heat into the living space.

In an *Indirect Gain* system, thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system will utilise 30–45 % of the sun's energy striking the glass adjoining the thermal mass.

There are two types of indirect gain systems: (a) Thermal storage wall systems and (b) Roof pond systems. The thermal mass is located immediately behind south facing glass in this system. Operable vents at the top and bottom of a thermal storage wall permit heat to convect from between the wall and the glass into the living space. When the vents are closed at night radiant heat from the wall heats the living space.

An isolated gain system has its integral parts separate from the main living area of a house. Examples are a sunroom and a convective loop through an air collector to a storage system in the house. The ability to isolate the system from the primary living areas is the point of distinction for this type of system. The isolated gain system will utilise 15–30 % of the sunlight striking the glazing toward heating the adjoining living areas. Solar energy is also retained in the sunroom.

12.3.3 Passive Solar Cooling

Passive Solar Cooling can be used to allow natural breezes into the buildings. These breezes can help cool down buildings and provide fresh air. For large buildings the stack effect can be used, due to the fact that hot air rises, where a solar chimney can help draw air out from a building.

A primary strategy for cooling buildings without mechanical assistance, passive cooling in hot humid climates is to employ natural ventilation. The Fan and Landscape sections also address ventilation strategies. The increased glazing on the south side needed for passive heating makes it possible to achieve helpful solar gain and ventilation with the following strategies:

- Place operable windows on the south exposure;
- Casement windows offer the best airflow. Awning or hopper windows should be fully opened or air will be directed to the ceiling. Awning windows offer the best rain protection and perform better than double hung windows; and
- Where a room can have windows on one side only, use two widely spaced windows instead of one window.

A thermal chimney employs convective currents to draw air out of a building. By creating a warm or hot zone with an exterior exhaust outlet, air can be drawn into the house ventilating the structure. Sunrooms can be designed to perform this function. The excessive heat generated in a south facing sunroom during the summer can be vented at the top. With the connecting lower vents to the living space open along with windows on the north side, air is drawn through the living space to be exhausted through the sunroom upper vents. The upper vents from the sunroom to the living space and any side operable windows must be closed and the thermal mass wall in the sunroom must be shaded. Thermal mass indirect gain walls can be made to function similarly except that the mass wall should be insulated on the inside when performing this function.

Thermal chimneys can be constructed in a narrow configuration like a chimney with an easily heated black metal absorber on the inside behind a glazed front that can reach high temperatures and be insulated from the house. The chimney must terminate above the roof level. A rotating metal scoop at the top which opens opposite the wind will allow heated air to exhaust without being overcome by the prevailing wind. Thermal chimney effects can be integrated into the house with open stairwells and atria. This approach can also be an aesthetic plus to the home.

12.4 Other Ventilation Strategies

In peri-urban areas passive solar may prove easier to install and implement as in these areas the buildings are new and under construction. Therefore it is possible to include the passive architectural design in newly constructed buildings flats or apartments for maximum benefits of passive solar techniques such as partially earth bermed buildings and cross ventilation, terrace micro gardening and glazing for better cooling. Proper inclination of the buildings is also important to maintain the inside temperature suitable for the season i.e. summer and winter as discussed above. By using passive solar along with active solar techniques in peri-urban areas, the cost of cooling machines like fans and air conditioners can be reduced leading to cost effective and better liveability. It would also prove to be a step towards a sustainable and eco-friendly society.

The following strategies may also improve energy efficiency of buildings:

- Design the outlet openings slightly larger than the inlet openings.
- Place the inlets at low to medium heights to provide airflow at occupant levels in the room.
- Inlets close to a wall result in air “washing” along the wall. Be certain to have centrally located inlets for air movement in the centre areas of the room.
- Screening a porch will not reduce air speeds as much as screening the windows.
- Night ventilation of a home should be done at a ventilation rate of 30 air changes per hour or greater. Mechanical ventilation will usually be required to achieve this.
- High mass houses can be cooled with night ventilation provided that fabric furnishings are minimized.
- Keep high mass houses closed during the day and opened at night.

12.5 Concluding Remarks

In this chapter, mainly active solar techniques are examined for urban areas and passive solar techniques for peri-urban areas. It is expected that by using the active and passive solar techniques, our society may prove to be more eco-friendly and leading towards a greener and sustainable future. It is evident that solar energy can play an important role in improving liveability in residential buildings in urban and peri-urban areas and reduce carbon emissions. The technical aspects of various solar energy techniques are discussed here and subsequently recommended for practical usage. Solar PV can be utilised for power generation for all electricity requirements in houses and buildings. By using solar cookers, most of the cooking needs can be fulfilled. Solar water heaters can be employed for heating water and by employing passive solar techniques for heating buildings and houses in winter, better liveability will result without the running consumption costs. In general, proper architectural planning of residential buildings for Passive Solar and equipping other solar energy systems for Active Solar are two requirements to practise sustainable living. In urban areas, besides solar PV and solar water heating, other passive solar techniques like glazing and roof top gardening can be employed for cooling in summer. In peri-urban areas, buildings can be designed and constructed in such a manner to ensure the maximum possible advantages from solar PV for electricity generation, water heating and passive architecture for cooling and heating in summer and winter respectively.

References

Guan X, Xu Z, Jia Q (2010) Energy efficient buildings facilitated by micro grid. In: IEEE power and energy society general meeting. doi:10.1109/PES.2010.5590040

Guiping B, Guangcai G (2011) Research on passive solar ventilation and building self-sunshading. In: International conference on computer distributed control and intelligent environmental monitoring. doi:10.1109/CDCIEM.2011.171

Jakhar OP, Mathur AN (2009) Solar passive cooling/heating of building at Bikaner in Rajasthan, India. In: First international conference on the developments in renewable energy technology (ICDRET). doi:10.1109/ICDRET.2009.5454182

Jardan RK, Nagy I, Cid-Pastor A, Leyva R, El Aroudi A, Martinez-Salamero L (2007) Combined photovoltaic/thermal energy system for stand-alone operation. In: IEEE international symposium on industrial electronics. doi:10.1109/ISIE.2007.4374983

Jiang Z, Rahimi-Eichi H (2009) Design, modeling and simulation of a green building energy system. In: IEEE power and energy society general meeting. doi:10.1109/PES.2009.5275755

Jin H, Zhou C (2010) Analysis of the application of passive solar collecting approaches for rural house in super-cold areas of China. In: 5th International conference on responsive manufacturing: green manufacturing. doi:10.1049/cp.2010.0423

Kaja H, Barki DT (2011) Solar PV technology value chain in respect of new silicon feedstock materials: a context of India and its ambitious National Solar Mission. In: Annual IEEE India conference (INDICON). doi:10.1109/INDCON.2011.6139596

Khan SI, Hague SMM (2012) Economic analysis of solar PV system for urban areas of Bangladesh. In: Seventh international conference on electrical and computer engineering (ICECE). doi:10.1109/ICECE.2012.6471694

Kim S, Choi J, Park G, Yoo J (1996) Photovoltaic power generation for air-conditioning system based on predictive control. In: Proceedings of the 1996 international conference on power electronics, drives and energy systems for industrial growth. doi:10.1109/PEDES.1996.537288

Kroposki B, Margolis R, Ton D (2009) Harnessing the sun. IEEE Power Energy Mag 7(3):22–33. doi:10.1109/MPE.2009.932305

Lim SH (1997) Thermal performance evaluations of passive solar building in Korea. In: Proceedings of the 32nd intersociety energy conversion engineering conference doi:10.1109/IECEC.1997.656717

Moreno LEG (2011) Concentrated solar power (CSP) in DESERTEC-Analysis of technologies to secure and affordable energy supply. In: IEEE 6th international conference on intelligent data acquisition and advanced computing systems (IDAACS) doi:10.1109/IDAACS.2011.6072908

Muneer T, Asif M, Munawwar S (2005) Sustainable production of solar electricity with particular reference to the Indian economy. Renew Sust Energy Rev 9(5):444–473. doi:10.1016/j.rser.2004.03.004

Sanneh ES, Hu AH (2009) Lighting rural and peri-urban homes of the gambia using solar photovoltaics (PV). Open Renew Energy J. http://www.ieem.ntut.edu.tw/ezfiles/0/academic/75/academic_51679_1238186_59632.pdf. Accessed 03 Sept 2013

Siang LT, Rajkumar R, Vaithlingam AC, Thio G (2010) Harnessing photo voltaic energy for thermal heating system. In: IEEE student conference on research and development (SCOReD). doi:10.1109/SCORED.2010.5704042

Solanki CS, Fernandes BG, Arora BM, Sharma P, Agarwal V, Patil MB, Vasi J, Phatak DB, Atrey M, Moudgalya K, Bijlani K (2012) Teach a 1000 teachers: a methodology for the rapid ramp-up of photovoltaics manpower required for India's national solar mission. In: 38th IEEE photovoltaic specialists conference (PVSC). doi:10.1109/PVSC.2012.6318097

Solanky B, Sharma A, Moulik TK (1997) Sustainable energy: 2012-policy and legislation. In: Proceedings of the 32nd intersociety energy conversion engineering conference. doi:10.1109/IECEC.1997.658234

Song J, Yang J, Hang W (2010) Solar building heating energy saving optimal analysis and empirical study. In: Second international conference on information science and engineering (ICISE). doi:10.1109/ICISE.2010.5691001

Stewart WD, Stewart NM (1991) Active solar space heating in a Canadian prairie farmhouse. In: IEEE Western canada conference on computer, power and communications systems in a rural environment. doi:10.1109/WESCAN.1991.160538

Szymanski BJ, Roslaniec L, Dmowski A, Kompa K, Szymanski J (2011) Operation of photovoltaic power systems with energy storage. In: 7th international conference-workshop on compatibility and power electronics (CPE) doi: 10.1109/CPE.2011.5942212

Tinglong Y, Yong W, Ying W (2011) Research on the promotion of solar energy house. In: International conference on materials for renewable energy and environment (ICMREE). doi:10.1109/ICMREE.2011.5930806

Twidell JW, Johnstone CM (1993) Low-energy passive-solar students residences at Strathclyde University using transparent insulation. In: IEEE Xplore http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=264112&isnumber=6638. Accessed 03 Sept 2013

Xiao J, Sun J (2011) Effect of building integrated photovoltaics on urban climate. In: International conference on remote sensing, environment and transportation engineering (RSETE). doi:10.1109/RSETE.2011.5965418

Xu N (2011) Green building assessment system considering the durability of structures. In: International conference on electric technology and civil engineering (ICETCE). doi:10.1109/ICETCE.2011.5776366

Yoshimi K, Osawa M, Yamashita D, Niimura T, Yokoyama R, Masuda T, Kondou H Hirota T (2012) Practical storage and utilization of household photovoltaic energy by electric vehicle battery. In: Innovative smart grid technologies (ISGT) IEEE PES. doi:10.1109/ISGT.2012.6175688

Part IV
Wastewater

Chapter 13
Renewable Energy Policies to Shrink the Carbon Footprint in Cities: Developing CSR Programmes

A. K. Kurchania and N. S. Rathore

Abstract The need for urban development patterns that are more ecologically sustainable becomes obvious in present context. Therefore, renewable energy is gaining importance day by day, particularly in the era of rapid urbanisation. As such, renewable energy could help in an organisation's Corporate Social Responsibility (CSR). As part of a CSR initiative, a business can set up renewable energy systems in urban and peri-urban areas that will be maintained by local residents who have undergone training. Installing a mix of solar panels, wind mills and biogas plants can make urban and peri-urban areas energy self-sufficient. By adding renewable energy projects to their CSR activities, businesses will make a very positive intervention that will go a long way in improving the socio-economic lot of the disempowered. Increased use of renewable energy sources and thus energy conversation is the main pillar of a sustainable energy supply. This paper deals with the importance of Renewable Energy Sources in this context and strategies to be adopted for integrating these sources as a means of a sustainable development mechanism for procuring carbon credits and meeting different energy tasks in urban and peri-urban areas.

Keywords Urbanisation · Peri-urban · Carbon footprint · Renewable energy · Corporate social responsibility · Environmental budgets

13.1 Introduction

Cities attract people hoping for a better life for themselves and their families. Cities and peri-urban areas in general are the face of the future. They provide opportunities, economics of scale and a future with more choices. However if they

A. K. Kurchania (✉) · N. S. Rathore
College of Technology and Engineering, MPUAT, Udaipur, India
e-mail: kurchania@rediffmail.com

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_13,

are not properly planned they are also blamed for causing environmental catastrophes, for marginalising communities and for diminishing the quality of life of the poor. They are reprimanded as centres of disease, social unrest and insecurity. Cities and peri-urban areas are also at risk from industrial hazards, natural disasters and the spectre of global warming. Proper city planning requires the assessment of its natural assets and its environment.

An urban area may be identified by the number of residents, the population density, the percent of people not dependent upon agriculture, or the provision of such public utilities and services as electricity and education. Some countries define any place with a population of 2,500 or more as urban; others set a minimum of 20,000. There are no universal standards and generally each country develops its own set of criteria for distinguishing urban areas. The United States uses a population density measure to define urban with a minimum population requirement of 2,500. The classification of metropolitan includes both urban as well as rural areas that are socially and economically integrated with a particular city.

Throughout most of history, the human population has lived a rural lifestyle, dependent on agriculture and hunting for survival. In 1800, only 3 % of the world's population lived in urban areas. By 1900, almost 14 % were urbanites, although only 12 cities had 1 million or more inhabitants. In 1950, 30 % of the world's population resided in urban centres. The number of cities with over 1 million people had grown to 83 (Moffatt 1999).

The world has experienced unprecedented urban growth in recent decades. In 2008, for the first time, the world's population was evenly split between urban and rural areas. There were more than 400 cities over 1 million and 19 over 10 million. More developed nations were about 74 % urban, while 44 % of residents of less developed countries lived in urban areas. However, urbanisation is occurring rapidly in many less developed countries. It is expected that 70 % of the world's population will be urban by 2050 and that most urban growth will occur in less developed countries. A city grows through natural increase—the excess of births over deaths—and because the in-migration of people from other cities, rural areas, or countries is greater than out-migration (Fig Report 2010).

Cities have expanded into the land around them at a rapid rate capturing valuable farmland. It is expected that cities in developing countries will absorb the maximum increase of world population in the future. Cities and peri-urban settlements must be prepared to meet the challenges of unplanned settlement or slum formation. The zones where urban and rural areas meet are peri-urban interfaces. If proper planning is not carried out they suffer from the greatest problems to humans caused by rapid urbanisation, including intense pressures on resources, slum formation, lack of adequate services such as water and sanitation, poor planning and degradation of farmland. These areas, home to hundreds of millions of people, face unique problems and need distinctive and innovative approaches and solutions.

Over 90 % of slum dwellers today are in the developing world. South Asia has the largest share, followed by Eastern Asia, sub-Saharan Africa and Latin America. China and India together have 37 % of the world's slums. In sub-Saharan Africa, urbanization has become virtually synonymous with slum growth; 72 % of the region's urban population lives under slum conditions, compared to 56 % in South Asia (Bartone 2001). Developed countries have about 6 % of their populations living in unacceptable housing conditions, says the report. One billion people worldwide live in slums and the figure will likely grow to 2 billion by 2030 (UN-HABITAT Report 2008).

13.2 City Environment Integration

Grave consequences may result if the urban environment of a city is misused. Environmental resources are assets to a city. It becomes less costly to avoid environmental degradation than dealing with the consequences or repairing the damage. Inadequate waste disposal leads to the spread of disease. The use of biomass fuel, coal for cooking and heating in a confined living space can produce toxic fumes that damage lungs. Poor air quality in informal settlements in urban and peri-urban areas is often exacerbated. Air pollution and particulate matter affect respiratory and cardiovascular systems and accelerate mortality outside the home. Nitrogen dioxide (NO_2), at relatively high concentrations, causes inflammation of the airways and long-term exposure may affect lung function. Exposure to carbon monoxide (CO) reduces the capacity of the blood to carry oxygen and deliver it to tissues. Sulphur dioxide (SO_2) causes constriction of the airways and may cause acute mortality. Exposure to high levels of lead (Pb) affects the haemoglobin, the kidneys, gastrointestinal tract, joints and reproductive system and damages the nervous system. It is estimated that 800,000 people die prematurely each year due to urban air pollution (WHO 2002). A city cannot disregard its environment if it is to grow and develop in the long term.

Fossil fuel combustion especially when based on oil and coal is the major contributor to increasing carbon dioxide concentration in the atmosphere, thereby contributing to probable global warming. This climate change is considered one of the most serious environmental threats throughout the world because of its potential impact on food production and processes vital to a productive environment. Therefore, concerns about carbon dioxide emissions may discourage widespread dependence on coal use and encourage the development and use of renewable energy technologies.

Even if the rate of increase of per capita fossil energy consumption is slowed by conservation measures, rapid population growth is expected to speed fossil energy depletion and intensify global warming. Therefore, the projected availability of all fossil energy reserves probably has been overstated. Substantially reducing the use of fossil fuels through efficient use of energy and the adoption of renewable energy technologies extend the life of fossil fuel resources and could provide the time needed to develop and improve renewable energy technologies.

Energy systems planning could enhance the competitiveness of local industry, while solar water heating, district heat and power systems micro-cogeneration (combined heat and power systems) and methane production all benefit the local economy (Moffatt 1999). This planning may include sustainable construction involving energy efficiency, environmental benefits and the use of compact fluorescent lighting, rainwater tanks/water-conserving irrigation systems, renewable energy alternatives (solar still, solar water heaters, insulation, geothermal heating and cooling systems, biogas, waste recycling and composting), and neighbourhood based sewerage systems (Swilling 2006).

13.3 Ecological Footprint Assessment

The Ecological Footprint is defined as "the area of productive land and water ecosystems required producing the resources that the population consumes and assimilate the wastes that the population produces, wherever on Earth the land and water is located" (Wackernagel and Rees 1996). EF represents the amount of biologically productive land and sea area necessary to supply the resources a human population consumes and to assimilate associated waste. Using this assessment, it is possible to estimate how much of the Earth it would take to support humanity if everybody followed a given lifestyle. In 2006, humanity's total ecological footprint was estimated at 1.4 planet Earths—in other words, humanity uses ecological services 1.4 times as fast as Earth can renew them (Global Footprint Network 2005).

Per capita ecological footprint is a means of comparing consumption and lifestyles, and checking this against nature's ability to provide for this consumption. The tool can inform policy by examining to what extent a nation uses more (or less) than is available within its territory or to what extent the nation's lifestyle would be replicable worldwide. Ecological footprints may be used to argue that many current lifestyles are not sustainable. Such a global comparison also clearly shows the inequalities of resource use on this planet at the beginning of the twenty-first century.

The EF is rooted in the fact that all renewable resources come from the earth. It accounts for the flows of energy and matter to and from any defined economy and converts these into the corresponding land/water area required for nature to support these flows. It compares actual throughput of renewable resources relative to what is annually renewed. Non-renewable resources are not assessed, as by definition their use is not sustainable. An ecological footprint compares the total resources people consume with the land and water area that is needed to replace those resources.

When compared to global standards, it indicates whether a city uses natural resources sustainably. In 2001, the global average EF was 2.2 hectares per capita, although there was only 1.8 hectare per capita of biologically productive land available on Earth (Global Footprint Network 2005). Therefore, it took more than twelve months for nature to replenish the renewable natural resources used by human activity in a single year. This challenge will intensify because it is estimated that the biologically productive land per capita will decline to 1.44 ha in 2050, due to global population growth. Most cities in the developing countries of Africa, Latin America and Asia have an EF below the global average, although neighbourhoods within those cities often show sharp differences.

13.4 Environmental Budgets and Audits

Environmental budget is to manage natural resources as efficiently as money based on environmental indicators measured in physical quantities. It is a management system, focusing on the management of natural resources and environmental quality by cities. Such a budgeting cycle goes hand in hand with the financial budgeting cycle with which the public, decision-makers and senior administrators are already familiar. Environmental budgeting runs parallel with environmental auditing. Potential for continual improvement would be neglected without eco-audits and local authorities would neglect political decision making without environmental budgets. The budget uses physical units, not monetary terms. Budget preparation involves the assessment of the expected environmental impact of ongoing operations and special projects in order to forecast the environmental expenditure and consider mitigation strategies.

Eco City planning uses strategic planning to establish a long term direction towards sustainable development. ECP could be seen as 'expert-driven', as it uses technical methods and specialized approaches such as material flow analyses/ ecological foot printing and green building certification. It may also use the Circular Economy4 approach, where energy planners try to develop local energy generation systems to create local jobs and enhance community economic development, or industrial planners form partnerships to re-use waste resources.

13.5 Carbon Footprint

A carbon footprint is the total set of greenhouse gas (GHG) emissions caused by an organisation, event, product or person. It also deals with resource usage but focuses strictly on the greenhouse gases released due to burning of fossil fuels. Greenhouse gas calculations make up a portion of an ecological footprint but are not used in the same way as those in a carbon footprint. Both calculations illustrate the impact of human activity on the environment. The carbon footprint is a measurement of all greenhouse gases we individually produce and has units of tonnes (or kg) of carbon dioxide equivalent (Panwar et al. 2008). It becomes time consuming to gather a large amount of data for calculating a carbon footprint. Hence a more practicable definition has been suggested (Wright et al. 2011).

> A measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent (CO_2e) using the relevant 100-year global warming potential.

Greenhouse gases can be emitted through transport, land clearance, and the production and consumption of food, fuels, manufactured goods, materials, wood, roads, buildings and services. For simplicity of reporting, it is often expressed in terms of the amount of carbon dioxide, or its equivalent of other GHGs, emitted (Wackernagel and Rees 1996).

The mitigation of carbon footprints through the development of alternative projects, such as renewable energy or reforestation, represents one way of reducing a carbon footprint and is often known as Carbon offsetting the main influences on carbon footprints include population, economic output, and energy and carbon intensity of the economy. These factors are the main targets of individuals and businesses in order to decrease carbon footprints.

In recent years there has been a trend towards the increased commercialization of various renewable energy sources. Little change is being done to reduce the consumption of fossil fuel resources which lead to climate change and global warming. Viable alternative energy sources should be exploited to curb the emission. Rapidly advancing technologies can achieve a transition of energy generation, water and waste management, and food production towards better environmental and energy usage practices using methods of ecology (Baksh and Fiksel 2003).

13.6 Corporate Social Responsibility and Renewable Energy

Corporate Social Responsibility (CSR) is a concept whereby organisations consider the interests of society by taking responsibility for the impact of their activities on customers, employees, shareholders, communities and the environment in all aspects of their operations. Businesses can make a very positive intervention in society by adding renewable energy projects to their CSR activities, which will help in improving the socio-economic conditions of the marginalised. CSR policy functions as a built-in, self-regulating mechanism whereby business monitors and ensures its active compliance with the spirit of the law, ethical standards and international norms. The goal of CSR is to embrace responsibility for the company's actions and encourage a positive impact through its activities on the environment, consumers, employees, communities, stakeholders and all other members of the public sphere (Bhattacharya et al. 2011).

The primary purpose organisation is to maximise shareholder value including economic profit and dividends and they are bound by legal as well as regulatory obligations. These obligations are now extending as a step to improve the quality of life of the surrounding community and people. Few of CSR activities include education, health care, training programs, medical check-up camps, development of gardens, tree plantation etc. In line with CSR a business can set up Renewable Energy Technologies like Solar and biogas to serve energy needs (Fialka 2006).

Corporate Social Responsibility and Environment Management are key issues for a wide range of businesses as they seek to resolve long outstanding operational and competitive challenges using socially and environmentally friendly technologies and processes. Renewable energy is gaining importance day by day and these could serve as tool for organisation's CSR.

Decentralized electricity generation using renewable energy and its distribution can become the new frontiers for CSR activities. Such projects reduce the load on the grid, bridge the growing electricity deficit, provide regular electricity supply and generate local employment. As part of a CSR initiative a business can set up renewable energy systems in peri-urban areas and villages that will be maintained by users who have undergone training. Installing a mix of solar panels, wind mills and biogas plants can make society energy self-sufficient. By adding renewable energy projects to their CSR activities, businesses will make a very positive intervention that will go a long way in improving the socio-economic lot of disempowered.

13.7 Sustainable Energy

Sustainable energy is the provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy sources are most often regarded as including all renewable energy sources, such as solar energy, wind energy, hydroelectricity, geothermal energy, bioenergy etc. (Fig. 13.1). It usually also includes technologies that improve energy efficiency.

Many nations count on coal, oil and natural gas to supply most of their energy needs, but reliance on fossil fuels presents a big problem. Fossil fuels are a finite resource. Eventually, the world will run out of fossil fuels, or it will become too expensive to retrieve those that remain. Fossil fuels also cause air, water and soil pollution and produces greenhouse gases that contribute to global warming.

Renewable energy resources, such as wind, solar and hydropower offer clean alternatives to fossil fuels (Fig. 13.2). They produce little or no pollution or greenhouse gases and they will never run out.

13.7.1 Solar Energy

The sun is our most powerful source of energy. Sunlight, or solar energy, can be used for heating, lighting, cooling homes and other buildings, generating electricity, water heating, and a variety of industrial processes. Most forms of

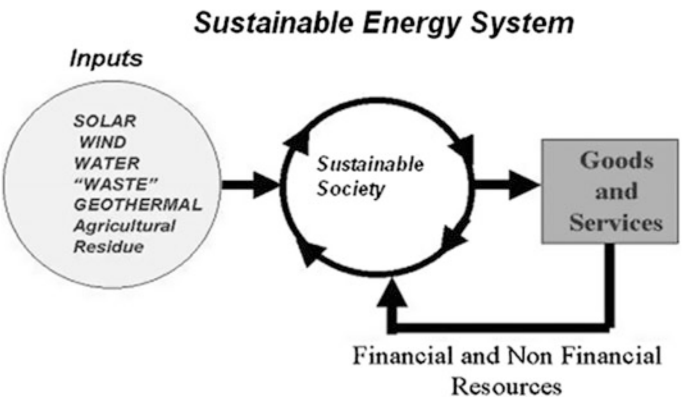


Fig. 13.1 Sustainable urban society through renewable energy sources

Fig. 13.2 Users can be trained to manage renewable energy projects

renewable energy come either directly or indirectly from the sun. For example, heat from the sun causes the wind to blow and contributes to the growth of trees and other plants that are used for biomass energy and plays an essential role in the cycle of evaporation and precipitation that makes hydropower possible.

Decentralised power generation with no need to set up long transmission lines. Solar PV Panels (Lantern, Home system, Solar Street Light) can be implemented very quickly and operated with minimum training. Photovoltaic cells produce electricity when sunlight excites electrons in the cells. As the size of the units is flexible and adaptable, photovoltaic cells are ideal for use in homes, industries, and utilities. Photovoltaic technology offers several environmental advantages in producing electricity compared with fossil fuel technologies. For example, using present photovoltaic technology, carbon dioxide emissions and other pollutants are negligible (Rathore and Kurchania 2001).

13.7.2 Wind Energy

Wind is the movement of air that occurs when warm air rises and cooler air rushes into replace it. The energy of the wind has been used for centuries to sail ships and drive windmills that grind grain. Today, wind energy is captured by wind turbines and used to generate electricity. For many centuries, wind power, like water power, has also provided energy to pump water and run mills and other machines. The availability of sites with sufficient wind (at least 20 km/h) limits the widespread development of wind farms. Promising areas for wind development include the Great Plains and coastal regions (Singh et al. 2004).

13.7.3 Hydropower

Water flowing downstream is a powerful force, a renewable resource and is constantly recharged by the global cycle of evaporation and precipitation. The heat of the sun causes water in lakes and oceans to evaporate and form clouds. The water then falls back to Earth as rain or snow and drains into rivers and streams that flow back to the ocean. Flowing water can be used to power water wheels that drive mechanical processes. When captured by turbines and generators, like those housed at many dams around the world, the energy of flowing water can be used to generate electricity.

By using clean hydro power sources, local air pollution and associated health risks will be avoided. In a country where coal is the primary fuel for electricity generation, these projects reduce pollution in the environment.

13.7.4 Biomass Energy

Biomass has been an important source of energy ever since people first began burning wood to cook food and warm themselves against the winter chill. Wood is still the most common source of biomass energy, but other sources of biomass energy include food crops, grasses and other plants, agricultural and forestry waste and residue, organic components from municipal and industrial wastes, even methane gas harvested from community landfills. Biomass can be used to produce electricity and as fuel for transportation or to manufacture products that would otherwise require the use of non-renewable fossil fuels.

13.7.5 Improved Cookstoves

The use of Improved Cookstoves helps to meet the rural energy needs with low emission levels. It enhances the local entrepreneurship in villages. Installation of such stoves will help to conserve the forest as wood is mainly used at present as fuel for cooking. There is an estimated potential of 120 million improved cookstoves in and so far about 36 million units have been constructed in India (Rathore et al. 2003).

13.7.6 Biomass Gasifier

Agricultural waste, normally free from sulphur, can be burnt to help generate heat and energy. Decentralisation systems for heat and power generation help in reducing CO2 as well. An average of 3 tons of (dry) woody biomass can be sustainably harvested per hectare per year with small amounts of nutrient fertiliser inputs. This amount of woody biomass has a gross energy yield of 13.5 million kcal (thermal). The net yield is, however, lower because approximately 33 l of diesel fuel oil per hectare is expended for cutting and collecting wood and for transportation, assuming an 80 km roundtrip between the forest and the plant. The economic benefits of biomass are maximised when biomass can be used close to where it is harvested. A city of 100,000 people using the biomass from a sustainable forest (3 tons/ha) for fuel would require approximately 220,000 ha of forest area, based on an electrical demand of 1 billion kWh (860×109 kcal = 1 kWh) per year. Nearly 70 % of the heat energy produced from burning biomass is lost in the conversion into electricity, similar to losses experienced in coal fired plants. The area required is about the same as that currently used by 100,000 people for food production, housing, industry, and roadways (Rathore and Kurchania 2001).

The energy input/output ratio of this system is calculated to be 1:3. The cost of producing a kilowatt of electricity from woody biomass ranges from 7 to 10 ¢, which is competitive for electricity production that presently has a cost ranging from 3 to 13 ¢. Approximately 3 kcal of thermal energy is required to produce 1 kcal of electricity.

13.7.7 Biogas Plants

Being an agriculture based economy with a huge animal population biogas plants could change the energy scenario at the village level. This is already an established and proven technology for gas generation (Panwar et al. 2008). Apart from cooking use (Fig. 13.3), biogas can be further cleaned and put into cylinders to be

Fig. 13.3 Biogas stoves

used as fuel for automobiles similar to Compressed Natural Gas (CNG) in urban areas. There is a potential for 12 million family size biogas plants in India and about 4 million have been installed. There is still a long way to go.

13.7.8 Biofuel

Biofuel is defined as solid, liquid or gaseous fuel obtained from relatively lifeless or living biological material and differs from fossil fuels, in that they are derived from long dead biological material. Biofuels are a renewable energy and can be sustainable (carbon neutral) in terms of greenhouse gas emissions since they are in the carbon cycle.

13.7.9 Hydrogen

Gaseous hydrogen, produced by the electrolysis of water, is another alternative to petroleum fuels. Using solar electric technologies for its production, hydrogen has the potential to serve as a renewable gaseous and liquid fuel for transportation vehicles. In addition hydrogen can be used as an energy storage system for electrical solar energy technologies, like photovoltaic (Winter and Nitsch 1988). Hydrogen has tremendous potential as a fuel and energy source but the technology needed to realise that potential is still in the early stages. Hydrogen is the most common element on Earth and in nature it is always found in combination with other elements; for example water is two-thirds oxygen. Once separated from other elements hydrogen can be used to power vehicles, replace natural gas for heating and cooking and to generate electricity.

Some of the oxygen gas produced during the electrolysis of water can be used to offset the cost of hydrogen. Also oxygen can be combined with hydrogen in a fuel cell, as used in the manned space flights. Hydrogen fuel cells used in rural and suburban areas as electricity sources could help decentralise the power grid, allowing central power facilities to decrease output, save transmission costs, and make mass-produced, economical energy available to industry.

13.7.10 Geothermal Energy

The heat inside the Earth produces steam and hot water that can be used to power generators and produce electricity for other applications such as home heating and power generation for industry. Geothermal energy can be drawn, by drilling, from deep underground reservoirs or from geothermal reservoirs closer to the surface.

13.7.11 Ocean Energy

The ocean provides several forms of renewable energy and each one is driven by different forces. Energy from ocean waves and tides can be harnessed to generate electricity, and ocean thermal energy, from the heat stored in sea water, can also be converted to electricity. Using current technologies, most ocean energy is not cost-effective compared to other renewable energy sources, but the ocean remains and important potential energy source for the future.

Increased use of renewable energy sources and promotion of energy conversation are the main pillars of a sustainable energy supply. The intervention of renewable energy technology in CSR helps to improve the quality of work with a sustainable effect on the society. It explains the positive impact that renewable energy and energy efficiency systems could have to an organisation's impact on society, the environment and our climate.

13.8 Case Studies

One case study is a programme with Arid Lands Information Network (ALIN) in Kagera District, northern Tanzania. ALIN is a Kenyan organisation working across East Africa to help bridge the 'digital divide'. It creates information exchange networks at 'Maarifa Centres' to enable poor farmers to maximise the price received for crops. They also help rural students to access better education facilities and equip unemployed youth with modern skills for employment.

Renewable World is working alongside ALIN, who were recently recognised by the Bill and Melinda Gates Foundation for their ground-breaking work, to promote the appropriate use of renewable energy across their network of centres.

Critically clean, affordable and reliable distributed energy allows ALIN to establish centres in extremely remote locations, bringing their award winning poverty alleviation, digital information access and peer-to-peer learning techniques to isolated, off-grid communities.

Working at the interface of renewable energy and international development Renewable World is well placed to help the industry enhance the provision of clean, affordable energy to some of the world's poorest people. As my presentation at the European Wind Energy Association (EWEA) Offshore conference highlighted, 2012 provides a unique opportunity for the industry to increase its contribution to an issue that is rising up the political agenda and has great relevance for the European public and emerging market consumers alike (Jeffery 2011).

Panasonic India unveiled a Solar Renewable Energy module to complement Everonn India Foundation's CSR efforts at SIPCOT Centre, Irungattukotai recently. Everonn India foundation is a trust, working towards spreading quality education across India. The decision to give the module to Everonn was made on the basis of the admirable CSR and business efforts to disseminate quality education and employable skills to millions of aspirants in India, thus aiming towards building an equitable society. With a firm belief that technology-enabled learning can truly negate socio- economic boundaries, the diverse and dynamic operations are testament to our firm focus and dedication. The basic objective of this collaboration is to demonstrate the convergence of renewable energy, skill development and eco conscious product solutions that reflect a development model that is both sustainable and scalable. This holistic concept is christened as the 'Life Innovation Centre.' The Solar Renewable Energy Module is at its heart an Energy Creating, Energy Storage and Energy Management Module, packaged within a twenty foot container, easily transportable by sea, rail and land. The Module is expected to provide electricity to power off-grid areas and support disaster-ridden areas as temporary infrastructure. This power system centre is an emission free eco-friendly comprehensive solution which can be utilised in areas with no power for audio-visual education to improve access to information in rural areas or small businesses. The Energy Module is a perfect example of optimum utilisation of earth's most renewable source of energy- solar energy. There are many areas in India which are deficient in terms of power supply, and with the introduction of the module, Panasonics' intent is to help in the development of such areas by providing a system for electricity generation which is also eco-friendly.

SIPCOT will enable use of their facilities for the placement and operation of the Energy Module. Panasonic will further extend education aids such as Plasma and Projector free of cost for the Facility, while Everonn India Foundation will extend vocational skill development and Very Small Aperture Terminal (VSAT) education programmes as applicable (Everonn Education Limited 2011).

ACWA Power International fully acknowledges that burning fossil fuel to generate power and water has a negative effect on the environment and contributes to climate change. In response, ACWA Power was one of the first companies in Saudi Arabia to declare a voluntary target of adding 5 % power generation from renewable sources to its assets portfolio over the coming 5 years. Considering the company's ambition of achieving a gross generation capacity of 30,000 MW over this period, this will translate into 1,500 MW of renewable energy. This would avoid the emission of over 2.4 million tons of carbon dioxide (CO_2) a year, depending on technology mix in the renewables portfolio. The company is also seeking to promote a project that captures and sequestrates three million tons of CO_2 a year emitted by one of the power plants in Saudi Arabia. Furthermore, one of ACWA Power focus areas with KAUST is to evaluate and field test photovoltaic and concentrated solar power systems for use in Saudi Arabia (ACWA Power 2012).

13.9 Concluding Remarks

Corporate Social Responsibility is a voluntary approach that businesses undertake to meet or exceed stakeholder expectations in the integration of ethical, social and environmental concerns together with their usual measures of revenue, profit and legal obligation. Organisation's obligations are now extending beyond maximising shareholder value and now also include steps to improve the quality of life of the surrounding community and people. As a part of CSR a business can set up Renewable Energy Technologies like Solar, Biogas to serve energy needs. Increased use of renewable energy sources and promotion of energy conversation are the main pillars of a sustainable energy supply. Our country is blessed with a variety of renewable energy sources. The intervention of renewable energy technology in CSR helps to improve the quality of work with a sustainable effect on society. It explains the positive impact that renewable energy and energy efficiency systems could have to an organisation's impact on society, the environment and our climate.

References

ACWA Power (2012) Renewable energy. http://www.acwapower.com/corporate-social-responsibility/renewable-energy.html. Accessed 10 Jan 2012

Baksh B, Fiksel J (2003) The quest for sustainability: challanges for process systems engineering. Am Inst Chem Eng J 49(6):1355. Accessed 04 April 2009

Bartone CR (2001) Urban environmental management and the poor. Environmental strategy background paper. Urban Development, Infrastructure Group, World Bank, Washington

Bhattacharya CB, Sen S, Korschun D (2011) Leveraging corporate social responsibility: the stakeholder route to business and societal value. Cambridge University Press, Cambridge

Everonn Education Limited (2011) Panasonic India unveils solar renewable energy module to complement Everonn's CSR efforts. http://www.everonn.com/panasonic-India-bring-solar-energy.html. Accessed 11 Jan 2012

Fialka J (2006) Politics and economics: big businesses have new take on warming; some companies move from opposition to offering proposals on limiting emissions. Wall Street Journal 4

Fig Report (2010) Rapid urbanization and mega cities: the need for spatial information management report. Research study by FIG Commission 3: ISBN 978-87-90907-78-5. The International Federation of Surveyors (FIG), Denmark, pp 91, 224

Global Footprint Network (2005) The ecological footprint: living well within the means of nature. ICLEI Congress, Cape Town

Jeffery N (2011) CSR in the renewable energy industry. http://www.renewable-world.org/whats-new/blog/csr-renewable-energy-industry (Submitted by Neil Jeffery—CEO on Thu, 15/12/2011: 01:00)

Moffatt S (1999) Creating an eco-city: methods and principles. The Sheltair Group Inc., Vancouver

Panwar NL, Kurchania AK, Rathore NS (2008) Mitigation of greenhouse gases by adoption of improved biomass cookstoves. Mitigation and Adaption Strategies for Global Change 14(6):569–578

Rathore NS, Kurchania AK (2001) Climatic Changes & Their Remedial Measures. Shubhi Publications, Gurgaon

Rathore NS, Kurchania AK, Jain S, Mathur AN (2003). Durable improved cook-stoves. Extension Bulletin No. CIAE/RES/2003/6

Singh P, Rathore NS, Kurchania AK, Mathur AN (2004) Sustainable development with renewable energy sources. Yash Publications, Bikaner

Swilling M (2006) Sustainability and infrastructure planning in South Africa: a Cape Town case study. Environ Urbanization 18(1):23–50

UN-HABITAT Report (2008) State of the World's Cities 2008/2009—harmonious cities, ISBN: 978-92-1-132010-7, HS Number: HS/1031/08E. UN-HABITAT, Earthscan, London, pp 224

Wackernagel M, Rees W (1996) Our ecological footprint. New Society Publishers, Gabriola Island

WHO (2002) Reducing risks. Promoting Healthy Life, Geneva

Wright L, Kemp S, Williams I (2011) Carbon footprinting: towards a universally accepted definition. Carbon Manag 2(1):61–72

Winter CJ and Nitsch J (1988) Hydrogen as an energy carrier. Springer, Berlin

Chapter 14
Perspectives on Urban Sanitation, Liveability and Peri-urban Futures of Indian Cities

Priyanie Amerasinghe and Rajiv Raman

Abstract Urbanisation and associated peri-urbanisation is widespread in India, however, the underlying processes and resulting impacts at its peri-urban interface needs better understanding. Peri-urbanisation, a dynamic process that changes the land use in the margins of growing urban centres (large and small), often displaying a form, structure and interaction that is unique and geared to support the urban centre, across many sectors. Urban sanitation is one of the sectors that face the greatest challenge, where the services are concentrated within municipal limits and disposal activities extend into peri-urban areas. The peri-urban area, due to its dynamic nature, has often fallen between the cracks of "rural" and "urban" development planning. In light of the emerging complexities of increased urbanisation in India, many are of the opinion, that the peri-urbanisation needs a critical review and new perspectives of understanding. This chapter looks at the evolving morphology of the urbanisation in India, the status and trajectory of urban sanitation initiatives and its impact on the liveability of cities and peri-urban areas and highlights the importance of looking at an urban-rural continuum for urban planning and governance.

Keywords Peri-urban · Urbanization · Sanitation · Septage · Solid waste · Liveability

P. Amerasinghe (✉)
International Water Management Institute, Hyderabad, Andhra Pradesh, India
e-mail: P.Amerasinghe@cgiar.org

R. Raman
Water and Sanitation Program—South Asia, Himachal Pradesh, India
e-mail: rajiv.raman@gmail.com

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_14,

14.1 Introduction

Urbanising India is exerting pressure on city municipalities to provide adequate sanitation infrastructure and services to all its urban dwellers. While the provision of urban sanitation services is generally within municipal limits the treatment and disposal of liquid and solid waste often reaches a wider area that stretches beyond the city fringes—the peri-urban areas. In the urban/peri-urban interface, the interactions between resource flows and waste flows emanating from the urban centres become critical to the liveability of cities, as well as the health and wellbeing of their people. The growing tension between urban sanitation arrangements and peri-urban citizen rights, as voiced in septage disposal issues (Special Correspondent 2012) and solid waste disposal (Jain 2012; Chackacherry and Kumar 2012; CMDA 2008) are reminders of the challenging sanitation impact issues that need judicious reassessment, especially at this interface. Thus, inadequate sanitation coverage, collection and treatment of sewage, absence of faecal sludge management facilities for large number of on-site systems and unsafe use of sewage/wastewater for irrigation in peri-urban agriculture are challenging problems for urbanising India (CPCB 2009; WSP 2011; WHO/UNICEF 2012).

The 2011 census of India indicates that urbanisation and associated peri-urbanisation is occurring at a rapid rate. Peri-urbanisation is a dynamic process that changes the land use in the margins of urban centres, in response to the demands of growing cities. The typology appears to be varied, according to different studies carried out across countries and is said to reflect the different sectoral influences exerted by cities (Low Choy et al. 2008). Transport, energy and communication play an important role in influencing this dynamism (Fig. 14.1).

The institutional mechanisms of governance and the socio-economics of this changing landscape have to be analysed on a case by case basis, which often mirrors the unfolding characteristics of the neighbouring urban complexes. In Indian cities, where economic growth takes precedence over all other forms of development, peri-urbanisation trajectories seem diverse and even ad-hoc. Where the Indian peri-urban landscape is primarily agrarian, urban sanitation effects perhaps are felt the most. Such areas become dumping sites for solid waste or the disposal of liquid waste into existing waterways and water bodies (CPCB 2009).

Many grapple with the definition of peri-urbanisation and the literature offers a variety of descriptions (Brooks and Davila 2000; Brook et al. 2003; Mycoo 2006; Simon et al. 2006; Narain and Nischal 2007; Marshall et al. 2009). Models for understanding the peri-urban interface are also available (Adell 1999). Literature shows that the definitions are largely influenced by the nature of the studies. For some, the physical demarcation is important as it facilitates research processes and data collection within the administrative boundaries. For others, the dynamic processes are important, where interactions between sectors define in part the peri-urbanisation process.

This chapter examines how urban sanitation can impact the peri-urban liveability and its futures. We discuss urbanisation in India, urban sanitation initiatives

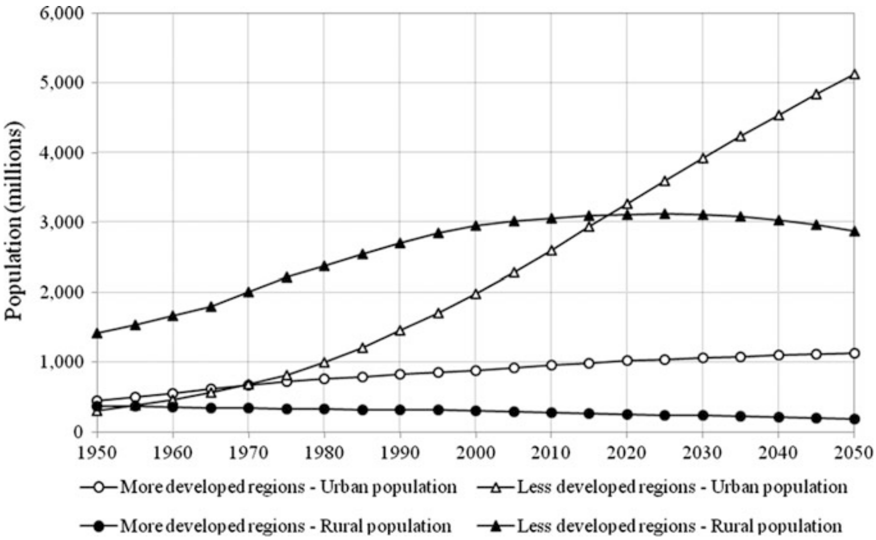


Fig. 14.1 Rural and urban populations in more developed and less developed regions in the world. *Source* UN (2012)

(management of human waste, solid waste, associated hygiene behaviour and drainage), with special reference to their nature, performance and how they impact on the peri-urban environs. The progress of these initiatives is critically examined to postulate on how liveability in peri-urban environs could be affected. The examination of the peri-urban interface issues from a sanitation perspective enables the exploration of new and alternative peri-urban futures that will be useful to planners and decision makers in urbanising India.

14.2 Urbanising India

The world's urban growth is occurring at a fast rate in the less developed regions as shown by the latest data (UN 2012). A sharp rise in urban populations compared to rural populations is projected for the coming decades. A similar trend is also witnessed in the urban growth in India. In absolute terms, the number signifying the urban Indian population is the equivalent of the population in some of the largest developed countries such as the United States of America. It is stated that one in every ten urban citizens of the world is an Indian (MGI 2010).

In 2011, nearly a third (31 %) of the population in India is resident in urban areas (COI 2011a, b). Urbanisation trends in India point to a population of 377 million today with an expected growth to 590 million by 2030 (MGI 2010). This represents a major shift as the absolute increase in urban population over the last 40 years will be matched by the anticipated growth in the next 20 years. India's

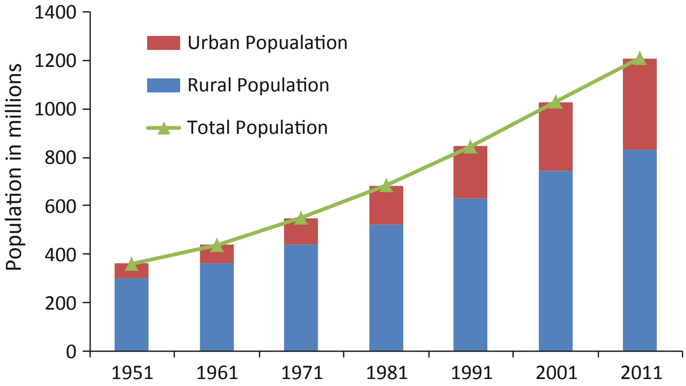


Fig. 14.2 Decadal urban and rural population trends in India

impressive economic growth over the last decade and emerging directions of economic growth drivers points to the dominance of the urban sector in the ensuing demographic and economic transition (Fig. 14.2).

The structure of urban India has several interesting features. The distribution of urban population in 2001, shows that megacities accounted for about 13 % of the urban population while the million-plus cities accounted for less than half (43 %) of urban population. Class I cities accounted for more than half (70 %) of the urban population in 2011 (COI 2011a). At the same time, it should be noted that the rate of growth has been declining in the larger cities. During the preceding decades (1981–2001), core regions of the older metropolitan cities have generally witnessed a decline in growth rates (Bhagat 2004). The newer million-plus cities have maintained the growth rate in both the core and outgrowths, possibly benefiting from economic growth and other spatial factors (COI 2011b). These urban concentrations have a demonstrable link with the national economic output (see Table 14.1), with the largest 100 urban centres accounting for slightly less than half (43 %) the national economic output.

The concentration of population in three mega-cities and 53 million-plus cities and the regional differences in urbanisation (southern and western states urbanising faster) command attention. The process of urbanisation extends well beyond these large agglomerations to multi-characteristic small and medium-sized localities. The number of urban centres has increased phenomenally (153 %) over the 2001–2011 period with a significant part of this increase accounted by towns, which have almost tripled their growth. Two-thirds of these new census towns are concentrated in six states (West Bengal, Kerala, Tamil Nadu, Uttar Pradesh, Maharashtra and Andhra Pradesh, COI 2011b) and within these in specific districts (Pradhan 2012). Amongst the new census towns that have emerged in 2011, about two-thirds of the population is not within the proximity of class-I towns, and only 13 % is within the proximity of million-plus cities (Pradhan 2012). Industry studies indicate a shift of organised manufacturing to rural areas, with a

Table 14.1 Urban concentrations and economic output—2011

Type of cities	Share of population (%)	Share of land occupied (%)	Share of economic output (%)
Top 10 cities	8	0.10	15
53 (million plus cities)	13	0.20	33
Top 100 cities	16	0.26	43

Source IIHS (2012)

preference for places with relatively better infrastructure and education facilities (Ghani 2012). Urban studies indicate a greater spread of the country's metro and secondary cities than was previously believed (Denis and Marius-Gnanou 2011). Also, from Geopolitics, standpoint, the Indian scenario exhibits all the signs of a very diffused process of urbanisation rather than a major demographic polarisation led by mega-cities. From this perspective, "the country seems to be firmly headed towards an extended process of metro-politanisation alongside diffused combinations of localised socio-economic opportunities including clusters, cottage industries, and market towns partially interlinked along developmental corridors" (Denis and Marius-Gnanou 2011). This form of urbanisation features many sub-regional settings that converge, overlap and diverge, in lieu of a well-defined rural-urban divide. The non-uniform criterion and method for urban classification in the census and state administration points to some disconnects and also opens up the debate on what constitutes the "urban" (Denis and Marius-Gnanou 2011). The slow rate of increase in statutory town numbers over the decade, also points to the economic forces that might have played a part in creating the new census towns.

Assessing the peri-urban spaces and their extent can be achieved using remote sensing and GIS studies. However, this is a complex process. Some municipalities will also have the municipal extent and the development areas identified (Table 14.2; Figs. 14.3, 14.4 and 14.5), and many of these peri-urban areas consist of a mixture of urban and rural characteristics worthy of exploration and study. Studies on peri-urban spaces have been of interest to scientists in India, as exemplified by the urbanisation trajectories of small towns (FIP 2012), influence of land development and migration in peri-urban Faridabad (Goel 2011), peri-urban settlements in metropolitan Chennai (Kölbl and Haller 2006), urban-rural linkages around Delhi (Narain and Nischal 2007) and also peri-urban water security (Narain 2010) to name a few.

Table 14.2 Metropolitan development areas in selected cities with over 1 million population

State	City	Status	Population (2011)	Wastewater disposal	Municipal area (km^2)	Metropolitan development area (km^2)
Andhra Pradesh	Vijayawada	UA	1491,202	–	61	110
Punjab	Ludhiana	City	161,3878	Buddha Nullah and canals (canals to Satluj River)	159	310
Jammu	Srinagar	UA	1273,312	Dal Lake and Jhelum River	236	416
Gujarat	Rajkot	UA	1390,933	Nyari, Aji Rivers	105	633
Gujarat	Vadodara	UA	1817,191	Vishwamitri River	150	715
Gujarat	Ahmadabad	UA	6352,254	–	464	1,295
West Bengal	Asansol	UA	1243,008	–	127	1,615
West Bengal	Kolkata	UA	14112,536	Hooghly River	185	1,851
Chandigarh	Chandigarh	UA	1025682	Canals (canals to Ghaggar River)	115	2,421
Andhra Pradesh	Hyderabad	UA	7749,334	Musi River	690	7,100

Source City Municipal Administration Websites (2012) accessed on December 2012 and verified by personal communication of officers

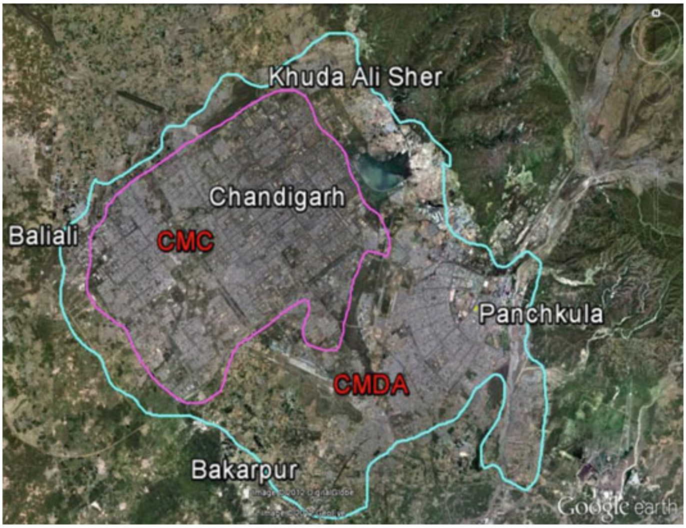


Fig. 14.3 City of Chandigarh with municipal corporation (CMC) and metropolitan development authority (CMDA) areas

Fig. 14.4 City of Kolkata with municipal corporation (KMA) and metropolitan development (KMDA) areas

Fig. 14.5 City of Hyderabad with greater Hyderabad municipal corporation (GHMC) and Hyderabad metropolitan development authority (HMDA) areas

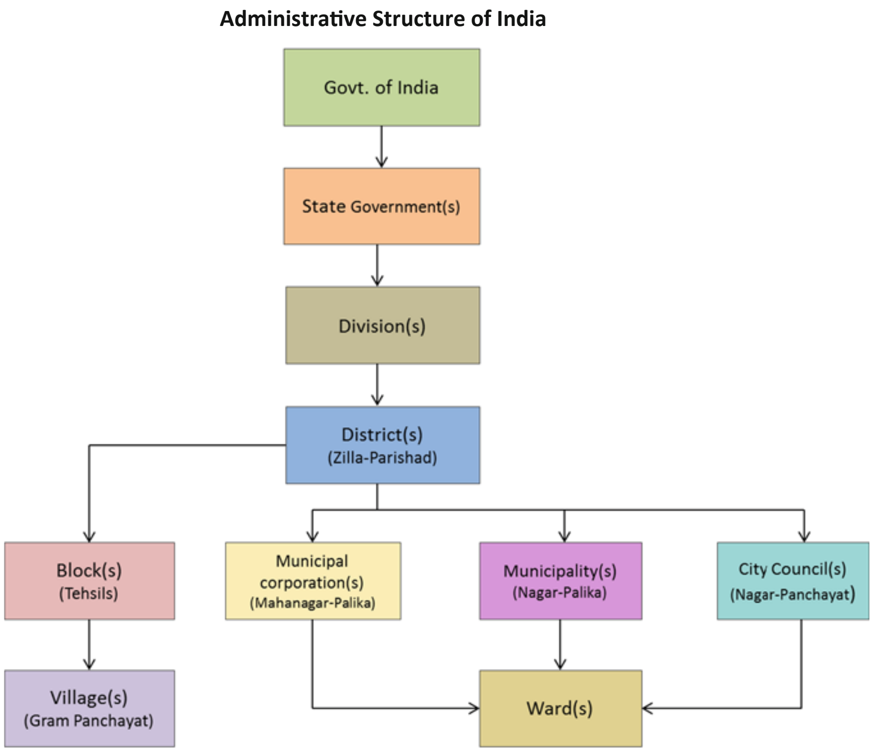


Fig. 14.6 Structure of public administration in India

14.3 Urban Nomenclature: Disconnect Between the Statistical and the Political Stance and Liveability Indices

Different types of local bodies govern urban centres including Municipal Corporations, Municipalities, Notified Town Area Committees and Nagar Panchayats (Town Councils) (Fig. 14.6). The last two are provided by the constitution for rural areas transitioning to urban areas. In India, the Census of India—an organ of the Central Government—classifies settlements into rural and urban although it is State governments that grant municipal status to urban centres. The slow or limited pace of according urban status by different state governments in the preceding decades, suggests a general trend toward reduced upgrading of villages to towns (Denis and Marius-Gnanou 2011). The financial inflows of urban local bodies are primarily from their own tax revenues, loans from Financial Institutions and grants from State and Central governments under different developmental initiatives. Considering the higher share of developmental funds from national ministries targeted at rural areas, there has been a strong incentive for State governments to not accord urban status to settlements that satisfy the statistical criteria at the time of a census. The desire to avoid higher rates of taxation and payment for services is also a strong incentive for rural political leadership to advocate maintenance of the status quo.

The silo-like nature of government programs and finance flows coupled with the delayed upgradation to statutory urban centres by administrative action brings with it a set of problems, illustrated here by two national flagship programs that are aimed at providing healthy and clean environs. The Total Sanitation Campaign, the national program for rural sanitation overseen by the Ministry of Rural Development, aims at achieving open defecation-free and clean villages through a program that creates a demand for household sanitation, solid waste management and liquid waste management services. However, the on-site solutions coupled with community management strategies that are advocated, have faced obstacles in the larger villages or rural areas that are displaying some of the predominant aspects of urban character. Here, the financial flows have not matched citizen aspirations (which are more urban) in some cases, thus forcing program managers to consider how the campaign can be tweaked for these settlements. The flagship Jawaharlal Nehru National Urban Renewal Mission (JNNURM) launched in 2005, an urban renewal mission for creating urban infrastructure and providing services, channels funds and technical assistance to 63 mission cities that include million-plus cities, state capitals and others selected for tourism/heritage status. The sub-mission Urban Infrastructure and Governance finances the creation of infrastructure in these urban centres, which consists mostly of larger Class-I cities (MoUD 2005a, b). The Urban Infrastructure Development Scheme for Small and Medium Towns, which guides and funds infrastructure creation in the other towns including all towns and cities according to the 2001 census except for the JNNURM mission cities, have been accessed more by larger towns (MoUD 2010). As a result, one finds that the middle range in India's rural-urban spectrum, large villages and small towns (less than 20,000 population) accommodating between 80 and 140 million people, are possibly being excluded from accessing and effectively utilising these development funds.

14.3.1 Understanding and Linking Liveability

Currently, a global Liveability Index is being used to assess the living conditions of cities and spaces (EIU 2012). This index looks at city space for its suitability for living by comparing broad categories such as stability, healthcare, culture and environment, education and infrastructure (e.g. The EIU's Global Liveability Report, Mercer's Quality of Living Survey, Monocle's Most Liveable Cities Index). The liveability index is calculated from a set of about 30 indicators with an overall ranking ranging from 1 to 100 to denote intolerable to tolerable. More recent surveys have also included in the index population density, air quality, connectivity and green space as new measures. Liveability indices also help to understand how cities respond to economic downturns or how resilient they are.

While variations in the overall results of these surveys and indices can be expected, globally, communities are looking for good living conditions. The literature shows that India is also beginning to assess the best cities for living based on how the governance and service sectors and cultural settings make living in cities a pleasant experience (IFC 2011, 2012).

Infrastructure development has been part of the engine of growth in Indian cities. While sanitation, nutrition and combating hunger are priority agendas, these priorities have not had a significant impact as described in the latest liveability reports of Indian cities (Mathur 2011). The Liveability Index that has been developed for the last 2 years is expected to guide the policy makers to plan development programmes for the future, a welcome prospect as governments focus more on liveability in the urban areas and its environs. From a long-term perspective, this is a promising way forward which will bring the multi-sectoral services that support living spaces to address some of the key issues like health and sanitation. Liveability of spaces needs good foresight and planning and linking the future scenarios in a realistic way. Sanitation is a major sector that will influence liveability and peri-urban areas. As such it will become very important in defining suitable indices for cities in India.

14.4 Sanitation in Urban India

Peri-urban spaces are marked by the dynamic nature of land-use change, due to the influence of neighbouring urban areas and governance related sectoral policies. Peri-urban areas are also inhabited by different groups of people, and often served with a low level of public services, especially sanitation (SWM and liquid waste). In India, peri-urban landscapes in the proximity of large cities generally have an urban character in terms of density and land-use, while similar landscapes near smaller towns have a predominantly agriculture base. Sanitation and water supply directly affect these peri-urban surroundings, and the following sections attempt to understand the magnitude of the problem and survey government interest. The following section also explores the evolution of various governance initiatives aimed at providing healthy and clean environs in the urban domain. It then looks at the current status of sanitation (including hygiene) and solid waste management in urban areas and moves to critically examine the resulting dynamics at the urban and peri-urban interface.

14.4.1 Programmes, Initiatives and Overall Trends

History records document the knowledge and practice of sanitary management in pre-historic India. This practice, however, appears to have faded away over centuries (Alok 2010). The emergence of current practices in public health management can be traced to the wave of sanitary reforms and public health initiatives that took place in Europe during the second half of the 19th century and found echo in India, albeit, on a limited scale. Starting with the first sewer network in Kolkata, India in 1870, the initiatives of the colonial government were mostly limited to sewer networks servicing the military cantonments and parts of adjoining areas. These were aimed to protect the health of the government and military personnel. While some progressive rulers and city governments followed suit, such as Thiruvananthapuram, Ahmadabad, fiscal conservatism meant that most municipalities were usually unable to provide the necessary funds for a new sanitation system based on the construction of sewers and labour-saving technologies. This early period also saw the intensification of manual scavenging of night soil and refuse removal (Chaplin 1999).

Looking back at the sanitation planning experience in urban India (Rao 2009), the initial periods were predominantly focused on rural issues with the slums in urban areas being a particular matter of concern. The Environmental Improvement in Urban Slums scheme in 1972 assumed legal powers for slum development during the fourth plan. Since then, there have been several initiatives focused on the provision of basic amenities and later shelter in slums and amongst the poor in urban areas (Fig. 14.7). The Ganga Action Plan tackled river pollution first in the Ganges, in 1985, and later in other river basins under the National River Conservation Program in 1995 with a focus on controlling municipal and industrial waste flows to the rivers. This was supplemented with the inland water quality monitoring network operating under a three-tier programme involving the Global Environment Monitoring System, Monitoring of Indian National Aquatic Resources System, the National Lake Conservation Plan (MoEF 2008) and the Yamuna Action Plan managed by the Central Pollution Control Board. These river conservation plans together have covered 172 towns and created treatment infrastructure of about 3,200 MLD by 2011 (NRCD 2012). The urban renewal mission, initiated in 2005, signalled the need for a focused effort on enhancing urban infrastructure and service provisions to upgrade the quality of life in Indian cities and to address the need for sustainable development of physical infrastructure in cities. The program also included the development of technical and management capacities in city governments and related institutions. The national government made a financial commitment of USD 32,610 Million during the period (2006–2012). Substantial portions of the budget have been earmarked for water supply and sewerage according to city demands. The national urban sanitation policy states the following objectives: "All Indian cities and towns become totally sanitised, healthy and liveable and ensure and sustain good public health and environmental outcomes for all their citizens with a special focus on hygienic and affordable sanitation facilities for the urban poor and women" (MoUD 2008).

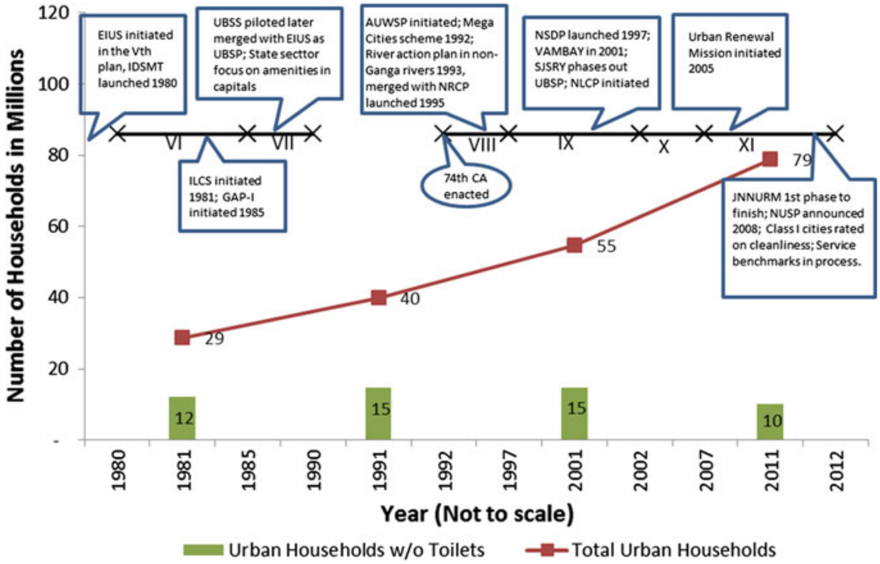
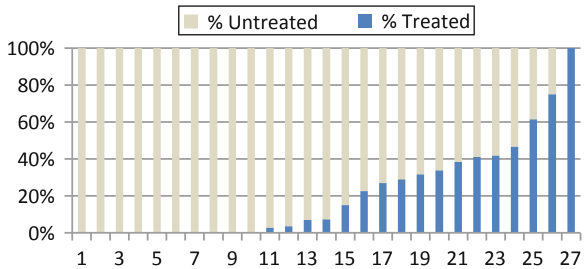


Fig. 14.7 Sanitation provision and state initiatives in urban India. *Source* COI (1981, 1991, 2001), Rao (2009), MoUD (2005a, 2005b, 2008, 2011)

Fig. 14.8 Sewage treatment capacity in 27 states of the country. *Source* CPCB (2009)



14.4.2 Sewerage

Urban India's greatest challenge is the safe collection, conveyance and establishment of treatment facilities for the disposal of human excreta and wastewater. It is estimated that only about 30 % of household sewage is collected and treated with the bulk coming from metro cities (Fig. 14.8; CPCB 2009; PCI 2012), thus accentuating the neglected status in the rest of urban India. In most cities, not all waste is collected and treated. When the partially treated sewage collected from households connected to the network mixes with polluted stormwater—untreated sewage and dumped solid waste the outcome of such ad-hoc and unsystematic infrastructure exacerbates the pollution loads of cities and affects the liveability of growing cities and their periphery.

The spatial evolution of sewer networks and treatment facilities in the urban centres show partial networks in the core area of towns with treatment facilities located at the urban fringes. Over time, the expansion of urban centres has overrun any targeted expansion of these facilities. The newly developed residential settlements within the urban area, the residential pockets that have emerged in suburban areas and the expanding outgrowths that later merge with the expanded cities, are usually bereft of adequate potable water, sanitation and waste management services.

Investments and the creation of sewerage infrastructure only serve to tackle part of the problem. For instance, in Bengalaru, the city has 3,610 km of sewage lines and 14 sewage treatment plants that generate an estimated 800–1,000 MLD (Million litres per day) of sewage, while the installed treatment capacity is roughly equivalent to 721 MLD. Engineers in Bengaluru report that the sewage treatment plants only receive some 300 MLD of sewage. In other words, less than half the sewage is collected and treated (PCI 2012). Adequate emphasis on awareness of creation processes and the suitable choice of technologies to enable improved household connectivity, safe conveyance, treatment and disposal must become part of the municipal governance tool-kit. Municipal governments also sometimes find it problematic to satisfy services in a now-denser core, due to space, topography and technology constraints. Alternatives to the one-size-fits-all approach of underground drainage are emerging, with the successful application of shallow-sewers. These have been tried successfully in the tsunami resettlement areas (MoUD 2012c), on-site ecosan solutions in small town development projects and decentralised treatment systems (CDD 2012) in different parts of the country. Based on the use of Public-private partnership models such as Build, Operate and Transfer systems (BOT), sewage treatment systems and the conversion of solid waste into compost are proving to be a promising prospect for many cities in India. Cities like Hyderabad and Chennai already have such successful functioning systems (WABAG 2012).

Eighty-two percent of urban households in India report access to household sanitation facilities in 2011 (COI 2012), a progressive trend from earlier decades (Fig. 14.7). It is estimated that the total annual economic impact of inadequate household sanitation in India (WSP 2011) amounted to a loss of INR 2.4 trillion (USD 53.8 billion) in 2006, implying a per capita annual loss of INR 2,180 (USD 48). A crude disaggregation by the urban contribution of the population indicates the annual loss from inadequate sanitation in urban India is about INR 700 billion. The study findings also show that urban households in the poorest income quintile bear the highest per capita economic impacts of inadequate sanitation, thus highlighting the disproportionate impacts of inadequate sanitation.

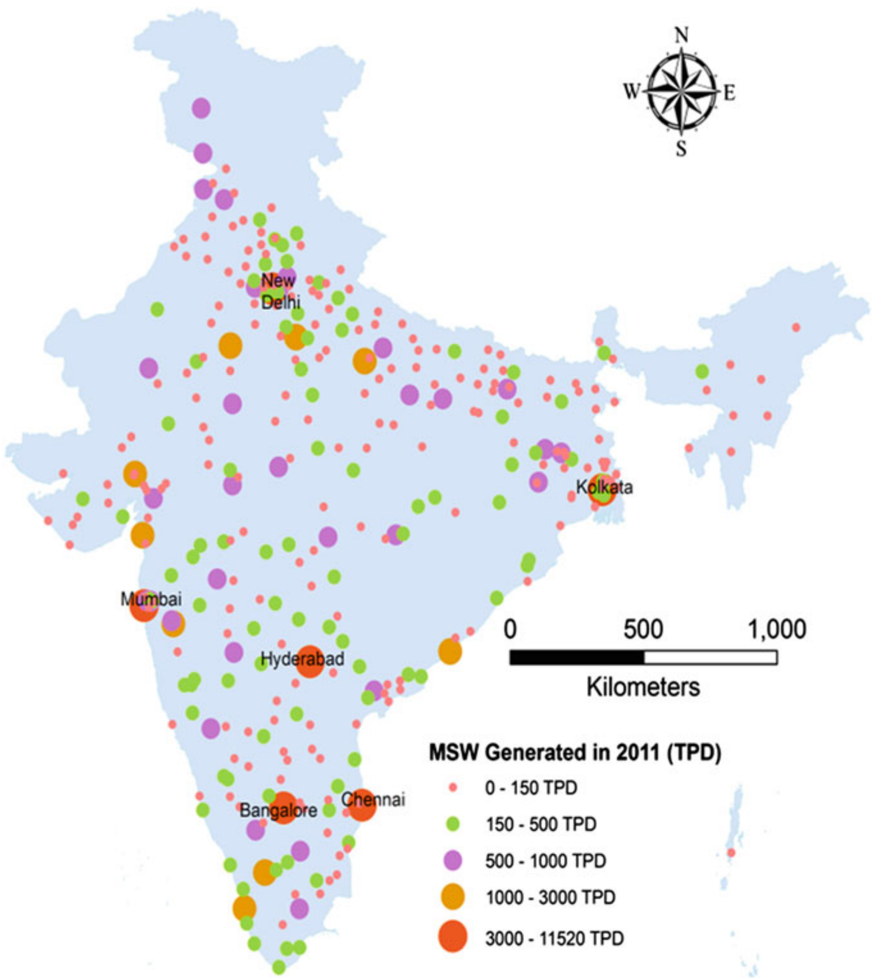


Fig. 14.9 Solid-waste generation in selected cities with over 100,000 population (n = 345) *Source*: Adapted from Annepu (2012)

14.4.3 Solid Waste

Urban India is said to generate an estimated 68.8 million tons per year (TPY) or 188,500 tons per day (TPD) of Municipal Solid Waste (Fig. 14.9). The per capita waste generation in the country is 0.55 kg/day, closely linked to the increased purchasing power and changing lifestyles, which is increasing pressure on the cities' governance for adequate infrastructure resources. During the last decade, the throughput of solid waste being treated and disposed of has also increased significantly. Efforts by large companies like A–Z, Ramky Enviro Engineers Limited, IL&FS and other smaller concerns that use cooperative and individual business models have been documented (MoF 2009) for cities like Kolkata, Hyderabad, Vijayawada, Ahmadabad, Thane and Jaipur. The solid waste generated from the 53 cities in India with a million plus population alone would be around 86,000 TPD (31.5 million tons per year) (Annepu 2012). Therefore, it is timely to assess the large efforts of the JNNURM programme which has invested about USD 21,739 Million (INR 100,000 crore) for the period 2005–2012, in 63 "priority cities". These investments are expected to benefit 150 million urban Indians by 2030.

While progress in infrastructure creation has taken place, there are still issues of SWM that need attention. Barring a few initiatives such as Swachcoop in Pune, Maharashtra, the overtly centralised feature of these waste management solutions excludes the informal sector stakeholders who had played a role in reducing waste-flow—rag-pickers in the solid waste sector and sewage collectors in the household sanitation sector. Again, the nature of the waste stream also suggests the need for planning and fitting different technology solutions to different scales of operation. For instance, a scientifically engineered landfill would possibly be economical at a regional scale for a cluster of urban centres, provided that downstream components of waste segregation and recycling/reuse are implemented at neighbourhood and sub-city scales and are suitably networked. The various "centralised management" solutions for solid waste, resulting from the "moving waste out of city remit" paradigm have become an administrative concern due to problems with technology choice and performance tracking and regulation. This has generated increasing resistance from peri-urban villages and resident communities who were impacted by their proximity in Bangalore and the cities of Kerala and Chennai. Similar resistance and citizen action have been voiced against the disposal practices of sewage, while the periodic monitoring of river water quality points to their continuing decline (CPCB 2009) due to pollution from municipal and industrial wastewater. The regulatory authority CPCB has been mandated through various laws legislated between 1974 and 1989 to ensure clean disposal. However, the outcomes appear hampered by implementation challenges that explain the current state of affairs.

The experiences from the national sanitation programme in rural areas point to the need to focus on sustained efforts to enable behavioural change (PCI 2013). This sectoral cross-learning is gaining more recognition in urban discourse and shows success in some of the smaller town initiatives (like Kolhapur in Maharashtra or Kalyani in West Bengal). Such process may achieve more traction. Further, the predominance of on-site sanitation treatment facilities amongst the urban households highlights the importance of construction norms and practice for safe sanitary outcomes. The unregulated construction sector is characterised by a workforce with varying skills and levels of technology awareness, sometimes and a tendency for improvisation on site; it is common to see outlets of septic tanks connected to stormwater drains and not to soakaways. Awareness programs, training and certification have been initiated on a limited scale (for example, by the National Institute of Construction Management and Research and a few of the larger construction firms). However, increased involvement and buy-in from the construction sector is necessary to supplement these efforts.

Urban planners, academics and administrators have pointed to the increased waste-flows from urban to the peri-urban and have emphasised that their magnitude is reaching critical limits. In the rating exercise of cities by the MoUD in 2010 (MoUD 2011), 421 of 423 participating cities lost marks (pers. Comm. Consultant, MoUD) owing to their lack of proper management of solid and liquid wastes impacting adversely on neighbouring settlements. Progress to date, on management of municipal solid waste, indicates an emphasis on the creation of disposal-treatment facilities and building of waste-transportation infrastructure, with insufficient attention to the administration-household interface and the essential principle of reduce-recycle-reuse. The re-orientation to a more centralised value chain has excluded the informal sector workforce and created scale issues that need resolution. Some urban waste management practitioners have also highlighted the deleterious impacts of breaking the natural nutrient cycle as a result of these urban management practices and worked towards developing appropriate technology and management models ecosan, septage-to-manure, septage-to-energy in the urban domain.

Sanitation services in urban areas and their periphery—wastewater, septage, solid waste—should ideally be geared to processes that preserve nutrient integrity and allow flows, natural or market-developed, to agriculture (MoUD 2012a). This alternative future would require several building blocks, institutional, technological, and markets, that are geared to considering an urban-rural ecosystem with mutual benefits rather than in conflict as at present. To achieve this, the discourse has to move beyond simplistic economics to a more comprehensive world-view that accommodates natural capital and ecosystem services and embraces a more decentralised and empowered local governance regime.

14.5 The Peri-urban Future

It is evident that multiple trajectories of urbanisation are occurring across the country, accompanied by peri-urbanisation, an interface that shows its own unique features. The challenges faced by urban India in deploying and managing appropriate systems for waste management services, notably household sanitation and solid waste management, points to a broader problem and the need for action on the planning, citizen engagement and financial fronts. It is apparent that peri-urban areas are regions of neglect, especially with respect to sanitation, which falls by the wayside and does not fit into classical urban or rural solution-sets. Planners will also have to take note of the fact that the historical markers for rurality, notably physical connectivity and communication, have witnessed tremendous changes in the last decade. Thus, it is imperative to develop appropriate models of urban planning that take into account the urban-rural continuum.

It is clear that urbanising India will need to look at its peri-urban areas through an "integrative" lens and the 12th five year plan appears to be clearly gearing towards this aim (MHUPA 2011). While "resilient cities" and "integrated management" are buzzwords amongst researchers, planners and decision makers the challenge is to define, conceptualise and operationalise action plans within the urban and rural continuum, with bridging peri-urban spaces in between. Sanitation plans will have to be a key component of these integrated plans (MoUD 2012b).

The planning process for the 12th five year plan recognises the importance of the urban domain and spatial demographic shift that might demand alternate planning trajectories. The National Mission on Sustainable Habitat which forms part of the eight national missions for climate change adaptation, offers opportunities to better study and plan resources flows, keeping the linkages within and between human habitats. Both these instruments suggest the need for shifting to a more trans-sectoral or cross-sectoral mode of planning and urban management. It is clear that peri-urban spaces are emerging in areas close to the city fringes and in new census towns. However, little information is currently available, on the morphology, land use, sociological composition and institutional arrangements for the peri-urban interface. In this context, future sanitation plans for peri-urban areas will have to consider the following:

- An understanding of the demographic, resource and financial flows between urban and proximal rural areas.
- An assessment of the resource flows related to sanitation, especially with regard to septage, organic waste and wastewater, to develop reuse and business options.
- The identification of peri-urban typologies and developing action research in collaboration with city and district governments to examine workable protocols for "integrated planning and management", regulation of ecosystem goods and services.
- An understanding of the role of stakeholders in a dynamic peri-urban region, one that considers it as a changing area.
- The use of modern technology (mapping and communication) and innovative methods to build and display the evidence base and for tracking drivers of change in peri-urban settings.

Peri-urbanisation will continue as economic development forges ahead and these areas will continue to support cities in many ways. Therefore, it is important to characterise the different types of peri-urban spaces that emerge and collect the evidence base that will help recast urban management perspectives including sanitation plans that suit the needs of a new urban India.

14.6 Conclusions

The multiple trajectories of urbanisation occurring across the country and the accompanying evolution of peri-urban spaces highlight the need for a more organic understanding of the urban and peri-urban interface. The emerging evidence points to a remarkably diverse set of spatial interactions resulting from the structural elements that define these spaces. The challenges faced by urban India in the provision of waste management services, notably household sanitation and solid waste management, points to a broader problem and the need for re-orienting urban planning and management practices towards a more trans-disciplinary paradigm. The paradigmatic shifts proposed in the approach taken to the twelfth plan and the climate change perspective embedded in the sustainable habitat mission provide a window of opportunity. Expanding the knowledge-base of the urban and peri-urban interface and its dynamics would be a crucial first step in this journey towards a more sustainable model of urban planning and management, one that sees the peri-urban as an evolutionary counterpart of urbanisation and not just an ephemeral space.

References

Adell G (1999) Theories and models of the peri-urban interface. A changing conceptual landscape. Development Planning Unit, University College London, London

Alok K (2010) Squatting with dignity. Lessons from India. Sage, Delhi

Annepu RK (2012) Sustainable solid Waste management in India. MSc Thesis, Master of Science in Earth Resources Engineering, Department of Earth and Environmental Engineering, Fu Foundation School of Engineering and Applied Science, Columbia University in the City of New York

Bhagat RB (2004) Dynamics of urban population growth by size class of towns and cities in India. Demography India 33(1):47–60

Brooks R, Davila J (2000) The peri-urban interface: a tale of two cities. University College London, London

Brook R, Purushothaman S, Hunshal S (2003) Changing frontiers. The Peri-urban interface Hubli-Dharwad, India. Books for Change, Bangalore

CDD (2012) DEWATS implementations by network consortium for DEWATS dissemination society. http://www.cddindia.org/decentralised-wastewater-treatment-systems-dewats/project database/e/1/1.html. Accessed 20 Oct 2012

Chackacherry G, Kumar D (2012) Waste management in Kerala: problems and solutions. http://www.kerala.gov.in/docs/publication/keralacalling/octo_11/14.pdf. Accessed 30 Aug 2013

Chaplin SE (1999) Cities, sewers and poverty: India's politics of sanitation. Environ Urban 11:145. Sage, Delhi

CMDA (2008) Chennai metropolitan development authority. Second master plan for Chennai metropolitan area, 2026. Vol I: vision, strategies and action plans. Solid Waste Manag 8:90–93. http://www.cmdachennai.gov.in/Volume1_English_PDF/Vol1_Chapter08_Solid%20Waste%20Management.pdf. Accessed 30 Aug 2013

COI (1981) Houses, household amenities and assets: availability and type of latrine facility. Registrar general and census commissioner, Government of India

COI (1991) Houses, household amenities and assets: availability and type of latrine facility. Registrar general and census commissioner, Government of India

COI (2001) Houses, household amenities and assets: availability and type of latrine facility. Registrar general and census commissioner, Government of India

COI (2011a) Provisional population totals paper 2 of 2011: India (Vol II). Census of India. Registrar general and census commissioner, Government of India

COI (2011b) Census of India. http://censusindia.gov.in/2011-prov-results/paper2/data_files/India2/1.%20Data%20Highlight.pdf. Accessed 30 Aug 2013

COI (2012) Houses, household amenities and assets: data sheet—availability and type of latrine facility. Registrar general and census commissioner, Government of India

CPCB (2009) Status of water supply, wastewater generation and treatment in class I cities, and class II towns of India. Central Pollution Control Board, New Delhi

Denis E, Marius-Gnanou K (2011) Toward a better appraisal of urbanisation in India: a fresh look at the landscape of morphological agglomerates. http://cybergeo.revues.org/24798. Accessed 22 Oct 2012

EIU (2012) The global liveability report. Economic intelligence unit, The Economist

FIP (2012) Subaltern urbanisation in India. http://www.ifpindia.org/Subaltern-Urbanisation-in-India.html. Accessed 30 Aug 2013

Ghani E (2012) Spatial development and urbanisation of manufacturing and services. Is India different? Centre for Policy Research, India. http://www.cprindia.org/seminars-conferences/4010-spatial-development-india. Accessed 29 Aug 2013

Goel N (2011) Dynamic planning and development of peri-urban areas: a case of Faridabad city. India J 8:15–20

MoF (2009) Position paper on the solid waste management sector in India. Department of economic affairs, ministry of finance, Government of India. Accessed Oct 2012

IFC (2011) The liveability index 2010: the best cities in India. Institute for Competitiveness, India

IFC (2012) The liveability index 2011: the best cities in India. A mapping of 37 cities. Institute for Competitiveness, India

IIHS (2012) Urban India 2011: the evidence report. 3rd edn. Indian Institute for Human Settlements, Bangalore

Jain B (2012) Civic body gets MPCB rap for flouting norms at dump sites. The Times of India. http://timesofindia.indiatimes.com/city/mumbai/Civic-body-gets-MPCB-rap-for-flouting-norms-at-dump-sites/articleshow/16999605.cms. Accessed 30 Aug 2013

Kölbl R, Haller R (2006) Periurban—a comparison between India and Western countries. Association for European Transport and Contributors. http://stuff.mit.edu/afs/athena/course/11/11.951/oldstuff/albacete/Other_Documents/Europe%20Transport%20Conference/planning_for_sustainab/periurban__a_compa1555.pdf. Accessed 10 Dec 2012

Low Choy D, Sutherland C, Gleeson B, Sipe N, Dodson J (2008) Change and continuity in peri-urban Australia: peri-urban futures and sustainable development. Monograph 4, Griffith University, Western Australia, Australia

Marshall F, Waldman L, MacGregor H, Mehta L, Randhawa P (2009) On the edge of sustainability: perspectives on peri-urban dynamics, STEPS Working Paper 35, STEPS Centre, Brighton

Mathur P (2011) Hand hygiene: back to the basics of infection control. Indian J Med Res 134:611–620

MGI (2010) India's urban awakening: building inclusive cities, sustaining economic growth. McKinsey Global Institute

MHUPA (2011) Report of the working group on urban strategic planning. 12th five-year plan

MoEF (2008) Guidelines for national lake conservation plan. National river conservation directorate. Ministry of environment and forests. http://envfor.nic.in/downloads/public-information/NLCP_guideline.pdf. Accessed 10 Oct 2012

MoUD (2005a) Urban sector reforms through on-going Jawaharlal Nehru national urban renewal mission. Ministry of urban development, Government of India

MoUD (2005b) Jawaharlal Nehru national urban renewal mission—overview. Ministry of urban development, Government of India. http://jnnurm.nic.in/wp-content/uploads/2011/01/PMSpeechOverviewE.pdf. Accessed 10 Oct 2012
MoUD (2008) National urban sanitation policy. Ministry of urban development, Government of India. http://www.urbanindia.nic.in/programme/uwss/NUSP.pdf. Accessed 10 Oct 2012
MoUD (2010) State wise town status. Ministry of urban development, Government of India. http://urbanindia.nic.in/programme/ud/uidssmt_pdf/StateWiseTown/StateWiseTown.htm. Accessed 10 Oct 2012
MoUD (2011) National urban sanitation policy. Rating of cities 2010. Towards city wide sanitation. Ministry of urban development, Government of India. http://www.urbanindia.nic.in/programme/uwss/FlyerRating.pdf. Accessed 10 Oct 2012
MoUD (2012a) Recent trends in technologies in sewerage system. Ministry of urban development, Government of India. http://urbanindia.nic.in/programme/uwss/dprs-checklists/swgrtech.pdf. Accessed 10 Oct 2012
MoUD (2012b) Improving urban water supply and sanitation services advisory note. Ministry of urban development, Government of India. http://urbanindia.nic.in
MoUD (2012c) Advisory on septage management in Indian cities. Draft for circulation. Ministry of urban development, Government of India. http://www.urbanindia.nic.in/programme/uwss/slb/SeptageMgmtAdvMay20.pdf. Accessed 29 Oct 2012
Mycoo M (2006) Sustainable livelihoods in the periurban interface: Anse La Raye, St. Lucia. In: McGregor D, Simon D, Thompson D (eds) The periurban interface: approaches to sustainable natural and human resource use. Earthscan, Virginia
Narain V (2010) Peri-urban water security in a context of urbanization and climate change: a review of concepts and relationships. Peri-urban water security discussion paper series. Paper No. 1, SaciWATERs. http://saciwaters.org/periurban/idrc%20periurban%20report.pdf. Accessed 8 Aug 2013
Narain V, Nischal S (2007) The peri-urban interface in Shahpur Khurd and Karnera, India. Environ Urban 19(1):261–273. doi:10.1177/0956247807076905
NRCD (2012) National river conservation directorate. http://envfor.nic.in/nrcd/NRCD/table.htm. Accessed 22 Oct 2012
PCI (2012) Report of the working group on urban and industrial water supply and sanitation for 12th five year plan (2012–2017). Planning Commission, Government of India
PCI (2013) Evaluation study on total sanitation campaign. Programme evaluation programme. http://planningcommission.nic.in/reports/peoreport/peo/rep_tscv1_2205.pdf. Accessed 28 Aug 2013
Pradhan KC (2012) Unacknowledged urbanisation: the new census towns of India. Centre for Policy Research
Rao Rama RV (2009) Basic services for the urban poor—innovative actions and interventions. India urban poverty report. Ministry of housing and urban poverty alleviation, Government of India. Oxford University Press, Delhi
Simon D, McGregor D, Thompson D (2006) Contemporary perspectives on the peri-urban zones of cities in developing areas. In: McGregor D, Simon D, Thompson D (eds) The periurban interface: approaches to sustainable natural and human resource use. Earthscan, Virginia
Special Correspondent (2012) Project to address septage issue. The Hindu. http://www.thehindu.com/todays-paper/tp-national/tp-kerala/article3224695.ece. Accessed 30 Aug 2012
UN (2012) World urbanisation prospects, the 2011 revision: highlights. United Nations, Department of Economic and Social Affairs, New York
WABAG (2012) Advanced solutions for sludge treatment: conversion of residues into an energy source. Technology report. http://www.wabag.com/wabag/wp-ontent/uploads/2012/04/SludgeDigestion_2012_EN_v21_WEB.pdf. Accessed 30 Aug 2012
WHO/UNICEF (2012) Joint monitoring programme for water supply and sanitation. Progress on drinking water and sanitation
WSP (2011) Economic impacts of inadequate sanitation in India. Global economics of sanitation initiative, Water and Sanitation Program

Chapter 15
Decentralised Wastewater Management for Improving Sanitation in Peri-urban India

Santosh Ojha

Abstract The most challenging characteristics that set peri-urban areas apart from the urban and rural sectors are poor site conditions, unreliable water availability, high population density, the heterogeneous nature of the population and the lack of legal land tenure. One of the major problems that dwellers in the peri-urban regions have to face every day are sanitation problems. In these peri-urban areas, there are inadequate facilities for waste water disposal and there is a need to improve the water quality through wastewater treatment processes. In this study, it is observed that conventional centralised approaches to wastewater management have generally failed to address the needs of communities for the collection and disposal of domestic wastewater and faecal sludge from on-site sanitation. There are opportunities for implementing wastewater management systems based on a decentralised approach that may offer opportunities for wastewater re-use and resource recovery as well as improvements in local environmental health conditions. A number of decentralised wastewater options are discussed in this paper which can be effectively implemented in peri-urban areas. Further, anaerobic treatment of wastewater is advocated for it generates biogas (mainly methane) which can be used in generators for electricity production and/or in boilers for heating purposes. Also, waste stabilisation ponds can be used for fish culture. The study emphasises the importance of building the capacity of local organisations in all aspects of decentralised wastewater management. A number of aspects related to the operational sustainability of decentralised technologies for wastewater management in peri-urban areas and their associated management requirements. In general, the choice of technology is limited by the need to ensure that the operation and maintenance requirements of the chosen technology are compatible with the levels of knowledge and skills available at the local level.

S. Ojha (✉)
Department of Agricultural Engineering, NIET, NIMS University, Jaipur, India
e-mail: santoshon16@yahoo.co.in

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_15,

Keywords Wastewater management · Sanitation · Sustainability · Decentralised approach

15.1 Introduction

Urbanisation is one of the most important demographic trends of the twenty-first century, and urban growth is particularly rapid in lower-income countries. The majority of urban growth is associated with the rapid expansion of smaller urban centres and peri-urban developments (Angel et al. 2005). India's slum-dwelling population rose from 27.9 million in 1981 to over 42.6 million in 2001, 15 % of urban India's population. In Greater Mumbai 1,959 slum settlements have been identified with a total population of 6.25 million, which forms 54 % of the total population of the city (Census of India 2001). After Mumbai, Delhi has the second largest slum Population in India with nearly 1.8 million people living in slum areas in New Delhi. Kolkata has 32 % of the population living in slums (NBO 2010). In 2001, 42.58 million persons in 640 cities and towns lived in slums and squatter settlements, representing 15 % of the country's total urban population and 23.1 % of the population of 640 cities and towns that reported slums.

According to the Census of India (2001), 41.6 % of the country's slum population is in cities with over 1 million population, with Mumbai, Delhi, Kolkata and Chennai accounting for about one-fourth of the total slum dwellers. The NSSO survey in 2002 has identified 51,688 slums in urban areas of which 50.6 % of urban slums have been declared as "notified slums". According to the census of India, 2001 Himachal Pradesh, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Daman and Diu, Dadra and Nagar Haveli, and Lakshadweep have not reported any slums in 2001 (MHFW 2011). India accounted for nearly three-fourths of the informal population in the sub-region, with 158 million. In India, an estimated 20 million people migrate temporarily each year. It is also estimated that over 60 % of this movement is between rural areas, with the majority migrating from drought-prone regions to areas of irrigated agriculture (DESA 2011).

Peri-urban areas are characterised by uncertain land tenure, inferior infrastructure, low incomes and a lack of recognition by formal governments (Fig. 15.1). Settlements are generally inhabited by communities of different economic status relating to land prices, which are affected by location in relation to the city and are considerably higher than in rural areas (Dupont 2005). Families who live in informal settlements build on the cheaper land outside city limits, on land within city limits that is not zoned for housing, on land that has not been urbanised with infrastructure or on land considered dangerous or environmentally fragile. Many informal settlements begin as land invasions with families illegally squatting on the land. The peri-urban population should, therefore, be a focus of concern. Spatially, peri-urban areas are growing much more rapidly than formal urban districts and in many cities, the peri-urban sections are already bigger than the formal areas

Fig. 15.1 A view of oldest peri-urban settlement in Bhopal, Madhya Pradesh, India

(Dupont 2005). The rapid growth and informal status of these high-density population areas has resulted in low levels of sanitation services. A lack of basic services, in particular the lack of adequate excreta management, threatens public health and the environment of peri-urban settlements and urban areas as a whole.

The homes and neighbourhoods in peri-urban areas share two characteristics that bear serious potential health effects: (i) lack of infrastructure, and (ii) adequate water supply for sanitation and safe disposal of excreta and wastewater from the crowded settlements. Due to these reasons, pathogenic micro-organisms tend to breed fast in these areas and therefore the removal of these organisms is critical for health and environmental needs. Many rivers in these areas are literally large open sewers, i.e., some 3.5 lakh people live in the 62,000 slums on the Yamuna riverbed and its embankments (MSPI 2009). Surface and groundwater contamination is widespread in many developing countries and the resulting environmental degradation is more and more apparent along rivers and coastal areas. Rivers, streams, canals, gullies and ditches are the destinations of most untreated human excrement and household waste. Such waste accumulates on streets, in open spaces between houses, in stagnant pools of water and on wasteland. In addition, collected sewage is disposed, untreated, into rivers which also serve as a source of water for drinking and bathing for families living in peri-urban settlements and irrigation for farmers living downstream.

Urban areas are growing faster than the rural areas of the country. A recent World Bank study suggests that, in contrast to higher-income urban dwellers and some rural populations, the urban poor have a lower life expectancy at birth and a higher infant mortality rate. In addition to threatening health, the lack of excreta management systems in Third World cities is having a tremendous negative effect on the environment contaminating surface and groundwater with organics, nutrients, and solids. Because of their current and growing size and density and their lack of adequate infrastructure, peri-urban areas are the largest source of faecal contamination in cities.

The main aim of this article is to increase the understanding of the serious and growing problem of inadequate disposal and management of human excreta in the exploding peri-urban areas of cities throughout the country. It emphasises the suitable approach of decentralised wastewater treatment for sanitation in peri-urban areas.

15.2 Characteristics of Peri-urban Areas

Peri-urban settlements have a number of unique characteristics that distinguish them from formal urban and rural areas; these characteristics are outlined below.

15.2.1 Poor Physical Site Conditions and Complicated Site Layouts

Almost 24 % of the slums are located along nallas and drains and around 12 % along railway tracks, according to a report released by NSSO. Nearly half of the non-notified slums do not have a latrine of any type. In contrast only 17 % of notified slums do not have a latrine (Jacobson 2007). Some peri-urban areas are undesirable for formal development, such as those located on steep slopes, along gullies and ravines, on soil that is too rocky to excavate easily, in desert lands or in areas prone to flooding. Poor families move onto these lands because they are relatively cheap to purchase or because illegal occupation of such sites is less likely to be challenged.

15.2.2 Limited Water Availability

Most peri-urban settlements do not generally have piped water. The National Sample Survey Organisation survey conducted in 2002 found that in 84 % of the notified slums the main water source is through tap water supply. But these numbers mask differences across the states of India. In Bihar none of the slums get water via the tap. In Chhattisgarh, Gujarat and Uttar Pradesh less than 35 % of slums get tap water. Nearly 44 % of non-notified slums do not have a drainage system of any type whereas only 15 % of notified slums do not have a drainage system (Jacobson 2007). This leads to low levels of personal and domestic hygiene and thus favours the transmission of excreta-related infections.

15.2.3 High Density Population

Demographic data are lacking for peri-urban areas because these communities are illegal and for the most part not recognised by the formal sector. Dharavi, Asia's second largest slum is located in central Mumbai and houses 800,000 people. The population has led to densities as high as 48,215 persons per km^2 in Mumbai and 16,082 per km^2 in suburban Mumbai. Population density of Chennai is 26,903 which is largest in the state of Tamilnadu. It is regarded as *India's* fourth *largest city* after Delhi, Mumbai and Kolkata. It is estimated that about 20 % of Bangalore's population reside in urban slums. Forty two per cent of the households *migrated* from *different parts of India.* High population density without basic infrastructure entails greater health and environmental risks than those found in rural and formal urban areas.

15.2.4 Organization of Communities and Social Characteristics

Peri-urban settlements, in general, are not homogeneous with respect to ethnic background, income level, language and social norms. Residents have migrated to these settlements from various parts of a region or country or, in many cases, from other countries. This heterogeneity often leads to misunderstandings and distrust among neighbours and may result in minimal contact among them.

15.2.5 Lack of Legal Land Tenure, Government Recognition and Services

In most developing countries, the existing legal, formal land development market is gridlocked by overregulation and its corresponding costs. This has been a major contributing factor to the creation of an illegal informal land market that is unencumbered by controls.

Because prohibitive costs lock them out of formally developed areas, in most peri-urban communities, occupants are in violation of tenure laws and/or development regulations. Residents of peri-urban areas often do not have legal land tenure, and, in most cases, the site itself has not been legally urbanized. Therefore, governments generally do not recognise the legality of these settlements.

15.2.6 Low Income Levels and Reliance on the Informal Economy

As noted above, families settle in peri-urban areas for rational reasons, primarily because land prices or rents are low. The economic crisis in many developing countries has reduced the purchasing power of low-income families and limited even further their ability to pay for formal sector housing or services. Many households in peri-urban areas do not enjoy a regular income.

In peri-urban areas, families' workers rely mainly on the informal economy and because cash in the informal economy is unsteady and unreliable, residents are not deemed creditworthy and cannot get conventional bank loans.

15.2.7 Limited Political Influence

Peri-urban settlements are not recognised as legal areas and as such their community leaders and residents have limited political influence. They are mostly economically poor, marginalised and uneducated and historically have held limited political power. Residents in formal urban areas, on the other hand, enjoy the status of being recognised as constituents to whose needs politicians must respond in order to stay in office.

15.3 Wastewater Production and Disposal in Peri-urban Areas

In peri-urban areas, increasing populations, combined with increasing water consumption create widespread wastewater disposal problems. In many cases, wastewater is discharged locally onto open ground and vacant plots, creating ponds of foul-smelling stagnant water Children and others may come in contact with polluted water, especially as they often play in open areas where wastewater and refuse collects. Open defecation by Mumbai's 4 million slum dwellers, who have no access to toilet facility, exposes us to about 1,000 tonnes of human excreta every day. Health risks are increased by the fact that household and surface water drainage systems are invariably combined, so floodwater becomes contaminated with excreta. Mosquitoes and other pests breed in blocked drains and ponds, spreading diseases such as filariasis.

The lack of infrastructure and services and effective systems for managing wastewater has led to widespread pollution of surface water and groundwater and deterioration in environmental health conditions. The greatest impacts are upon the health and livelihoods of poor communities, who often inhabit low lying and marginal land, for instance wetlands and alongside drainage channels, which are polluted with excreta and other wastewater. At the same time, increasing competition for limited water resources has resulted in a tendency for farming communities in peri-urban areas to use untreated wastewater for irrigation and aquaculture. Farmers often find it cheaper to utilise wastewater than incur capital and recurring costs in pumping groundwater to irrigate crops. The re-use of wastewater for irrigation is likely to be most prevalent in regions where water from other sources is scarce for part or all of the year. Wastewater comprises of both domestic sewage and industrial effluents. It therefore contains a variety of pollutants including pathogens and heavy metals which can potentially harm the environment as well as human and animal health. Inadequate and un-safe discharge of untreated domestic/municipal wastewater has resulted in contamination of 75 % of all surface water, i.e., the rivers, ponds and lakes across India (Seshadri 2009).

15.4 Decentralised Approaches to Wastewater Management

The lack of adequate peri-urban sanitation for informal settlements has grave environmental consequences that indirectly jeopardise human health. Peri-urban areas are the largest nonpoint source of faecal contamination in a given city. The inadequate disposal of human waste contaminates surface and groundwater with organic compounds, nutrients and solids. Organic compounds decompose in receiving waters, depleting oxygen and harming some aquatic life Nutrients can be toxic to fish and humans and can also cause eutrophication (the excessive growth of algae and aquatic plants utilising the nutrients which can lead to decreased oxygen concentrations when the algae and plants die and decay). Decaying solids use up oxygen and this can harm benthic organisms living at the bottom of water bodies. The environmental problems associated with urban areas are a consequence of the number of people producing wastes and their high concentration. Centralised systems for wastewater collection and disposal require disproportionately large investments which are unaffordable to the majority of the peri-urban poor. There is some truth in this argument when municipal administrative systems are centralised. However, experience shows that centralised systems have been particularly poor at reaching peri-urban areas, particularly those that fall outside municipal boundaries and have not been responsive to local needs and resources. In response to the deficiencies of centralised approaches to service delivery, there has been increasing emphasis on the potential benefits of adopting decentralised approaches to sanitation and wastewater management, which are considered to be particularly appropriate for peri-urban areas. The Centre for Scientific Research Trust (CSR), Auroville, Pondicherry has pioneered the decentralised *wastewater treatment system in India.* Decentralisation is also seen as a way of strengthening the role of local government and democracy in general and as an effective means of addressing environmental and health concerns.

There has also been an increased emphasis on a more holistic approach to waste disposal that stresses the benefits of reducing the strength or quantity of waste at source and, where possible, recycling or re-using it close to the point where it is produced. One conceptual model which incorporates these different aspects is the household-cantered environmental sanitation approach. This model starts from the assumption that sanitation problems, including wastewater disposal, should be solved as close to their source as possible, with decisions and the responsibility for implementing them flowing from the household to the community to the city and, finally, to higher levels of government. The decentralized wastewater treatment systems (DEWATS) uses natural treatment techniques and bio meditation in different combinations. It has a filter chamber to filter debris, a septic tank for primary treatment, a baffle filter reactor for secondary treatment, a reed bed system for tertiary process and an underground sump for storage and safe disposal into river downstream.

15.4.1 Benefits of Decentralised Approaches of Wastewater Management

15.4.1.1 Decentralised Decision Making and Participatory Planning

Decentralised planning and decision-making in wastewater management offers potential benefits relating to increased responsiveness to local demands and needs and, hence, increased willingness of communities to pay for improved services. Where poor people are already involved in local agricultural systems, there is a possibility that improving decentralised management systems will achieve a better distribution of benefits than more centralised management approaches. In relation to infrastructure provision, NGOs can play a key role in assisting communities to develop their basic services i.e., CURE India is a development NGO that works with poor communities and local government which improved access to basic services. A decentralised system has been built on the Kuchpura drain under the slum in Agra, state of Uttar Pradesh in India.

15.4.1.2 Financial Advantages of Decentralised Management

The capital investment for decentralised wastewater systems is generally less than for centralised systems in peri-urban areas and they are also likely to be cheaper to construct and operate. By tackling wastewater problems close to the source, the large capital investment of trunk sewers and pumping costs associated with centralised systems can be reduced, thus increasing the affordability of wastewater management systems. Decentralised approaches to faecal sludge collection and disposal are particularly appropriate for peri-urban areas as they reduce haulage distances and thus reduce the cost of transportation.

15.4.1.3 Segregation of Wastewater at Source

Domestic wastewater consists of "black" water, the mixture of water and faeces flushed from WCs and pour-flush toilets and "grey" water, the sullage from kitchens and bathrooms. Grey water contains much lower pathogen levels and has a lower oxygen demand than black water and therefore represents a much smaller health and/or environmental threat. Grey water and black water are produced separately and ensuring that they remain separate can facilitate management of the two wastewater streams. This option may be considered where it is possible to dispose of black water to a leach pit or septic tank followed by a soakaway. Grey water can then be used for irrigation or discharged into a local watercourse with little or no treatment. This option creates the need periodically to remove and treat the sludge that accumulates in the leach pit or septic tank and therefore tends to place greater demands on individual households than options that remove all wastewater from the house. However, it is arguably easier to ensure that households maintain their own facilities than to ensure effective management at the community level.

The segregation of industrial and commercial effluents from domestic wastewater at the source is also an important benefit of decentralised wastewater management; in as much as wastewater from residential areas is less likely to receive highly polluted industrial flows, which is particularly important where wastewater is to be re-used. It will therefore be necessary to introduce systems for regulating and treating wastewater discharges and local communities can be an effective means of monitoring the activities of the commercial sector.

15.4.1.4 Compatibility with Local Demands for Wastewater Re-use

Decentralised wastewater systems are likely to be compatible with local demands for wastewater re-use in peri-urban areas where water and the nutrient content in wastewater increase agricultural productivity and contribute to the livelihoods of peri-urban communities. Wastewater may also be re-used for aquaculture where aquatic plant biomass is used either directly or as an ingredient in a feed-mix to raise fish or livestock for human consumption. Wastewater re-use can promote incentives for local people to operate and maintain local systems and thus help to ensure long-term operation and financial sustainability. The re-use of waste can increase local agricultural productivity, resulting in increased revenue for local producers.

15.4.2 Options for Decentralised Waste Water Treatment

In order to ensure that decentralised wastewater management systems protect against adverse impacts on health and the environment, some form of treatment will be required before effluents are discharged or re-used. The level of treatment is dictated by the disposal or re-use option, for example, pathogen reduction is important when wastewater is re-used but less important when it is discharged into a watercourse. The relative sophistication of conventional treatment processes presents difficulties for operation and maintenance at the local level and these technologies are unlikely to be appropriate for local use because they require careful and skilled attention. However, a range of alternative technologies are available which may be used for decentralised wastewater management systems and these are briefly discussed below. Although these technologies are less dependent upon power for operation than more advanced technologies, they require increasing amounts of land, especially where wastewater is re-used. A potential constraint on localised management is therefore the limited availability of land for treatment facilities. This is particularly important in the case of simple options such as waste stabilisation ponds and constructed wetlands, which require a large land area [13, 14]. Land ownership can constrain the implementation of decentralised wastewater management systems due to the ineffective planning and control over informal development.

15.4.2.1 Anaerobic Treatment

Anaerobic digestion is the most common (mesophilic) treatment of domestic sewage in septic tanks, which normally retains the sewage from one to two days, reducing the *Biochemical Oxygen Demand* (BOD) by about 35–40 %. Anaerobic treatment of wastewater is considered to be an appropriate form of technology for the treatment of black water and faecal sludge from household latrines, as it requires less land area and produces a well stabilised sludge in lesser quantities than aerobic treatment (source: sustainable sanitation and water management). Anaerobic treatment may also be cheaper than most aerobic treatment processes because the process of anaerobic digestion produces energy and is therefore not dependent upon an external power source. One major feature of anaerobic digestion is the production of biogas (with the most useful component being methane) which can be used in generators for electricity production and/or in boilers for heating purposes. The simplest form of anaerobic treatment is the septic tank, which both settles suspended solids and achieves some anaerobic digestion of those settled solids. A Decentralised Wastewater Treatment and Reuse System has been established for a College in Badlapur, state of Maharashtra, India. In the multi-step treatment process no energy is required. Moreover, during the anaerobic treatment process, 97 % of the methane is collected and can be used for energy purposes. Anaerobic treatment systems such as upflow anaerobic sludge blanket (UASB) and baffled reactors can provide an improved performance over simple septic tanks (85–90 % removal of the organic load), but this is dependent on adequate attention to operation and maintenance.

15.4.2.2 Waste Stabilisation Ponds

Waste stabilisation ponds are any pond, natural or artificial, receiving raw or partially treated sewage or waste, in which stabilisation occurs through sunlight, air and microorganisms. Waste Stabilisation Ponds (WSP), are also known by the name of oxidation ponds or lagoons (Fig. 15.2). They act as holding basins for secondary wastewater treatment, Here organic matter is decomposed naturally, i.e. biologically. In WSP waste is stabilised and pathogens reduced through the action of bacteria and algae. The process aims to convert organic content of the effluent to more stable forms. These ponds are large shallow excavations, in which sewage from various sewer systems drain into. The sewage in the pond uses biological process to destroy various disease-causing organisms. They can produce economic benefits in that maturation ponds provide a good environment for growing fish such as tilapia (a species of cichlid fish). The effluent from ponds has fairly high algae concentrations, so it is a good resource for irrigation. One of the disadvantages of waste stabilisation ponds is that they require a relatively large area of land, especially when combined with wastewater re-use.

Wastewater stabilisation ponds may be integrated with re-use systems for the production of plants (e.g. duckweed and water hyacinth). These plants grow prolifically in nitrogen-rich environments and can be harvested and composted and subsequently used to fertilise and condition agricultural soils. The removal of the plant biomass stimulates the continued growth of the plants and also contributes to the removal of nutrients from wastewater and reduces eutrophication in receiving waters.

These systems may also be combined with pisciculture (fish-farming), where the production of fish provides income generation for local people. A Community-managed waste stabilisation ponds and aquaculture in Kolkata Waste stabilisation ponds were constructed around the city of Kolkata in the early 1990s under the Ganga Action Plan. Capital costs were funded by the Government of India while operation and maintenance were the responsibility of the state government (WSP 2008).

15.4.2.3 Constructed Wetlands

Constructed wetlands (reedbeds) can provide a low-cost and appropriate technology for the treatment of domestic wastewater and faecal sludge, but will normally require pre-treatment and so can only be considered as a secondary treatment option (Fig. 15.3). Constructed wetlands provide a high degree of biological improvement and depending on design, act as a primary, secondary and sometimes tertiary treatment.

Fig. 15.2 Sewage treatment plant (oxidation/waste stabilization ponds) at Saharanpur, Uttar Pradesh, India

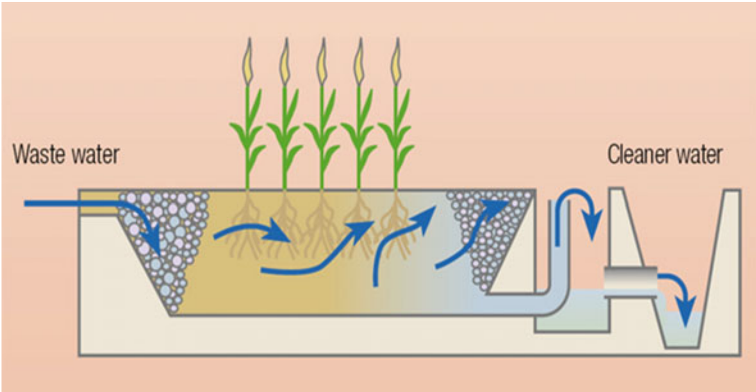


Fig. 15.3 Constructed wetlands

15.4.3 Constraints on Implementation of Decentralised Waste Water Management

15.4.3.1 Lack of Management Expertise

Even where policy makers accept the validity of the decentralised approach, a lack of capacity to plan, design, implement and operate decentralised systems is likely to be a severe constraint on efforts to ensure its wide adoption. Planning and implementation of wastewater re-use systems at the neighbourhood/user level will only take place successfully when the need for improved systems has been “internalised” by members of households and communities. The sustainable operation of decentralised wastewater management systems must be compatible with the knowledge and skills available at the local level. Local NGOs can help to identify the main causes of wastewater production in the specific area and also be beneficial to convey the appropriate approach to minimise the sanitation problem through government expertise.

15.4.3.2 Institutional Constraints

There is a lack of suitable institutional arrangements for managing decentralised systems and a lack of a suitable policy framework that encourages a suitable technique of decentralised wastewater management approaches. There is a danger that decentralisation will lead to fragmentation and a failure to address overall problems adequately. Also, without a formal institutional framework within which decentralised systems can be located, efforts to introduce decentralised management are likely to continue to be fragmented and unreliable.

Decentralisation requires greater coordination between government, the private sector and civil society and there is a need to look at the most appropriate institutional arrangements for managing decentralised wastewater systems and for monitoring and regulating those organisations that are responsible for their monitoring. One of the consequences of decentralization may be a lack of attention to pollution control and it is therefore necessary to consider the regulation of wastewater discharges, which may prove difficult where there are many smaller decentralised systems.

15.4.3.3 Economic Constraints

Decentralised systems may reduce the cost of investment required for wastewater management, but the majority of local government agencies and departments lack the resources to invest in new infrastructure and rely on grants from higher levels of government to finance improvements in service provision. Many poor communities lack the financial resources to invest in improved infrastructure. Lack of access to credit may also be a critical factor, inhibiting communities’ ability to invest in improved services. Those with a lack of secure tenancy also lack the incentive to invest in infrastructure to improve wastewater management practices. The acquisition of land for the more extensive forms of treatment that are effective in removing pathogens may prove difficult for those with limited financial resources.

In the absence of adequate cost-recovery mechanisms, investments in wastewater management may become a financial liability and this may constitute a major hindrance to the sustainable operation of decentralised wastewater management systems. Cost recovery in wastewater management is generally very poor and even where sufficient monetary resources exist; there is often little willingness to pay for improved wastewater disposal. Wastewater re-use is widely practiced in the informal sector but is limited to a few official schemes and benefits are not widely recognised in the wider macro economy.

15.4.3.4 Social Constraints

This brings us to perhaps the key constraint; the fact that there is currently no real demand for implementing effective systems for wastewater and faecal sludge management and, partly as a result of this, there is generally little willingness to pay for services, particularly wastewater treatment. This may relate to a lack of concern or awareness of environmental pollution and of the health implications relating to wastewater disposal and re-use.

Cultural factors may influence the way in which people view the reuse of excreta in food production, and the attitudes of the public and the policy makers towards the perceived risks to public health play a role in the adoption of wastewater management systems where wastewater is used for irrigation or aquaculture. Also, traditional excreta re-use practices are generally not recognised or accepted by government authorities and are likely to be seen by officials as being archaic and redundant, especially when alternative technologies, which require less land, exist. At the same time, the lack of government commitment to address wastewater related problems creates a political and institutional environment that offers little incentive to manage wastewater effectively. This lack of commitment is reinforced by a lack of financial resources to develop and implement effective policies and programmes for managing wastewater.

15.5 Concluding Remarks

There are a range of technologies for the treatment of wastewater that are suited to decentralised management systems and which may be adopted for use in low-income peri-urban communities i.e. anaerobic treatment, chemically enhanced primary treatment, wastewater storage and treatment reservoirs, waste stabilisation ponds, maturation ponds and constructed wetlands, however, most of these have not been utilised widely and remain in localised areas and pilot projects.

Given the overall sanitation situation in India, there is a need to promote decentralised initiatives in waste water treatment by providing incentives and a supporting policy environment and through capacity building of implementing institutions and stakeholders. More specifically, there is a need for exchange of information and innovations amongst rural and urban bodies and technical support for introducing alternative technologies and processes. Intensive capacity building programs, appropriate information, education and communication (IEC) materials, technical manuals and documentation, and sharing of best practices amongst facilitators are required urgently so that practices such as DEWATS can provide solution to the many sanitation crisis that are unfolding. A single wastewater treatment technology would be inappropriate for a country like India which has several different geographical and geological regions, varied climatic conditions and levels of population. It is more appropriate to address the potential for identifying appropriate solutions for different regions. In addition, the solutions for wastewater treatment are a response to several factors including: (i) the volume of wastewater; (ii) type of pollutants; (iii) the treatment cost; (iv) extent of water scarcity, and (v) dilution of pollution in the water resources.

The choice of technology is limited by the need to ensure that the operation and maintenance requirements of the chosen technology are compatible with the levels of knowledge and skills available at the local level. There is often a lack of knowledge on decentralised options and a shortage of a qualified workforce and skills for operation and maintenance. There is therefore a need to focus on the training of local stakeholders to enable them to understand how various technologies operate, their operational and maintenance requirements and the implications in terms of possible effluent re-use. There is also the need to disseminate technical information in appropriate forms and languages, in ways that are understandable and relevant to the needs of those who are responsible for the design and operation of decentralised wastewater and faecal sludge collection and disposal systems.

References

Angel S, Sheppard SC, Civco DL (2005) The dynamics of global urban expansion. Transport and Urban Development Department, World Bank, Washington

DESA (2011) Population distribution, urbanization, internal migration and development: an international perspective. Department of Economic and Social Affairs, Population division, United Nations, 378 pp

Dupont V (2005) Peri-urban dynamics: population, habitat and environment on the peripheries of large Indian metropolises: a review of concepts and general issues. CSH occasional paper no. 14, Centre de Sciences Humaines, 2, New Delhi, India, 151 pp

Jacobson M (2007)Dharavi: Mumbai's shadow city. National Geographic Magazine. Accessed 28 April 2009

MHFW (2011) Family welfare statistics in India. Statistics Department, Ministry of Health and Family Welfare, Government of India, 306 pp

MSPI (2009) India - urban slums survey: NSS 65th round: July 2008–June 2009, NSS Report No. 290: condition of slum areas in cities, Ministry of Statistics and Programme Implementation, Government of India. http://mospi.nic.in/Mospi_New/site/inner.aspx?status=3&menu_id=31. Accessed 12 Dec 2013

NBO (2010) Report of committee on slum statistics/census. Ministry of Housing and Urban Poverty Alleviation, National Building Organization, New Delhi, Government of India, 74 pp

Seshadri A (2009) Decentralised wastewater management—an overview of community initiatives. The Vigyan Vijay Foundation, New Delhi 6 p

WSP (2008) A guide to decision-making: technology options for urban sanitation in India. Water and Sanitation Program, Government of India, New Delhi, 124 pp

Part V
Urban Agriculture

Chapter 16
Wastewater Treatment Capacity, Food Production and Health Risk in Peri-urban Areas: A Comparison of Three Cities

Daniel Van Rooijen, Ian Smout, Pay Drechsel and Trent Biggs

Abstract Growing cities and their demand for water challenges the management of water resources and provides opportunities for wastewater use in irrigated agriculture. In the cases studied, large volumes of fresh water are extracted from sources often located increasingly further away from the city, while investments in wastewater disposal often lag behind. The resulting environmental impact in peri-urban areas can have multiple consequences for public health, in particular through the use of untreated or poorly treated wastewater in irrigated agriculture. Despite significant efforts to increase wastewater treatment, substantial volumes of untreated wastewater are applied in irrigated agriculture in Addis Ababa (Ethiopia), Accra (Ghana) and Hyderabad (India). Additional options for safeguarding public health are required to allow the cities to maintain the benefits from already existing, but largely informal, wastewater reuse.

Keywords Wastewater treatment · Cities · Wastewater use · Irrigated agriculture · Developing countries

D. Van Rooijen (✉)
UNICEF, Addis Ababa, Ethiopia
e-mail: dvanrooijen@hotmail.com

I. Smout
Water Engineering and Development Centre, Loughborough University, Loughborough, UK

P. Drechsel
International Water Management Institute, Colombo, Sri Lanka

T. Biggs
San Diego State University, San Diego, USA

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_16,

16.1 Introduction

Cities are large ‘organisms’ which consume and transform energy, water, food and materials into goods and waste products. Water is a particularly vital resource needed for the survival of humans and cities. In places where, due to rapid urbanisation, water supply has outpaced sanitation coverage and wastewater management, pollution of natural water bodies and the use of wastewater in irrigated agriculture have become common (Raschid-Sally and Jayakody 2008).

This chapter investigates this nexus and options to safeguard public health, taking examples from three growing cities in the developing world; Accra, Ghana; Addis Ababa, Ethiopia; and Hyderabad, India. The main research questions were: How have wastewater generation and treatment changed over the period 1950–2010; how will it develop to the year 2030; and what are the practical implications for irrigated farming in the vicinity of cities? Results of this research will be useful for urban planners and policy makers in cities that are likely to follow a similar development path towards improving access to water supply and sanitation (e.g. as part of the Millennium Development Goals).

16.1.1 Study Locations

The three cities included in this study are engines of economic growth and the political centres of their country or State. Accra located on the West African coastline, is the capital of Ghana, and together with its close neighbour Tema, is today home to around 3.3 million inhabitants in the larger Accra-Tema Metropolitan Area (ATMA). This is slightly less than the number of urban dwellers (3.5 million) living currently in Addis Ababa, the capital city of Ethiopia. Hyderabad is the capital of the Indian State of Andhra Pradesh and in 2010 had an urban population which is as large as both African cities combined (6.8 million) (UN-Habitat 2010).

In all three cities farmers irrigate with highly polluted water from streams and rivers and in part also raw wastewater. The background conditions in each city are summarised below to provide the context for the analyses.

16.1.1.1 Accra

With a population growth rate of 6–9 % in its administrative fringe, unregulated urban sprawl in the city of Accra has significantly outpaced expansion of public infrastructure and services. To improve service provision and private sector participation, urban water supply in Ghana was separated from sanitation and rural water supply in 1999 with the creation of the Ghana Water Company Limited. Since 2006, the operation of the public urban water supply utility is under private sector management to improve its efficiency and delivery. It currently supplies water to Accra from two river basins. Management of wastewater is under the control of the Waste Management Department of the Metropolitan and Municipal Assemblies while the existing wastewater and sludge treatment facilities are governed by various Ministries, depending on the plant location (hospital, army camp, university). Most of them are in a state of disrepair and nearly all the collected excreta is dumped into the ocean by tanker trucks transporting septage from on-site sanitation systems. Household greywater, often mixed with other waste, also from open defecation, drains into local gutters and streams, including the Odaw River, which has a catchment covering about 60 % of Accra (without Tema) and is severely polluted (Obuobie et al. 2006).

Along the tributaries of the Odaw River and other streams, extensive urban farming takes place on any unoccupied open spaces. In 2006, about 680 ha were under rain-fed maize cultivation. The total irrigated area is estimated at around 300 ha, of which 47 ha under irrigated vegetables and 251 ha under irrigated mixed cereal/vegetable systems (Table 16.1). On some of the fields, vegetables have been cultivated for more than 50 years. There are about 800–1,000 market-oriented vegetable farmers producing about 60 % exotic and 40 % indigenous local or traditional vegetables, with only the latter using parts of their production for home consumption. Cultivated areas in the city range between 1 and 30 ha; with plots around 0.05 ha per farmer. Although the total area appears to be small, farmers crop up to 8 times per year and supply 60–90 % of the perishable vegetables consumed in the city (Obuobie et al. 2006). Most sites belong to government institutions or private developers who have not yet started construction. Farmers have only informal land use agreements with the landowner.

The common method of irrigation is with watering cans, while seldom furrow irrigation is practised (Table 16.1). In some cases motor pumps are used to fill small intermediate ponds. Where the topography allows it, gravity is used to support furrow irrigation. Compared to Addis Ababa (annual average range of daily maximum is 21–25 °C) the climate is hotter and the irrigation frequency higher in Accra (28–33 °C). For example, lettuce is irrigated three times a week in Addis Ababa but twice a day in Accra.

16.1.1.2 Addis Ababa

The management of water supply and sewage disposal is the responsibility of the Addis Ababa Water Supply and Sewerage Authority (AAWSSA) set up in 1972 and formerly known as the Water Services Section under the Addis Ababa Municipality. The authority currently supplies water from three reservoirs (75 % of the total supply) and a well field system (25 %).

Due to the combination of poor sanitation and undulating topography almost all wastewater generated in the city finds its way through a dense network of streams into the Akaki River, which originates in the North and flows, via two branches (Little and Great Akaki), to the south of the city. Several factories also dump their

Table 16.1 Characteristics of irrigated urban agriculture with wastewater (IWMI, unpublished)

Wastewater irrigation characteristics	Accra	Addis Ababa	Hyderabad
Crop types cultivated with wastewater	Vegetables	Vegetables	Rice, paragrass, vegetables
Common irrigation method	Watering can, seldom furrow irrigation	Furrow and flood irrigation	Flood irrigation, furrow irrigation
Average plot size (ha)	0.05	1.0	1.5
Irrigation schemes	None (hand-made high beds)	Hand-made channels and furrows	Extensive network of irrigation and drainage channels
Water storage facilities	Dug-outs, sand-bag dams	Small ponds, self-made dams	Check dams in river, large ponds (tanks)

untreated effluents into the Akaki River. Wastewater collection and treatment are limited and treated wastewater is discharged into the river. Addis Ababa currently has two secondary treatment plants that are in operation.

Since the 1940s, a variety of vegetables have been produced within and around the city, mainly using water from the Akaki River. Irrigation is carried out informally by smallholders without conventional irrigation infrastructure (Table 16.1). In most cases approximately 1,300 farmers block upstream waterways and allow a proportion of the water to flow through temporary channels into a larger system of furrows. Further downstream, in the peri-urban periphery, pumps are also used to flood fields. There is no legislation that prohibits or permits the use of wastewater for crop production in the study area, although there have been campaigns to try and alert people to the related risks. Urban farmers do not pay for the water but there is an annual tax on their farmland. They produce vegetables for both market and home consumption, in a ratio of approximately three to one, and provide about 60 % of the vegetables for the city's vegetable markets, which is their main source of household income (Weldesilassie 2008).

16.1.1.3 Hyderabad

In Hyderabad, water supply and sewage disposal are managed by the Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB). In contrast to the institutional separation of water and sewerage in Ghana, the HMWSSB came into being in 1989 with the merger of the previously separate State level agencies in charge of water supply and municipal sewerage services. This re-organisation was encouraged as a means to achieve greater financial and operational authority as well as increasing accountability to consumers (Davis 2006). One of the HMWSSBs key goals is to reduce the quantity of water that is unaccounted for, losses through the distribution system, which currently stands at the least as 40 %

of the supply. Consumption was estimated at 80 L cap^{-1} d^{-1} compared to 55 in Accra and 35 in Addis Ababa, and intermittent water supply (some hours per day or week without water) has become the norm in Hyderabad, like in all major cities in India and Africa.

In Hyderabad, the Musi River receives the majority of all wastewater from both domestic and industrial sources. The wastewater contribution causes the river to flow continuously downstream of Hyderabad in the dry season, because the entire upstream flow is utilised in the city and the river would be dry without the wastewater flow. Within the city itself, irrigated farming is negligible compared to the peri-urban area. In contrast to both other cities, irrigation infrastructure is available and consists of weirs located every few kilometres along the river, diverting water into an extensive network of irrigation and drainage channels on both sides of the river (Table 16.1). An estimated area of over 8,000 ha, primarily of rice (*Oryza sativa*) and paragrass (a fodder crop) are irrigated with water from the Musi River, with the paragrass located nearer the city and rice further downstream (Ensink 2006). Irrigation enables farmers to harvest paragrass throughout the year or to produce two rice crops annually. Utilisation of this wastewater in the peri-urban and rural areas downstream of Hyderabad is estimated to support, directly and indirectly, the livelihoods of approximately 150,000 people (Buechler et al. 2002).

16.2 Methods

Data collection and semi-structured interviews were conducted with the respective water supply and sewerage authorities. Analysis was based on the period 1950–2030 considering population growth and investments in infrastructure (former, current and planned). The water supply/demand gap was estimated by dividing the difference between the city water supply and demand by city water demand, using local per capita norms for the demand. Net water supply is calculated from the gross supply (recorded and projected) minus physical losses in the distribution system, which were derived from estimates of the respective water supply companies; 25 % for Accra (AVRL 2006), 33 % for Addis Ababa (AAWSSA 2008) and 40 % for Hyderabad (HMWSSB 2004). The physical losses may return to local streams as return flow, but here we assume they are lost and unavailable for irrigation. City wastewater production was estimated by multiplying net city water supply estimated by a standard return fraction for all water use sectors which is usually assumed to be 0.8 (Tchobanoglous and Schroeder 1985).

Per capita domestic wastewater generation was calculated by dividing the net domestic water supply by city population multiplied by the water return fraction. In the description of wastewater generation we distinguish between black (toilet water) and grey (kitchen and bathroom) water. The fraction of all generated wastewater that is used for irrigation was based on expert consultation (Addis Ababa), literature (Hyderabad) and GIS/calculations (Accra).

16.3 Results

16.3.1 Water Supply and Wastewater Generation

In response to growing water demands, water supply agencies in all three cities have planned and carried out urban water supply expansion projects. While Addis Ababa and Accra have significant freshwater resources within a radius of 35 and 60 km, respectively, Hyderabad is increasingly seeking water from new sources located up to 250 km from the city, an increasingly common situation in India (CSE 2012). In all three cases, current water supply lags behind population growth, resulting in irregular supply in time and space. The water supply/demand gap in 2005 was 39, 69 and 56 % for Accra, Addis and Hyderabad respectively. However, the gap varies widely inter-annually. The actual gap might be smaller due to informal water supplies such as private groundwater abstraction and vending.

Domestic wastewater generation in 2005 was calculated from gross water production records as 134, 91 and 380 million cubic metres per year (MCM yr^{-1}) for Accra, Addis Ababa and Hyderabad respectively multiplied with a composite return factor that accounts for city-specific losses during both distribution and use (0.5–0.6). This results in a total wastewater generation of 80, 49 and 213 MCM yr^{-1} (Fig. 16.1). The lower wastewater volume generated in Addis Ababa compared to Accra results from much lower average water consumption per capita in Addis Ababa.

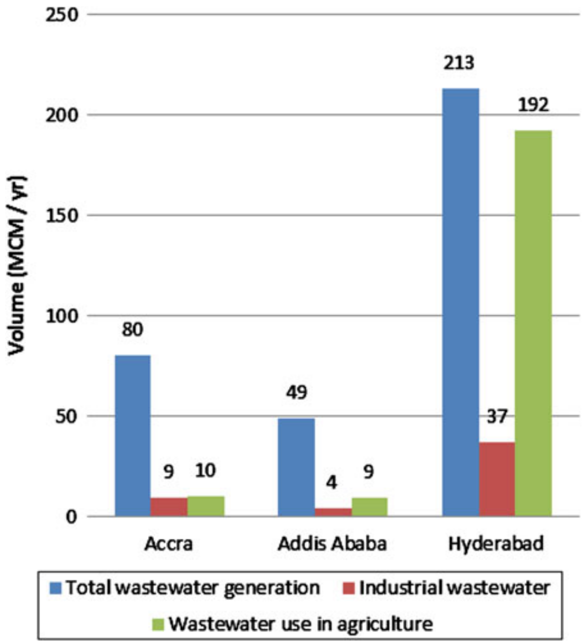
The fraction of households that are connected to sewers is small: about 5 % in each of the African cities and 19 % in Hyderabad. The percentage of households with a septic tank ranges from 11 to 28 % (AAWSSA 2008; GSS 2006; IIPS 2007). However, these figures do not account for shared on-site facilities, which are about 70 % in urban Ghana, 40 % in urban Ethiopia and 20 % in urban India (WHO-UNICEF 2012).

Black water from toilets either flows away from the household through sewerage or remains on site in latrines, pits or septic tanks. Some of the wastewater infiltrates into the soil or evaporates while the septage is removed when septic tanks are emptied. In Addis Ababa and Hyderabad, septic sludge is disposed of in corresponding treatment plants, while in Accra nearly all of it is dumped in the ocean due to lack of other facilities.

Larger *functional* wastewater treatment plants were only found in Addis Ababa (total installed treatment capacity 39,000 m^3 d^{-1}) and Hyderabad (design capacity 133,000 m^3 d^{-1}). Only a fraction (ca. 30 % in Addis and 23 % in Hyderabad) of the total wastewater volume generated matches installed treatment capacities (Table 16.2). Furthermore, only the smaller of Hyderabad's two treatment plants (treating less than 5 % of the city's wastewater) has the capability to carry out more than primary treatment (Gerwe 2004). Unfortunately no time-series data was available on actual treatment volumes.

In all three study cities, water quality data obtained from urban surface water bodies show evidence of high levels of faecal contamination (EEPA 2006;

Fig. 16.1 Wastewater production and use in Accra, Addis Ababa and Hyderabad for 2005. Total wastewater generation was calculated, based on water production records and city specific loss factors. Includes domestic and industrial fraction



Ensink 2006; Karikari et al. 2006; Mensah et al. 2001). In the use of this water for irrigated agriculture, the presence of excreta-related pathogens gives particular reason for caution especially where irrigated vegetables are grown and consumed uncooked as is the case in both African cities. Besides human health risks, environmental concerns have been raised. For example, the water quality of the Musi River only improves gradually over 40 km downstream of the city, while the Aba Samuel Lake and Awash River south of Addis Ababa, and aquatic life in the Gulf of Guinea in the case of Accra, suffer severely from the urban pollution load (Boadi and Kuitunen 2002; Ensink 2006; Kebbede 2004). Also salinity problems have been reported (Jiang et al. 2004). Special attention has to be given to wastewater generated by industries, which is currently less than 20 % in the three cities (Fig. 16.1). Elevated concentrations of heavy metals were reported from the Musi and Akaki Rivers (Chary et al. 2008; EEPA 2006; Gerwe 2004; Itanna 2002; Melaku et al. 2007), while in Accra, metal concentration in water and crops were classified as tolerable (Lente et al. 2012).

16.3.2 Wastewater Use in Irrigated Farming

All urban streams in and around the three cities are heavily polluted and farmers depending upon them as the single source of water for irrigation have little alternative. In none of the three cases 'wastewater irrigation' is a planned activity

Table 16.2 Wastewater generation and treatment in Accra, Addis Ababa and Hyderabad for 2008 and in brackets 2020

		Accra	Addis Ababa	Hyderabad
Wastewater generation1	1,000 m^3 d^{-1}	225 (307)	130 (453)	585 (807)
Installed treatment capacity2	1,000 m^3 d^{-1}	16 (29)	39 (238)	133 (590)
Potential wastewater treated	%	7 (9)	30 (53)	23 (73)
Untreated wastewater volume	1,000 m^3 d^{-1}	209 (278)	91 (215)	452 (217)

[1] Wastewater generation is calculated on the basis of data for city water supply, physical water supply and distribution losses and a general water return fraction of 0.8, adapted from Tchobanoglous and Schroeder (1985)

[2] Key figures for current and future installed treatment capacity were derived from AfDB (2005) for Accra, NEDECO (2002) for Addis and GHMC (2005) for Hyderabad

to reduce city water stress based on rising urban freshwater demand. Despite the informality of the activity, its positive and potentially negative impacts are significant. In Accra, about 1,000 farmers produce vegetables consumed by about 200,000 people every day. While this contribution supports healthy diets, it also puts these urban dwellers at risk especially through pathogens as illustrated by Amoah et al. (2007). The microbial risk appears lower in Addis Ababa due to lower pathogen levels and less frequent watering thus a higher natural die-off. This risk is lowest in the case of Hyderabad, not only due to the much smaller percentage of vegetables produced with Musi water, but also the more common cooking of vegetables. The risk varies however locally with wastewater dilution and farm location along the receiving streams.

The volumes of generated wastewater and wastewater used in agriculture vary a lot by city (Fig. 16.1). The percentage of wastewater that is eventually used for irrigation varies between seasons and could be estimated, even in the dry season, to be as low as 10 and 20 % in Accra (Lydecker and Drechsel 2010) and Addis (Adebaw, *Pers Comm*) and around 90 % in Hyderabad (Van Rooijen et al. 2005). The significant re-use of wastewater in Hyderabad is linked to the drainage system, which is almost entirely discharging into the Musi River, and the extended irrigation network that recovers most of the wastewater (except in the rainy season). Most of the upstream Musi water is actually absorbed by the city, making its downstream a pure wastewater flow. Like the Musi River, the Akaki River in Addis Ababa receives most of the wastewater but is much more efficient in diluting it and the informal irrigation network along the river is much smaller. As the ocean takes all the area downstream of Accra, only a small fraction of all wastewater is used; merely by those farmers along tributaries of the Odaw River. In both cities, Hyderabad and Addis, occupational health risks of farmers have been documented (Ensink 2006; Weldesilassie et al. 2010).

16.4 Potential of Wastewater Treatment for Risk Reduction

Comparing current and planned wastewater treatment capacities in Accra with the current and expected wastewater volume, the treated fraction will only change slightly from 7 % in 2008 to 9 % in 2020 (Table 16.2). Given the problems with the existing treatment plants, the probability that the new plants will operate at maximum design capacity is doubtful. There are a few other treatment plants scattered across Accra but most of them are not functional and those that do work are usually privately owned by large hotels (Murray and Drechsel 2011). Following current treatment capacity expansion plans in Addis Ababa (NEDECO 2002) the wastewater treatment fraction will increase from the present 30–53 % by 2020 (Table 16.2) if funding for the project can be secured.

Hyderabad has two sewage treatment plants in operation, and the water utility has started construction of several additional treatment plants (HMWSSB 2002). Under these plans the total wastewater treatment capacity will reach about 590,000 $m^3 d^{-1}$ by 2020 (Mekala et al. 2009), which would account for 73 % of the estimated wastewater volume of that year, including industrial wastewater but excluding most grey and stormwater (Table 16.2). Comparing the three cities, only Addis Ababa currently treats more wastewater (30 %) than farmers use (20 %).

The planned increases in wastewater treatment capacity of 50–70 % of the wastewater flow in the cases of Addis Ababa and Hyderabad are definitely impressive and will cut down the general pollution load but this will not really affect the faecal coliform concentrations that are commonly in the range of $0.1–10 \times 10^6$ counts per 100 ml. Even a 90 % removal of faecal coliforms still keeps concentrations above the 1,000 per 100 ml count, the maximum level recommended for unrestricted irrigated agriculture (Mara and Cairncross 1989). However, wastewater treatment does support the natural purification process. A good example is Hyderabad's Musi River, where over a stretch of 40 km a 99.9 % removal of Ascaris (resulting in worm infections) and E. *coli* (as indicator of faecal contamination) was observed (Hofstedt 2005). This will enhance the safety of rural farmers while it still leaves peri-urban farmers at risk.

16.5 Concluding Remarks

The urban centres discussed here have seen considerable demographic growth and spatial expansion in the last seven decades and are expected to continue to do so. Urban population growth and rising living standards have caused water demand to grow, a demand that is supported by investments to upgrade and extend existing water supply capacities. The continuous growth in urban water use has changed irrigated farming within the urban and peri-urban area. The growing wastewater volume is not being matched by investment in wastewater collection and treatment. The resulting gap has led to large-scale water pollution affecting the health of peri-urban farmers and potentially the health of the consumers of their produce.

The increasing efforts to close the gap between water supply and wastewater treatment in Hyderabad and Addis Ababa are positive examples but while more sewer connections and treatment capacity might reduce water pollution in the near future the remaining pathogen load remains high. Exposure to health risks for farmers and consumers will not reduce at the same rate as the improvements in sanitation coverage or wastewater treatment might imply, but at a much slower rate. The only exception would be if the treatment efforts could concentrate on a certain sub-basin or watershed in a city where farming could then be allowed. As this is seldom the case, alternative risk reduction strategies (e.g. Amoah et al. 2011; Drechsel et al. 2010) in line with the multi-barrier approach promoted by World Health Organisation (2006) have to be applied. The prerequisite for such measures is that wastewater collection and treatment should separate industrial from domestic waste streams as non-treatment options for chemical risk mitigation are significantly more limited than for microbial risks (Simmons et al. 2010).

Where health risks are controlled or farmers find a market for alternative crops, such as fodder grass in Hyderabad, wastewater irrigation in peri-urban areas has a significant potential to contribute to urban food supply. Where freshwater is scarce, the agricultural reuse of urban wastewater should be considered as an important factor for integrated water resources management in the rural/urban interface. It is also noteworthy that in Accra and Hyderabad the current land application of wastewater for irrigation is 'treating' more wastewater than the official wastewater treatment plants.

This paper has demonstrated that wastewater is an important and growing source of irrigation water for the production of high-value crops, which generates income for urban and peri-urban farmers and food for growing urban populations. However, the risks to health and potential risks to long term crop production are not well documented. Data on the health impacts of wastewater use, both for farmers and urban consumers are limited. While efforts are being made to treat increasing fractions of the wastewater in some cities, a significant fraction of the wastewater will remain untreated, resulting in a continuing risk to the health of peri-urban farmers and urban residents. Given the importance of wastewater irrigation for food production, efforts to increase sanitation in urban areas should be accompanied by efforts to (a) implement non-treatment options for risk reduction which create further barriers along the farm-to-fork contamination pathway, and (b) monitor contamination of the food supply and subsequent impacts on human health.

References

AAWSSA (2008) Water production and distribution in Addis Ababa. Addis Ababa Water Supply and Sewerage Authority, Addis Ababa

Adebaw C (2008) Personal communication with Mr. Adebaw. Bureau of Agriculture, Addis Ababa, 23 July 2008

AfDB (2005) Accra sewerage improvement project appraisal report Accra, African Development Bank, Abidjan

Amoah P et al (2007) Irrigated urban vegetable production in Ghana: microbiological contamination in farms and markets and associated consumer risk groups. J Water Health 5(3):455–466

Amoah P et al (2011) Low cost options for health risk reduction where crops are irrigated with polluted water in West Africa, IWMI. http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB141/RR141.pdf. Accessed 31 Aug 2013

Asfaw F (2007) Modelling on Akaki Rivers liquid waste disposal and base flow separation. Dissertation, Addis Ababa University

AVRL (2006) Accra water supply figures received from Aqua Vitens Rand Ltd in October 2006 (unpublished data)

Boadi KO, Kuitunen M (2002) Urban waste pollution in the Korle Lagoon, Accra Ghana. Environmentalist 22:301–309

Buechler S, Devi G, Raschid-Sally L (2002) Livelihoods and wastewater irrigated agriculture along the Musi River in Hyderabad City, Andhra Pradesh, India. Urban Agri Mag 8:14–17

Chary NS, Kamala CT, Ray DSS (2008) Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol Environ Saf 69:513–524

CSE (2012) Excreta matters: State of India's environment, vol 1. Centre for Science and Environment, New Delhi

Davis J, Tankha S (2006) The Hyderabad metropolitan water supply and sewerage board. Massachusetts Institute of Technology, Cambridge

Drechsel P et al (2010) Wastewater irrigation and health: assessing and mitigating risks in low-income countries. Earthscan IDRC IWMI, London

Drechsel P et al (2008) Reducing health risks from wastewater use in urban and peri-urban sub-Saharan Africa: applying the 2006 WHO guidelines. Water Sci Technol 57(9):1461–1466

EEPA (2006) Awash River water quality assessment. Ethiopian Environmental Protection Authority, Addis Ababa

Ensink JHJ (2006) Wastewater quality and the risk of hookworm infection in Pakistani and Indian sewage farmers. Dissertation, University of London

Gerwe C (2004) An assessment of heavy metals contamination in the wastewater-irrigated area of the Musi River. In: International conference on soil and groundwater contamination, Hyderabad, India

GHMC (2005) Hyderabad city development plan. Greater Hyderabad Municipal Corporation, Hyderabad

GSS (2006) Multiple indicator cluster survey 2006 MICS. Ghana Statistical Service, Accra

HMWSSB (2002) Musi river conservation project. Hyderabad Metropolitan Water Supply and Sewerage Board, Hyderabad

HMWSSB, PA Consulting Group (2004) Water reuse preliminary concept and feasibility study (Hyderabad). Hyderabad Metropolitan Water Supply and Sewerage Board, Hyderabad

Hofstedt C (2005) Wastewater use in Andhra Pradesh, India: an evaluation of irrigation water quality in reference to associated health risks. Dissertation, Uppsala University

IIPS (2007) National Family Health Survey (NFHS-3), 2005–06: India: vol I. International Institute for Population Sciences, Macro International, IIPS, Mumbai, p 588

Itanna F (2002) Metals in leafy vegetables grown in Addis Ababa and toxicological implications. Ethiop J Health Dev 16(3):295–302

Jiang B, Biggs TW, Ensink J (2004) Soil salinity and cropping patterns in wastewater irrigated area, Musi River, Hyderabad. In: International conference on soil and groundwater contamination, Hyderabad, India

Karikari AY, Asante KA, Biney CA (2006) Water quality characteristics at the estuary of Korle Lagoon in Ghana. West African J Appl Ecol 10:73–85

Kebbede G (2004) Living with urban environmental health risks: the case of Ethiopia. Ashgate, Hants

Lente I, Keraita B, Drechsel P, Ofosu-Anim J, Brimah AK (2012) Risk assessment of heavy metal contamination on vegetables grown in long-term wastewater irrigated urban farming sites in Accra, Ghana. Water Qual Expo Health. doi: 10.1007/s12403-012-0077-8, Online First™

Lydecker M, Drechsel P (2010) Urban agriculture and sanitation services in Accra, Ghana: the overlooked contribution. Int J Agri Sustain 8(1):94–103

Mara D, Cairncross S (1989) Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture. WHO, Geneva

Mekala GD, Samad M, Davidson B, Boland AM (2009) Valuing a clean river: a case study of Musi River, Hyderabad, India. Paper presented at the 53rd annual conference of Australian agricultural and resource economics society, Cairns, 10–13 Feb 2009

Mekonnen A (2007) Suitability assessment of the little Akaki River for irrigation report. Department of Chemical Engineering, Addis Ababa University, Addis Ababa

Melaku S, Wondimu T, Dams R, Moens L (2007) Pollution status of Tinishu Akaki River and its tributaries (Ethiopia) evaluated using physico-chemical parameters, major ions and nutrients. Bull Chem Soc Ethiop 21(1):13–22

Mensah E, Amoah P, Abaidoo RC, Drechsel P (2001) Environmental concerns of (peri-) urban vegetable production—case studies from Kumasi and Accra. In: Drechsel P, Kunze D (eds) Waste composting for urban and peri-urban agriculture—closing the rural-urban nutrient cycle in sub-Saharan Africa. Wallingford, IWMI/FAO/CABI, pp 55–68

Murray A, Drechsel P (2011) Why do some wastewater treatment facilities work when the majority fail? Case study from the sanitation sector in Ghana. Waterlines 30(2):135–149

NEDECO (2002) Wastewater master plan—existing situation, vol 2. Netherlands Engineering Consultants, Addis Ababa

Obuobie E et al (2006) Irrigated urban vegetable production in Ghana: characteristics, benefits and risks. CSIR-INSTI, Accra

Raschid-Sally L, Jayakody P (2008) Drivers and characteristics of wastewater agriculture in developing countries. Results from a global assessment. IWMI http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB127/RR127.pdf Accessed 31 Aug 2013

Simmons R, Qadir M, Drechsel P (2010) Farm-based measures for reducing human and environmental health risks from chemical constituents in wastewater. In: Drechsel P, Scott CA, Raschid-Sally L, Redwood M, Bahri A (eds) Wastewater irrigation and health: assessing and mitigation risks in low-income countries. Earthscan-IDRC-IWMI, London, pp 209–238

Tchobanoglous G, Schroeder D (1985) Water quality. Addison-Wesley, Reading

UN (2007) World population prospects: the 2006 revision, Highlights. United Nations, New York

UN-Habitat (2010) State of the world's cities 2010/2011. Bridging the urban divide, Nairobi

Van Rooijen DJ, Turral H, Biggs TW (2005) Sponge City: water balance of mega-city water use and wastewater use in Hyderabad, India. Irrig Drain 54:81–91

Van Rooijen DJ (2011) Implications of urban development for water demand, wastewater generation and reuse in water-stressed cities. Case studies from South Asia and Sub Saharan Africa. Dissertation, Loughborough University

Weldesilassie AB (2008) Economic analysis and policy implications of wastewater use in agriculture in the central region of Ethiopia. Dissertation, University of Hohenheim

Weldesilassie AB, Boelee E, Drechsel P, Dabbert S (2010) wastewater use in crop production in peri-urban areas of Addis Ababa: impacts on health in farm households. Environ Dev Econ 16:25–49

WHO (2006) Guidelines for the safe use of wastewater, excreta and greywater (vols 1–4). World Health Organisation, Geneva

WHO-UNICEF (2012) Joint monitoring program for water supply and sanitation, 2012 update. Ghana, Ethiopia, India. www.wssinfo.org Accessed 31 Aug 2013

Chapter 17
Urban Agriculture: A Response to the Food Supply Crisis in Kampala City, Uganda

E. N. Sabiiti and C. B. Katongole

Abstract Kampala, the capital city of Uganda, has experienced increases in the prices of basic food commodities since 2002, with the sharpest increase noticed over the period 2007–2011. Major factors contributing to this trend include rapid growth in the demand for food due to the increase in population, urbanisation, drought (climate changes) impacts in the agricultural areas of Uganda and a sharp increase in the cost of living driven by inflation. The increase in food prices has made it difficult for many low income earners in Kampala to meet their daily food requirements. In response, urban and peri-urban agriculture is making a very important contribution to the general food supply of the city. Besides making a significant contribution to the food basket of Kampala city, urban and peri-urban agriculture represents an important economic activity within the city. Emerging policy and planning frameworks support the continued positive contribution of urban and peri-urban agriculture. To that effect Kampala Capital City Authority (KCCA) now recognizes urban agriculture as a land use system and a vital policy issue. However, more is still needed from the public, urban authorities, urban planners and policy makers to strengthen this vital sector. The purpose of this paper is to discuss the development of urban and peri-urban agriculture and its contribution to the food supply crisis in Kampala city, as well as the process of developing policies to enable urban agriculture in Kampala city.

Keywords Food supply · Land use · Urban agriculture · Urban planning

E. N. Sabiiti (✉) · C. B. Katongole
School of Agricultural Sciences, Makerere University, P.O. Box 7062Kampala, Uganda
e-mail: esabiiti@caes.mak.ac.ug

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_17,

17.1 Introduction

Kampala is the capital city of the Republic of Uganda. It is located on the Northern shores of Lake Victoria (around 1,200 m above sea level) and surrounded by swamps in various areas. Its history can be traced back to the 1600s when it was established as the capital of the tribal Kingdom "*Buganda*" and it served as a political and administrative capital until 1893. In 1894 the British declared Uganda their protectorate and transferred the capital to Entebbe. Kampala returned as the capital city in 1962 with Uganda's independence. According to Nyakaana et al. (2007), Kampala has evolved from a "city of seven hills" (8 km^2) at independence (1962) to a city of more than 25 hills (covering an area of approximately 197 km^2). Kampala derives its name from the Luganda word "*Mpala*" (antelope species—*Aepyceros melampus* that roamed around the area at that time).

Currently, Kampala is the only city in Uganda. In 2011, Kampala Capital City Authority (KCCA) replaced Kampala City Council (KCC). The Authority is the governing body of the city on behalf of the central government subject to the KCCA Act 2010. The Authority is a corporate body with perpetual succession and may sue or be sued in its corporate name. The Authority consists of the following members (who are citizens of Uganda): The Lord Mayor; The Deputy Lord Mayor; one councillor directly elected by secret ballot to represent each electoral area in the city on the basis of universal adult suffrage; two councillors representing the youth, one of whom is female; two councillors with disabilities representing persons with disabilities, one of whom is female; one woman councillor directly elected by secret ballot to represent each electoral area in the city on the basis of universal adult suffrage; and one councillor representing each of the following professional bodies: Uganda Institute of Professional Engineers, Uganda Society of Architects, Uganda Medical Association and Uganda Law Society.

Kampala is growing faster than Uganda. The population of Kampala has grown from 458,503 in 1980 to the present estimate of about 1.79 million people. The urban population in Uganda is estimated at about six million, of which approximately 30 % live in Kampala (UBOS 2013). According to the 2002 Uganda Population and Housing Census, Kampala city had a population of 1.2 million people. At that time, the population of the city was estimated to be growing at a rate of 5.1 % per year, and was projected to reach 3.03 million people by the year 2020 (UBOS 2006). The rapid population growth is largely explained by rural–urban migration. The net migration rate of Kampala was estimated at 11.7 % (UBOS 2006). People migrate from rural areas to urban centres due to declining agricultural productivity and the search for better employment opportunities as well as income (UNEP 2002). The population increase in Kampala has had profound effects on the demand for food, housing, land for various uses, infrastructure and social services. This process has caused declining living conditions among the poor, increases in unplanned and illegal settlements, and increases in the growth of slums as well as land use and land cover change (Nyakaana et al. 2007; JPII and JPC 2008; Mukiibi 2011).

17.2 Food Demand and Supply in Kampala City

Having food available at any level, whether national or local, is of little value unless households have access to it or have the ability to purchase it (Diskin 1994). Hence, it is impossible to speak credibly of food security as being a problem of food supply, without at least making reference to the importance of accessibility and utilization (Maxwell 2001). Availability includes not only the production of food, but also distribution and exchange networks. Accessibility comprises affordability, market functionality, and whether or not preferences are met. Utilization denotes nutrition and the proper use of food, along with food safety.

The high urban population has necessitated the "importation" of food from distant production areas to Kampala on a daily basis to meet the high demand. Therefore, transport cost is one of the major factors that either directly or indirectly influences food availability and accessibility in Kampala. As transport fuel prices rise, transport costs increase, so do food prices. For instance, at the beginning of the year 2010 fuel prices increased by over 75 % within a period of only 24 months: from 2,025 UGX (US$ 0.86) per litre of diesel in January 2010 to 3,567 UGX (US$ 1.51) in December 2011 (UBOS 2010, 2011). As a result transport costs increased sharply and food became very expensive, which made it more difficult for many city dwellers to meet minimum food requirements. The challenge of the food supply crisis in Kampala is exacerbated by low incomes and the high cost of living driven by inflation. For instance, the monthly headline inflation rate went up almost fourfold from 8.8 to 27.0 % between January 2010 and December 2011 (UBOS 2010, 2011).

Food in Kampala city has become very expensive. According to the Uganda Bureau of Statistics, food prices have undergone the sharpest increase over the period 2007–2011 compared to all the other basic items in Kampala (Fig. 17.1). There are several reasons for the high cost of food in Kampala, which include, among others, high urban population growth, high transport costs, inflation and adverse weather conditions. Due to the expensive cost of food the low-income earners are finding it difficult to meet the minimum food requirements. As a response, own-food production (crop and livestock) has become a common feature in Kampala city.

Urban agriculture has become a significant contributor to the food supply systems in Kampala city. Unlike the past when urban farmers belonged to low-income groups, they now belong to low through to high-income households for different reasons and with different strategies (Prain and Lee-Smith 2010). For the wealthy households, it is largely an entrepreneurial response to the ready market, whereby the high demand has opened the door for them to take advantage of market proximity and the large urban market.

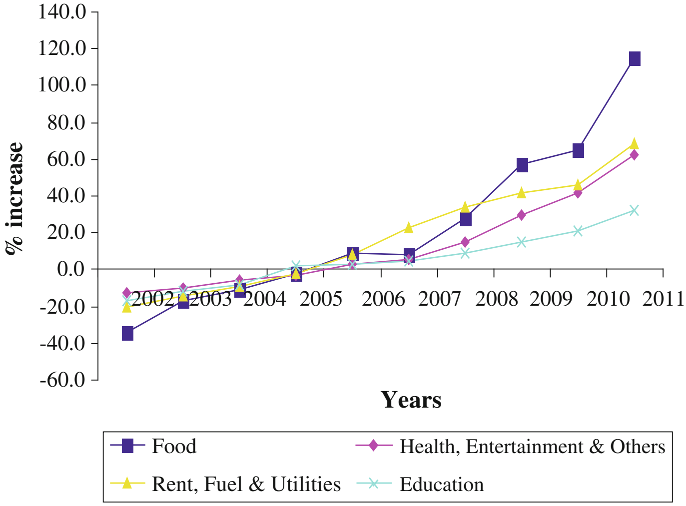


Fig. 17.1 Price increases for selected basic goods and services in Kampala over 10 years (calculated from consumer price indices for Kampala. *Base* 2005/2006 = 100)

17.3 Role of Urban Agriculture in Kampala City

Agriculture within African cities is not a recent occurrence and has been well established for decades (Sawio 1993). In Kampala, the increase in urban agriculture dates to the time of the Idi Amin regime (1971–1979) when the formal economy started to decline (Maxwell 1995). The formal economy was severely damaged by the "war of economic independence" of the regime, which was initiated with the expulsion of the Indian minority from Uganda in 1972. This rapidly gave rise to a highly informal economy dominated by smuggling, illegal currency transactions and state appropriation of private property (Banugire 1985). Idi Amin's dictatorship was followed by the guerrilla war in the early to mid-1980s, which brought the current President Yoweri Kaguta Museveni's National Resistance Movement (NRM) government into power. This guerrilla war was centred on the outskirts of Kampala city. These combined factors had a devastating impact on the urban economy. The value of wage labour drastically declined, which resulted in the massive growth of the informal economy (Bigsten and Kayizzi-Mugerwa 1992).

The civil unrest (1971–1985) was followed by the implementation of the structural adjustment policies, which were characterized by drastic cuts in jobs and public expenditure, trade liberalisation, increased interest rates and currency devaluation. As a consequence, unemployment increased and real incomes fell, while at the same time prices rose and welfare services declined. The urban poor were particularly hard hit (Tinker 1994; Drakakis-Smith et al. 1995). As a result many urban households resorted to all kinds of income generating activities in the informal sector in order to make a living. Farming was one such option. However today, after the crisis periods, urban agriculture is increasing and is still critical to the survival of many households in Kampala. There are various factors to explain the status quo; most importantly, the rapid growth in the demand for food as a result of the high urban population growth, the ever increasing cost of living as a result of inflation and adverse weather conditions (due to climate change/variability), which has made access to food an even greater issue.

In the year 2000, the Government of Uganda launched the Plan for Modernisation of Agriculture (PMA) whose mission is "*eradicating poverty by transforming subsistence agriculture to commercial agriculture*" (MAAIF and MFPED 2000). It was envisaged that improving the welfare of poor subsistence farmers in rural areas would require that they re-orient their production towards the market. More of their production must be marketed to enable them to earn higher incomes. For that reason, the Government of Uganda put the focus on agricultural development in rural areas with the view that the expanding urban population will stimulate food markets in urban areas and hence eradicate poverty among the rural producers. However, the rapid population growth in Uganda's urban areas, particularly Kampala city, has not been in tandem with economic growth and development and many city dwellers are still struggling below both the food poverty line and the absolute poverty line.

As a response own-food production (crop and livestock) is becoming increasingly common among households within and around Kampala city. Food production activities in Kampala city are carried out in such locations as backyards (home compounds), undeveloped plots, wetlands/swamps, roadsides, waste dump sites and under power-lines among other places. It is also a common practice to leave animals to roam or scavenge around the city. In the early 1990s the proportion of households engaged in urban and peri-urban agriculture in Kampala was estimated to range between 25 and 36 % (Azuba 2002). Currently, the proportion is estimated at 49.2 % (David et al. 2010). This includes as many as 20–25 % of the residents of densely populated residential areas, and over 50 % in the peri-urban parts of the city. In a national study on urban agriculture, Azuba (2007) reported that 89 % of urban households purposely engage in urban and peri-urban agriculture for domestic food provisioning, while 53.3 % farm to supplement their income.

According to Lee-Smith (2008), extensive studies have categorized Kampala's farming households into four types: commercial farmers; food self-sufficiency farmers; food security farmers and survival farmers. Commercial farmers, who are very few and generally well-off, are mostly found at the peri-urban periphery. These are the farmers that produce almost entirely for the urban market, though farmers in the other categories are also attempting to commercialise. The food self-sufficiency farmers are generally well-off and are found in all areas except the inner urban areas. These farmers produce food for household consumption. Food security farmers are those among the middle income or well-off households in the urban areas but among the poor in the peri-urban areas. These households practice urban agriculture as a secondary form of employment as well as a source of food.

They have other sources of income with farming helping them to save or supplement urban life-styles. The fourth category, “survival farmers” includes a very large number that are farming in order to avoid hunger. The majority of survival farmers are female-headed households (recently widowed or abandoned by their husbands) with very limited economic options (few resources and barely making ends meet). Such households are found in the urban areas where people cannot get enough food from smaller pieces of land and are more desperate for survival (David et al. 2010). However, Azuba (2007) reported another category of UPA practitioners in Kampala, which includes institutions such as educational institutions, health centres, prisons and police barracks.

Urban agricultural activities in Kampala city have evolved from purely subsistence to small-scale commercial production for both crops and livestock. However, commercialisation is more associated with livestock production (Sebastián et al. 2008; David et al. 2010; Katongole et al. 2011), with opportunities for sale of products such as milk, eggs and meat (Prain and Lee-Smith 2010). Livestock production is also associated with higher income households. The size of cultivated areas varies from 5.0 m^2 to 10 ha (NEMA 1997). According to Azuba (2002), 83 % of the farming households in Kampala have backyard gardens (in most cases of less than 0.4 ha), 10 % cultivate between 1 and 3 acres (chiefly urban farmers), while 7 %, which includes institutions and households mainly in peri-urban areas farm on two or more hectares.

17.4 Policy Environment for Urban Agriculture

Even though urban and peri-urban agriculture in Kampala city has been on the increase since independence (1962), its activities have been defined as illegal or a concern to many including state bureaucracies (David et al. 2010). For many years, the prevailing laws worked against urban agriculture in Kampala city, and studies and documentation acknowledging its existence were minimal. City authorities and state officials considered urban agriculture as an illegal practice, economically insignificant and a threat to public health (Maxwell and Zziwa 1992). The raising of livestock in and around Kampala city was considered a health risk for residents due to air pollution and offensive odours, road accidents caused by roaming livestock, and grazing areas acting as breeding grounds for mosquitoes and rodents (Maxwell et al. 1998).

There was also a fear that accidents could occur in the city due to reduced visibility caused by tall crops like maize and cassava being grown, especially near road bends. Other fears included indiscriminate drainage of swamps (leading to loss of their function of wastewater purification), destruction of green belts within the city (decreasing sink for carbon dioxide), increased solar radiation in the city, reduced soil water capacity and accelerated erosion (Matagi 2002). While many of these problems could be solved by sensitisation, Kampala city authorities often responded by evicting urban farmers from public land and destroying their crops (Maxwell 1995). The 1964 Town Planning Act provided the basis for Kampala City enforcement officials to harass those who carried out urban farming in the city. The Act viewed farming as an activity at odds with urban standards.

According to Lee-Smith (2005), it was in the early 1990s that the Government of Uganda appointed the first officer in charge of agriculture in Kampala city/ district. This officer did not have extension staff, resources or budget (Lee-Smith 2005). Maxwell (1994) published his research on Kampala in an IDRC book with the title "Cities Feeding People". He strongly argued the case for the legitimization of urban farming and the review of municipal by-laws, basing his argument on the evidence of improved nutritional and food security status of households that had some access to land in the city for farming. However, it was not until 2005 that the then Mayor of Kampala city (His Worship John Ssebaana Kizito) announced new ordinances (urban agriculture; livestock and companion animals; meat; milk; and fish) at a press conference. Under the Local Government Act (1997), Sections 39 and 41 empower local authorities to enact by-laws for regulating all activities within their areas of jurisdiction. Accordingly, KCCA formerly KCC enacted five ordinances of 2006 (Urban Agriculture, Livestock and Companion Animals, Milk, Meat), which provide for the licensing, control and regulation of crop and livestock production activities in the city.

The changing policy environment is having an effect on official attitudes towards urban agriculture in Kampala city. Currently, there is official recognition and support to urban agriculture from government programmes and city authorities. The city now has a section known as the Urban Agriculture Unit, which was established within the city's Department of Production and Marketing. Its broad responsibility is to support and guide urban farmers and to ensure household nutrition and food security. Government programmes under the Poverty Eradication Action Plan (PEAP), particularly the National Agriculture Advisory Services (NAADS) programme no longer have rural areas as the only target areas for agricultural development. NAADS is a Government programme for agricultural development in the country. The programme has mainstreamed urban agriculture in its implementation framework and has rolled out its program activities in Kampala. Currently, Kampala city has an Agricultural Advisory Services Officer who is in charge of the NAADS programme in the city. Additionally, the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF) is also in the process of formulating a National Urban Agriculture Policy. The Development Strategy and Investment Plan (DSIP) of MAAIF (2010) also provides an opportunity for the consideration of urban agriculture. The strategy aims at transforming subsistence farming to commercial agriculture" and has recognized and included urban agriculture into investment strategies.

17.5 Conclusions

Kampala city has been experiencing increases in the price of basic food commodities since 2002, with the sharpest increase during the period of 2007–2011. Major factors that have contributed to this trend include rapid growth in the demand for food as a result of the high urban population growth, drought effects, rising fuel prices and the declining value of the Uganda shilling. This has led to many city dwellers finding it difficult to meet minimum food requirements. The costly food supply and the high demand for food due to the high urban population have led to an increase in urban agriculture in Kampala city. Based on the positive contribution of urban agriculture to the general food basket of the city, the city authority has now changed its legal and administrative framework towards more enabling regulations to urban agriculture.

Acknowledgments The authors gratefully acknowledge Dr. Jon Padgham who informed us of the workshop and the global change System for Analysis, Research & Training (START) for the funding support.

References

Azuba MS (2002) An overview of urban agriculture in Kampala City. Paper presented at a SIUPA-Kampala planning workshop, Kampala. Unpublished report

Azuba MS (2007) Urban agriculture in Uganda: a rapid appraisal of the characterisation, opportunities and challenges that would influence policy formulation. Unpublished report

Banugire F (1985) Class struggle, clan politics and the 'Magendo' economy. Mawazo 6(2):52–66

Bigsten A, Kayizzi-Mugerwa S (1992) Adaption and distress in the urban economy: a study of Kampala households. World Dev 20(10):1423–1441

David S, Lee-Smith D, Kyaligonza J, Mangeni W, Kimeze S, Aliguma L, Lubowa A, Nasinyama GW (2010) Changing trends in urban agriculture in Kampala. In: Prain G, Karanja N, Lee-Smith D (eds) Urban harvest: agriculture in the cities of Cameroon, Kenya and Uganda. International Potato Centre (CIP), Rome

Diskin P (1994) Understanding linkages among food availability, access, consumption and nutrition in Africa: empirical findings and issues from the literature. MSU international development working paper 46, Michigan State University, East Lansing, MI. http://www.afr-sd.org/publications/11linkag.pdf. Accessed 1 Oct 2012

Drakakis-Smith D, Bowyer-Bower T, Tevera D (1995) Urban poverty and urban agriculture: an overview of the linkages in Harare. Habitat Int 19(2):183–193

JPII, JPC (2008) The Kampala basic needs basket. Cost of a basic needs basket in six informal settlements Kampala—Uganda. John Paul II justice and peace centre. Paulines Publications Africa. http://jp2jpc.org/downloads/uganda%20basic%20needs%20-%20vol%201.pdf. Accessed 4 Oct 2012

Katongole CB, Sabiiti E, Bareeba F, Ledin I (2011) Utilization of market crop wastes as animal feed in urban and peri-urban livestock production in Uganda. J Sustain Agric 35(03):329–342

Lee-Smith D (2005) Development of new city ordinances on urban agriculture, Kampala: timeline and analysis and process and partnership for pro-poor policy change. What influences pro-poor policy changes? ODI/ILRI/CIP-Urban Harvest. http://www.pppppc.org/content/files/Documents/Kampala%20UA%20case%20study%20DLS%20Timeline.pdf. Accessed 3 Oct 2012

Lee-Smith D (2008) Urban food production in Kampala: community perceptions of health impacts and how to manage them. In: Cole D, Lee-Smith D, Nasinyama G, (eds) Healthy city harvests: generating evidence to guide policy on urban agriculture. International Potato Center (CIP) and Makerere University Press, Kampala

MAAIF, MFPED (2000) Plan for modernization of agriculture (PMA): eradicating poverty in Uganda, "government strategy and operational framework", ministry of agriculture, animal industry and fisheries & ministry of finance planning and economic development. Kampala, Uganda

MAAIF (2010) Agriculture for food and income security. Ministry of agriculture, animal industry and fisheries. Agriculture Sector Development Strategy and Investment Plan: 2010/11–2014/15. http://agriculture.go.ug/userfiles/Agricultural%20Sector%20Development%20Strategy%20and%20Investment%20Plan%282%29.pdf. Accessed 5 Dec 2013

Matagi SV (2002) Some issues of environmental concern in Kampala, the capital city of Uganda. Environ Monit Assess 77:121–138

Maxwell D, Levin C, Csete J (1998) Does urban agriculture help prevent malnutrition? evidence from Kampala. Food Policy 23(5):411–424

Maxwell D, Zziwa S (1992) Urban farming in Africa: the case of Kampala. Nairobi ACTS Press, Uganda

Maxwell DG (1994) The household logic of urban farming in Kampala. In: Egziabher AG, Lee-Smith D, Maxwell DG, Memon PA, Mougeot LJA, Sawio CJ (eds) Cities feeding people: an examination of urban agriculture in East Africa. IDRC, Ottawa

Maxwell DG (1995) Alternative food security strategy: a household analysis of urban agriculture in Kampala. World Dev 23(10):1669–1681

Maxwell S (2001) The evolution of thinking about food security. In: Devereaux S, Maxwell S (eds) Food security in sub-Saharan Africa. ITDG Publishing, London

Mukiibi S (2011) The effect of urbanisation on the housing conditions of the urban poor in Kampala, Uganda. Second international conference on advances in engineering and technology, 20th–21st December, Noida, India. http://mak.ac.ug/documents/Makfiles/aet2011/Mukiibi.pdf. Accessed 3 Oct 2012

NEMA (1997) District state of environment report: Kampala. National environmental management authority report

Nyakaana JB, Sengendo H, Lwasa, S (2007) Population, urban development and the environment in Uganda: the case of Kampala city and its environs. Faculty of arts, Makerere University, Kampala, Uganda. http://www.cicred.org/Eng/Seminars/Details/Seminars/PDE2007/Papers/NYAKAANA_paperNairobi2007-2.pdf. Accessed 3 Oct 2012

Prain G, Lee-Smith D (2010) Urban agriculture in Africa: what has been learned? In: Prain G, Karanja N, Lee-Smith D (eds) Urban harvest: agriculture in the cities of Cameroon, Kenya and Uganda. International Potato Center (CIP), Rome

Sawio C (1993) Feeding the urban masses? Towards an understanding of the dynamics of urban agriculture in Dar-es-Salaam, Tanzania. PhD. Thesis, Clark University

Sebastián R, Lubowa A, Yeudall F, Cole DC, Ibrahim S (2008) The association between household food security and urban farming in Kampala. In: Cole D, Lee-Smith D, Nasinyama G (eds) Healthy city harvests: generating evidence to guide policy on urban agriculture. International Potato Center (CIP) and Makerere University Press, Kampala

Tinker I (1994) Urban agriculture is already feeding cities. In: Cities feeding people: an examination of urban agriculture in East Africa. International Development Research Centre (IDRC), Ottawa

UBOS (2006) The 2002 Uganda population and housing census analytical report, population size and distribution. Kampala, Uganda. http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/2002%20CensusPopnSizeGrowthAnalyticalReport.pdf. Accessed 2 Oct 2012

UBOS (2010) Consumer price index January 2010, press release, Uganda Bureau of statistics. Kampala, Uganda. http://www.ubos.org/onlinefiles/uploads/ubos/cpi/cpijan2010.pdf. Accessed 11 Dec 2012

UBOS (2011) Consumer price index December 2011, press release, Uganda Bureau of statistics. Kampala, Uganda. http://www.ubos.org/onlinefiles/uploads/ubos/cpi/cpidec2011.pdf. Accessed 11 Dec 2012

UBOS (2013) 2013 Statistical abstract, Uganda Bureau of statistics. Kampala, Uganda. http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/abstracts/Statistical%20Abstract%202013.pdf. Accessed 8 Apr 2014

UNEP (2002) Africa environment outlook: past, present and future perspectives. Earthprint Limited, UK

Chapter 18
Feeding Sydney: Assessing the Importance of the City's Peri-urban Farms

Phillip O'Neill and Sarah James

Abstract Peri-urban agriculture is common to cities worldwide. Large cities depend on the availability of fresh foodstuffs and traditionally these have been supplied competitively by small scale farmers located on the fringes of cities. A peri-urban location gives access to urban markets as well as the opportunity to tap into urban water infrastructure and temporarily idle land. These opportunities mean, however, that peri-urban farmers are displaced by urban expansion. This chapter examines these dynamics through a case study of peri-urban agriculture in Sydney, Australia. The chapter combines four recent studies by the authors to give an appraisal of the relative importance of Sydney basin farmers to the supply of fresh fruit and vegetables to Sydney's 4.3 million residents. The study finds there is much uncertainty over the future of these farmers.

Keywords Peri-urban agriculture · Local food · Sydney · Urban planning

18.1 Introduction

There has been peri-urban agriculture in the Sydney basin for most of the time since Europeans established a penal colony in 1788. Urbanisation established the conditions for this agriculture supplying labour, water infrastructure and a market. Initially, the use of inappropriate farming practices within a relatively dry region with phosphate deficient soils saw residents in the fledgling colony nearly starve to

---

P. O'Neill (✉)
Urban Research Centre, University of Western Sydney, Sydney, NSW, Australia
e-mail: p.oneill@uws.edu.au

S. James
Australian National University, Canberra, Australia

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_18,

death. A hundred years on, though, advanced commercial farming in Australia's interior river valleys and in the tropical north and intensive market gardening in the urban fringes produced regular food surpluses and a supply chain characterised by variety and quality. However, recently, the sustainability of Sydney's food supply chain has been questioned. Population growth is squeezing Sydney's remaining farms onto floodplains between escarpments and national parks on one side and suburban housing estates on the other. This comes at a time when, what we might call, 'the politics of food' is intensifying: systems of food production, transportation and consumption are implicated significantly in global warming concerns; access to quality food is recognised as systematically biased against particular population groups if not corrupted by marketing strategies; food consumption is linked to disturbing health outcomes; and control over food sources and distribution chains is seen to be over-concentrated in the hands of large retail corporations. In this context, it needs to be asked whether too much is being expected of peri-urban agriculture as a prime contributor to Sydney's future food needs.

This chapter explores Sydney's food politics by drawing on four studies the authors have undertaken. One involved major research commissioned by the New South Wales (NSW) government to examine claims that Sydney basin farming land was in danger of extinction. The second is a scoping study which attempts to use employment data to measure the size and extent of Sydney's integrated food economy. A third modelled the discarded value of Sydney's food waste and the fourth involved innovative research into the origins of Sydney's fresh fruit and vegetable supplies. The chapter interrogates these studies to make observations about the nature and extent of Sydney's surviving peri-urban agricultural lands, and the role these play in material aspects of Sydney's food supply as well as in broader political and cultural discourses. The chapter concludes with comment on the types of planning interventions required to enhance the sustainability and quality of Sydney's fresh food supply into the future needs. The chapter's primary concern is the supply of fresh fruit and vegetables. While peri-urban agricultural lands in Sydney play a role in the supply of poultry meat and eggs and of dairy products, discussion of their contribution is beyond the scope of this chapter.

18.2 The Context of Sydney

Greater Sydney had 4.4 million people at the 2011 census. The city is predicted to reach six million people by the middle of the 2030s. The current state government expects that at least half of all new dwellings will be built on greenfields sites. Given the physical geography of the Sydney basin—based on the Hawkesbury–Nepean catchment confined by the coast to the east and dissected sandstone plateaux and ranges everywhere else—Sydney's residential growth necessarily eats away at the basin's available agricultural land (James 2009; Malcolm and Fahd 2009; Sinclair et al. 2004; Sydney Food Fairness Alliance 2010).

Also affecting Sydney's food equations are its social and cultural characters. Sydney's rich multiculturalism means its demand for food is diverse. Currently, 64 % of Sydneysiders record one or both parents as born overseas, with growing proportions of migrants now coming from non-European countries. Sydney is also a very wealthy city by world standards with its large proportion of professional services employment responsible for high incomes and significant levels of discretionary spending. Sydney's socio-cultural mix has transformed food for many Sydneysiders into something more than sustenance. Sydney's food streets are now central to the city's evening and weekend liveliness and its celebrity chefs and food entrepreneurs are big news in Sydney media. Yet relative to other key aspects of the city, such as finance and the economy, transport, housing, jobs and the environment, knowledge about Sydney's food systems is thin, just as food knowledge is neglected in public and policy discourses in other nations (Goodman 2002; Pothukuchi and Kaufman 1999). This knowledge deficit comes, though, at a time when there are concerns about the environmental sustainability of Sydney's food supply chain in the context of the city's long run growth trajectory.

The politics of food in Sydney is also affected by wider understandings. There is growing awareness of the environmental turmoil faced by Australian farming in agricultural regions such as the Murray Darling Basin as the long term sustainability of water and soils is questioned (Kirkpatrick 2011; see also Morgan et al. 2006 for the United Kingdom). Climate change and peak oil considerations also focus attention on the use of fossil fuels for agricultural tillage and fertiliser and for the ways food is hauled and flown over long distances using carbon-intensive transportation. Geopolitical and equity considerations question food distributional processes and outcomes. There are also micro-concerns about the conditions of food production and preparation and their implications for the biology of food, the ethical treatment of the plants, animals and workers involved. There are also concerns about access for many households to a reliable food supply at all. Finally, there are issues of market power with concerns as to how to positively steer a now globalised agri-food system towards sustainable urban food practices (Morgan 2009).

These concerns materialise in specific ways in Sydney. There is rejection by a growing number of households of the conventional food system because they see it as socially and culturally undesirable and environmentally unsustainable. Thus there is a rise in demand for foods seen to be produced by alternative food systems especially with local origins. The alternate food agenda is represented most prominently by the inner city activist group, Sydney Food Fairness Alliance (SFFA). This group sees itself as "…a network of consumers, rural producers, health professionals, community workers and advocates who want to see food security for all within a socially, economically and environmentally sustainable food system" (Sydney Food Fairness Alliance 2010). The SFFA agenda includes political events, support for growers' markets, mobilisation of the power of collective consumption and support for the protection of agricultural lands within the Sydney basin. Often these campaigns are in coalition with farmers, community and environmental groups.

In this context, this chapter assesses the claims for significance of Sydney's peri-urban farms, discusses the politics involved and draws conclusions for planning interventions. Our approach is to view peri-urban agriculture as one contribution to the supply and circulation of food as it moves through stages from production to consumption. This approach helps highlight the relationship between food and urban policy, drawing together the key domains of land use planning, economy and industry, population health and environment. First, though, we discuss the need to consider food as a core urban planning issue.

18.3 Food as an Urban Issue

Commentators point to 2008 as a catalyst year for the centrality of food as an urban policy and planning consideration. This was the year that the world's urban population exceeded its rural population for the first time (de Zeeuw and Dubbeling 2009). It was also the year that the world confronted both the aftermath of a global financial crisis and a growing global food crisis. Together, these events provided the context for food to jump scales—up and down—as a political issue (Howitt 2000). Certainly, post-2008, concerns about food in relation to environmental change, nutrition-related disease and food security among the poor continue (Ambler-Edwards et al. 2009; Chatham House 2008; de Zeeuw and Dubbeling 2009). These are now seen as general concerns across urban communities regardless of national income levels. They are also seen as influenced, if not determined, by global trends in finance, trade and corporate behaviours, as well as being implicated in global environmental and development issues. One response to the looming impact of environmental change and resource shortages on food supplies has been the emergence of a 'food miles' discourse, the idea that responsible food choices should minimise the contribution of hydrocarbon-intense fuels to transport, preservation and storage. The discourse favours a more localised food system, accessible to and observable by city dwellers, and aggressively supported by them (for example Flisram et al. 2009; Garnett 1999; Halweil 2002; Mougeot 2005; Nasr et al. 2010; Ohri-Vachaspati et al. 2009). The food miles discourse, then, translates concerns over the environmental impacts of lengthy, high-volume supply chains into a simple consumption formula; and local farmers' markets and other local food sourcing schemes become material ways of expressing such concerns (see Zukin 2008 for New York examples).

The link between food and energy supplies is also promoted by the idea of 'peak oil', the moment when global oil demand exceeds proven reserves (Holmes 2006). The absence of cheap energy is seen to undermine a food production and supply system where fossil fuel inputs have been seen as independent of the environmental conditions of production and where energy costs have been seen as either insignificant or recoverable (Lerch 2007).

The notion that urban food supply may well be precarious is increasingly discussed via the idea of 'food security'. Food security is defined by the World

Health Organization as access to adequate, safe, nutritious and culturally appropriate food (World Health Organization 2009). The question of an adequate food supply for vulnerable groups in high income cities has now become a key aspect of food security (Fraser and Mabee 2004; London Development Agency 2006). The food security discourse is also propelled by the argument that the promotion of sustainable food supply and consumption practices through localisation of sourcing, processing and marketing are effective ways to strengthen local economies and generate local jobs (Stringer 2009). So food can be a regeneration device.

These concepts—food security, food miles and protection of local economies—are slowly being captured as urban public policy issues. London, for instance, has developed an explicit food policy (London Development Agency 2006). According to its then mayor Ken Livingstone, the aim of London's policy is to "…develop the capital's food system to make London a truly sustainable world city" (London Food Link 2005). Vancouver (City of Vancouver 2007), Toronto (Toronto Food Policy Council 1999), New York State (Stringer 2010) and Scotland (The Government of Scotland 2008) have also begun developing food polices.

Yet rising public concern and growing scientific evidence are yet to translate into food policies across Australia, including Sydney. Certainly, threats to farming in the Sydney basin were raised as a concern in the city's 2005 Metropolitan Strategy (New South Wales Department of Planning 2005) and the authors were commissioned to provide advice to the government about the extent of these threats as a direct result (James et al. 2010). While this advice has been since incorporated into food supply questions in the subsequent Sydney basin regional plan (NSW Department of Planning and infrastructure 2012), recognition of a land availability problem has not yet translated into effective planning actions. Indeed, out of 41 local government areas within the metropolitan region only four had food policies in 2009 (Galvin 2009; Noble 2008). The question of appropriate planning responses to threats to Sydney's agricultural lands is returned to below.

18.4 Sydney's Peri-urban Agriculture

Estimates of the significance of the commercial agricultural sector on Sydney's peri-urban fringe vary widely. There seems general agreement that the basin has an estimated 2,000 vegetable farmers, with over 80 % of these farmers from non-Anglo cultural and linguistic backgrounds (Parker and Suriyabanadara 2000). Importantly, peri-urban agriculture has provided waves of Australian migrants, especially those from rural backgrounds, with the opportunity to engage in self-directed employment in the areas where they have skills alongside the opportunity for substantial wealth gains as rural land holdings are re-zoned for residential use. Perhaps because peri-urban agriculture has been dominated by low-income migrants and activity outside the formal economy, details of the contribution of local farms to the city's food supply are deficient and contested. This problem is compounded by the not-unsurprising keenness of many groups to propagate information claiming that these lands make highly significant contributions to Sydney's food supply and economy and that these contributions are threatened by urban growth.

So, to examine the state of knowledge on the area, the authors were commissioned by the NSW government to undertake an historical analysis of information on farming in the Sydney region. The analysis covered the period from 1992 to 2009 which is when major reports and data collection on Sydney's agriculture proliferated. Our report concentrated on a perceived undercounting of Sydney's farms by the Australian Bureau of Statistics (ABS) agricultural census. ABS estimates of the area and number of farms, and of the value of the Sydney fresh vegetable industry, were seen as unfairly low by farming lobby groups, activists, and sympathetic researchers. The common claim was that Sydney's vegetable farms were systematically under-recognised by a data collection methodology designed for broad scale agriculture, with a number of reports presenting alternative (and higher) estimates of the basin's agriculture.

Subsequent changes to the ABS collection methodology in the 2005–2006 agricultural censuses saw a significant shift in results between the 2000–2001 and 2005–2006 ABS agricultural census findings. Methodological changes for the 2005–2006 census resulted in substantial increases in estimates of the area and number of Sydney farms. That these increases were particularly evident in the vegetable industry indicates that small-scale, culturally diverse Sydney farmers had indeed been left out of previous ABS surveys. Furthermore, our report also cautions about estimates from the non-ABS reports due to their methodological and technical limitations. These reports typically portray Sydney agriculture as much more significant than ABS censuses indicate, and are consistently mobilised in public debate. Gillespie (2003), for example, argues that there are approximately 8,000 direct jobs in Sydney-based agriculture comprising 11 % of all NSW agricultural employment (Gillespie 2003), an unlikely possibility based on employment counts from other sources. Even other ABS data seems to produce exaggerated estimates of significance. ABS (Australian Bureau of Statistics 2008b), for instance, claims that output from the Sydney basin accounts for over 40 % of the value of vegetables produced in NSW, including 95 % of Asian vegetable production (by value), 82 % of cucumbers, 78 % of lettuce, 74 % of mushrooms and 65 % of fresh market tomatoes. These claims sit uneasily with other data which we cite below.

In any event, the principal finding of our analysis is that ABS statistics from the 2005 to 2006 agricultural census provide relatively reliable data on Sydney basin agriculture. These data reveal that Sydney agriculture is increasingly intensive in nature while at the same time decreasingly soil reliant through the use of greenhouse, elevated and hydroponic structures. Importantly, ABS census data reveal that Sydney's stock of farms has been reduced to about 2,000 in number. Moreover, a recent report from NSW Department of Primary Industries staffers indicates that over 50 % of the basin's vegetable farms are under threat by housing developments planned in Sydney's next major greenfields release areas (Malcolm and Fahd 2009). In short, Sydney's remaining farms are severely threatened.

18.5 Fresh Produce Flows at Sydney Markets

A novel data collection exercise was undertaken in 2010–2011 in conjunction with Sydney Markets Ltd (SML) to ascertain the nature and extent of that part of Sydney's fresh fruit and vegetable supply chain that is processed through SML's 43-ha operations at Flemington, a large wholesaling site on Parramatta Road near to the geographic centre of Sydney. SML operates Sydney's most significant open market trading operations and is responsible for approximately one-third of the city's fresh fruit and vegetable flows. The remainder of the flows are internal to a small number of large retailers especially the supermarket duopolists, Coles and Woolworths. While there are limits to claims for representativeness of the SML data, the data reveal sufficient information on Sydney's fresh fruit and vegetable supply chain to cast doubt over claims as to the significance of the basin's agricultural output.

The data was collected from the supply records of on-site trucking and wholesaling firms as well as from a survey of 330 of those local growers who participated directly in market sales. In total, details for the 2010 calendar year of over a million third-party delivery transactions and the annual contribution of 250 direct local growers' transactions were processed through a geographical information system (GIS). The final report (O'Neill and Dimiski 2013) reveals the following claims in respect to the issues relevant to this chapter:

- NSW-sourced fruit and vegetables contribute only 35.2 % by weight of the produce that is distributed through Sydney Markets, even though the home state is Sydney Markets' largest supply state. The study shows the very important role played by Victoria (27.5 %) and Queensland (20.7 %) in the fresh fruit and vegetable supply chain and the significant though lesser role played by South Australia (14.9 %). Interestingly, Tasmania, Northern Territory, Western Australia and our near neighbour, New Zealand, each fail to contribute one percentage point of volume (by weight) to total supply.
- Reflecting the major role of sources in Victoria and Queensland as food suppliers, data in the report show that most food supplied to Sydney Markets (by weight) travels between 500 and 1000 km. Just 3.33 % of fruit and vegetables, as a proportion of total weight, originates within 150 km of Sydney Markets. In other words, fruit and vegetables supplied to Sydney consumers through the Sydney Markets is overwhelmingly sourced outside the 100 mile zone considered to be a yardstick for food sustainability practice. Local supply sources contribute minimally to the supply chain.
- The supply of produce to Sydney Markets from within the Sydney basin was found to be less than 1 % by weight. And in the leafy or stem vegetables category, where Sydney basin farmers are seen by other studies to specialise, the local region supplies only 2.3 % of produce (by weight) to the Flemington markets.

We note the discrepancies between these findings and other claims for a more significant contribution to agriculture from the Sydney basin. There are potential explanations for the different claims. One is that the SML data measures produce flows by weight rather than value. Another is that the supermarket chains may take a greater proportion of total supplies from local sources. A reasonable judgement, however, is that neither of these explanations is sufficient to counter our claim that Sydney-based agriculture is currently a minor contributor to the city's total fresh food supply chain.

18.6 The Sydney Food Processing and Consumption Chain

Beyond the 'farm gate' end of the food supply chain, our work has shown that food plays a significant role in the Sydney basin economy in other ways (O'Neill et al. 2009). This contribution has also been neglected by policy makers and in the new food politics. Food manufacturing, for example, is the largest contributor to value added in Australia's manufacturing industry generating over $20 billion in 2004–2005 (Short et al. 2006). Food manufacturing is also a particularly urban industry with Sydney accounting for the majority of the state's food and manufacturing activity (Australian Bureau of Statistics 2009). In fact, the significance and strength of food manufacturing in Sydney contrasts starkly with the framing of Australian cities as 'post-industrial', with industrial sectors in decline. At the very least, food manufacturing is one manufacturing sub-sector that counters the de-industrialisation trend.

At the retail end of the food chain, the food retail and services sector is a large employer, contributing substantially to the Australia economy. This sector generated $107 billion turnover at a national level in 2006–2007, equivalent to 47 % of total retailing turnover (Department of Agriculture Fisheries and Forestry 2008). For Sydney, the Transport Data Centre (TDC) indicates there were over 55,000 jobs in food retailing in 2006, scattered throughout the metropolitan area especially in large supermarkets in regional and sub-regional centres (Transport Data Centre 2008). Nationally, around 60 % of food retail turnover is accounted for by the groceries category (Department of Agriculture Fisheries and Forestry 2008), and it is reasonable to assume that this high proportion also applies to Sydney.

The trend towards the commodification of household services also affects the operation of the food supply chain. According to the TDC, Sydney hosts close to 95,000 jobs in food services, the majority of which are in the inner city, eastern and north shore suburbs (Transport Data Centre 2008). This location patterns shows, firstly, the high spend of the wealthier and childless households concentrated in these suburbs on food prepared outside the home; and, secondly, the concentration of commercial food services in areas of where there are high concentrations of workers needing lunches and snacks.

In summary, these data show that food is highly significant to Sydney's urban economy irrespective of the declining significance of primary production of food on Sydney's peri-urban fringes. Feeding over 5 million persons (when visitors are included) daily requires a large assemblage of economic operations that stretch across all economic sectors and throughout all geographical spaces. Food, in all its guises, is arguably Sydney's most valuable economic enterprise.

18.7 Population Health and Food Security

Food is also significant for population health concerns, both positively and negatively. Illnesses resulting from poor diets are a serious and expensive problem for western nations. On its own, obesity is ranked as Australia's top three preventative health concerns alongside alcohol and tobacco consumption (National Preventative Health Taskforce 2008). Not unexpectedly, a lack of fresh fruit and vegetables in diets is identified as one of the nation's leading health risk factors (National Preventative Health Taskforce 2008).

Less understood is the issue of food security. One NSW study found that an average of 6 % of households with young children had experienced food insecurity—defined as having 'run out of food and could not afford to buy more'—at some point during a 12 months period (Centre for Epidemiology and Research 2002). Not surprisingly, food insecurity is concentrated in lower socio-economic pockets of Sydney. A 2006 study of three low income suburbs in Sydney's south west found that up to 22 % of households had experienced food insecurity, with particular vulnerabilities among renters and those with young children (Nolan et al. 2006).

Yet guaranteeing access to 'healthy' food at the right price, for example via a supermarket, seems insufficient in producing desirable food consumption outcomes. Our analysis of Sydney's food spend shows the complexities involved. While Sydney householders spend on average $23 more per week on food than the typical Australian household (Australian Bureau of Statistics 2006), the majority of this additional expenditure is accounted for by extra spending on take-away and eaten-out food. Moreover, a typical Sydneysider household spends nearly 30 % of their food budget on meals out and take-away foods (Australian Bureau of Statistics 2006), while on average eating less vegetables than a rural NSW household (Population Health Division 2008). Indeed, ABS data showed that Sydney households spent almost as much on alcohol in 2004 as they did on fruit and vegetables.

18.8 Environmental Sustainability

Urban food is also an environmental issue. Urban food, from primary production to final consumption, accounts for 43 % of the average Sydney household's total ecological footprint, including 26 % of household greenhouse production and 45 % of household water use (Australian Conservation Foundation 2009).

An important aspect of food's environmental impact is waste. A study by the Australia Institute found that the nation throws away over $5 billion worth of food purchases each year (Hamilton et al. 2005). For Sydney, food waste is estimated to comprise 37 % of all household waste, amounting to over 400,000 tonnes per year (Department of Environment and Climate Change NSW 2008). Note, this figure does not include food waste on farms, in manufacturing or at the supermarket, cafe, restaurant or fast-food end of the chain. To generate an estimate of the specific value of Sydney's food waste we recently applied the findings of the Australian Institute's study, making the assumption that Sydney's food behaviour by and large replicated the national average. We calculated that Sydney households would have wasted approximately $1 billion of food in 2004, with over $600 million of this being fresh food (O'Neill et al. 2009). With inflation, the retail value of food thrown away in Sydney is probably now higher by approximately 24 %.

The most significant implication of this re-calculation, in addition to what it reveals about the sheer amount of food wasted, is that the value of fresh food wasted in Sydney is roughly equal to the estimated farm gate value of fresh food produced by Sydney's farmers. In the 2005–2006 ABS agricultural census (the most recent), the value of Sydney production was estimated at $630 million (Australian Bureau of Statistics 2008a) almost equivalent to our estimated $600 million of fresh food waste in 2004.

18.9 Concluding Remarks

This paper has used a variety of data sources, including from our work to assess the significance of food agriculture in the Sydney basin, in the context of urban growth and sustainability concerns and as part of a large, complex food supply and processing system. Our analysis cautions about the ways we value local food and about knee-jerk rejections of the mainstream food supply system as unsustainable. While growing support for locally produced food is a welcome trend, addressing issues of access to food and the sustainability of food chains requires a more comprehensive approach to the urban food chain. Such an approach, we believe, requires moving beyond a dichotomy of 'alternative' and 'mainstream' food systems. We have shown how these systems are profoundly interconnected; and are available for development and nurturing for healthier and more sustainable outcomes. A focus on local food sourcing to the neglect of the mainstream could well undermine the chances of a more sustainable urban food system. There is certainly a strong argument for land use policies that preserve Sydney's surviving farmlands. But such measures cannot ensure commercial viability for urban growers. Indeed, removing a residential re-zoning option may well strip growers of their prime wealth creation option. Neither will protection generate sufficient land area to produce a significant contribution of fresh fruit and vegetables for a large growing city. The noble objective of a 100 food mile zone can never be anything more than a romantic aspiration with the volume and variety of produce required by a city such as Sydney. In any event, recent trends among farmers to expand production of cut flowers and turf, and to provide irrigated pasture for horse agistment, especially for recreational polo clubs, shows the difficulty in translating the food ideals of urbanists into actual farming practices in peri-urban areas. Nonetheless, non-food agriculture at least keeps farming in the Sydney basin, ensuring landscape diversity, and boosting peri-urban tourism through food trails, short stay holidays and the chance for an urban population to observe actual-existing farming.

The preponderance of our work shows, however, that focussing solely on peri-urban agriculture in this stage of Sydney's history will not address environmental and health concerns sufficiently. Urban design and diet management, alongside redress of income and education inequality, will have far greater impacts on improved health than insistence of peri-urban fresh food output. Likewise, a better understanding of the vast and complex way food is processed and re-processed via very urban, very non-rural food manufacturing, service and retailing sectors is needed before real gains in health outcomes will be achieved.

Then in respect to environmental sustainability, our work shows that Sydney Markets on its own generated 700 billion kg–km of payload in 2010. Over 25 % of this payload was bananas trucked from coastal regions to Sydney's north. Certainly, Australia boasts the capacity to grow and supply year round a diverse range of fresh fruit and vegetables from its many agricultural regions. The Sydney Markets study shows the payload consequences of this lengthy supply chain. Over 60 % of Sydney Markets produce is tropical and sub-tropical fruits, like bananas, or fruit bearing vegetables, like tomatoes. It would be foolhardy to mount consumer campaigns to avoid such produce. Rather, substantial environmental gains, for example in reduced greenhouse gas emissions, are securable from more efficient trucking and handling systems. Likewise, attention to reducing Sydney's food waste stream offers major opportunities for reducing the negative environmental impacts of the way the city runs its food chain.

Finally, there is the matter of consumer behaviour. If consumers—whether from richer or poorer households—choose to spend more money on, say, alcohol and meals out than on fresh produce, the economic viability of growers, wherever their location, is threatened, and health and environmental outcomes deteriorate. Furthermore, our calculation that Sydney households throw out an equivalent value of fresh food as is produced by Sydney growers brings into question the public's appreciation of fresh food. It seems there is a sizeable gap between good intentions in front of barrows of fresh fruit and vegetables and the neglect of a parcel on the bottom shelf of a household refrigerator that is just as likely to end up in a waste cycle as a hungry stomach. That fresh local food could be so valued by the alternative food movement yet be accorded such low appreciation among wider consumers complicates demands to prioritise actions around local produce in food policy agendas. Clearly, consumer choices and practices are key factors in determining the sustainability of the urban food chain and the role of peri-urban growers in it. Indeed such choices and practices seem as important as protecting peri-urban land for local food production. This holistic perspective illustrates why Sydney food policies must address the urban food system as a whole, including the consumption end, rather than solely focusing on what is happening among surviving local food growers.

References

Ambler-Edwards S, Bailey K, Kiff A, Lang T, Lee R, Marsden T, Simons D, Tibbs H (2009) Food futures: rethinking UK strategy. Chatham House Royal Institute of International Affairs, London. http://www.chathamhouse.org.uk/files/13248_r0109foodfutures.pdf. Accessed 10th Nov 2009

Australian Bureau of Statistics (2006) Household expenditure survey, Australia: detailed expenditure items, 2003–2004. Commonwealth Government of Australia, Canberra. ABS Cat. no. 6535.0.55.001

Australian Bureau of Statistics (2008a) Agricultural commodities: small area data, Australia 2005–2006 (Reissue). Australian Commonwealth Government, Canberra. ABS Cat. no. 7125.0

Australian Bureau of Statistics (2008b) Agricultural Commodities: Small Area Data, Australia, (2006–2007): NSW—State and SD—All Commodities. Australian Bureau of Statistics, Canberra. ABS Cat. no. 7125.0

Australian Bureau of Statistics (2009) Manufacturing Industry, Australia, 2006–2007. Commonwealth Government of Australia, Canberra. ABS cat. no. 8221.0

Australian Conservation Foundation (2009) Australian consumption atlas. Australian Conservation Foundation. www.acfonline.org.au/consumptionatlas. Accessed 13 Feb 2009

Centre for Epidemiology and Research (2002) New South Wales Child Health Survey 2001. NSW Department of Health, Sydney

Chatham House (2008) Thinking about the future of food: the Chatham House food supply scenarios. Chatham House, London. www.chathamhouse.org.uk/files/11622_bp0508food.pdf

City of Vancouver (2007) Vancouver food charter. City of Vancouver. www.Vancouver.vancouver.ca/commsvcs/socialplanning/initiatives/foodpolicy/tools/pdf/Van_Food_Charter.pdf. Accessed 20 Feb 2009

de Zeeuw H, Dubbeling M (2009) Cities, food and agriculture: challenges and the way forward. Food and Agriculture Organisation of the United Nations, Rome

Department of Agriculture Fisheries and Forestry (2008) Australian food statistics 2007. Commonwealth Government of Australia, Canberra

Department of Environment and Climate Change NSW (2008) Waste avoidance and resource recovery progress report. New South Wales Government, Sydney

Flisram G, Haller G, Groc IA (2009) A serious flirt with dirt. Planning 75:14

Fraser EDG, Mabee W (2004) Identifying the secure city: research to establish a preliminary framework. Can J Urban Res 13:89–99

Galvin N (2009) Not-so-super market society. Sydney Morning Herald 27 January Good Living: 5

Garnett T (1999) Urban agriculture in London: rethinking our food economy. Growing cities, growing food. Havana, Cuba, pp 477–500

Gillespie PD (2003) Agricultural trends in the Sydney Region 1996-2001: census comparisons. New South Wales Agriculture, Orange

Goodman D (2002) Rethinking food production-consumption: integrative perspectives. Sociologia Ruralis 42:271–277

Halweil B (2002) Home grown: the case for local food in a global market. Worldwatch Pap 163:5–79

Hamilton C, Deniss R, Baker D (2005) Wasteful consumption in Australia. The Australia Institute, Canberra. www.tai.org.au/?q=node/8&offset=3. Accessed 5th Feb 2009

Holmes J (2006) Peak oil? Television, Australia.10 July 2006. Distributed by Australian Broadcasting Corporation, Sydney

Howitt R (2000) Nests, webs and constructs: contested concepts of scale in political geography. In: Agnew J, Mitchell K, Tuathail G (eds) A companion to political geography. Blackwell, Oxford, pp 138–157

James S (2009) Re-visioning Sydney from the fringe: productive diversities for a 21st century city. PhD thesis. University of Western Sydney, Sydney

James S, O'Neill PM, Dimeski B (2010) Sydney's agricultural lands: an analysis. In Prepared for the NSW department of planning by the urban research centre, University of Western Sydney, Sydney

Kirkpatrick JB (2011) The political ecology of soil and species conservation in a 'Big Australia'. Geogr Res 49:276–285

Lerch D (2007) Post carbon cities: planning for energy and climate uncertainty. Post Carbon Institute, Portland

London Development Agency (2006) Healthy and sustainable food for London: the Mayor's food strategy. Mayor of London, London

London Food Link (2005) Mayor unveils strategy to improve London's food. SustainWeb, London. www.sustainweb.org/news.php?id=156 Viewed 13 Jun 2008

Malcolm P, Fahd R (2009) Ground truthing of Sydney vegetable industry in 2008. Horticulture Australia Limited and NSW Department of Primary Industries, Sydney

Morgan K (2009) Feeding the city: the challenge of urban food planning. Int Planning Stud 14:341–348

Morgan K, Marsden T, Murdoch J (2006) Networks, conventions, and regions: theorizing 'worlds of food'. In: Morgan K, Marsden T, Murdoch J (eds) Worlds of food: place, power, and provenance in the food chain. Oxford University Press, Oxford

Mougeot LJA (2005) Agropolis: the social, political and environmental dimensions of urban agriculture. Earthscan, London

Nasr J, MacRae R, Kuhns J (2010) Scaling-up urban agriculture in Toronto: building the infrastructure. Metcalff, Toronto

National Preventative Health Taskforce (2008) Australia: the healthiest country by 2020. Australian Commonwealth Government, Canberra

New South Wales Department of Planning (2005) City of cities: a plan for Sydney's future. New South Wales Government, Sydney

NSW Department of Planning and infrastructure (2012) Sydney over the next 25 years: a discussion paper. NSW Government, Sydney

Noble M (2008) Gastronomic planning policy: planning for food in Sydney. Bachelor of Planning thesis. University of New South Wales, Sydney

Nolan M, Rikard-Bell G, Mohsin M, Williams M (2006) Food insecurity in three socially disadvantaged localities in Sydney, Australia. Health Promot J Austral 17:247–254

O'Neill PM, James S, Crabtree L, Piquer-Rodriguez M (2009) Sydney's food value chain: a discussion paper. Feeding Sydney conference. Richmond, NSW: 24 September. Copy available from the author

O'Neill PM, Dimeski B (2013) The origins and destinations of produce flows through Sydney Markets Ltd, Flemington site. Prepared for SML by Urban Research Centre, University of Western Sydney

Ohri-Vachaspati P, Masi B, Taggart M, Konen J, Kerrigan J (2009) City fresh: a local collaboration for food equity. J Extension 47:6

Parker F, Suriyabanadara K (2000) The safe use of farm chemicals by market gardeners of non-English speaking background: developing an effective extension strategy for the Sydney Basin, 00/180. Rural Industries Research and Development Corporation (RIRDC), Commonwealth Government, Canberra

Population Health Division (2008) Health of the people of New South Wales: report of the NSW chief health officer 2008. Centre for Epidemiology and Research NSW Department of Health, Sydney. www.health.nsw.gov.au/publichealth/chorep/toc/list_bmiindex.asp#bmi. Accessed 13 Mar 2009

Pothukuchi K, Kaufman JL (1999) Placing the food system on the urban agenda: the role of municipal institutions in food systems planning. Agric Hum Values 16:213–224

Short C, Chester C, Berry P (2006) Australian food industry: performance and competitiveness. Australian Bureau of Agriculture and Resource Economics, Canberra

Sinclair I, Docking A, Jarecki S, Parker F, Saville L (2004) From the outside looking in: the future of Sydney's rural land: background issues and workshop outcomes. University of Western Sydney, Sydney

Stringer S (2009) Public interest: how New York City's food policy holds the key to hunger, health, jobs and the environment. Office of Manhattan Borough President, New York City

Stringer S (2010) FoodNYC: a blueprint for a sustainable food system. Borough of Manhattan, New York City

Sydney Food Fairness Alliance (2010). Sydney Food Fairness Alliance: working towards food security and sustainable food systems. Sydney Food Fairness Alliance, Sydney

The Government of Scotland (2008) National food and drink policy for Scotland. The Government of Scotland, Edinburgh. www.scotland.gov.uk/Topics/Business-Industry/Food-Industry/national-strategy. Accessed 10 Aug 2009

Toronto Food Policy Council (1999) Feeding the City from the Back 40: a commercial food production plan for the city of Toronto. Toronto Food Policy Council, Toronto

Transport Data Centre (2008) Journey to work data, 2006. New South Wales Government, Sydney

World Health Organization (2009) Food security. World Health Organization, www.who.int/trade/glossary/story028/en/. Accessed 10 Nov 2009

Zukin S (2008) Consuming authenticity: from outposts of difference to means of exclusion. Cultural Studies 22:724–748

Chapter 19
Who Feeds the Cities? A Comparison of Urban, Peri-urban and Rural Food Flows in Ghana

Pay Drechsel

Abstract The present study quantified for the two major cities of Ghana, Accra and Kumasi, the contribution of peri-urban agriculture, rural agriculture and urban agriculture to urban food supply, and analysed how much of the nutrients needed in peri-urban areas could be recovered from urban waste recycling. While the majority of calorie rich food derives from rural areas, urban and peri-urban farms cover significant shares of certain, usually more perishable but vitamin rich commodities. With every harvest, the soils in the production areas export parts of their nutrients or soil fertility. Thus the "urban nutrient footprint" is significant and calls for options to close the rural-urban nutrient loop. Currently, between 70 and 80 % of the nitrogen and phosphorous consumed in Kumasi pollutes the urban environment, especially ground and surface water. Based on the available waste transport capacity in Kumasi, the entire nitrogen (N) and phosphorus (P) demand of urban farming could be covered, and 18 % of the N and 25 % of the P needs of peri-urban agriculture in a 40 km radius around Kumasi, if the already collected organic municipal waste and fecal sludge would be co-composted.

Keywords Compost · Nutrient cycling · Nutrient footprint · Faecal sludge · Waste

19.1 Introduction

Rapid urbanisation in developing countries raises the challenges of how to make sufficient food available for the increasing city population. An increasing body of literature is highlighting the importance of urban and peri-urban agriculture in the context of city feeding programs (Smit et al. 2001; Van Veenhuizen 2006;

P. Drechsel (✉)
International Water Management Institute (IWMI), Colombo, Sri Lanka
e-mail: p.drechsel@cgiar.org

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_19,

Prain et al. 2010; FAO 2012a). At the same time there is usually little or no return of food related residues into the food production process transforming cities into vast nutrients sinks, while the production areas become increasingly nutrient deficient. The objectives of this study were (a) to analyse the contribution of (i) urban and (ii) peri-urban areas for urban food supply compared to the food supply from rural agriculture and (b) to determine how much of the nutrients needed in urban and peri-urban areas could be recovered from urban organic waste.

19.2 Study Sites

The study was carried out in Accra and Kumasi, Ghana. Accra is the capital city of Ghana with a population of 1.66 million during the study period. Within the city boundary, about 680 ha are under maize, 47 ha under vegetables and 251 ha under mixed cereal-vegetable systems. About 50–70 additional hectares are distributed over 80,000 backyards (Obuobie et al. 2006). A major peri-urban feature around Accra manifests in large-scale pineapple plantations. The analysis of the extent of the peri-urban areas applying the approach of Adam (2001) concluded for Accra an average radius of 38 km from the city center with more outreach along the Accra-Kumasi road, and less in between the major roads. Kumasi is the capital town of Ghana's Ashanti Region and the second largest city in the country with a population of about 1.1 million during the study period. Due to the hilly landscape of Kumasi, most streams run through inland valleys unsuitable for construction but have a high value for open-space irrigated vegetable production (approximately 41 ha in the urban area). At least two out of three households have some kind of backyard farming (Obuobie et al. 2006). The peri-urban area of Kumasi was estimated by the United Kingdom based Natural Resources Institute (NRI) as 40 km from the city center using the same approach (Adam 2001). It is characterised by a concentration of larger poultry farms.

19.3 Methodology

The study was based on an assessment of urban/urban, peri-urban/urban and rural/urban food flows for each city, typical marketing channels, household consumption patterns, and the analysis of nutrient flow related urban footprints. As secondary data on food production, import and export as commonly derived from FAOSTAT (http://faostat.fao.org) in regional or national studies were not available for the rural/urban comparison, the study followed a bottom-up approach based on market surveys for the food flows and household plus street surveys to assess consumption patterns (Drechsel et al. 2007).

Table 19.1 Surveyed food items

Category	Main commodities considered
Cereals	Rice, maize, millet, sorghum, wheat
Tubers and other starchy plants	Cassava, yam, cocoyam, plantain
Fruits	Banana, orange, pineapple
Vegetables	Tomato, garden egg, onion, cabbage, lettuce
Others (non-crops)	Milk, poultry, fish, meat, egg

Source Drechsel et al. (2007)

The markets surveys covered all major, as well as some smaller (specialized) markets, and were carried out as far as possible in the season of good supply (peak season) and low supply (lean season) and addressed over 900 market traders. The consumption survey covered about 1,700 households and street food consumers in Accra and more than 1,100 in Kumasi. The data obtained were analysed with special focus on the contribution of urban versus peri-urban agriculture to urban food supply. "Urban" refers, in our context, to the city boundary as an aerial photograph would show it while the extent of the peri-urban area was analysed in a separate study according to the outreach of urban services, commuter movement and market access as described in detail by Adam (2001). The area beyond the peri-urban fringe was considered as rural. Imported food was also recorded. Table 19.1 shows the different food items considered in the market surveys.

The results of the market and consumption surveys were used to compute related cropping areas and nutrient flows. In this context 'urban nutrient footprint' is referred to as nutrients exported from farmlands to supply the city with food and other organic materials and the fate of the nutrients in the city. The study was supported by 'Material Flow Analysis' (Leitzinger 2001; Erni et al. 2010).

19.4 Food and Nutrient Flows

19.4.1 Inflow of Food Items to Urban Areas

Around 900,000 tons of food is traded in Accra's and Kumasi's markets every year (Table 19.2). In the case of Kumasi, this amount requires a standard 7-tonne-transporter entering the city every 2 min during the day which is a significant logistical challenge in view of common traffic jams. Based on their weight, staple crops like yam, cassava and plantain form the major part of all food items brought to Kumasi's markets, reflecting the tuber based diet in the West African forest zone.

Table 19.2 Yearly inflow of food crops (in tons) into the two cities. n.d.: not determined (not abundant)

Crop	Accra	Kumasi
Yam	141,000	246,700
Cassava	132,800	213,800
Cocoyam	42,800	3,400
Plantain	127,700	144,500
Rice	107,400	30,000
Maize	45,500	25,300
Sorghum	n.d.	n.d.
Millet	n.d.	n.d.
Wheat	30,300	17,600
Pineapple	59,600	n.d.
Orange	56,600	n.d.
Banana	32,700	n.d.
Tomato	24,000	120,900
Eggplant	17,700	112,200
Onion	16,900	25,700
Cabbage	11,400	7,400
Lettuce	950	1,350
Total	847,350	948,750

Source Drechsel et al. (2007)

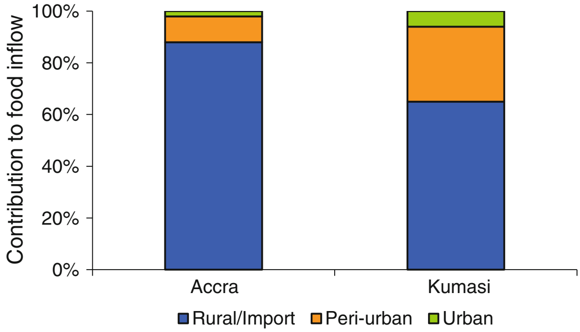


Fig. 19.1 Contribution of different areas to urban food inflows on weight basis (Drechsel et al. 2007)

19.4.2 Sources of Food Crops

In the two cities, food flows originating from rural areas are the most important overall food sources. Depending on the city, they contribute between 65 and 88 % of the total inflow to urban areas with percentages largely determined by the weight of tuber crops (Fig. 19.1).

Differentiating between commodities and seasons is of more interest (Table 19.3). In Kumasi a strong seasonality can be observed in the origin of the food supply. Rural-urban food flows are the most important ones (88 %) in the lean season. In the peak season, however, peri-urban agriculture reaches an aggregate contribution of 36 %. Mainly, vegetables like tomato, garden egg and

Table 19.3 Geographical sources of selected food items on Kumasi markets at different seasons in percent

Food item	Urban		Peri-urban		Rural		Import
	Lean season	Peak season	Lean season	Peak season	Lean season	Peak season	
Yam	0	0	0	0	100	100	0
Cassava	10	20	40	70	50	10	0
Cocoyam	<2	<2	<8	<10	90	90	0
Plantain	<5	10	<10	20	85	70	0
Maize	<5	10	5	25	90	65	0
Rice	0	0	0	<5	10	5	90
Onion	0	0	0	10	30	20	70
Garden egg (aubergine)	0	0	0	60	100	40	0
Tomato	0		45		40		15
Lettuce	90		5		0		5
Spring onion	90		10		0		0
Poultry	15		60*		<5		20
Egg	10		80		10		0
Meat	5		10		85		0
Wheat	0		0		0		100
Fresh milk	>55		<25		0		20

Source Drechsel et al. (2007)

*Share is declining due to cheap frozen import poultry

cabbage are harvested during this time on peri-urban farms. Main sources for yam, maize and plantain are the rural areas of Ghana's Brong Ahafo, Upper East and Ashanti Region. The demand for fresh leafy vegetables, like spring onion and lettuce, is 90 % covered by inner-city production. Also, most fresh milk found in Kumasi is produced in the urban area at the local university. In the peri-urban areas of Kumasi, large poultry farms produce 80 % of the eggs for the urban market while poultry meat is increasingly imported.

Table 19.4 shows the origin of food items on Accra's markets, split up into urban, peri-urban and rural contributions. The contribution of urban and peri-urban agriculture to Accra's market supply is dominated by fruit (pineapples) and vegetables (lettuce, cabbage, garden eggs) while for staple crops Accra relies mainly on rural areas. During the major dry season in Accra more lettuce is brought from other cities. Food imports play a strong role in supplying the cities with processed food but also certain commodities such as rice, wheat and poultry. The large majority (60–90 %) of the rice found in Ghana's urban centers comes from Asia and the United States of America (USA), while onion comes largely from Niger, wheat from USA and frozen poultry meat from Brazil. Ghana's peri-urban poultry industry, which supplied about 95 % of the domestic poultry meat demand in the nineties, is today approaching a one-digit figure (Zachary 2004; Kudzodzi 2006). A similar picture can be found across Africa where poultry imports have increased since 1995 more than threefold while prices dropped by more than 40 % (CTA 2005).

Table 19.4 Geographical sources of selected food items on Accra markets in percent

Crop	Urban	Peri-urban	Rural	Import
Yam	0	0	100	
Cassava	<2	5	95	
Maize	<2	5	95	
Plantain	<2	10	90	
Rice	0	0	10	90
Cocoyam	0	0	100	
Cabbage	10	50	40	
Lettuce	75*	20	5	
Tomatoes	<5	5	95	
Onions	0	20	20	60
Garden eggs	<5	45	55	
Bananas	0	0	100	
Oranges	0	13	87	
Pineapple	0	85	15	

*Grown in urban Accra and Kumasi for the Accra market

19.4.3 Consumption and Outflows

As Kumasi is a major trade center, the inflow of food is very high. However, only about 48 % is actually consumed within the city (Fig. 19.2). Goods traded 'through' Kumasi are mainly staple crops such as yam, cassava, and plantain. In the case of Accra, about 64 % of the food brought into the city is also consumed within the city (Fig. 19.2). The relatively low outflow can be explained by the location of Accra as it is a "dead end" for many national food flows coming from the central and northern parts of Ghana. Cocoa, Ghana's main agricultural export commodity was not included in the flow analysis as it does not pass Accra's markets but goes straight to the harbor at Tema. Only a minor part of it is processed in Ghana which reflects the generally poor development of the food processing sector and dependency on imports.

Urban calorie and protein intake is mostly derived from rural areas. However, the peri-urban supply of fresh vegetables and poultry complements rural production in view of micronutrients, protein and vitamins. In the study cities, food rich in Vitamin A, such as carrots, local spinach, tomatoes, lettuce, beans, eggs and milk derive predominantly from urban and peri-urban farms (Drechsel et al. 2007).

19.4.4 Urban Nutrient Footprint

The consumption footprint includes the area needed to produce food and other materials consumed and the area needed to absorb the waste. Table 19.5 gives an overview of the areas required to meet the demands of the respective cities for

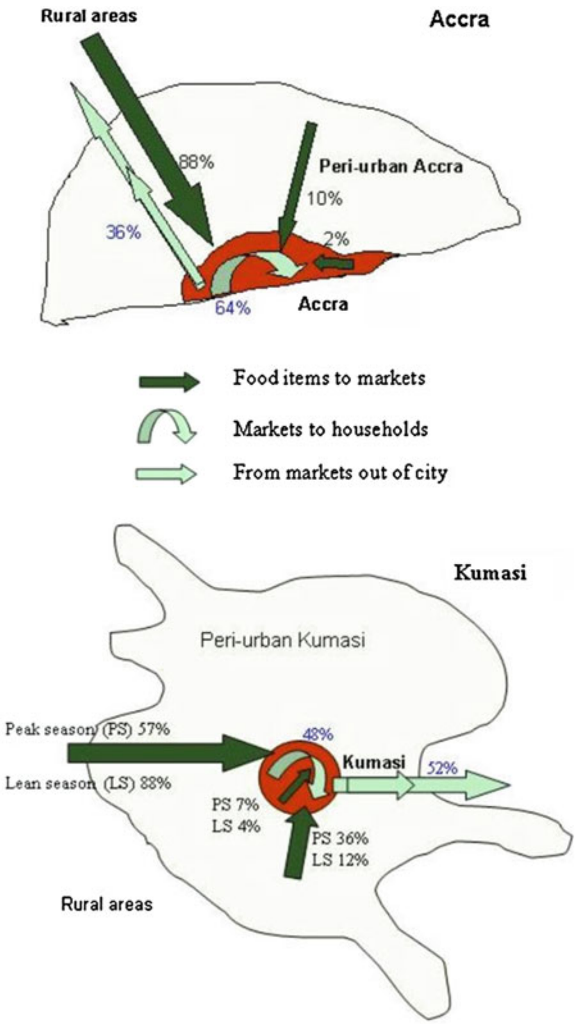


Fig. 19.2 Inflows and outflows of food items in Accra and Kumasi (Drechsel et al. 2007)

Table 19.5 Required area (ha) to produce the main staple crops consumed in the two cities

Crop	Average yield (t/ha)	Area (ha) required to feed	
		Accra	Kumasi
Cassava	12.3	6,756	6,724
Yam	13.0	6,800	5,308
Cocoyam	6.6	2,909	1,955
Plantain	8.3	5,373	4,928
Maize	1.5	37,181	16,376
Rice	2.3	16,535	13,114
Total		75,554	48,403

Source Drechsel et al. (2007)

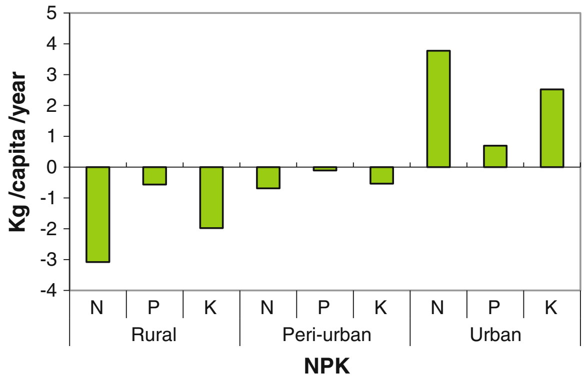


Fig. 19.3 Average nutrient balance (exports = negative; imports = positive) in the rural-urban continuum, harmonized for an average urban population number (Drechsel et al. 2007)

major staple crops assuming common yield levels as reported by the Ghanaian Ministries of Food and Agriculture. Notably the urban maize supply has the largest urban footprint, i.e. is most space-demanding, as regularly extra fields have to be opened following two maize harvests (shifting cultivation). Cassava has lower soil fertility requirements and occupies the abandoned maize fields. The yield used for rice reflects a Ghanaian average between upland rice (1 t/ha) and paddy rice (4.5 t/ha). However, currently, about 90 % of the rice found in the markets of Accra and Kumasi is imported from Asia or USA. Local rice varieties are not very popular in urban Ghana (Drechsel et al. 2007).

Urban agricultural production accounts for only 1–7% of the overall nutrient flow. Peri-urban areas do not provide more than 10 % of nutrient inflows for Accra, but more than 20 % for Kumasi. Nutrient inflows from rural areas account for more than 90 % for Accra, and 70 % for Kumasi. The corresponding shift of nutrients along the rural-urban continuum is shown in Fig. 19.3 using the "urban nutrient balance" as indicator.

19.4.5 Environmental Impact

About half of the biomass imported into Kumasi leaves the city again through trade. What happens to the rest of which most is passing the human body? A 'Material Flow Analysis' combining solid and liquid flows (Leitzinger 2001; Erni et al. 2010) showed that:

- Groundwater and surface waters receive about half of the total nitrogen and phosphorus losses, largely through leaking or overflowing septic tanks and latrines.
- The result of this massive pollution is that the amount of nitrogen and phosphorus that leaves the city via waterways is over 10 times more than the amount that enters the city in the same surface and subsurface streams and through precipitation.

- About 22 % of the nitrogen and 29 % of the phosphorus are emitted to the soil.
- About 15 % of the nitrogen is transferred to the atmosphere from the households.
- About 15 % of both elements are sent with municipal waste to landfills.
- Less than 5 % of the nitrogen and phosphorus end up in fecal sludge treatment plants.

Thus only 20 % of both nutrients are retained in the sanitation system, the rest contributes to urban pollution. Measures taken to support household waste management and collection could greatly enhance resource recovery and environmental protection. About 18 % of the generated solid waste (175 t/day) and 66 % of the fecal sludge (413 m^3/day) remain uncollected in Kumasi's streets, pits and septic tanks (Mensah 2004; Vodounhessi 2006).

19.4.6 Reducing the Urban Nutrient Footprint

The quantities of nutrient involved are very high in terms of their fertilizer value. The annual nitrogen flow with food to Kumasi, for example, equals the nitrogen content of Ghana's cumulative Ammonium Sulphate imports between 2003 and 2010 (FAO 2012b).

From a technical perspective, part of this (environmental) load could be recycled through co-composting of fecal sludge and municipal solid waste. In a "realistic" scenario, which only considered the waste already collected, the entire N and P demand of urban farming could be covered, and 18 % of the nitrogen and 25 % of the phosphorus needs of peri-urban agriculture (Belevi 2002). This would easily replace any mineral fertilizer used in the whole Ashanti region around Kumasi.

The reduction of environmental pollution in this scenario was less than 20 % but could be increased significantly with improved collection capacity. This concerns, in particular, improved excreta management since the most significant nitrogen and phosphorus fluxes to soil, surface waters and groundwater occur via faeces and urine transfers. How far such a closed loop concept via co-composting can be realised in practice depends, however, on many economic, institutional and technical factors (Drechsel et al. 2010).

19.5 Conclusions

The present study highlights the role of peri-urban areas compared to rural and urban areas in the supply of food to cities in the example of Accra and Kumasi in Ghana. While the majority of calorie rich food derives from rural areas, urban and peri-urban farms cover significant shares of certain, usually more perishable commodities, like vegetables rich in Vitamin A. Many of these food items, like "exotic" salads, are not part of the traditional diet, but are a key component of the growing urban fast or street food sector. This sector reflects a change in diets with increasing urbanisation, a development which takes advantage of cheap imports of rice, wheat, and poultry.

With every harvest, the soils in the production areas export parts of their fertility without organic waste being channelled back into the system. Flow analysis shows that about 80 % of the nutrients the city consumes end up either in unproductive landfills or pollute the environment. There is a huge potential to recycle nutrients and organic matter especially where both are in short supply in city-feeding production areas. The main entry points for better waste management are the majority of urban households with poor facilities and services and where most nutrient losses occur.

It is important to factor hidden environmental costs into the debate on rural nutrient depletion and urban waste accumulation. The nutrient value, for example, of the non-collected solid and liquid waste (sludge) in Kumasi would be sufficient to pay the service costs of solid waste management for the whole city. About 80 % of this amount is spent on waste collection and transportation to disposal sites. Waste volume and transport costs could be drastically reduced through composting for the additional benefit of the farming community. In particular, the comprehensive collection and treatment or co-composting of faecal matter should receive highest attention to reduce the pollution of urban and peri-urban soils and water bodies. As in and around the cities these streams are used for irrigation, the pathogen cycle has to be interrupted before the urban dwellers receive this particular kind of "feed-back" from vegetable markets.

Acknowledgments The author likes to acknowledge the support of the Water, Land & Ecosystems Research Program of the CGIAR, and the ETH Zurich and SANDEC/EAWAG for assistance with the Material Flow Analysis.

References

Adam M (2001) Definition and boundaries of the peri-urban interface: patterns in the patchwork. In: Drechsel P, Kunze D (eds) Waste composting for urban and peri-urban agriculture: closing the rural-urban nutrient cycle in Sub-Saharan Africa. CABI Publishing, Wallingford, pp 193–208

Belevi H (2002) Material flow analysis as a strategic planning tool for regional waste water and solid waste management. In: Proceedings of the workshop "Globale Zukunft: Kreislaufwirtschaftskonzepte im kommunalen Abwasser- und Fäkalienmanagement". Munich, pp 13–15. http://www2.gtz.de/Dokumente/oe44/ecosan/en-material-flow-analysis-wastewater-and-waste-management-2002.pdf. Accessed 31 Sept 2013

CTA (2005) Feeding the towns: a weighty dilemma. SPORE 117:4–5

Drechsel P, Cofie O, Danso G (2010) Closing the rural-urban food and nutrient loops in West Africa: a reality check. Urban Agric Mag 23:8–10

Drechsel P, Graefe S, Fink M (2007) Rural-urban food, nutrient and virtual water flows in selected West African cities. International Water Management Institute, Colombo, pp 35 (IWMI Research Report Series 115)

Erni M, Drechsel P, Bader H-P, Scheidegger R, Zurbruegg C, Kipfer R (2010) Bad for the environment, good for the farmer? Urban sanitation and nutrient flows. Irrig Drainage Syst Spec Issue Wastewater Reuse 24(1–2):113–125

FAO (2012a) Growing greener cities in Africa: first status report on urban and peri-urban horticulture in Africa. FAO, Rome

FAO (2012b) FAOSTAT online database on Ghana fertilizer imports. http://faostat.fao.org/

Kudzodzi W (2006) Trade-Ghana: the chilling effect of frozen poultry imports. IPS, Ghana, p 25

Leitzinger C (2001) The potential of co-composting in Kumasi—quantification of the urban and peri-urban nutrient balance. In: Drechsel P, Kunze D (eds.) Waste Composting for urban and peri-urban agriculture—closing the rural-urban nutrient cycle in Sub-Saharan Africa. IWMI/FAO/CABI, Wallingford, pp 150–162

Mensah A (2004) Strategy for solid and liquid waste management in Kumasi. In: Paper presented during the IWMI-SANDEC-KMA-KNUST workshop on “Co-composting of solid and liquid waste for agriculture: review of progress and next plans”, KNUST, Kumasi, 27. Jan 2004

Obuobie E, Keraita B, Danso G, Amoah P, Cofie OO, Raschid-Sally L, Drechsel P (2006) Irrigated urban vegetable production in Ghana: characteristics, benefits and risks. IWMI-RUAF-CPWF. IWMI, Accra, pp 150

Prain G, Karanja N, Lee-Smith D (Eds) (2010) African urban harvest: agriculture in the cities of Cameroon, Kenya and Uganda. Springer, New York

Smit J, Nasr J, Ratta A (2001) Urban agriculture: food, jobs and sustainable cities, 2nd edn. http://jacsmit.com/book.html. Accessed 31 Sept 2013

Van Veenhuizen R (ed) (2006) Cities farming for the future—urban agriculture for green and productive cities. RUAF, IDRC and IIRR, Ottawa

Vodounhessi A (2006) Financial and institutional challenges to make faecal sludge management integrated part of ecosan approach in West Africa. Case study of Kumasi, Ghana. MSc thesis, UNESCO-IHE, Delft, NL, p 130

Zachary GP (2004) Cheap chickens: Feeding Africa’s poor. World Policy J 21:47–52

Chapter 20
Why and How to Sustain Agriculture Around Our Cities: A Case Study of Sydney, Australia

David Mason and Brian Davidson

Abstract In the peri-urban regions that surround cities traditional industries, such as agriculture, tend to suffer as the process of urbanisation occurs. These industries tended to survive because their proximity to urban centres provided them with all the advantages of a natural monopoly in selected products. However, this natural protection is eroded by improvements in transport systems, amongst other factors, and in the end the traditional industries succumb to development pressures. In the past this process of change has not been managed well, with many instances of peri-urban regions and industries being swallowed up by new urban developments. The purpose in this paper is to outline an example of a program that is designed to manage the interests of those in the traditional industries in peri-urban regions as the process of development occurs. The program is known as the Hawkesbury Harvest and it is applied to the peri-urban region to the west of Sydney, Australia. In this paper, the history of agriculture in the region is initially presented in order to provide a context of how Hawkesbury Harvest operates. The region itself had a number of natural assets that protected it from competition, but these ceased with the development of improved transport networks. Hawkesbury Harvest operates within a competitive environment promoting the products and ecosystem services of traditional activities in a region that is subject to severe urban development pressures. It serves to manage the process of change in an ever changing environment and acts as a template for other regions suffering from similar pressures.

Keywords Agricultural development managing government intervention · Marketing

D. Mason (✉)
NSW Department of Primary Industries, Locked Bag 4, Richmond, NSW 2753, Australia
e-mail: dwmason@bigpond.com

B. Davidson
Melbourne School of Land and Environment, University of Melbourne, Parkville, VIC 3010, Australia

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_20,

20.1 Introduction

At the Royal Australian Planning Institute Conference in 1993 a debate arose on the planning provisions for agriculture in the Sydney region. The view then was that: 'There is no place for agriculture in the Sydney region. Agriculture belongs over the Great Dividing Range (west of Sydney) and any agricultural lands are lands awaiting higher economic development.' This response was very much a reflection of the political, bureaucratic, development industry and general community thinking of that time. Yet at that time Sydney's agriculture had a farm gate value in the order of $1 billion per annum. This region produced 12 % of NSWs agricultural production on less than 1 % of the State's agricultural land and employed 11 % of the State's agricultural workforce (Gillespie and Mason 2003). The argument sparked a strategic response from the NSW Department of Agriculture (now Department of Primary Industries) who intended at least to provide the Sydney community and numerous decision makers with a better knowledge of what Sydney's peri-urban agriculture offered socially, economically and environmentally.

The Department of Primary Industries (DPI) began a consultation process that resulted in the release of the Strategic Plan for Sustainable Agriculture—Sydney Region in 1998. In this document a framework was presented that would maintain a sustainable agricultural presence in the Sydney region. A significant driver for maintaining agriculture in Sydney was a growing appreciation of the many benefits offered by local food systems, particularly when it is strategically linked with other social, economic and environmental disciplines. All these factors, it was argued, could contribute to the quality of life of urban and peri-urban dwellers, especially in light of climate change, population growth and associated food security concerns. A number of processes have been established within the framework including an emphasis on land planning, water security, food equity, human health, city green space, food produce and product marketing options.

A significant player in raising the profile of local agriculture in the Sydney Region has been Hawkesbury Harvest. Hawkesbury Harvest is a grass roots organization that is used to promote the products and ecosystem services in the peri-urban region of western Sydney. It was established in 2000. In many ways it is a far cry from the way the products were once marketed in the region; an approach that relied on using the natural monopolistic advantages it once had.

In this paper the contribution Hawkesbury Harvest has made to the Sydney Region and the implications this has for other Australian cities is explored. This contribution can and should be viewed in the context of the changing environment of peri-urban Sydney. As a consequence the history of agriculture in the region is reviewed as a backdrop to what Hawkesbury Harvest has been able to contribute to peri-urban agriculture.

20.2 The History of Agricultural Development in Western Sydney

20.2.1 The Early Settlement

Formal agricultural practices cannot commence until the property rights questions of ‘who owns what’ and ‘what can be done with select pieces of property’ are settled. This did not occur in the region until European settlement in 1788. Prior to that, the local indigenous people harvested the natural bounty of the land using traditional hunter and gatherer techniques. So, not only did the urbanisation of Sydney begin with the occupants of the First Fleet, under the leadership of Captain Arthur Phillip, so too did its agricultural development. Governor Phillip’s charter was to establish a non-urban, non-commercial, and as Karskens (2009) observes, a subsistence settlement isolated from the rest of the world. This was the start of a paradox of Sydney’s agriculture/urban land use dichotomy. It has been exacerbated by the application of English agricultural practices to a geographical and metaphorical antipodean landscape, soil and climate regime. The agriculture, associated cultural practices and urban development were incompatible with the original intent of the colony.

Development forces overrode Governor Phillip’s mission to the extent that by the beginning of the nineteenth century the military, in cahoots with free settlers and land owners, had established a near-monopoly of trade and land grants. Davidson (1981) argues that Governor Phillip experienced a number of unforeseen problems in establishing agriculture in the region. The first was the lack of suitable arable land, with only small pockets of alluvial soils, the rest being infertile sands overlaying sandstone and shale rock beds. Second, any good soils were lands that were covered with hard to remove eucalypts. Third, the fertility of these lands was regenerated by flooding, which is incompatible with growing crops. Couple that with frequent droughts and there is little wonder that the new colony nearly starved to death in its first few years. Fourth, it soon became apparent that the method of utilising labour to grow crops, i.e. offering convicts increased rations for work on farms, would not be sufficient. Davidson (1981, p. 46) “… in desperation Phillip encouraged his officers to grow crops. After 1789 these were joined by convicts who had served their sentences. … Phillip was also instructed to offer land to marines after 3 years of settlement …”.

This desperate need for food led to a scenario where land and the means for trade (which was rum) were monopolised by a few large settlers with links to the military establishment. It was exacerbated by the imbalanced, inequitable and limp leadership of governors and interregnum acting governors subsequent to Governor Phillip. When the colony’s fourth governor, Captain William Bligh challenged this power in 1808, he was arrested by the military at the behest of the powerful free settlers in what was Australia’s only military coup (Parliament of NSW 2008).

Many of the private good and public good land use conflicts and inequities that had developed since the arrival of the First Fleet were addressed by Lieutenant Lachlan Macquarie, the fifth (and last autocratic) governor, during his tenure from

1810 to 1821. His vision was an agrarian civil society which he hoped, despite the paradox of harnessing powerful forces of self-interest for the public good, would ensure an egalitarian legacy for future generations of Sydney residents (Mason and Knowd 2010).

In this regard he was seemingly successful, beginning with the proclamation of what was to become known as the five Macquarie Towns in north-west Sydney on 6 December 1810. The purpose of the towns of Wilberforce, Pitt Town, Green Hills (now Windsor), Richmond and Castlereagh was to service the surrounding rich farming lands to ensure that the fledgling and rapidly expanding settlement of Sydney, 60 km to the south-east, had a reliable food supply. Food security was a major issue. The area became known as Sydney's 'food bowl' (Mason and Knowd 2010).

Proclaiming service towns and promoting agriculture does not insulate society from the ravages of the climate. The region suffered periodically from droughts (in 1798 and from 1813 to 1816) and floods (in 1799, 1800, 1801, 1806, 1809 and 1819), which led to a highly variable supply of grain to the colony. A variable supply, coupled with an expanding demand, led inevitably to fluctuating prices; prices that were excessive during those periods of drought and flood. The governor's approach to this problem was to purchase grain at a fixed price that was lower than what could be obtained in the free market during periods of scarcity and greater than the market price during surplus years. The chaos that this marketing scheme wrought on the agricultural community in Western Sydney should not be underestimated and it contributed to the chaos that characterised the colony during its first 25 years (King 1948). This chaos was inevitable and would have occurred in any situation where the supply is limited, controlled by a few producers and has a major single buyer (at times a corrupted Government).

This monopoly situation did not however last much beyond 1815. Davidson (1981) notes that while the population of Sydney grew from 3,388 in 1795 to nearly 30,000 in 1821, the area of grain cropped per capita in NSW fell from approximately 1.8 acres to 0.95. The reasons why this occurred was the establishment of cropping enterprises in Tasmania and the opening up of a way through the Blue Mountains to the west of Sydney. Opening up more lands not only increased competition by increasing the imports of grain from Tasmania, but also took pressure off land use in Sydney. While the production of wheat to the west of Sydney was economically not feasible until the development of railways, the production of wool in the new lands to the west was highly profitable. The Sydney region thus developed into a region where goods that were difficult to transport (i.e. fresh fruit, vegetables and dairy products) were produced.

20.2.2 Developments in a Mature Region

Agricultural production in Western Sydney only started to decline in the 1880s through to the early 1900s due to urban development. This tended to occur in parallel with the building of railway lines (Gaynor 2005; WSROC 2009). Between the 1920s and the 1940s a subdivision boom occurred, fuelled in part by the real estate industry, but also by the expansion of the tram and train infrastructure (Spearritt 1999).

Quite clearly the level of development was of concern to some. In 1948 the County of Cumberland Plan was introduced, which included a green belt (Gaynor 2005). Yet running counter that, the trend towards settling the Post-World War II immigrants who either leased or acquired land on the outskirts of urban Sydney, continued (Burke 2009). Water supplies, always a concern in Sydney, became so acute that in the 1950s Warragamba Dam was built. Additionally in the 1950s and 1960s supermarkets began to spread across Sydney resulting in the demise of the corner store, industrial growth and the building of public housing estates continued (WSROC 2009). By 1968, after much lobbying by the housing industry and developers, Sydney's green belt was excluded from the new Sydney Region Metro Plan (Mason and Knowd 2010).

In the 1970s, the Sydney urban core was seen as a site of global business activity (Buxton et al. 2006). With that, changes to Australian settlement patterns began to occur as the restructuring and deregulation of the Australian economy occurred. This created a new planning paradigm, with parts of inner Sydney becoming economic service sectors. In Western Sydney housing development continued, where a greater proportion of the fast food outlets were established and variation in the quality of fresh food and vegetables offered at supermarkets across Sydney became dependent on the socio-economic standard of locality in which it was sold (Burke 2009). In the late 1970s food imports, especially the fresh variety that were produced in Western Sydney increased. By the end of the 1980s technological improvements in agriculture and transportation had led to higher yields and fresh food was transported to the Sydney market from inter-state producers. Farmers who produced these goods and enjoyed the natural monopoly advantages that distance afforded them, up until that time, became 'price takers' and their profitability was reduced (Knowd et al. 2005).

In the last 20 years producers in Western Sydney faced a truly competitive market situation, one in which they were at a considerable disadvantage. Their costs of production associated with land (rates for instance) were higher than their competition elsewhere and, because their land and enterprises were highly desired by the developers, they were disinclined to invest in new technologies. In the 1980s agricultural land was viewed by state planning departments to be 'awaiting higher economic development' (Mason and Knowd 2010). Buxton et al. (2006) argues that because of this view 80 % of Sydney's population growth occurred in its peri-urban region. The 1988 Sydney Metropolitan Strategy made no mention of protecting Sydney's agriculture; neither did the 1993 Sydney's Future Plan (Knowd et al. 2005). Furthermore, in the 1980s and 1990s the construction of the M4 and M7 motorways commenced (WSROC 2009), a sign that housing development had overtaken agricultural development.

20.2.3 Influence of Urban Development

This urban development has considerable advantages to the individual farmers who remain, as the asset values of their holdings rise. This type of development requires land, something existing farmers hold in abundance. However, rural land held in urban areas also attracts a lot of costs, not normally associated with agriculture conducted in more rural settings. The increase in local government rates can be considerable, the complaints from urban neighbours can be loud, long and costly to resolve, and the ease to which inputs and outputs are moved on and off the farm can become restricted.

From society's perspective the costs of losing an agricultural presence can also be significant. For instance the loss of this presence can mean that society loses touch with where its food comes from and the benefits it provides. This has been seen in the increasing concerns over the rising overweight status of Sydney residents, particularly those in Western Sydney. Since 1995, the rate of obesity in Australia has risen from 19 to 24 % (ABS 2011). In the 1990s the human health concerns arising in Western Sydney lead to the creation of a number of programs, including the Penrith Food Project (PFP). The purpose of the PFP was to establish infrastructure and processes designed to enhance the health status of the residents of Penrith City Council area (Reay and Webb 1998). The PFP provides a template for the development of the Hawkesbury Food Program.

By 1992 environmental concerns in the region were such that Greening Australia began restoring the bushland on publicly owned lands in Western Sydney and questioning the health of the river systems. Only a few percent of Sydney's original vegetation remains (Buxton et al. 2006). In 1994 the Sustainable Agriculture for the Environment (SAFE) process was established within NSW Department of Agriculture. The aim was to develop a strategic plan for sustainable agriculture in the Sydney region, something it achieved in 1998 with the release of the Strategic Plan for Sustainable Agriculture—Sydney region (NSW Agriculture 1998). Despite these innovations, it was too late to save much of agriculture and by the late 1990s rural lifestyle living (hobby farming) had overtaken farming as a major use of land (Sinclair 2001).

However the first decade of the twentieth century saw the formation of a number of food advocacy groups and the increasing popularity of alternative food networks, e.g. Sydney Farming Network, Sydney Food Fairness Alliance, community garden co-ops, farmers' markets, and Aussie Farmers Direct. One of the early innovations was Hawkesbury Harvest, which emerged from the Local Cuisine Sub-committee of the Hawkesbury Food Program, in the year 2000.

20.2.4 Food Production and Pressure of Urban Development

These efforts in achieving a better market for the agricultural products of the region need to be weighed against the relentless pressures for urban development.

By 2005 the water allowed to flow from Warragamba Dam fell from 50 to 25 megalitres per day. In 2003 the estimated housing requirements in Sydney's growth centres resulted in a reduction in the number of agricultural lots by 7 % for intensive plant agriculture and by 21 % for intensive animal agriculture in the north-west sub-region. In the south-west sub-region the reductions of intensive plant industries were in the order of 50 and 43 % in the intensive animal agriculture industries (Sinclair 2003). In 2004 the NSW Government's Sydney Metropolitan Strategy (Direction 3—Manage growth and Value Non-Urban Areas) it was recognised that non-urban land is not to be treated as 'land in waiting' for urban development (NSW Planning 2005). The Sydney Metropolitan Plan 'City of Cities' was released in 2005. In it, there was the suggestion that Sydney would be comprised of five cities—Sydney CBD, North Sydney, Parramatta, Liverpool and Penrith, three of which were located in Western Sydney (NSW Planning 2005). Development has been so rapid that in 2005 the NSW Auditor-General (quoted in Buxton et al. 2006) reported that '… Sydney's water supplies are inadequate to meet long-term metropolitan demand requirements'.

It is interesting to note that despite all this development, government authorities still maintain an interest in food production. For instance, in 2008 the Sydney City Council began a process to develop the Greening Sydney Plan, and in that advocated for green roofs, community gardens and a city farm among other programs (Sydney City Council 2011). By 2008, the NSW Minister for Primary Industries established a forum to set directions for Sydney's agricultural industries. This forum, hosted by the NSW DPI, NSW Department of Planning and the Penrith City Council, resulted in the formation of the Sydney Agriculture Reference Group (industry, local government and community) whose task it was to make recommendations to the State Government on the agriculture in the region.

In 2010, the Metropolitan Plan for Sydney 2036 was released. Sydney's population was estimated to grow by 1.7 million people between 2006 and 2036 to 6 million. In the plan agriculture was recognised as a rightful land use. The objectives include delivering an agriculture policy for Sydney that will maintain viable local food production, mapping areas to inform future strategic policy with respect to agricultural activities and resource lands, promoting agricultural activities positively in Sydney, land use conflict and preparing and releasing guidance on planning for agricultural activities (NSW Planning 2010).

By 2011 there was a belief that Australia's supermarket duopoly dominated the country's food system, having an impact on the viability of small family farms and on ethnic and rural communities. When coupled with free trade, cheap imports and, in some cases, loss of export markets, the future for agriculture looked dim for a significant number of fruit and vegetable growers. This was especially the case for those in the region who relied on traditional marketing processes, such as Sydney's central produce markets at Flemington.

20.2.5 Where from here?

The above provides a brief snapshot of how Sydney and its environs have developed in the context of political forces, urban/rural land use tensions, capacity to meet water requirements, food systems and human and environmental health from the time of the landing of the First Fleet on 28 January 1788 to the present. What is not surprising is the relentless pressures agriculture has faced from continuing urban development. Rather, what is surprising is that any agriculture still exists in the region at all. It is quite clear that for many decades, government authorities thought so little of agriculture in the region that farmed lands were considered to be nothing more than awaiting housing development. That attitude in recent times does appear to be changing.

What are arguably of more interest are the role markets and marketing have played in the story of agriculture in Western Sydney. In the early years of settlement the agricultural industry benefited from (and to a degree suffered from) a government sanctioned natural monopoly. That monopoly changed after 1815, with the opening up of new regions to the west and in Tasmania. Despite this a degree of natural monopoly existed for producers in the region because of inadequate transport networks. Provided producers produced products that were hard to transport (turf and racehorses) and sold for premium if fresh (things like vegetables, milk and fruit) they were afforded a degree of protection from competitors outside the Sydney region. However, by the mid-1980s these natural protection measures were breaking down with the improvements in the transport networks. The beneficiaries of these improvements were undoubtedly consumers, who received more choice of products at a lower price. The losers were the farmers of the Sydney region.

It is ironic to note that in the end the argument for helping farmers in this locality is to some degree based on the need to protect them from a new monopoly, the duopoly of the supermarket chains. It is within a much tougher marketing situation for local Sydney producers that this summary of the development of the agriculture in the region was offered and it offers a context for the origins and on-going development of the Hawkesbury Harvest phenomenon which is discussed below.

20.3 The Hawkesbury Harvest Story

The marketing of agricultural products has played an important role in the region in the past; a role that is expected to continue. While producers relied on imposed or natural monopolies to survive, since the 1980s this protection no longer exists. Marketing for the region now has to rely on selling a better product than its competitors to consumers who have benefitted from a wide range of choices. Hawkesbury Harvest is that attempt to sell a higher quality 'product' from the region.

20.3.1 How Hawkesbury Harvest was Established

Hawkesbury Harvest Inc. was formed in 2000 in response to concerns related to:

- Sydney's urban sprawl on farming lands, and its associated effects on rural and ethnic communities.
- The supermarket system and its effects on price equity and the viability of small family farms.
- The fast food system and it affects on human health in Western Sydney, particularly amongst the young.

Its genesis was the result of global, regional and local forces that were concerned about food, farming and human health. Globally, at the United Nations Rio de Janeiro Conference of 1992 the concepts of sustainability and economic development were articulated in the Brundtland Report and in the Agenda 21 program. The global Healthy Cities program that developed out of this manifested itself in the Western Sydney region through the Hawkesbury Food Program. It became the regional institutional context for making the arguments on the connections between food, farming and health in the Sydney region. This emphasis was further enhanced by the Strategic Plan for Sustainable Agriculture—Sydney region, released by the NSW Minister for Agriculture in May 1998 (NSW Department of Agriculture 1998). The local force for change came through community surveys undertaken by Hawkesbury City Council during the 1990s (again verified in 2007) to determine what its constituents valued most about living in the Hawkesbury local government area (LGA). In the overall responses to those local surveys the highest priority value was the lifestyle offered by the rural landscape of the LGA (Hawkesbury City Council 2000).

The challenge was to develop mechanisms that would contribute to the multiple objectives of on-farm viability, sustainable development, resilience and capacity building and associated community development. Initially the forces impacting on farming and associated rural communities at the local, regional, national and international levels had to be identified. This provided a context in which the knowledge, creativity and energy of people is captured, providing the grass roots input required in dealing with the situation, the process and its outcomes.

20.3.2 Outcomes

Marketing works on informing potential consumers of what is available to them to consume. It is a difficult task to undertake in a region as diverse as Western Sydney which produces a wide range of products. In the year 2000 a map of the region was produced to inform consumers. It consisted of 13 destinations in the Hawkesbury LGA set up as a trail of discovery consumers could follow (and is known as the 'Original Hawkesbury Harvest Experience'). Since then tens of thousands of people each year have visited the Farm Gate Trail. In the seventh edition of the Hawkesbury Harvest Farm Gate Trail map, released in July 2011, 60 farm-based experiences and 20 complementary hospitality experiences were presented. This map extended the original Hawkesbury Harvest Experience to four other geographically based agri-tourism experiences in the Sydney Hills-Brooklyn, the Penrith Valley, Wollondilly and the South Coast.

A Hawkesbury Harvest brand has been established to represent fresh and local food in the context of the 160 kilometre (100-mile) radius from the centre of Sydney. One of its commercial members, Pepes Ducks Pty Ltd, uses the Hawkesbury Harvest brand on the packaging of its Grimaud Duck to indicate the product is fresh and grown in the Sydney region. Each Farm Gate Trail destination has the Hawkesbury Harvest logo displayed in a prominent position. This activity ties the Hawkesbury Harvest organisation to the 'food miles' movement, which could be considered both a blessing and a curse. A beneficial aspect of this connection is that consumers are aware and react to the message on food miles. The problem is that the food miles movement is both illogical and harks back towards the creation of natural monopolies, which are detrimental to consumers. Monopolies, as has been found in Sydney before, lead to higher prices and restrictions in supply.

Hawkesbury Harvest also has a role as a business incubator. An example of this is Kurrajong Native Foods. The owner of this successful local business, Lee Etherington, began with Hawkesbury Harvest in 2000 providing an eco-tourism experience at Kurrajong Heights. One tour group came across a native tree in fruit and it was suggested that the fruit be made into a value added product. This resulted in the development of a range of native food products which he sold through the farmers' market system. So successful was this move that the operator no longer runs the eco-tourism business. He has received enquiries from all around Australia and overseas about the product. The demand has been so great that he has had to reduce his presence in the farmers' market system to concentrate on the development of the national and international markets. The Kurrajong Native Foods hibiscus is found in many major airports and in quality food outlets around the world.

Hawkesbury Harvest has played a significant role in the development of the 'pick-your-own operations' on farms around Sydney. Two chestnut and walnut farms at Mt Irvine in the Blue Mountains can have more than 1000 people picking nuts on a weekend during the season. Virtually the entire crop is harvested by pick-your-own customers. One apple orchardist in north-west Sydney estimates that 40 % of his crop is harvested in this manner, with the balance of the crop sold through his farm gate shed.

In addition to farm gate sales, other mechanisms developed by Hawkesbury Harvest have increased the income stream of farmers. This has involved the development of direct marketing mechanisms associated hospitality industries. They include establishing Farmers' and Fine Food Markets, open farm days, special events and slow food activities. Hawkesbury Harvest is also involved with

'Schools Harvest', a program to engage school students in growing, preparing, cooking and serving of local food.

Hawkesbury Harvest does a lot to promote its activities. Many of its members have been featured on major lifestyle television programs across Australia. The 'What's happening on the Farm Gate Trail this weekend' segment is a feature of the Australian Broadcasting Commission (ABC) radio broadcast in the Sydney region. It is estimated that every Saturday morning it reaches an audience in excess of 100,000 people. Through this mechanism, the aim of Hawkesbury Harvest is to play a major role in engaging the Sydney urban community with its local peri-urban agriculture. It also contributes to a political base that will support its retention.

In 2010 the Hawkesbury Harvest Board contributed to the Australian Government report on the 'Drivers of regional agri-tourism and food tourism in Australia' (Ecker et al. 2010). This report led in 2011 to agri-tourism being included as a component of the Farm Ready program. This program aims to improve the adoption rate of risk and business management skills, new technologies and best practice management that will enable primary producers and industries to respond to the impacts of climate change. Through activities like this, Hawkesbury Harvest has played a role on the political stage, influencing policies and activities of governments.

20.3.3 The Wider Picture: Hawkesbury Harvest as a Role Model

Hawkesbury Harvest is emerging as Australia's leading example of multifunctional agriculture. This concept is based on the idea that agriculture has many functions in addition to producing food and fibre including environmental protection, landscape preservation, rural employment, community development, human health rehabilitation, value-adding, regional branding, agri-tourism and education (OECD 2000).

In regional NSW the Hawkesbury Harvest concept is a template for the development of Southern NSW Harvest (SNSWH) which extends across thirteen LGAs in the southern part of the state. SNSWH has also embraced the multifunctional agriculture concept.

The Western Australian Government's Department of Agriculture and Food and the Department of Planning are investigating how the Hawkesbury Harvest model can be applied to Perth's peri-urban area to ensure ongoing agricultural land use in the context of loss of export markets, competition from cheap imports, free trade, the power of the supermarket duopoly and climate change. The Victorian Government consulted with the Hawkesbury Harvest board members in the preparation of its report, 'Inquiry into Sustainable Development of Agribusiness in Outer Suburban Melbourne' (Parliament of Victoria 2010).

20.4 Conclusion

Hawkesbury Harvest is a grass roots innovative concept, supported by the three levels of government, which emerged and developed in response to factors that directly impacted on the rural communities in Western Sydney. It is an empowering process and provides the opportunity for those players to have some control of their economic and social destiny within the context of the factors that are causing them concern. In so doing it provides the opportunity and means for those players to take responsibility for the environmental impact of their activities. Improving the quality of life is the ultimate outcome.

In essence The Hawkesbury Harvest is a model for marketing agricultural products and ecosystem services in a competitive environment. In the past the region relied on its natural monopolistic advantage provided by proximity and before that reinforcement by government sanctions. However, with the development of transport services these advantages were eroded. The region was further disadvantaged by the relentless pressure of urbanisation which accompanied its proximity to the largest city in the country. What Hawkesbury Harvest allows its (traditional) communities to do is manage this process of urbanisation in a way that does no harm and they would be harmed if they were isolated and exposed to the pressures of land development. The Hawkesbury Harvest model does not rely on compulsion to achieve its outcomes as anyone is free to partake or leave the organisation at any time; unlike the marketing models that preceded this one and that relied on maintaining its monopoly powers in one way or another.

Finally, it could be asked: How long can Hawkesbury Harvest survive? The answer to that question is as long as it needs. Ultimately the agricultural producers and communities in the region will succumb to the pressures of urbanisation. Those producers and the people in the communities will be enticed to part with the assets they purchased for a low price which are now highly valuable. If they are not so enticed, then a following generation will be, as this has been the process that has been at work in peri-urban regions for a long period of time. Once the numbers become critically low, the organisation will fold and in doing so its work will have been achieved. That work is to manage the process of urbanisation in a peri-urban region, marketing the products and services from its traditional communities in a way that is compatible with a modern competitive economy. Peri-urban regions will always, by definition, exist around cities and the organisation is made to move with the peri-urban as has happened in Sydney. As a concept that could be applied anywhere, it has real and tangible benefits over a model that attempts to protect producers and insulate them from market forces.

References

ABS (2011) One in four Australian adults obese. Available at http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbyReleaseDate/01ADF9FA15B6AAB3CA25789C0023DCE3?OpenDocument

Burke M (2009) Constrained harvests: a historical view of land use planning and nutrition in Australian cities. Healthy cities—making cities liveable conference program, 25th Mar 2009

Buxton M, Tieman G, Berkessy S, Budge T, Mercer D, Coote M, Morcombe J (2006) Change and continuity in peri-urban Australia, state of the peri-urban regions: a review of the literature (monograph 1). RMIT University, Melbourne

Chittleborough C, Grant J, Phillips P, Taylor A (2007) The increasing prevalence of diabetes in South Australia: the relationship with population ageing and obesity. Public health 121(2): 92–99

Davidson B (1981) European farming in Australia: an economic history of Australian farming. Elsevier Scientific Publishing, Amsterdam

Ecker S, Clarke R, Cartwright S, Kancans R, Please P, Binks B (2010) Drivers of regional agri-tourism and food tourism in Australia, ABARE and BRS, Australian Government http://adl.brs.gov.au/data/warehouse/pe_abarebrs99001744/Agritourism_2010_REPORT_11a.pdf. Accessed Mar 2012

Gaynor A (2005) Harvest of the suburbs: an environmental history of growing food in Australian cities. University of Western Australia Press, Crawley

Gillespie P, Mason D (2003) NSW agriculture environmental planning and management sub-program: the value of agriculture in the Sydney region. NSW Agriculture, Sydney

Hawkesbury City Council (2000) Hawkesbury social plan: Hawkesbury community survey. Hawkesbury City Council, Windsor

Isaacs B (2010) Identifying and characterising resilient urban food systems to promote population health in a changing climate: Domain 0—characterising food sub-systems in the Sydney basin. NCEPH, Canberra

Karskens G (2009) The colony. Allen and Unwin, Sydney

King CJ (1948) The first fifty years of agriculture in New South Wales. Rev Market Agric Econ 16:362–386

Knowd I, Mason D, Docking A (2005) Urban agriculture the new frontier. Changing City Struct 23:1–22

Mason D, Knowd I (2010) The emergence of urban agriculture: Sydney, Australia. Int J Agric Sustain 8(1–2):62–71

NSW Agriculture (1998) Strategic plan for sustainable agriculture—Sydney region, NSW agriculture, orange, NSW. Available at http://www.dpi.nsw.gov.au/environment/landuse-planning/agriculture/sydney. Accessed Mar 2012

NSW Planning (2005) City of cities: a plan for Sydney's future: metropolitan strategy, NSW department of planning, Sydney. www.metrostrategy.nsw.gov.au/dev/uploads/paper/introduction/index.html

NSW Planning (2010) Metropolitan plan for Sydney 2036. Available at http://metroplansydney.nsw.gov.au/Home.aspx. Accessed Mar 2012

OECD (2000) Agricultural policies in OECD countries: monitoring and evaluation. OECD, Paris

Parliament of NSW (2008) The governor of NSW. Available at www.parliament.nsw.gov.au/prod/web/common.nsf/key/resourcesSystemTheGovernorofNewSouthWales. Accessed Mar 2012

Parliament of Victoria (2010) Inquiry into sustainable development of agribusiness in outer suburban Melbourne, outer suburban/interface services and development committee, Government Printer, Melbourne. http://www.parliament.vic.gov.au/osisdc/inquiries/article/980. Accessed Mar 2012

Reay L, Webb K (1998) Penrith food project. Triennial Report, Penrith City Council

Spearritt P (1999) Sydney's century: a history. UNSW Press, Sydney

Sinclair I (2001) Lifestyle living, in: a view from the edge: issues in rural and metropolitan fringe planning. New planner 49. Planning Institute of Australia (NSW Division), Sydney

Sinclair I (2003) Western Sydney rural land use study. Prepared for department of infrastructure, planning and natural resources by Edge Land Planning, Bowral

Sydney City Council (2011) Greening Sydney plan. Available at http://www.cityofsydney.nsw.gov.au/Council/OnExhibition/documents/Plan-Greening_Sydney_PlanDOCUMENT-FinalDraftpre-exhibitionSet2011.PDF. Accessed Mar 2012

WSROC (2009) Greater Western Sydney regional organisation of councils. Community profile: 2001 and 2006 enumerated census information, created 20/11/2009, ID consulting Pty Ltd

Chapter 21
Protected Horticulture in Peri-urban Areas: An Alternative for Meeting Future Challenges of Malnutrition and Livelihood Security

R. A. Kaushik and K. D. Ameta

Abstract Rapid urbanisation in India faces several challenges and among them food and nutritional security appear to be the most important to feed the millions in these new urban hubs. As the majority of the population is vegetarian India needs fresh fruit and vegetables to meet their dietary needs. Under these circumstances we need quality horticultural produce along with higher production levels. On average an Indian household spends about 50 % of its expenditure on food items. Growing fruit and vegetables in and around cities increases the supply of fresh, nutritious produce and improves the urban poor's economic access to food. Cultivation of vegetables offers distinct advantages in quality, productivity and a favourable market price to growers. Vegetable growers can substantially increase their income by protected cultivation of vegetables in the off-season as the vegetables produced during their normal season generally do not fetch good returns due to large supplies in the market. Growing urban middle class requires a regular supply of quality and high value vegetables to fulfil their demand. MPUAT in Udaipur, Rajasthan (India) has carried out research work on this aspect which is reported in this paper to give an idea about the cultivation, economy and marketing of some high value horticultural crops in different types of greenhouses under Udaipur conditions. Technology has been found very effective in producing horticultural crops out of season and economically viable crops that can be successfully utilized to combat some of the future challenges of urbanisation.

Keywords Green houses · Peri-urban · Protected cultivation · Vegetables

---

R. A. Kaushik (✉) · K. D. Ameta
Department of Horticulture, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur 313001 Rajasthan, India
e-mail: kaushik_ra@yahoo.co.in

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_21,

21.1 Introduction

India is the second largest producer of fruit and vegetables, after China, but productivity is not on a par with global norms (production of vegetables in 2009–2010 was 133.7 million MT). India's share in the global market is 41 % in Mangoes, 36 % in Green peas, 30 % in Cauliflower, 23 % in Bananas and 10 % in Onions (Kaushik 2012). Horticultural crops are grown on 7–8 % of gross cropped areas and contribute over 18 % of the gross value of agricultural output. Horticultural crops account for half of the export earnings from agricultural produce. The farm value of significant fruit and vegetables is estimated at over US$13 billion (Kaushik 2012). Rapid urbanisation, increased literacy and rising per capita incomes have all caused rapid growth and changes in demand patterns, leading to many new opportunities for exploiting this large latent market. The average Indian household spends about 50 % of its expenditure on food items. Growing fruit and vegetables in and around cities increases the supply of fresh, nutritious produce and improves the urban poor's economic access to food. India has recently entered into the area of protected vegetable cultivation with a total area under protected vegetable production of about 25000 ha. As India is a vast country with diverse and extreme agro-climatic conditions the protected cultivation technology can be utilized for year round production of high quality horticultural crops, for raising virus free seedlings, production of off-season vegetables, hybrid seed production of high value vegetables and as a tool for disease resistance breeding programs.

A growing urban middle class requires a regular supply of quality vegetables for their nutritional requirements, and Central and State Governments want to avoid 'scarcities and price peaks' in the lean production months. High priority has been accorded under the Horticulture Mission to promote protected cultivation, particularly for cultivation of vegetables under greenhouses and shade net houses in the peri-urban areas.

People have food security when they are able to grow, or buy, enough food to meet their daily needs for an active, healthy life. Poor urban households spend from 60 to 80 % of their income on food which makes them highly vulnerable when food prices rise or their incomes fall. The Food and Agricultural Organisation of the United Nations (FAO) estimates that in the wake of global food price inflation in 2007/2008, and the subsequent economic recession, the number of chronically hungry people in the world has risen by at least 100 million to more than one billion people (Growing Greener Cities 2013). The greatest increase has been among the urban poor, women and children. Fruit and vegetables are the richest natural sources of micronutrients but in developing countries, daily fruit and vegetable consumption is just 20–50 % of FAO/World Health Organization (WHO) recommendations. In India diet-related chronic diseases, such as diabetes, are growing health problems and occur mainly in urban areas. Urban and peri-urban horticulture helps developing cities meet all those challenges. Firstly, it boosts the physical supply of fresh, nutritious produce available year round. Secondly, it improves the urban poor's economic access to food by reducing their food bill. Thirdly, growers can earn a living from vegetable sales.

21.2 Methodology

A model hi-tech horticultural unit was established at the Rajasthan College of Agriculture, Udaipur with the financial support of Rs. 282.00 lakh from ICAR, New Delhi. The college aim is to make the Mewar and Hadothi regions a horticultural bowl of Rajasthan and develop entrepreneurship in the area of protected cultivation, of vegetables, flowers and medicinal and aromatic plants. This forced ventilated greenhouse with cooling system is the first in Rajasthan and three naturally ventilated green houses have already been installed. Rose, gerbera, capsicum and cucumber are being produced and marketed. Also three poly houses for nurseries (128 m^2 each) have been established to produce disease free, good quality vegetable seedlings of improved varieties for supply to the farmers. A fully controlled computerised fertigation unit and drip irrigation systems have been installed in all the green/poly houses. Also, the horticulture farm at the Rajasthan College of Agriculture has been totally modernized. This farm is providing not only quality planting material but it also assists in the dissemination of new technologies for increasing income and livelihood security. Small replicable models of the hi-tech horticulture units have also been established under NAIP in some villages. Every KVK will have such units in the near future so that farmers can receive training and gain knowledge about new technologies.

With this infrastructure the university aims to achieve the following objectives:

- Improve the living standards of the farming community by achieving higher quality yields at a minimal cost of production.
- Provide customized practical training programs in horticulture, bridging the gap between theory and practice through innovative practical programs.
- Serve as a major demonstration-cum-training centre.
- Train personnel in the areas related to commercial horticulture and promoting agricultural entrepreneurship.
- Demonstrate advanced horticultural technology for the promotion of entrepreneurship in Horticulture.
- Provide training on technical aspects of fruit, vegetable and flower production.

There are several types of protected cultivation and depending upon the climatic conditions and economic status of the grower they may choose any of the options listed in Table 21.1.

One of the objectives was to find suitable crops and then standardize technologies for their cultivation and to achieve this objective we tried different vegetable

Table 21.1 Comparison of cost of production of vegetables under different protected structures

S. no.	Kind of protected structures	Cost (Rs./m^2)	Suitable crops	Duration crops (days)	Yield (t/l000 m^2)	Break even cost (Rs./kg)
1	Climate controlled greenhouse	3,200–3,500	Tomato	320	18.0	22–25
			Cucumber	300	6.0	45–50
			Sweet pepper	360 (4 crops)	25.0	20–25
2	Semi-climate controlled greenhouse	1,400–1,500	Tomato	290	20.0	15–18
			Cucumber	260	5.0	35–40
			Sweet pepper	280 (3 crops)	15.0	15–18
3	Naturally ventilated greenhouse	500–600	Tomato	270	16.0	8–9
			Cucumber	240	4.0	18–20
			Sweet pepper	280	15.0	7–8
4	Insect proof net-house	80–100	Sweet pepper	200–240	3.5–4.0	15–16
5	Plastic low tunnels	5-6	Summer squash	90–95	5.0–6.0	1.5–2.0
			Musk melon	110–120	2.0–3.0	3.0–4.0
			Bitter gourd	110–120	1.0–1.5	4.0–5.0
			Bottle gourd	80–90	2.0–3.0	3.0–4.0

Source Singh (2004)

crops (cucumber, coloured capsicum, tomato and cherry tomato) with different growing season, varieties, plant geometry and fertilization along with plant canopy management practices. The results obtained are discussed below.

21.3 Results and Discussion

Different high value vegetables such as cherry tomato and parthenocarpic cucumber were grown in both types of greenhouses during different seasons and a standard package of practices have been developed. Some of the results obtained by Kaushik and Ameta (2010) and Ameta et al. (2011) are summarized as follows:

- Standardized the package of practices for cultivation of high value horticultural crops like capsicum, cucumber, tomato, and gerbera in different types of greenhouses under climate conditions of Southern Rajasthan.
- Extended the growing season of vegetables (year round) with a slight modification (provision of foggers) in the naturally ventilated greenhouses.
- Developed a technique for raising quality planting material of horticultural crops through pro trays. Optimum time of sowing and media in plug trays has been standardized and as a result the optimum time of sowing seed in pro tray is deemed to be the period between the last week of December to mid-January when seedlings became ready. Farmers can prepare seedlings for the field in advance when it is occupied by other rabi crops. After mid-January temperatures rise and the weather becomes suitable for warm season crops. By this technique one can harvest produce at least one month earlier and fetch higher prices (Singh

and Sirohi 2002). The significant growth and survival rate was observed to improve with media containing vermiculite, perlite and cocopeat in the ratio of 1:1:2 on a volume basis.

- Among the exotic processing tomato variety 'H 9881' was found to be promising with respect to yield and processing quality. This variety gave significantly maximum fruit yield, total sugar, pulp recovery percentage and ascorbic acid content.
- It was concluded that capsicum should be grown at a spacing of 45 × 45 cm and retaining four shoots for gaining higher fruit yield per unit area under controlled poly house condition.
- The cucumber cultivar Hilton was found to be the best and plant spacing (60 × 30 cm) gave highest yield per unit area under naturally ventilated greenhouse conditions. Fertigation practice recorded significantly a higher yield (14.49 kg/m^2) as compared to the conventional method (13.22 kg/m^2).
- Cherry tomato cultivar BS.834 should be grown at a spacing of 75 × 60 cm along with NPK at 250:125:125 kg ha^{-1} fertigation practices for sustaining the higher fruit yield and quality under zero energy polyhouse conditions at Udaipur.

Cucumber (*Cucumis sativus* L.) is one of the most popular cucurbitaceous crops of Rajasthan and India. Being a warm season crop cucumber is mostly cultivated in rainy season, whereas growing cucumber during autumn–winter and spring–summer seasons provides an off season supply to the market. This is not possible under open field conditions because of unfavourable climates and damage due to insects and pests. Hence, producing cucumbers using cost effective plastic naturally ventilated greenhouses is advantageous (naturally ventilated greenhouses are protected structures where no heating or cooling devices are provided for climate control). These are simple and medium cost greenhouses which can be erected with a cost of Rs. 600–800/m^2 and provide an alternative for raising crops in periods of scarcity. This also ensures a year round supply of fresh produce with more efficient resource utilization. Protected cultivation also enables vegetable growers to realize greater return per unit area and offer other benefits, like early harvest, longer harvest duration and efficient use of fertilizers. Increasing demand for high quality cucumbers in big cities and particularly during off season can fetch higher prices. Three crops of cucumber can be grown in a naturally ventilated greenhouse in a year (Singh et al. 2004). Tomato and coloured capsicum are also important crops which remain in high demand year round especially in peri-urban areas. In poly houses production of quality tomatoes is possible irrespective of seasons with 5–6 times more yield compared to open field (Singh et al. 2005). Similarly, coloured capsicum can be grown in poly houses with good economic feasibility (Singh et al. 2002).

The benefits of technology have been reported from other parts of India and several countries. In Bolivia, FAO helped to introduce community greenhouses and micro-gardens in the municipality of El Alto, where 70 % of residents live in poverty and 40 % of children under five are malnourished (Growing Greener Cities 2013).

Some 1,500 families were trained to grow a wide variety of vegetables, herbs, medicinal plants and fruits in small, low-cost greenhouses. The result was a general improvement in child nutrition and family savings (averaging US$30 a month), which were spent on eggs and meat. These findings further support and justify promoting protected cultivation in India.

21.3.1 Major Constraints in Protected Cultivation of Horticultural Crops

- The initial construction and operational cost of climate controlled greenhouses is very high.
- Regular power supply is required for operating cooling and heating systems in the greenhouses which is problematic in the country.
- Very little work on standardization of designs of greenhouses and other protected structures has been done for different agro-climatic regions of the country.
- Non-availability of tools and implements for facilitating crop production operations under greenhouses like electric vibrators for pollination in greenhouse tomatoes.
- Lack of quality planting material.
- Vegetable production technologies of potential crops under different greenhouse conditions for various agro climatic regions of the country have not been standardized and documented.

  In several areas, such as Delhi, solar radiation in certain critical periods may limit the yield of some vegetables like sweet pepper during foggy winter months (Singh and Sirohi 2004).

21.3.2 Future Thrust for Protected Cultivation of Horticultural Crops in India

- Breeding of suitable varieties and hybrids in vegetables and other horticultural crops is an urgent research priority for development of this technology in India.
- Development of regional and crop cultivation practices for important crops.
- Development of location and region specific suitable greenhouse designs to lower costs.
- More efforts on techniques for water saving and water harvesting should be made for protected horticulture.

- The nursery industry in India is still very weak, which is one of the main reasons that the quality of vegetables and flowers is not high. There is an urgent need to develop a stronger nursery industry to produce quality planting material of horticultural crops.
- The market of greenhouse cladding material and accessory equipment needs to be expanded in the country and the material should be made available at a reasonable price to the growers.

In this context, under the present scenario of perpetual demand for vegetables and drastically shrinking land holdings, protected cultivation of vegetable crops suitable for domestic and commercial purposes is the best alternative for using land and other resources more efficiently. Protected horticulture is a labour intensive industry, which provides a good opportunity for Indian horticulture products to sell in overseas markets especially after India's entry in the World Trade Organization. There is no doubt that protected horticulture specially the protected cultivation of vegetables and flowers in India will become increasingly important in near future.

21.4 Conclusions

Increased population pressure on Indian cities and shrinking land due to industrialization and urbanization make protected horticulture a viable option to meet the food and nutritional requirements of the large Indian urban population. Scientific research work is needed on this aspect and some work has already been initiated in this direction, but there is a need to invest heavily in this sector, train farmers, provide construction material at low cost and near to the production sites. Development of greenhouse production technologies, which may vary from region to region (Indian being a vast country) is also essential for the success of the programme. All these efforts will provide quality produce to the consumer, reduce pressure on transport, generate employment and provide better returns to the growers.

References

Ameta KD, Kaushik RA, Dubey RB, Pareek S (2011) Standardization of raising seedlings of cucurbits in plug trays for off season cultivation. In: Proceedings of the international conference on issues for climate change, land use diversification and biotechnological tools for livelihood security, Meerut (UP), 8–10 Oct 2011, pp 150

Growing Greener Cities (2013) FAO. http://www.fao.org/ag/agp/greenercities/en/whyuph/index.html. Accessed 11 Dec 2013

Kaushik RA, Ameta KD (2010) Protected cultivation of Horticultural crops—a boon for peri urban areas. In: Proceedings of 4th Indian horticulture congress-2010, New Delhi, 18–21 Nov 2010, pp 173

Kaushik RA (2012) Horticulture revolution—through post-harvest management, processing and value addition. In: Proceedings of 12th national convention, RCA, alumni association, Udaipur, Rajasthan, 22 Jan 2012

Singh B, Sirohi NPS (2002) High tech nursery raising technology for vegetables. Indian Hort 47(3):22–24

Singh B, Sirohi NPS (2004) Protected cultivation of vegetables in India: problems and future prospects. In: Proceedings of the international symposium on greenhouses, environmental controls and in-house mechanization for crop production in the tropics and sub-tropics, Pahang, Malaysia, 15–17 June 2004, pp 121–125

Singh B, Kumar M, Singh A, Singh V (2004) Economic feasibility of cucumber cultivation under greenhouses. Agric Ext Rev 16(4):28–30

Singh B, Neubauer E, Sirohi NPS (2002) Performance of sweet pepper varieties under high-tech greenhouse condition of northern plains of India. Paper presented in international conference on vegetables, Bangalore, India, 11–14 Nov 2002, pp 191

Singh B, Kumar M, Vasanthan B (2005) Techno-economic feasibility of tomato cultivation under naturally ventilated greenhouse cultivation. Fertilizer News 50(2):51–53

Singh B (2004) Status of protected horticulture in the world and its future prospects in India. Invited paper presented in the international seminar on recent trends in hi-tech horticulture and post-harvest technology, CSAUA&T, Kanpur (UP) India, 4–6 Feb 2004, Souvenir pp 40–50

Chapter 22
Constraints and Opportunities of Urban and Peri-urban Dairy Production in Central Tigray of Northern Ethiopia

Tesfaye Gebrekidane, Rohatash Kumar Bhardwaj and S. K. Gangwar

Abstract The purpose of this study was to explore the constraints and opportunities of dairy production in the urban and peri-urban areas of central Tigray, Northern Ethiopia. A total of 160 dairy holding households were selected for the study by a systematic random sampling technique. Feed shortage and inadequate land were ranked as the first and second order constraints in urban and peri-urban areas respectively. Diseases followed by waste disposal were rated as the third and fourth order constraints in urban areas whereas a lack of exotic breeds ranked third in the peri-urban areas. Increased demands of dairy products, increased farmers' awareness about dairying and access to credit services were some of the opportunities to increase dairy production in the area. The problem of availability of feed and land were significant both in urban and peri-urban areas and it has to be addressed both in terms of utilisation and management.

Keywords Constraints · Dairy cattle · Opportunities · Urban · Peri-urban · Dairy production · Tigray · Ethiopia

22.1 Introduction

Urban and peri-urban dairy production has been developed in response to the fast growing demand for milk and milk products. During the past 2 decades a rapidly increasing urban population size has created better markets and a growth of the demand for dairy products. Currently, the price of milk in major towns of northern Ethiopia, including central Tigray, has increased from 3 to 6 ETB (Ethiopian birr) per litre over the last 2 years. Moreover, comparable increases in prices of

T. Gebrekidane · R. K. Bhardwaj (✉) · S. K. Gangwar
UNDP, MOHE, Mekelle University, Mekelle, Ethiopia
e-mail: dr_rohitaash@yahoo.co.in

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_22,

processed dairy products such as butter, hard cheese and fermented milk has been observed in the region (Negussie 2006). This situation is an opportunity and has potential for the development of milk production and processing industries in urban and peri-urban areas of the region.

However, studies on urban and peri-urban dairy production are sparse in Ethiopia, and, in the study area in particular, most of the efforts are directed towards rural agricultural activities. The few studies carried out so far are concentrated in and around Addis Ababa, the capital city of the country. As a result, urban and peri-urban dairying is not well incorporated in the country's research agenda and the overall agricultural development program. Given the new urbanisation trends, urban dairying is becoming an important agricultural activity around major urban and peri-urban centres, and should be institutionalised to cater to the rising demands. This requires the development of relevant strategies and site specific interventions for dairy development in urban and peri-urban dairy production. Thus this paper examines the constraints and opportunities of existing dairying systems, to understand the need for mainstreaming.

22.2 Materials and Methods

The study was carried out in the central zone of the Tigray region, Northern Ethiopia. Central Tigray Zone is one of the five zones in Tigray National Regional State. The zone approximately extends between 13°15′ and 14°39′ North latitude, and 38°34′ and 39°25′ East longitude. The altitude of the zone mainly falls within the category of 2000–3000 masl. A large part of the zone receives a mean annual rainfall ranging from 400 to 800 mm. The mean monthly maximum and minimum temperatures of the zone are 30 and 10 °C, respectively (NMSA 1996). Central Tigray zone is bound by Eritrea in the north, East Tigray zone in the east and south east, West Tigray zone in the west and Amhara National Regional State in the south. The central zone, with the ancient city of Axum as its capital, encompasses ten *woredas* (districts) and has the largest human population in the region.

The specific study sites were Adwa and Axum urban and peri-urban areas at distances of 1006 and 1024 km from the capital city of Ethiopia Addis Ababa respectively. These two districts were selected purposely based on their conducive agro-ecological conditions for dairy production and a large human population in the zone.

A cross sectional survey was carried out with a pre-tested questionnaire, and a multi-stage sampling technique, to collect data on the constraints and opportunities of dairy production. First, cattle holding households were categorized as either urban or peri-urban based on distance to the city. Axum and Adwa, the larger towns in the zone, were considered as urban. The smaller towns of Wukro, Dura, and Mahiber-selam are found around Axum. The remaining small towns of Bete-Hanis, Debre-genet and Gendebta and Mariam-shewito are found around Adwa. All these small towns are found within a 20 km radius of the centres of the two larger towns and are considered as peri-urban. Farms were then categorised into large (>10 dairy cattle), medium (5–10 dairy cattle) and small (<5 dairy cattle) according to the guideline of ILRI (1996). Finally, based on the sampling frame obtained from the District Office of Agriculture, a total of 160 cattle holding households were chosen using systematic random sampling technique (Table 22.1). To analyse the information, a ranking analysis was undertaken. Hence, in the preference ranking method, an index was computed with the principle of weighted average and indexes were ranked against each other using auto ranking with MS-excel 2007. The following formula was used to compute an index as employed by Musa et al. (2006).

$$\text{Index} = R_n * C_1 + R_{n-1} * C_2 \cdots + R_1 * C_n / \sum R_n * C_1 + R_{n-1} * C_2 \cdots + R_1 * C_n$$

where, R_n = value given for the least ranked level (example if the least rank is fifth, then $R_n = 5$, $R_{n-1} = 4$, $R_1 = 1$), and C_n = Counts of the least ranked level (in the above example, the count of the fifth rank = C_n, and the count of the first rank = C_1).

22.3 Results and Discussion

22.3.1 Factors That Hinder the Productivity of Dairying in the Study Area

According to the respondents, there were various challenges faced by the dairy cattle holding households. These included feed shortages, land problems, shortage of water, inadequate access to veterinary drugs and services, lack of improved dairy animals, unavailability of credit services, inadequate extension service and lack of knowledge and skills. Among these problems, feed scarcity, land problems, poor extension services, water shortage, lack of exotic breeds, waste disposal and limited access to veterinary services were the major problems identified by the respondents (Table 22.1). But in both urban and peri-urban areas feed shortages and land problems were ranked first and second respectively. Diseases were the third most important constraint in urban areas whereas lack of exotic breeds ranked third in the peri-urban areas.

22.3.1.1 Inadequate Feed Resources

Dairy farms faced problems related to availability of feed and fodder. With regards to a change in land use, a large proportion of respondents indicated that grazing lands have been continuously converted to crop lands or utilised for commercial

Table 22.1 Constraints of dairy production in the study area

Constraints	Location			
	Urban		Peri-urban	
	N (index)	Rank	N (index)	Rank
Inadequate land	72 (0.26)	2	66 (0.21)	2
Feed shortage	78 (0.27)	1	79 (0.29)	1
Poor extension service	48 (0.09)	6	55 (0.12)	5
Disease	60 (0.14)	3	61 (0.14)	4
Lack of exotic breed	48 (0.113)	5	60 (0.16)	3
Waste disposal	46 (0.114)	4	28 (0.04)	6
Others	8 (0.015)	7	14 (0.03)	7

N number of respondents, *1* most serious constraint, *7* less serious constraint

purposes as a consequence of urbanisation. This has emanated from an increase in human population and the expansion of urban areas leading to overgrazing of the limited natural pastures and land degradation. For these reasons, feed shortage has become a serious problem for dairy cattle farmers in the study area. There is a serious problem in exploiting the genetic potential of improved dairy breeds due to the lack of good quality year round feed at the farm level. In addition to this, there is significant seasonality of fodder supplies and concentrate prices.

The quantity and quality of feed resources supplied to the animals was found to be below the requirement of animals both in urban and peri-urban areas and this has been well recognised by dairy farmers and reported as a severe problem. For higher milk yields, the high-grade dairy type animals raised in the majority of the urban larger farms have higher nutrient demands which further exacerbate the problem. Moreover no feed processing plant is established in the area apart from the small scale flour factories in Axum and Adwa that produce a limited quantity of wheat bran. The increased cost of feed in the study area relative to other parts of the country caused by the above problems resulted in insufficient nutrition, which was expected to decrease the productivity of cows and raised the mortality of calves.

The major feed resources were natural pasture and crop residue and these are of poor quality affecting the fertility of cows and milk production. Similarly, Zelalem (2007) reported that shortage of feed is the first priority in Bahir Dar urban and peri-urban areas. Ranjhan (1999) also reported that feeding systems in smallholder dairying are primarily based on grazing of native pasture with low productivity. This also agrees with the report of Leng (1999) who indicated that feed resources from crop residue (straw and stover) and pastures (both green and mature) are of low digestibility and on these feed resources the overall productivity of animals is reduced. Animals reach puberty at a later age and the calving interval is prolonged resulting in a fewer number of dairy animals being milked and therefore the productivity and reproductive performance is reduced.

22.3.1.2 Inadequate Land Size

A majority of the interviewed households, both in urban and peri-urban areas, reported inadequate land size as the major constraint hindering farm expansion, product processing and the construction of appropriate facilities. Consequently they ranked this as the second important constraint that holds back dairy development both in urban and peri-urban areas. It was also pragmatic that some dairy farms even shared the same room with the family and others rented land. In line with this study, Zelalem (2007) ranked land as a second constraint both in Bahir Dar urban and peri-urban areas. Moreover, there was environmental pollution from wastes that calls upon strict regulations set by the municipality. Similarly Yoseph et al. (2003) and Lobago et al. (2007) also reported, where urban farmers have only a very small amount of available land, the animals are mostly kept in the backyard. The inadequacy of land limits the farmers trying to grow improved forage in their backyard. These situations prohibited farmers from maximizing production possibilities through efficient use of low cost inputs. The total land area owned by the farmers was very small; less than a hectare. Therefore, land availability was the main limiting factor for dairy production and farm expansion so it needs to be addressed.

22.3.1.3 Animal Health Aspects

Disease was also presented as a major constraint to cattle production in the study area. Dairy producers in the urban area ranked disease as a third priority next to feed and land problems. Improved animal health care is essential as unhealthy animals pose a serious loss of food and income. Diseases often rank, with the availability of feed resources and nutrition, as the major constraints to production. Some of the reasons reported were poor service giving, unavailability of drugs in the clinic and the high price of drugs. Similarly, Tambi et al. (2001) reported that, a variety of diseases (e.g. mastitis and brucellosis) affect the calf and milking cow. Losses due to disease are variable across countries and are dictated largely by the level of management, knowledge base, access to drugs and services and the efficiency of extension services.

In the peri-urban areas respondents ranked animal health as the fourth problem and they use the traditional healer and different types of herbs to treat their animals as an alternative. According to the respondents and personal observations in the study area, there was a shortage of veterinary experts. Similarly, Ibrahim and Olaloku (2002) reported that poor animal health service and lack of improved management are the major constraints for dairy development in Ethiopia, which caused poor performances across the production systems.

22.3.1.4 Unavailability of Improved Dairy Cattle Breeds

In the peri-urban areas where the majority of small herds (small farms) are found the lack of exotic breeds was ranked as a third priority (Table 22.1). Those small farms were dominated with local zebu breeds. Bulls were commonly run with cows all year round and breeding is thus uncontrolled. As cattle herders do not use control breeding, the reproduction of their cattle was primarily regulated by seasonal feed availability. Cattle breeds available, particularly in the peri-urban areas, were mostly indigenous and the major disadvantages of the local cattle are: low productivity, failure to let milk down without the presence of a calf and late maturity. However, these cattle are well adapted to the local feed resources, local housing facilities and scavenging systems.

There has been little effort made to improve milk production through cross-breeding in the peri-urban areas. During the group discussion, a need for an improved breed of dairy cattle has been stated as a major issue of concern in the peri-urban areas. Artificial insemination was found to be the major sources of exotic genes except some farms use exotic bull service and others purchase exotic breed cows from other towns and cities. In addition to this, there was no institution dealing with bull service provision and distribution of improved breed cows for milk production in both the urban and peri-urban areas apart from the farmers who were purchasing better productive dairy animals from other areas.

22.3.1.5 Institutional Services

Different types of institutional supports were required in order to develop the urban and peri-urban dairy production in the study area. These include extension services, credit provision services, creation of dairy farmer cooperatives and processing and marketing facilities. Since most of these dairy farmers particularly those found in the peri-urban areas had little formal education and hence have limited knowledge on dairy production. Moreover, there is a lack of coordination between organisations. The district Office of Agriculture and Rural Development, the city administration and the municipality were responsible for looking after the production system particularly in the urban areas. The district Office of Agriculture and Rural Development is playing the greatest role with its development workers. There is an obvious information gap as these organisations undertake activities on their own.

The district Office of Agriculture needs to increase the number of farmers involved in dairying and expand the sector. Whereas, the municipality is reluctant to allocate land for dairy production to the farmers and even set some rules and regulations with penalty systems by delineating zones where cattle should not appear. In the peri-urban areas, the major problems were not related to lack of coordination but to provision of services like training, supply of improved breeds, creation of cooperatives and marketing facilities. Although the importance of coordination of activities related to smallholder dairy production and marketing systems is recognised, the above situations indicate a lack of adequate cooperation. Such lack of coordination among the key institutions might hinder improvements of the dairy production particularly in the urban areas of the study.

22.3.1.6 Poor Record Keeping

In both urban and peri-urban areas of the study, no record keeping was practiced. If practiced at all, particularly in some commercial farms (like Tsehaye Reta dairy farm in Adwa), it was done in a disorganised manner and lacked consistency. Farmers are expected to keep daily records of all farming activities such as reproductive records, production records, health records and relevant measures taken. The records are so important for an improved level of production performance. These problems limited the identification of strengths and weaknesses of the farms and give advisory services by different support giving individuals and organisations. Hence, there is a need to train the producers on the importance of record keeping whenever they want to establish dairying in the study area.

22.3.1.7 Environmental Aspects

With the development of dairy production, competition between humans and animals coexisting in the same place was severe. Space was limited and there was also environmental pollution from animal manure. There are strict regulations for land use so farmers cannot build animal houses in their fields without permission from the municipality specifically in the urban areas. The study showed that farm size (land holding) was very small but on average farmers held 6.78 head of dairy cattle in the urban area and 4.83 in the peri-urban areas. While they are making great contributions to the dairy industry, urban dairy holding households are incapable of dealing with animal manure, which is one of the major factors affecting their dairy production in urban areas.

22.3.2 Opportunities of the Dairy Industry

Though there are many difficulties and limitations, the progress of dairying in the study area is promising due to the under mentioned factors.

22.3.2.1 Increased Demand for Milk

The fast paced urbanisation that is taking place around Axum and Adwa, which are the two larger towns in the central zone, together with a rapid increase in human population growth as well as analogous increasing demand for food, suggests there is good potential for dairy production. This is to say that rapid economic growth and increasing human population in the towns would create demand for milk and milk products, which in turn brings about a significant improvement in productivity of the dairy business. This would have a positive impact on the peri-urban dairy farmers as they could transport their milk to the high demand nearby towns.

22.3.2.2 Increased Farmers' Awareness About Dairying

Both the urban and peri-urban production systems in the study area are comprised of small-scale fresh milk producers. Small farm owners realised that they would not be competitive unless they increase their current level of production. They are in need of improved breeds to maximise production and obtain greater benefits from the farming systems. This situation was thought as an advantage towards dairy development in the study area in both the urban and peri-urban areas. Availability of Artificial Insemination (IA) technicians in both districts and better AI delivery systems could result in larger numbers of crossbred cows and improve the blood level of the local breeds, create better dairy stock, reduced costs and higher incomes for smallholders. Therefore, these all create a good opportunity for the dairy producers in the study area.

22.3.2.3 Access to Credit Services

Despite the dairy farmers' lack of awareness, there exists a number of credit offering institutions in the study area. These are the Debit Credit and Saving Organization and Commercial Bank of Ethiopia. Every farmer can have access to credit provided that he/she can fulfil the requirements of the rules and regulations of the institution from which he/she is planning to get credit. The district Office of Agriculture has an assignment to create awareness of credit services to farmers keeping dairy animals or intending to keep dairy animals.

22.4 Conclusions

Apart from the above improvements, different constraints and challenges which hinder the productivity of the dairy farm were identified. Feed shortage and inadequate land were ranked as the first and the second constraints in both urban and peri-urban areas. Disease followed by waste disposal were ranked third and fourth in urban areas whereas, lack of exotic breeds followed by disease problem were rated third and fourth in the peri-urban areas. Hence, any development interventions aimed at improving the productivity of dairy cattle and the livelihood of urban and peri-urban dairy farmers should be planned and put into practice in relation to the urban and peri-urban areas.

References

Ibrahim H, Olaloku E (2002) Improving cattle for milk, meat and traction. ILRI, manual 4. ILRI (International Livestock Research Institute), Nairobi, p 135

ILRI (1996) International livestock research institute. Annual project report. ILRI, Addis Ababa

Leng R (1999) Feeding strategies for improving milk production, pp 207–224. In: Smallholder dairying in the tropics. ILRI (International Livestock Research Institute), Nairobi, p 462

Lobago F, Bekana M, Gustafsson H, Kindahl H (2007) Longitudinal observation on reproductive and lactation performances of smallholder crossbred dairy cattle in Fitche in Oromia region, central Ethiopia. Trop Anim Health Prod 39:395–403

Musa LM-A, Peters KJ, Ahmed M-KA (2006) On farm characterization of Butana and Kenana cattle breed production systems in Sudan. Livest Res Rural Dev 18:56–61

NMSA (1996) Climatic and agro climatic resources of Ethiopia, vol 1, no 1. NMSA, Addis Ababa

Negussie G (2006) Characterization and evaluation of urban dairy production system in Mekelle city, Tigray region, Ethiopia. MSc. thesis, University of Hawassa, Awassa

Ranjhan SK (1999) Dairy feeding systems, 117–132 pp. In: Smallholder dairying in the tropics. ILRI (International Livestock Research Institute), Nairobi, p 462

Tambi E, Nicholson C, Staal S, Thorpe W (2001) Patterns of change in dairy production and consumption in developing countries from 1985 to 1998. Market-oriented Smallholder dairy research working document 7. ILRI (International Livestock Research Institute), Nairobi, 65 pp (in press)

Yoseph M, Azage T, Alemu Y (2003) Evaluation of the general farm characteristics and dairy herd structure in urban and peri-urban dairy production system in the Addis Ababa milk shed. In: Challenges and opportunities of livestock marketing in Ethiopia. Proceedings of the 10th annual conference of the Ethiopian society of animal production, held in Addis Ababa, Ethiopia, 22–24 Aug 2002. Ethiopian society of animal production, Addis Ababa (Ethiopia) ESAP, pp 39–144

Zelalem A (2007) Milk yield losses due to blind mammary quarters and occurrence of clinical mastitis in milking cows of urban and peri-urban areas of Bahir Dar, Ethiopia. MSc. thesis, Hawassa University

Chapter 23
Challenges and Opportunities for Recycling Excreta for Peri-urban Agriculture in Urbanising Countries

Olufunke Cofie, Daniel Van Rooijen and Josiane Nikiema

Abstract As urbanisation increases, so does the challenge of meeting water, sanitation and food requirements in urban areas. In particular, the management of human excreta from on-site sanitation facilities remains a challenge and continues to endanger public health and degrades the environment through soil and water pollution. Yet much of the excreta consist of organic matter and nutrients that are valuable inputs for agriculture. Recycling in agriculture has often neglected the recovery of nutrients and organic matter in faecal sludge collected from on-site sanitation facilities in developing countries. Exploring the high proportion of resources in excreta can provide a win–win strategy by reducing the environmental pollution, enhancing soil fertility and therefore improving livelihoods. Challenges to maximising these benefits include: type of sanitation facility used in developing countries, nature of faecal materials, prevailing treatment technologies which are usually designed for waste disposal not for reuse, institutional and market factors as well as negative perceptions regarding excreta use in agriculture. Nevertheless, urban and peri-urban agriculture presents a good opportunity for nutrient recycling, provided that technological and socio-economic strategies for optimum recovery are taken into account. The paper concludes with a description of successful recycling options that can contribute to improving farm productivity, using evidence from Ghana.

Keywords Sanitation · Urban · Excreta · Urine · Agriculture

O. Cofie (✉) · J. Nikiema
International Water Management Institute, Accra, Ghana
e-mail: o.cofie@cgiar.org

J. Nikiema
e-mail: j.nikiema@cgiar.org

D. Van Rooijen
UNICEF, Nairobi, Kenya
e-mail: dvanrooijen@hotmail.com

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_23,

23.1 Introduction

Nowadays, farming in and around cities, commonly referred to as Urban and Peri-urban Agriculture (UPA), prevails in urbanising countries. This phenomenon is sustained by the following factors: (1) the increase in food demands and changes in diets in cities, from the traditional high energy staple food to more diversified food crops including vegetables; (2) the prevalence of nutrition-related health problems due to inadequate or unbalanced diets; (3) the dependency of low-income urban dwellers on emergency food sources during civil unrest and wars; (4) the existence of market opportunities due, e.g. to growing number of food establishments such as restaurants, hotels, fast food places, supermarkets; and (5) the availability of treated/untreated wastewater for crop irrigation. There is therefore an important linkage between sanitation and UPA as liquid/solid wastes can be turned into agricultural inputs.

On the other hand, rapid urban growth and changing water and food consumption patterns generate increasing amounts of solid and liquid wastes including excreta. Yet, the present infrastructure and installed treatment capacities are generally insufficient to adequately collect and treat wastewater (Van Rooijen 2011). This is particularly critical in densely populated urban agglomerations, where it causes environmental pollution and impairs public health. On-site and unsewered sanitation facilities such as latrines, aqua privies and septic tanks are the predominant options for capturing excreta either at the household level or in shared facilities such as public toilets. Globally, about 2.4 billion urban dwellers rely on such on-site installations. Wastes captured in such on-site facilities, which are collectively called Faecal Sludge (FS), must be emptied either mechanically or manually (e.g. more than 200 million toilets are desludged manually) and treated for disposal. Unfortunately, in many developing countries, FS is often discharged into open drains, nearby water bodies and open spaces, without proper treatment (Koné et al. 2010; Kvarnström et al. 2012).

23.2 Sanitation in Urbanising Countries

One of the main constraints for sanitation in urban areas is the growing densities which exert pressure on land, thereby making the installation of latrines more difficult (Koné et al. 2010). This situation is likely to continue if the urban population continues to grow at a current average rate of 2.4 % for sub-Saharan Africa (UNFPA 2011). In West Africa for instance, 19–73 % of the urban population uses a shared sanitation facility (Fig. 23.1; JMP 2012; WHO/UNICEF 2012). Ghana is a country highly affected by this phenomenon. Obirih-Opareh and van de Geest (2001) reported some of the reasons for the increasing use of public toilets by residents in Accra, the capital city, to include: high cost of building and operating their own

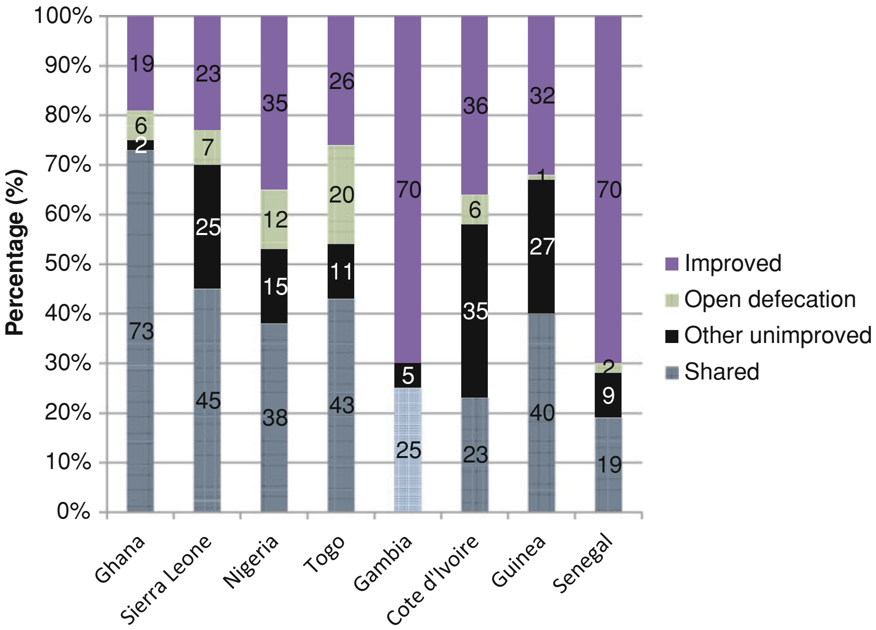


Fig. 23.1 Use of sanitation facilities in urban areas of selected countries of West Africa having a high proportion of the population using a shared sanitation facility (WHO/UNICEF 2012)

toilet, lack of water for the preferred flush toilet, general misconception among the population that money should not be wasted on toilets (until the 1990s no user fee was charged for the use of public toilets in Accra, Ghana). Hence over the years, there has been an increasing demand for public toilets and presently, 73 % of the Ghanaian urban population (58 % as national average) depend solely on public and other shared facilities (JMP 2012). Public urinals are also common installations especially in central business districts in major cities. Urinals are not always equipped with a water connection and usually, effluents flow directly into the drain.

Indeed, up to 85 % of the sanitation facilities in many developing countries are unsewered (Montangero and Strauss 2002). Therefore, on-site sanitation facilities are mostly connected to septic tanks for storage of excreta. When the tanks are full, the contents are desludged and transferred to designated dumping sites or treatment plants, where available, which unfortunately is rare in many countries. In Ghana, for example, out of the 70 wastewater and faecal sludge treatment plants constructed since the 1960s with a design capacity to serve up to 25 % of the urban population, less than 10 % of public treatment plants are operational (Murray and Drechsel 2011; IWMI 2012). Thus, a large proportion of excreta that is generated every day is not treated notwithstanding that, up to 35 % of the budget of municipal government is spent on environmental sanitation annually (GOG 2010).

23.3 Excreta and Urine for Use in Urban and Peri-urban Agriculture

Human excreta are excellent fertilizer, rich in organic matter and essential plant nutrients such as nitrogen, phosphorus and potassium. Each year, humans excrete about 500 l of urine and 50 l of faeces. These contain around 30 kg organic matter (i.e. 10 kg of carbon), 4 kg of nitrogen, 0.5 kg of phosphorus and 1 kg of potassium (Jönsson et al. 2004). While most of the organic matter is contained in faecal matter, most of the nutrients (88 % of the nitrogen, 67 % of the phosphorus, and 71 % of the potassium) are found in urine (Heinonen-Tanski and van Wijk-Sijbesma 2005) in forms that are readily available for crops. It is being claimed that the excreta produced annually by a single person contains nearly enough nutrients to grow the amount of grain (250 kg) required to meet the nutritional needs of that person (Drangert 1998; Jönsson et al. 2004).

Apart from its fertilising ability, the organic matter from decomposed excreta serves as a soil conditioner, a property not shared by chemical fertilisers; it improves soil structure, increases water-holding capacity, reduces pests and disease and neutralises soil toxins and heavy metals (Esrey et al. 2001). The phosphorus concentration in faeces aids in the development of roots and young plants. Faeces also act as a good soil conditioner by contributing to increasing the ion-buffering capacity of the soil due to the addition of macro and micro-nutrients as well as organic matter. The recycling of faeces to complement inorganic fertilizers could also reduce environmental pollution from sludge dumping sites. So, excreta from urban areas can be used as an input to sustain UPA productivity. In some parts of India and Ghana for example, human excreta has been used in agriculture for decades (Cofie et al. 2005, 2010). Faeces can only be safely used as a fertiliser after it has been treated suitably (e.g. extended storage of >1 year; composting or co-composting) to kill off intestinal worm eggs and other pathogens that might be present.

Human urine can be collected separately from faeces in public urinals or where urine diverting toilets are used. Risk assessments have established that human urine is safe to use if stored for 1–6 months (WHO 2006; Richert et al. 2010). The level of safety depends on type of storage (e.g. in simple plastic container or concrete structures provided with a seal to avoid ammonia loss), temperature and other local logistical conditions (Lennartsson and Ridderstolpe 2001).

No toxicity to plants has been detected from the use of urine, but urine can be contaminated with small amounts of heavy metals and pharmaceuticals which come from the body. The content of heavy metals, which relates to the food consumption, is less than that in commercial fertilisers (Lennartsson and Ridderstolpe 2001). The dynamics of pharmaceutical contaminants in urine is not yet fully understood.

The volumes of urine generated in cities are significant. An investigation of 20 urinals in the central business unit (CBU) in Accra recorded a total urine generation rate of 7264 l/day (2.2 million l/yr). The annual nitrogen and potassium generation rates at the urinals were also estimated from patronage values and are 13 and 6 t/yr respectively, i.e. 0.08 and 0.2 % of Ghana's nitrogen and potassium imports in 2005, respectively. Nevertheless, faeces and urine fertilizers are not often chosen by UPA farmers who prefer animal manure because of a lack of knowledge, negative perception and the health risk associated with excreta use.

Recovery of nutrients for use in agriculture will require some changes in policy (the practice still remains outside existing legal frameworks) and infrastructure, resources and most importantly, a market for the products (Tettey-Lowor 2008). This will then open up a business opportunity for small scale entrepreneurs in urban sanitation services (Kvarnström et al. 2012).

23.4 Challenges in Recycling Excreta

Various challenges are associated with the recycling of excreta in urban and peri-urban agriculture. These include: separation and storage of urine and faeces, necessary capacity for excreta collection, nature of faecal sludge being biochemically unstable, adjusting treatment technology to reuse, and lack of supportive institutional framework.

When stored separately from faeces, urine is highly sterile and therefore requires little treatment for reuse (Jönsson et al. 2004). Most of the pathogens in excreta are in faeces (Adamtey et al. 2009). The rate of FS production is a function of the amount and quality of food consumed, liquid intake, climatic conditions and the level of activity undertaken by an individual. Given an estimated rate of 1 l FS/cap/day, a city of million inhabitants will generate 1000 m^3 of FS to be collected daily. This presents a management challenge to municipal authorities; hence in reality about one third or half of what is generated is collected (Koné et al. 2010).

The challenge associated with the recovery of nutrients from FS is exacerbated by the variability in the characteristics of FS. The characteristics are influenced by the level of dilution, the means of storage, storage duration, temperature, intrusion of groundwater into storage vessel, performance of storage vessels, size of the storage vessel and the tank emptying technology and pattern (Heinss et al. 1998). Sludge with a low retention time in the septic tanks is high in biological oxygen demand as well as in ammonium and pathogen concentrations (Table 23.1) and is considered biochemically unstable. On the other hand, sludge with a longer retention time in the septic tanks is biochemically more stable due to the longer storage period. All these factors impart distinctive characteristics on FS in contrast to sludge from conventional wastewater treatment plants as found in developed countries. In fact, the pathogen concentration in FS is higher than that of municipal wastewater by a factor of 10–100 (Montangero and Strauss 2002). The implication is that it is difficult to treat such FS. The widely varying characteristics of FS require careful selection of appropriate treatment options.

Some low cost technology options for the treatment of FS include use of settling/thickening tanks or waste stabilisation ponds; drying beds; constructed wetlands; anaerobic digestion with biogas utilisation; land application in hot arid and semi-arid regions and composting (Koné et al. 2010). Although resource

Table 23.1 Characteristics of faecal sludge mixture in Kumasi, Ghana

Parameter	Average concentration	Typical low-strength FS	Typical high-strength FS
pH	8.1	–	–
EC (μS/cm)	17,685	–	–
TS (mg/l)	30,450	≤20,000	≥35,000
TVS (% of TS)	71	–	–
SS (mg/l)	14,600	10,000–14,000	≥30,000
COD (mg/l)	38,200	<20,000	20,000–50,000
BOD (mg/l)	10,000	–	–
NH_3–N (mg/l)	1,500	<1,000	2,000–5,000
Helminth eggs (no./l)	14,600	≈4,000	20,000–60,000

Source Adapted from Cofie et al. (2005)
EC electrical conductivity, *TS* total solids, *TVS* total volatile solids, *SS* suspended solids, *COD* chemical oxygen demand, *BOD* biological oxygen demand

recovery is possible from some of these systems, it is not usually designed for that purpose. Many municipal decision-makers are well aware, though; that developing and applying sound recycling strategies would greatly contribute to alleviating management problems. There will be a need to redesign treatment technologies to treat waste for re-use. Moreover, institutional frameworks and technology for recycling is lacking and will need to be considered for effective recycling processes. Along the sanitation value chain, the conscious focus on recycling has hitherto been missing, albeit it is beginning to emerge.

23.5 Opportunities for Recycling Excreta

In UPA, small farms are established on vacant lands, along roadsides, on house frontages, and in valleys. These soils are prone to degradation due to continuous cropping. This kind of farming can only be sustained through adequate replenishment of the organic matter (OM) and nutrient contents. Several opportunities exist for recovering nutrients and organic matter from FS to enhance UPA productivity. Three of them are discussed here, by describing the recycling process, required investments, risks and potential for scaling up.

23.5.1 Urine as (Liquid) Fertilizer

Urine is collected from urinals or Urine-Diverting Dehydration Toilets (UDDT's), then sanitised and used as fertilizer in UPA. The required investment are: urinals or UDDT's; urine storage tanks jugs for collecting the waste; jugs for selling the fertilizer; a means of transportation of the waste to point of use. Occupational and consumer risk are minimal if properly handled. Potential for scaling-up is limited to backyard gardening or farms not too far away from the point of urine collection. Potential use is possible after some value addition e.g. through crystallisation. Some practical examples have been documented in Africa, Asia and Europe (von Münch and Ingle 2012).

23.5.2 Land Application of Faecal Sludge

The recycling process is agricultural land application of raw faecal sludge with an integrated on-farm risk reduction strategy. Raw FS is spread on the land during the dry hot season, allowed to remain on the field for 3–4 months before ploughing into the soil to grow crops that are not consumed raw (e.g. cereals). The recycling scheme is a win-win situation for farmers and sanitation services, although it is seasonal. No infrastructure is required for treatment. Vacuum trucks for transporting faecal sludge from cesspits/latrines are redirected against a token to farmlands. Primary cost of the practice could be the training of farmers to apply safe handling practices. Costs are limited to costs for transportation of the raw sludge to the field. High crop yields and cost savings on fertilizer translate into an increase in farmers' revenue which on average could be threefold greater for those using FS than those not using any product (Cofie et al. 2010). FS contains a high pathogen load; however, the application can help to control those risks. Some farmers will need to wear protective clothing during application.

The application of FS to fields during the dry season and the extended drying period prior to spreading it as well as restricted application to selected crops, such as cereals; facilitate pathogen inactivation and consumer risk reduction. Epidemiological studies (Seidu 2010) confirm the safety of the practice for consumers and also for farmers as long as drying periods are maintained. Land application of FS is socially accepted by farmers in many towns in the Sahel, and its effect on yields and cost-savings enhance its desirability. The main constraints are its seasonal character and its stigma of health risks. The latter prevents authorities from supporting the practice despite its obvious benefits.

23.5.3 Faecal Sludge Composting and Co-composting with Organic Solid Waste

This recycling process is faecal sludge treatment using unplanted drying beds and aerobic composting. Investment requirements are land and infrastructure, including sealed platforms, roofing, filter material (gravel, sand), storage space. Costs, primarily on the operating expense, are labour. A pre-identified market with reliable demand and willingness to pay is essential for long-term sustainability of sales. In terms of the occupational risk, solid waste requires manual sorting and compost is manually turned; both activities present opportunities for exposure to pathogens and other contaminants. Risks to workers can be mitigated by wearing protective clothing. A 2–3 months composting period produces compost in compliance with WHO standards for pathogen reduction (Cofie et al. 2008). There is potential for scaling up this recycling option. The biggest challenge is financing for capital investment; secondary challenges include consumer and community acceptance, market demand and transport costs. Wider adoption at scale could take place if the product is fortified with some mineral fertilizer or Pelletization (Adamtey et al. 2009; Nikiema et al. 2013).

23.6 Conclusions

Municipal authorities in many cities face enormous difficulties, in coping with a massive population growth and associated challenges, with meeting basic human needs such as water, sanitation, and food. The urban water system itself is complex with multiple stakeholders and parallel planning and implementation processes. The related challenges are also complex, interlinked and involve many actors. In research, the linkages between water, sanitation and agriculture have been acknowledged by various researchers (Niemczynowicz 1999; Van Rooijen 2011). An integration of the required improvement could benefit all water use sectors and improve water use efficiency while reducing environmental pollution.

In order to realise the potential that the water-sanitation-agriculture nexus offers in urban agglomerations, significant shifts in conventional thinking on urban water and sanitation management will be essential. An established link to respond to urbanisation related water, sanitation and food challenges lies in the recycling of excreta for food production. Urban and peri-urban agriculture creates an avenue for recycling readily available urban organic wastes and human excreta, thereby improving the productivity of farming systems as well as environmental health.

Development planners, policy makers, and society at large need to realise the potential opportunities and challenges that lie in the productive use of these waste resources for urban livelihoods. One radical shift will be to see public sector officials actively integrating their thinking on urban planning with an approach that enables the combination of public sector resources and private sector self-interest. Involving the necessary people through multi-stakeholder processes can help in this regard.

References

Adamtey N, Cofie O, Ofosu-Budu GK, Danso SKA, Forster D (2009) Production and storage of N-enriched co-compost. Waste Manage 29:2429–2436

Cofie O, Kranjac-Berisavljevic G, Drechsel P (2005) The use of human waste for peri-agriculture in northern Ghana. Renew Agric Food Syst 20(2):73–80

Cofie O, Abraham EM, Olaleye AO, Larbi T (2008) Recycling human excreta for urban and peri-urban agriculture in Ghana. In: Parrot L, Njoya A, Temple L, Assogba-Komlan F, Kahane R,

Ba Diao M, Havard M (eds) Agricultures et développement urbain en Afrique subsaharienne. Environnement et enjeux sanitaires. L'Harmattan, Paris, pp 191–200
Cofie O, Adeoti A, Nkansah-Boadu F, Awuah E (2010) Farmers perception and benefits of excreta use in southern Ghana. Resour Conserv Recycl 55:161–166
Drangert JO (1998) Fighting the urine blindness to provide more sanitation options. Water South Africa 24(2):157–164
Esrey SA, Andersson I, Hillers A, Sawyer R (2001) Closing the loop: ecological sanitation for food security, UNDP, SIDA, 96 pp
GOG (2010) Government of Ghana, national environmental sanitation strategy and action plan. Ministry of local government and rural development, Accra, Sept 2010
Heinss U, Larmie SA, Strauss M (1998) Solids separation and pond systems for the treatment of faecal sludges in the tropics. SANDEC report no 05/98, 2nd ed, 57 p
Heinonen-Tanski H, van Wijk-Sijbesma C (2005) Human excreta for plant production. Bioresour Technol 96(4):403–411
IWMI (2012) WP2: assessment of biotechnological practices—case study. Water biotech project, Ghana, 48 p
JMP (2012) Progress on drinking water and sanitation, 2012 update. p 60 http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-report-2012-en.pdf. (date of visit 28 Nov 2012)
Jönsson H, Richert Stintzing A, Vinnerås B, Salomon E (2004) Guidelines on the use of urine and faeces in crop production. Report 2004–2. EcoSanRes publications series. Stockholm Environment Institute, Stockholm, p 35
Koné D, Cofie O, Nelson K (2010) Low-cost options for pathogen reduction and nutrient recovery from faecal sludge. In: Drechsel P, Scott C, Raschid-Sally L, Redwood M, Bahri A (eds) Wastewater irrigation and health: assessing and mitigating risk in low income countries. Earthscan, London, pp 171–188
Kvarnström E, Joep V, Mats N, Vishwanath S, Shubha R, Karan S (2012) The business of the honey-suckers in Bengaluru (India): the potentials and limitations of commercial faecal sludge recycling—an explorative study. (occasional paper 48), The Hague. IRC International Water and Sanitation Centre. Available http://www.irc.nl/op48
Lennartsson M, Ridderstolpe P (2001) Guidelines for using urine and blackwater diversion systems in single-family homes. Coalition Clean Baltic, Uppsala, p 22
Montangero A, Strauss M (2002) Faecal sludge treatment. Lecture notes, IHE Delft, SANDEC, Delft, 14 Feb 2002
Murray A, Drechsel P (2011) Why do some wastewater treatment facilities work when the majority fail? Case study from the sanitation sector in Ghana. Waterlines 30(2):135–149
Nikiema J, Cofie O, Impraim R, Adamtey N (2013) Processing of faecal sludge to fertilizer pellets using a low-cost technology in Ghana. Environ Pollut 2(4):70–87
Niemczynowicz J (1999) Urban hydrology and water management—present and future challenges. Urban Water 1:14
Obirih-Opareh N, van de Geest S (2001) Toilet and sanitation in Ghana an urgent matter. Institute of Scientific and Technological Information (INSTI) of CSIR, Accra
Richert A, Gensch R, Jönsson H, Thor-Axel S, Linus D (2010) Practical guidance on the use of urine in crop production, EcoSanRes. Stockholm Environment Institute, Stockholm, p 69
Seidu R (2010) Disentangling the risk factors and health risks associated with faecal sludge and wastewater reuse in Ghana. Dissertation, Department of Mathematical Sciences and Technology, Norwegian University of Life Sciences
Tettey-Lowor F (2008) Closing the loop between sanitation and agriculture in Accra, Ghana. Dissertation, Wageningen University
UNFPA (2011) State of world population 2011: people and possibilities in a world of 7 billion. United Nations Population Fund, New York, p 132
Van Rooijen DJ (2011) Implications of urban development for water demand, wastewater generation and reuse in water-stressed cities. Case studies from South Asia and sub Saharan Africa. Civil and building engineering, Loughborough University. Loughborough, PHD: 190. PhD 2011

von Münch E, Ingle R (2012) Compilation of 25 case studies on sustainable sanitation projects from Africa. Sustainable Sanitation Alliance (SuSanA) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany

WHO/UNICEF (2012) joint monitoring programme for water supply and sanitation. progress on drinking water and sanitation. 2012 update UNICEF, New York, WHO, Geneva, p 60

WHO (2006) Guidelines for the safe use of wastewater, excreta and grey water: wastewater use in agriculture, vol 2. World Health Organization, Geneva

Chapter 24
Nutrient Recycling from Organic Wastes Through Viable Business Models in Peri-urban Areas in Sub-Saharan Africa

G. Danso and P. Drechsel

Abstract A major challenge of urbanisation, for relevant decision makers, is the provision of sufficient food and water for the emerging mega-cities and appropriate peri-urban sanitation management. This paper focuses on the results of a project carried out by International Water Management Institute (IWMI) in three major cities in Ghana. The project was designed to provide decision support for nutrient recycling from organic waste in peri-urban areas, through waste composting or co-composting with nightsoil. Experiences of existing compost stations from Nigeria, Benin, Mali, Burkina Faso and Togo were taken into consideration to formulate the research framework. Apart from the technical aspect, the study looked at actual waste supply and its quality, a quantification of the compost demand as well as economic viability of different scenarios and legal implications. The analysis showed that from the city perspective cost savings are only possible if large volumes of waste can be composted to reduce waste transport costs while compost sale (and agricultural use) is not a necessity from the perspective of cost savings. In fact, despite much interest the farmers' willingness to pay remained limited at the reservation price of US$5 per 50 kg bag. As this includes transport costs peri-urban areas will be those benefiting most from composting projects. Closing the *rural*-urban nutrient cycle appears unrealistic given the increasing transport distance; at least as long as smallholder farmers are targeted. However, the consideration of alternative customer segments and implementation of innovative business models could help in reaching different scales.

Keywords Food security · Water security · Decision support · Waste recycling · Economic analysis

G. Danso (✉) · P. Drechsel
International Water Management Institute (IWMI), Colombo, Sri Lanka
e-mail: gdanso@cgiar.org

P. Drechsel
e-mail: p.drechsel@cgiar.org

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_24,

24.1 Introduction

Sub-Saharan Africa (SSA) is experiencing one of the fastest rates of urbanization in this decade especially in peri-urban areas with large coastal cities, such as humid West Africa, where today already more people live in peri-urban areas than in rural areas. These peri-urban areas are growing because of rural migration which is coupled with natural population growth. This ever increasing trend in peri-urban populations has not only brought about congestion and waste generation but also put stress on the countries with limited resources and services, which are already suffering from food insecurity, malnutrition, unemployment, poverty and deterioration of the environment. Policy makers in these countries have started to respond to these challenges. Usually, the provision of sufficient food and basic sanitation services are the major challenges in urban centers and increasing peri-urban areas. Both challenges are linked as the urban food supply contributes significantly to the generation of urban waste (Drechsel and Kunze 2001).

In an attempt to revitalize the urban environmental deterioration and ensure urban food security, there is the need to recover nutrients from organic waste for food production. There are several benefits that could be derived from this approach; for instance if it is well planned, the costs of waste disposal could be reduced and the funds saved could be invested in composting or other productive sectors of the economy. However, what appears like a logical win–win situation for city authorities and farmers is uncommon in the developing world. A combination of factors account for urban areas not being able to successfully operate composting stations as a review across Togo, Benin, Nigeria, Mali and Burkina Faso showed. The study showed that Municipal authorities often consider composting as a high-risk, low-yielding business venture. Too often, stations were set up as initial funds were available but no analysing was undertaken regarding the different segments of the recycling loop, especially the institutional settings, demand and marketing, and related profitability analysis. In fact, the data showed that most stations under study were not financially viable, unless social and environmental impacts are valued. This was however not the case and at the point of writing only one of the studied stations was still in operation (Oyo State Pace Setter Organic Fertilizer Plant in Ibadan, Nigeria) because of a strong partnership between local community and the university.

In general, the case studies showed that compost stations in the sub-region suffer from one or more of the following omissions: (1) Missing market and feasibility analysis (no consideration of alternative soil inputs, transport costs, farmers demand and willingness to pay etc.), thus unsustainable compost sales (2) Missing strategic partners, thus—for example—unsustainable waste collection or compost marketing (3) Missing (maintenance) funds after initial set up, thus unable to address equipment breakdowns (4) Missing legal frameworks and difficult land access, thus subject to conflicts. All these points enforced the need for using multiple criteria when analysing the potential feasibility of compost stations. It became obvious that comprehensively planned composting stations, based on a business plan are an exception as confirmed from India (Rouse et al. 2008).

There are various reasons, like the traditional dependency of the sanitation sector on public subsidies and the overwhelming challenges faced by waste management authorities. Given the priority needs of "waste collection" and "safe disposal", which consumes half of the municipal budgets in low-income countries as cost recovery is low, it is understandable that for many authorities recycling appears a "luxury" given their limited resources and more urgent priorities (Drechsel et al. 2010, 2011). In order to develop decision support on the possible scale of composting in three Ghanaian municipalities a multi-criteria approach was used. This paper describes the result of the project which was funded by the Canadian International Development Research Center (IDRC).

24.2 Description of Study Area

In Ghana, the feasibility of composting at scale was studied in Accra, Kumasi, and Tamale. All these cities are located in a different agro-ecological zone (Fig. 24.1) from the humid forest belt to the border of the Sahel, i.e. along a trajectory of declining biomass availability. Accra, the capital, is located on the coast with about 1.6 million inhabitants at the time of the research. Population growth rate of Accra is approximately 3.4 % per annum in the city itself but up to 10 % in its peri-urban districts (Obuobie et al. 2006). Kumasi is located in the humid forest zone and had in the study period a population of about 1 million and an annual growth rate of 6 %. Tamale is in the northern savannah zone with a population of 200,000 with a comparatively low growth rate of 2.5 % (Ghana Statistical Services 2002).

24.3 Research Approach and Methodologies

The overall objective of the project was to analyse the possible scale of municipal composting and to understand possible strategies to close the rural–urban nutrient cycle, which would consequently help to preserve the quality of the urban environment by reducing waste accumulation and the pollution effects thereof. It aimed, in a more concrete sense, at decision support for the Municipalities on composting options which should—in short—be viable in a specific city context. The idea was to go beyond any theoretical idea of compost production and use and to work on a realistic, qualitative and quantitative assessment of all related strengths and weaknesses. Figure 24.2 presents the framework (nutrient recycling loop) used for this project.

The nutrient recycling loop has the following study segments:

1. The **supply** of organic waste (production, quality, quantity, time, availability),
2. The **demand** for waste compost (who, where, how much, when, perception, possible price),

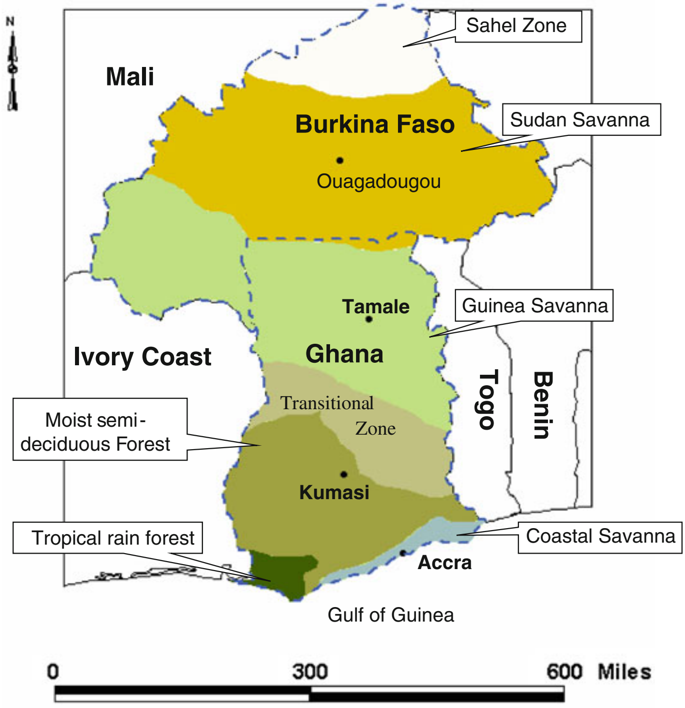


Fig. 24.1 Main study sites (Accra, Kumasi, Tamale)

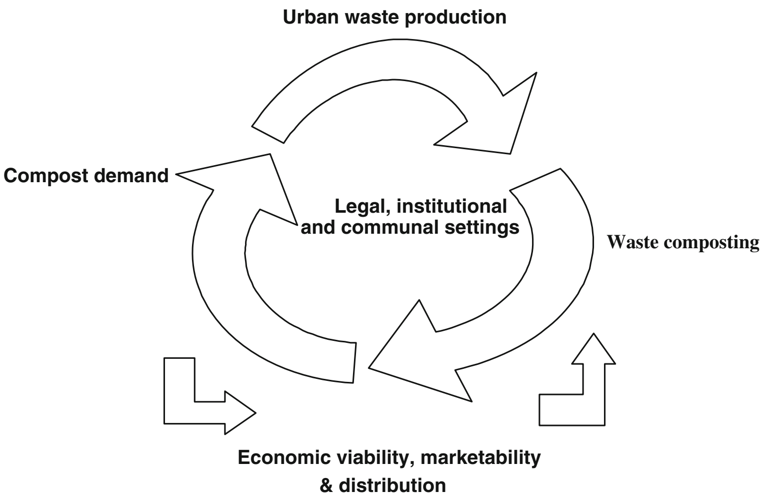


Fig. 24.2 The project framework with the five study segments of the loop

3. The **process** of waste composting including the determination of optimal number, capacity, and location of compost stations per city (linked to segment 1, 2 and 4),
4. The **economic** analysis linking supply, demand and process segments,
5. **Legal, institutional and communal** factors affecting the set-up and sustainable management/ownership of compost stations.

The successful implementation of the project was based on a 'multidisciplinary research problem and stakeholder analysis' and conducted by a competent project team involving more than 15 different university departments in the three cities and supported by European universities, which emphasizes the multidisciplinary nature of the study. Other stakeholders were urban and peri-urban farmers, the community suggested station locations, municipal authorities, especially the waste management departments, schools, and parts of the private sector.

24.4 Methodologies for the Various Segments of the Recycling Loop

24.4.1 Supply Analysis

The key question was: *Where* within the rural–urban zone is *which* amount of waste of *what* kind of quality and *when available* for composting? With this question, the supply segment focused on the various types, amounts, quality, present and potential usage, current value and availability of organic municipal waste for composting. Only major sources were considered (markets, households, agro-industry, abattoirs, septage, timber mills, etc.), because of data availability and the cost of data collection. The data was collected through: Firstly, secondary data collection on the amount, location, quality and disposal of municipal waste from the waste management departments, Non-Government Organizations (NGO) or relevant research projects: Secondly primary data collection of organic waste producers using stratified random sampling techniques per product; Thirdly, we conducted a laboratory analysis of the amount of nutrients in the waste as well as potential contaminants including heavy metals and *Escherichia coli*. Following the nutrient recycling loop presented in Fig. 24.2, the methodology differed between the segments of the loop.

24.4.2 Demand Analysis

The demand assessment started with the characterization of all potential buyers under consideration of their willingness-to-pay (WTP) and ability-to-pay (ATP). As part of the demand analysis, the optimal distribution of compost to various buyers was assessed. The demand analysis also considered socio-cultural aspects, production economics, attitudes/perceptions of the users of waste compost (e.g., with or without nightsoil, i.e., faecal matter), and actual demand projections. Methods used to answer these questions were: (1) Identification of different potential buyers with and without experience in compost application in and around the cities. The identification process focused on the different urban and peri-urban (UPA) farming systems, as well as Parks and Gardens and estate and landscape developers. (2) This is followed by stratification (in terms of farming systems in urban and peri-urban areas, farm size, crops grown, current input use, number of buyers etc.) of the various potential and actual compost users to determine the number to be interviewed. (3) Development of structured questionnaires consisting of both open-ended and closed-ended questions. The open-ended questions gave the potential buyers the chance to express their views about the use of compost and other factors that will influence their WTP for it. Questionnaires were pretested in all cities. (4) For the assessment of attitudes and perceptions of buyers, individual interviews were followed by focus group discussions, differentiated by gender and buyers with and without experience of compost application. (5) Contingent Valuation Method (CVM) was used to assess potential buyers' WTP for compost. This involved direct questioning of individuals in a survey to determine if and how much they are willing to pay for waste compost in a hypothetical context. This exercise resulted in a bidding game which helped to determine the maximum amount the individuals are WTP for the compost. It was assumed that certain variables like income, age, sex, and experience with or no experience with compost, level of education etc. would have an influence on the individual WTP. Because of the dichotomous nature of the respondents' answers to the WTP questions (i.e., yes or no), the probit model was used to analyse the impact of these variables on their WTP, as compared to traditional ordinary least square (OLS) regression analysis. (6) To give the WTP analysis a reality check, the different UPA farming systems were analysed for their farm incomes and actual ATP for further soil inputs.

24.4.3 Economic Analysis

The first part of the analysis focused on possible ways of composting as well as the number of potential compost stations and station capacity, two factors which largely depend on the other two segments of waste supply and compost demand. The approaches used under this segment include: (1) Visits to related compost plants in Accra and neighbouring countries to observe, study, exchange and obtain information on the technical/operational, institutional and economic aspects of composting. In this regard, we studied different composting plants in Nigeria, Benin, Ghana and Togo which differ in scale and level of sophistication to allow us to determine and recommend the most appropriate technology and composting facility for each city in order to minimize system cost and maintenance requirements as much as possible. (2) A co-composting pilot station was built in Kumasi which provided the team with hands-on experience in station operation and different options for solid waste and faecal sludge co-composting. The co-composting station was built in collaboration with the city of Kumasi, the Kwame Nkrumah University Science and Technology (KNUST), and our Swiss partners of SANDEC/EAWAG. Field trials (three) were carried out to test different options and combinations of solid and liquid organic waste for safe use on farms and to provide healthy vegetables for consumers. The second part of the economic analysis linked the supply, demand and process segments of the above described nutrient recycling loop. It also used data on the viability of existing compost stations in the sub-region, the economic performance of the pilot station in Kumasi, and a comparison of the compost option with landfill and incineration.

Different scenarios (with and without subsidies) were calculated under consideration of different demand estimates, WTP and transport costs using a tool provided by GTZ-GFA (1999). Scenarios addressed different levels of technical sophistication and the actual and potential (but realistic) transport capacity of the city-specific waste collection system. The analysis included: (1) assessment of the viability of different compost stations in the sub-region (2) profitability and investment analysis for constructing and operating compost facilities in the example of Accra, and (3) a comparison of the economic and financial costs and benefits of composting, incineration and landfills considering set-up as well as running costs under the economic conditions of Accra. Besides computer-based simulation models, standard economic indicators, such as the Net Present Value (NPV) were used to evaluate the viability of different waste management options.

24.4.4 Institutional Analysis

The study dealt with the legal, institutional and administrative context within which composting and use of compost could be feasible. It involved an assessment of environmental and sanitation by-laws and policies as well as public awareness and the roles and perceptions of authorities and other stakeholders, especially community based organizations (CBOs) and Non-Governmental Organizations (NGOs) in waste management, with special regard to organic waste recycling. The key question was who should own and manage a planned compost station and who should be involved as a partner? The methods used included: (1) Study of the legal framework, sanitation policies, medium term plans, project plans and other documents; (2) Stakeholder identification through expert consultation; (3) Questionnaires for assessing strength, weaknesses, opportunities and threats of stakeholders as well as their perceptions through open interviews with municipal authorities, their clients and other interest groups (NGOs, CBOs, Projects, World Bank, etc.) and the private sector; (4) Focus group discussions with community leaders and community members on environmental issues, waste management, and organic waste recycling discussing possible scenarios of community-based compost station (perception, options, by-laws, realization potential, etc.); (5) Stakeholder clustering analysis based on their potential roles and linkages for the visualization of an institutional framework (Vázquez et al. 2003).

24.5 Results and Discussions

The following sections present the results associated with the segments of the recycling loop.

24.5.1 Supply of Waste and Demand for Compost

The analysis of the waste supply and demand segments of the recycling loop showed that the availability of organic waste is not the limiting factor for compost production in our study cities. However, the supply analysis was useful to avoid an overestimation of the amount of actual available organic waste to set an upper boundary for any compost plant. An important finding was that not every waste is available as there are often alternative uses (fodder, fuel, etc.) and seasonal variations. As could be expected, the largest share of waste derives from households (Table 24.1). However, this does not automatically make households the favourite source as their dispersed locations make the implementation and monitoring of waste separation and organic waste collection an expensive (transport) task.

Thus, organic waste from markets and agro-industries are usually more accessible for compost operators as their sources are concentrated in some few points and often also are of better quality for composting. Waste analyses conducted in Accra and Kumasi indicated relatively low levels of heavy metal contamination. Market waste combines very high organic content and a low risk of metal contamination. The analysis of the seasonality of the waste supply showed that more food products are produced, traded and processed in the rainy season than the dry season. As matured, dried compost can be stored, we concluded that there should be no significant seasonal shortage.

In relation to Demand segment of the loop, our assumption was that the design capacity of a municipal compost station(s) will largely depend on the quantification of the compost demand. The survey of different potential compost clients such as farmers growing vegetables, staple crops, fruits, and ornamentals indicate that most of the farmers have positive perceptions and are willing to use compost but mostly without any experience of it. The analysis showed that compost use, even from farm residues, is not common in Accra and Kumasi, although all farmers know the related "black soil" (Dark, mostly organic soil from old waste dumps, which is considered very valuable.). Farmers' interest in compost concerned both, a plant-growth enhancing (fertility) effect and soil amelioration. Large variations

Table 24.1 Waste and nutrients available for composting standardized per capita in case study cities in kg/head/year

Type	Accra	Kumasi	Tamale
Total available waste	153–220	223–243	49–58
Household waste	100–167	62	38–44
Market waste	44	58	9.6
Food processing waste	2.8	0	0
Abattoir waste	0	2.3	2.0
Sawdust	1.7	102–117	0
Settled sludge	3.4	1.1	2.9
Poultry manure	1.6	2.7	0
Total N	2.12–3.22	1.60–1.66	0.78–0.91
Total P	1.05–1.58	0.83–0.84	0.39–0.45
Total K	0.46–0.66	0.41	0.16–0.17

in WTP were recorded between farmers with and without compost experience and among different farming systems. Also, variations were observed between urban and peri-urban farmers, as well as between different cities with different compost alternatives. Although most of the farmers were optimistic about the potential of the addition of compost to the soil, the actual amount farmers were willing to pay was low (ranging usually between US$0.2 and 2.0 per 50 kg bag). A major reason was the availability and very low price of poultry manure in the study area. The reference price of compost reflecting a self-sustaining station was set as ca. US$3–5 per 50 kg bag. Only a relatively small group of commercial pineapple growers (and exporters) around Accra and cotton growers near Tamale expressed a corresponding WTP under the condition that product quality and (fertilizer like) packaging would be satisfactory. The WTP expressed by farmers who already used compost was in several cases lower than among non-users. This discouraging result was based on the unsatisfying performance of the existing compost produced in Accra (at the now demolished Teshie plant). The municipal compost produced at Teshie was low in nitrogen, especially when compared to farmer's favourite input poultry manure and tended to absorb the manually applied irrigation water which was not appreciated.

Without subsidies only a few farmers, mostly in compost station vicinity, could afford a viable compost production price of US$5 per 50 kg as transport cost would reduce their spending ability. Also scenarios assuming a fully subsidized production, showed spatial limitations in compost dissemination due to transport costs. The consideration of transport costs showed clearly that the idea to "close the rural/peri-urban nutrient loop" is not realistic even if compost is distributed for free. While it is feasible to transport high value (food) products over long distances with different middlemen into the city, it is not feasible to transport a low value product back the same way, unless the client can organize bulk transport (filling trucks which bring goods to the city but drive back empty) and sees value in the product. Another reason for low demand is the practice of shifting cultivation in rural areas, which has lower (opportunity) costs than any intensification measures. Thus mostly urban and peri-urban agriculture (UPA) with no or very short fallow periods could benefit from compost application. Another exception is commercial pineapple growers in Accra and cotton growers near Tamale. A significantly higher demand for compost was also estimated from housing (estate) developers than from farmers around the three cities. The house building sector is generally using black soil from local waste dumps for gardening and landscaping and is contributing to land degradation through topsoil mining in forests where black soil is scarce. If a policy could be applied where the use of compost became mandatory for all "black soil" suppliers of real estate companies then significant amounts of compost could be sold especially around the sprawling capital city. In comparison with agriculture, the real estate sector has much lower qualitative requirements as compost will mostly be used for lawns and ornamentals. Thus the real estate sector could be the "favourite" customer group with interesting options for private–public partnerships and win–win situations as the first example in Accra showed. The financial strength of the real estate sector could, in this set-up, even subsidize parts of the compost production for agriculture and organize compost transport. Another option for a new customer segment could be the tree crop plantations in Southern Ghana as their centralized management offers opportunities where the client arranges the transport to its out-growers. It would be worth exploring this with the Cocoa Board, rubber (plantation) industry and oil palm sector Ghana, like the Oil Palm Development Company Ltd. The existing cocoa and oil palm plantations operate on the basis of a nucleus estate with associated smallholder schemes and independent out-growers. The out-growers own and cultivate oil palm on their land, receive planting material and other inputs and technical advice from the companies (usually on credit) to whom they are contractually obliged to sell their product. Beyond agriculture and housing, other financially strong sectors might need organic materials for the rehabilitation of mining areas.

24.5.2 Economic Analysis of Composting

The studies revealed that all the stations surveyed in the sub-region were established (and are in part running) with financial aid and are not profitable. The survey also showed that these reasons are often poor partnerships with the local communities or a poor market analysis. The economic analysis was carried out for two contrasting years in terms of interest rate on borrowed capital on the assumption that whoever builds the compost station will have to pay for it, bearing in mind that the establishment will not be free. Thus all stations in the sub-region sell their compost under production value, which can vary between US$200 and 500 per ton of compost under consideration of discounted investment costs. Sales prices are usually in the range of US$15–30 per ton and often hardly covering station running costs. Even with consideration of collection fees etc., a deficit remains. A reasonable (unsubsidised) price would be US$60–100 per ton or US$3–5 per 50 kg to cover O&M costs. This, however, is hardly competitive in view of alternative local poultry manure (current price in Accra is US$1.5 per 50 kg) and black soil even with convincing evidence of its better quality than the available compost. A comparison of land-filling, incineration and composting in Ghana confirmed that no alternative is actually profitable. However, the overall cost of building and operating composting facilities in the Accra–Tema Metropolitan Area is much lower than the other two options. Furthermore, land-filling is about 95 % cheaper than incineration under prevailing Ghanaian conditions. The unavailability of land for landfills, incinerators and their transfer stations and the requirements for meeting environmental quality standards are the major causes of the high capital cost of land filling and incineration in the area. On the benefits side, composting urban solid waste appears to have the highest total economic benefits especially through labour-absorption. A combination of composting and land filling could be associated with higher economies of scope and scale than any single method.

The analysis considered two basic scenarios; (a) of a fully subsidized production and (b) a self-sustaining production. The later addressed the vulnerability of many stations due to common arrears in payments. It considered cost recovery, actual compost demand, station running costs and farmers' willingness to pay. Our municipal project stakeholders preferred the first scenario stressing that compost production already makes sense without any demand as it is reducing the waste volume. The general challenge we see is that potential/actual savings through composting were, in the case studies, used neither to invest in composting nor to maintain existing stations. One reason might be that the waste volumes were insignificant and station costs higher than any savings. The challenge would become even larger, if different public and private entities were in charge of compost station, waste collection and landfill operation. This confirms the need for a clear legal/financial framework describing tasks and duties, allowing savings in transport or landfilling to support compost production. While the project had its main focus on municipal compost stations, the municipal stakeholders stressed the importance (but also risks) of household composting. The general consensus was that household composting should not be mandatory (especially in low-income, high-density areas for risk of rodents) but focus on increasing, awareness among the households with the highest potential (middle income), particularly those with composting space in backyards and own demand for gardening.

24.5.3 Institutional Setting of Composting

The study did not only explore composting options with urban and peri-urban stakeholders but also canvassed the communities of possible compost stations to understand their perception and acceptance. In general, all institutions expressed their supportiveness and willingness to participate if a composting project was to be initiated. It was mentioned that in order to overcome obstacles, care must be taken in every planning stage that all stakeholders' inputs are considered.

The survey revealed a constellation of stakeholders' roles to play in project implementation based on the expertise and abilities of each organization. A cluster analysis was used to group the identified stakeholders into four general clusters—(1) Regulators: i.e. institutions in power to draft by-laws, legal instruments, and policies; (2) Organisation and Management: institutions in charge of running composting plants; (3) Supporters of initiatives: institutions providing external support (financial, material, knowledge); (4) Beneficiaries: users of sanitation services (households and markets), communities and workers receiving income through composting (composting producers), and farmers (users of compost). Some of the institutions fall into more than one cluster so they are in a position to work as inter-cluster channels of linkage facilitating the flow and exchange of information. The institutional platform at the centre of the rural–urban nutrient cycle is to facilitate the framework of regulations, managerial and organisation skills and provide external support to the beneficiaries. In the case of Kumasi, at the very centre is the Kumasi Metropolitan Assembly (KMA), this institution plays a role as regulator, a manager, a supporter of initiatives and as a beneficiary due to municipal savings; its central role does not mean it should be the institution in charge, but it should be the main facilitator (Vázquez et al. 2003).

24.6 Concluding Remarks

The study showed that the amount of organic waste available for composting is not a limiting factor. Already the market waste would be sufficient in every city to satisfy the payable compost demand from the combined agriculture and estate development. Compost contamination does not appear as a limiting factor either, while ever the nutrient content is only modest. Thus a prerequisite for many customers was to obtain a product of high quality. Due to the large quality variations among the waste inputs, a standardized high value compost product was so far only achieved in the Bodija plant in Ibadan through blending with mineral fertilizer. Similar trials of blending and also pelletizing compost for easier marketing were initiated by IWMI in Ghana over the last few years. A key lesson was that a detailed demand and stakeholder analyses appears crucial for compost sale and station set up, especially where subsidies might not be lasting. Major prerequisites for long term success and project sustainability are careful financial planning, effective project partnerships linking public and private sectors, the local community and (at least for monitoring) research institutions. One lesson was that the target to close the rural–urban loop would remain unfulfilled as long as smallholder farms are targeted. To reduce transport costs more powerful clients have to be targeted, such as out-grower companies or industrial crop plantations. Until then it will only be possible to close the loop partially by serving urban and peri-urban farmers and peri-urban estate developers. A win–win situation could be a business model of private/public partnerships linking public compost stations and private/public plantations. These are commercial investors with a higher WTP for compost and also have less quality requirements unlike urban or peri-urban vegetable farmers. To support related business models which explore unconventional options, IWMI and its partners have started a new research program in resource recovery and reuse in Africa, Asia and Latin America (Drechsel et al. 2011). The project seeks to identify existing business models in the sanitation sector and use lessons from these models to develop viable business models with alternative analysis for the decision makers on resource recovery and reuse in the developing world. Ultimately, the aim is to develop viable business models that could close the recycling loop and generate social benefits such as poverty reduction and ecosystem improvement.

Acknowledgement The author likes to acknowledge the support of the Water, Land & Ecosystems Research Program of the CGIAR, and ETH Zurich and SANDEC/EAWAG for assistance with the Material Flow Analysis.

References

Drechsel P, Kunze D (eds) (2001) Waste composting for urban and Peri-urban agriculture—closing the rural–urban nutrient cycle in sub-Saharan Africa. IWMI/FAO/CABI, Wallingford, p 229

Drechsel P, Cofie OO, Danso G (2010) Closing the rural–urban food and nutrient loops in West Africa: a reality check. Urban Agric Mag 23:8–10

Drechsel P, Cofie OO, Keraita B, Amoah P, Evans A, Amerasinghe P (2011) Recovery and reuse of resources: enhancing urban resilience in low-income countries. Urban Agric Mag 25:66–69

Ghana Statistical Services (2002). 2000 population and housing census. Republic of Ghana

GTZ-GFA (1999) Utilization of organic waste in peri-urban centers. The decision makers' guide to compost production (with financial analysis tool); software tool—economic model, version 0.9 E. GFA, Germany

Obuobie E, Keraita B, Danso G, Amoah P, Cofie OO, Raschid-Sally L, Drechsel P (2006) Irrigated urban vegetable production in Ghana: characteristics, benefits and risks. IWMI-RUAF-IDRC-CPWF, IWMI, Accra, p 150

Rouse J, Rothenberger S, Zurbruegg C (2008) Marketing compost. EAWAG, Duebendorf

Vázquez R, Cofie OO, Drechsel P, Mensa-Bonsu IF (2003) Linking urban agriculture with urban management: a challenge for policy makers and planners. In: Brebbia CA et al (eds) The sustainable city II. Urban regeneration and sustainability. WIT Press, London, pp 925–934

Part VI
Future of Peri-Urban Landscapes

Chapter 25
Implications of Labour Migration and Land Use Changes on Food Production in the Peri-urban Area of Rajsamand District of Rajasthan, India: A Case Study

P. S. Rao and D. C. Pant

Abstract This study examines the situation of land utilization and migration of population from farming sector to marble sector of the district, and identifies the causes of reduction of crop productivity. To achieve these objectives the peri-urban area of Amet tehsil of Rajsamand district is the most affecting tehsil where marble industry has flourished strongly and substituting the agriculture industry causing reduction of crop and livestock production drastically over the period. Thus, Amet tehsil of Rajsamand district has been selected purposively for the study. For in-depth study, a case study of "Jetpura Panchaayat" has been selected randomly. Besides, it is again important that this Panchaayat is growing for quartz production where 10–15 crusher plants are already established in the area. Primary data have been collected from pre-tested schedules and raw data have been analysed with the help of % and averages and conclusions have been drawn accordingly. It is concluded that land use pattern of the district is changing rapidly after the introduction of marble industry. The area under forest was decreasing from 24,663 hectares in 2001 to 23,214 hectares in 2010; this may be due to conversion of the area into non-forest purposes. Similarly, the area under non-agricultural use has been decreased from 1,27,697 hectares in 2001 to 1,85,439 hectares in 2010, which further strengthens the statement of introduction of marble industry. It is further clear from the results that productivity of all the crops have been on the decline over the study period and as such this has implication for food security in the region.

Keywords Land use · Migration · Marble industry · Farm labour availability and agricultural policy options

P. S. Rao (✉)
Department of Soil and Water Conservation, Maharana Pratap University of Agriculture and Technology, Udaipur, India
e-mail: pratapsinghrao10@gmail.com

D. C. Pant
Department of Agriculture Economics and Management, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, India

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_25,

25.1 Introduction

Migration and peri-urbanization to urbanization are direct manifestations of the process of economic development in the world, particularly in the contemporary phase of globalization. Understanding the reasons and effects of the former in terms of the changes in the distribution of population and economic activities, along with the success and failures of the interventions by state and other organizations would be extremely important for evaluating the available policy options and exploring areas of possible strategic intervention.

The migration peri-urbanization to urbanization in the less developed countries has historically been linked to stagnation and volatility of agriculture and lack of sectoral diversification within agrarian economy, India is also facing the same problem. The growth rates in agricultural production and income has been noted to be low, unstable and disparate across regions over the past several decades, resulting in lack of job opportunities in rural areas as compared to peri-urban and urban areas. A low rate of infrastructural investment in public sector in the period of structural adjustment—necessary for keeping budgetary deficits low—also have affected agriculture adversely. This has led to out-migration from several backward rural areas, most of the migrants being absorbed within peri-urban areas of the cities. The main emphasis of migration related policies must therefore be addressing the problems reflecting ecological footprints of large cities in regions that have become chronically out-migrating and stabilizing their agrarian economy through creation of livelihood opportunities. Enabling rural people avail urban amenities without having to shift to a peri-urban town and strengthening rural-urban linkages and commutation would also be important manoeuvre in addressing the problem of rapid urbanization in most of the regions.

Rural urban migration has often been considered the major factor for growth of slums in the peri-urban areas. United Nations has warned that rapid urbanization and migration would lead to tripling of slum population by 2050. One must however point out that the technological shift from cheap labour based modes of mass production to knowledge based system is likely to bring down the demand for migrant workers, particularly of unskilled labour force and decelerate urbanization. Given this emerging scenario, one would ask “Is indeed the scale of migration and urbanization very high and alarming?” The rates of peri-urbanization have already declined in many parts of the world, much more than what can be attributed to decline in natural growth in population. While it is true that the share of natural growth in incremental urban population would decline even the rate of RU migration is likely to decelerate in future years. Most of the mega cities have grown at a rate much below what was projected by the UN organizations. Migrants are often noted to be better off and relatively skilled than those left behind implying that the unskilled peasantry is finding it increasingly difficult to put a foothold in the urban centres in the present globalising environment. Migration to the large cities that have global linkages has become relatively more difficult as persons need access to information, market friendly skills and “some sort of bank roll." The implications of the deceleration in the rates of migration and urbanization need to be analysed in the context of both sending and receiving regions.

The argument that poor constitute a large majority of rural urban migrants and consequently account for much of the growing urban population is not borne out with the recent data in the Indian context as most of the cities reporting significant decline in the level of poverty, much more than in small towns. However, with appropriate changes in the nature and form of peri-urban expansion, as envisaged under inclusive growth strategy in the Eleventh Plan, the present exclusionary peri-urban growth based on restrictions to migration and slum evictions can be reversed. Under a more proactive vision of inclusive development, provision of land for the poor can be made within the cities, as envisaged under the above mentioned document. Indeed, all concerned international agencies should examine the possibilities of supporting economic opportunities by providing the migrants access to also infrastructure and basic services, besides removing discriminatory regulations that deny migrants equal access to employment and basic services.

Migration and peri-urbanization to urbanization must also be looked in the context of emergence of global cities, many of which have acquired vibrancy in recent years by establishing linkages with national and international market. It is argued that the process of urbanization in India, as in other developing countries, is being determined by macro-economic factors at national and global levels and is not strongly linked to the developments in rural economy. The strategy of economic reform and globalization has given a boost to growth of industries and business in these global cities, resulting in inflow of capital from outside the region or country as also investment by local entrepreneurs. Given this perspective, it would be important to consider policies to harness the potential of migration in these and other urban centres for promoting a balanced settlement structure, ensuring equity and sustainability in development process.

It would be erroneous to restrict the analysis of peri-urbanization to urbanization and migration to a few mega cities and ignore the smaller towns in India as the data suggest that the latter report higher levels of poverty and greater deprivation in terms of quality of life. Furthermore, globalisation strategies have opened up possibilities of resource mobilisation for large cities by strengthening their internal resource base and enabling them to attract funds from global capital market and institutional sources. Given the above perspective and concerns, the present paper begins by over viewing the trends and processes of peri-urbanization to urbanization and migration in India at the macro and state levels over the last five decades in the section which follows the present introductory section. An attempt is made here to explain the temporal and regional variation in levels of migration and urbanization and link it with the growth dynamics in the country. The third section probes further into the factors behind migration in different size class of settlements and its impact on the household and individual characteristics, based on unit level data from National Sample Survey, focusing on women and children. The programmes and schemes for urban and peri-urban development in operation during the last two and a half decades, particularly those launched in the wake of the 74th Constitutional Amendment Act have been reviewed in the fourth section. It also analyses how the emerging institutional structure and new initiatives in urban and peri-urban rules and planning, stipulating a shift away from Master Plan approach and prepare vision for urban planning, covering of capital market, judicial interventions etc. are impacting or could impact on the migration, urbanization and morphology of the cities. The fifth section attempts an assessment of the impact of the programme and policies of the government and rapidly changing institutional system on urban and peri-urban structure and situation of cities.

25.2 Study Area

Rajasthan is the largest state in the country. The Aravali range, running from northwest to southeast, divides the state diagonally into two distinct regions, the western arid region and the eastern semi-arid region. Over 61 % of the State, mostly in the western part, is desert. The State has only 1.1 % of India's total water resources as against 10.5 % of the country's geographical area and 5.5 % of the country's population.

The % of population below the poverty line fell from an estimated 50 plus % in the early 1970s, to 15.4 % in 1999–2000. However, the rapid growth in agriculture decelerated during the late 1990s due to repeated droughts, depleting groundwater reserves, un-favourable agriculture trade policies, and crop support prices that pushed crops suitable for the State's agro-climatic features to the marginal areas, as a result of which the State lost its advantages.

25.3 Methodology

The lack of opportunities in rural areas and small towns also saw an increase in rural to per-urban migration, and increasing urban growth in the larger cities, which could be attributed to population growth as well as migrants in search of better livelihoods. This trend has continued to date, however the peri-urban labour market has apparently not been able to fully integrate the migrant population, and a unique feature of Rajasthan is that the State has larger proportions below the poverty line in peri-urban areas as compared to the rural areas (NSSO 2001). Given Rajsamand's vast mineral reserves, and the fact that majority of the rural population still subsist on agriculture, industrial development has focused mainly on mineral-based and agro-based industries in the peri-urban areas. The total revenue value of minerals received from peri-urban Rajsamand district was Rs. 72.02 crores in 2007–2008. Peri-urbanization and then urbanization will continue at an accelerated pace, and about 70 % of the world's population will be urban (compared to 49 % today, Singh et al. 2013). Income levels will be many multiples of what they are now. In order to feed this larger, more urban and richer population, food production (net of food used for bio-fuels) must increase by 70 %. Annual cereal production will need to rise to about 3 billion tons from 2.1 billion today and annual meat production will need to rise by over 200 million tonnes to reach 470 million tons. But the fact is that globally the rate of growth in yields of the major cereal crops has been steadily declining, it dropped from 3.2 % per year in 1960 to 1.5 % in 2000 (Stark 1978).

Looking to the above problem this study has been conducted to achieve the following objectives:

(a) to find out the changing scenario of land utilization and migration of population from farming sector to other sector of the peri-urban areas of the district; and
(b) to find out the causes of reduction of crop productivity in rural and peri-urban areas of the study under consideration.

To achieve these objectives Amet tehsil, i.e., peri-urban area of Rajsamand district has been selected purposively. The peri-urban area of Amet tehsil of Rajsamand district is the most affecting tehsil where marble industry has been flourishing strongly and substituting the agriculture industry due to reduction of crop and livestock production drastically over the period. For in depth study the Jetpura Panchaayat of Amet tehsil has been selected randomly. Besides it is again important that this Panchaayat located in the peri-urban area is growing for quartz production where 10–15 crusher plants are already established in the area (see Fig. 25.1). The raw data has been collected from pre-tested schedules and analysed with the help of percentage and averages and conclusions have been drawn.

25.4 Results

Rural and peri-urban population along-with their proportion has been presented in the Table 25.1. Data shows that more than 86 % population of the Rajsamand district is residing in rural areas and only 13–14 % population is living in peri-urban areas. The percentage of the district population to the total population of the state is 1.75 %. The population density is 217 persons per sq. km., while sex ratio of the district is nearly 1:1.

25.4.1 Land Use Pattern

The socio-cultural and economic factors have significant influence over land use, both in rural and peri-urban areas. Land forms, slope, soils and natural resources are some of the important factors which control the land use pattern of the district.

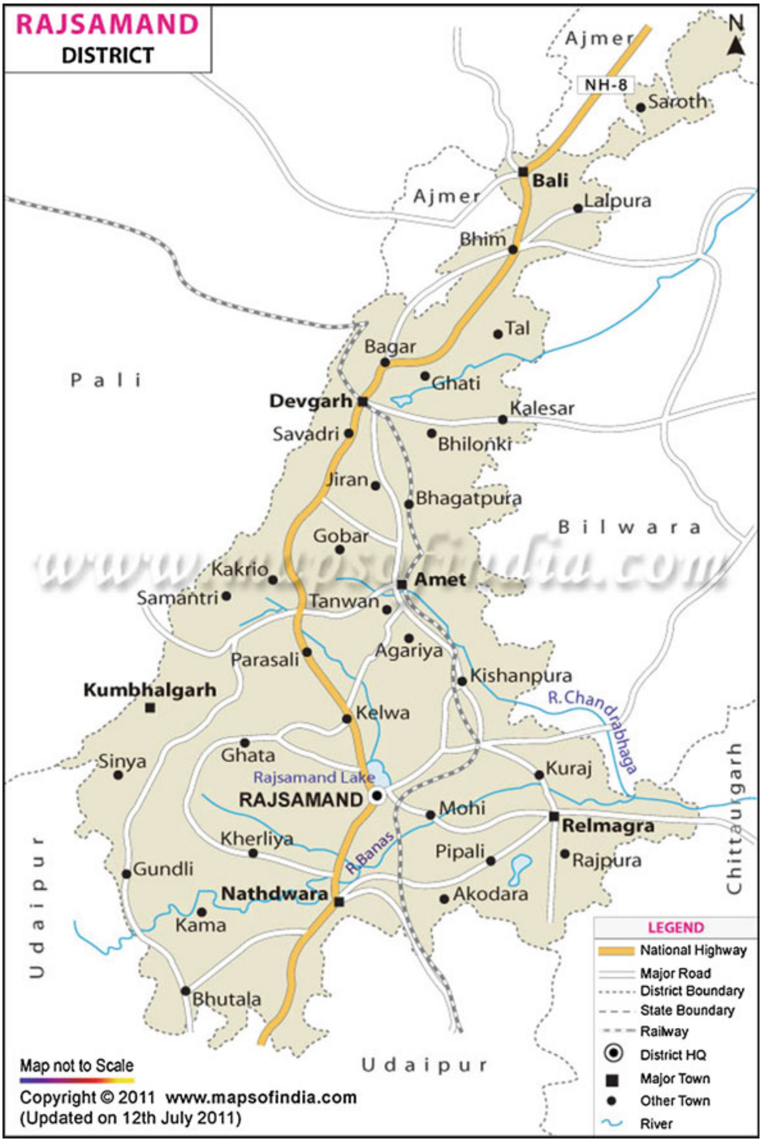


Fig. 25.1 Map of Rajsamand district

Out of the total area of 4,52,952 hectares, approximately 1,19,180 hectares land was cultivated during the year 2010 the land use pattern is as given in Table 25.2.

Land use pattern of the peri-urban area of the Rajsamand district has been given in the Table 25.2. Table shows that land use pattern of the district is changing rapidly after the introduction of marble industry in the peri-urban area of the district. The area under forest was decreasing from 24,663 hectares in 2001 to

Table 25.1 Rural and peri-urban population of Rajsamand district (2011)

Particulars	Male	Female	Total
Rural	4,24,520	4,29,470	8,53,990
	(86.34)	(87.40)	(86.90)
Peri-urban	66,829	61,894	1,28,723
	(13.60)	(12.60)	(13.10)
Total	4,91,349	4,91,364	9,82,713
	(100.00)	(100.00)	(100.00)

Figures in parenthesis indicates percentage of total rural and peri-urban population

Table 25.2 Land use pattern of peri-urban area of Rajsamand district of Rajasthan

Classification	Area (ha) 2001	Area (ha) 2010	Percentage change in area
Total reporting area	455093	452952	−0.05
Area under forest	24663	23214	−5.88
Area under non agri. use	127697	175439	+38.39
Fellow land	155415	135119	−15.02
Dupaj land	47055	45696	−2.97
Total cultivated area	147318	119180	−23.61
Total irrigated area	30971	56631	+82.85
Actual cultivated area	100263	97731	−2.59

23,214 hectares i.e. −5.88 % in 2010, which may be due to conversion of the area into non-forest purposes. Similarly the area under non-agricultural use has been decreased from 1,27,697 hectares (38.39 %) in 2001 to 1,75,439 hectares in 2010 i.e. +38.39 %. Which further strengthen the statement of introduction of marble industry. It is important to note that the area under irrigation has been increased from 30,971 hectare to 56,631 hectare during the said period which is 82.85 % more than the area of year 2001.

Railmagra and Nathdwara tehsils have the maximum cultivated area of 24,542 hectares and 21,486 hectares, respectively. Kumbhalgarh has the minimum cultivated area of 11,834 hectares (Table 25.3). Relmagra and Nathdwera tehsils also top the list in the double cropped area. Nathdwara and Railmagra tehsils have the maximum irrigated area.

Area, production and productivity of the peri-urban area of the Rajsamand district over the period have been shown in the Table 25.3. It is clear from the table that productivity of all the crops has been increased except pulses and sugarcane over the period which may be due to increase in the area under irrigation in Railmagra and Nathdwara Tehsil or changing scenario of technology but net sown area under all the crops is declining which may be due to priority to working in the marble industry as well as non-availability of agricultural labourers.

Table 25.3 Agriculture area sown and Production of food-grains in peri-urban area of the district (1993-1994and 2005-2006)

Crops	Total area sown 1993–1994	Total production (MT) 1993–1994	Total area shown (ha) 2005–2006	Total production (MT) 2005–2006
Food grains	1,07,888	8,63,10 (0.799)	96,173	80,730 (0.839)
Pulses	5,877	3,840 (0.653)	5798	3,262 (0.563)
Oil seed	14,022	8,150 (0.581)	13,090	9,508 (0.726)
Cotton	4,473	111 (0.024)	620	18 (0.029)
Sugarcane	565	10 (0.018)	146	1 (0.007)
Others	17,007	11,077 (0.651)	10,868	8,085 (0.743)
Total	1,49,832	1,09,498 (0.730)	1,26,268	1,01,604 (0.805)

Figure in the parenthesis shows the productivity of the crop in MT

Table 25.4 Source wise irrigated area of peri-urban area of the Rajsamand district (2006–2007)

S. No.	Source of irrigation	Number	Net area irrigated (ha)
1	Total wells	59066	21,869 (70.61)
	(A) Diesel pump sets	5706	10,100
	(B) Electric pump sets	7683	11,769
2	Tube wells	619	4,371 (14.11)
3	Tanks	11	2,136 (6.90)
4	Other sources	05	2,595 (8.38)
5	Total	–	30,971 (100.00)

Figures in parenthesis are percentage to the total

25.4.2 Irrigation

The principal means of irrigation in the district are wells though the small area is irrigated by tank also. Ground water plays an important role for irrigation and is utilized through dug wells, dug cum bored wells and tube wells. The details of the wells, tanks, pumping sets and tube wells and gross irrigated area by different sources have been given in Table 25.4.

Since most of the irrigation in the peri-urban area of the district is done through wells so the ground water development activity in the district is in advanced and accelerated stage. Source wise irrigated area has been presented in the Table 25.4. The table reveals that 70.61 % area is irrigated by wells in which the lifting of water is through diesel and electrical pump sets. About 14 % irrigation is through tube wells and remaining 15 % irrigation is covered through tanks and other sources.

Total number of villages and tehsil wise rural and peri-urban population of Rajsamand district of Rajasthan have been depicted in the Table 25.5. The district covering 7 tehsils having 1072 total villages and 9,82,713 total population. Out of seven tehsils two tehsils namely Amet and Rajsamand is Marble rich area and

Table 25.5 Tehsil wise population (Rural + peri-urban and urban) of Rajsamand district

Name of Tehsil	Total villages	Population	Percentage population to the district
Amet	155	1,05,589	10.74
Bhim	142	1,34,627	13.70
Deogarh	138	92,707	9.43
Kumbhalgarh	167	1,30,384	13.27
Nathdwara	218	2,08,877	21.27
Railmagara	98	1,13,268	11.53
Rajsamand	154	1,97,261	20.07
Total	1072	9,82,713	100.00

Table 25.6 Demography of peri-urban area of Amet Tehsil (2001)

Particular	Number/percentage
Population	1,04,834
Female	52,225
Male	52,609
Literacy	53.22 %
Literacy Male	70.40 %
Literacy female	36.08 %
SC Population	16.45 %
ST Population	7.99 %
Sex ratio	993
Number of house holds	19,797
Total workers	38,325
Non workers	66,509
Number of workers directly attach in marble business	20,132(52.52)
Number of workers indirectly attach in marble business	7,366 (19.22)
Total no. of workers indirectly attach in marble business	27,498 (71.75)

Relmagra is having high quantity of Zinc. Nearly one third population (Amet and Rajsamand tehsil) livelihood is through mines and minerals only, two tehsil namely Nathdwara and Railmagra is agriculturally dominated. Kumbhalgarh tehsil is forest abundant and Bhim and Deogarh tehsil are low water profile.

Demography of Amet tehsil of Rajsamand district has been shown in the Table 25.6. Data shows that the overall literacy rate of the tehsil is 53.22 % while 70 % male were literate. Sex ratio of the tehsil is nearly equal (993). There was 38,325 total workers available in the tehsil out of which 20,132 (52.52 %) were directly engaged in marble business and nearly 19.22 % workers are indirectly employed in this business shows the migration of farming population into industrial sector.

Demography of Jetpura Panchaayat of Amet tehsil has been shown in the Table 25.7. The Panchaayat having 5601population out of which 2,713 are workers and remaining 2,888 are non-workers. Table 25.7 further shows that 76 %

Table 25.7 Demography of Jetpura Panchaayat

Name of village	Population	No. of House holds	Mining workers	Percentage of workers per household	Literacy (%)
Jetpura	1769	351	745	2.12	53.90
Agalgoan	439	76	160	2.10	43.37
Bhakroda	1059	192	411	2.14	63.16
Panotia	680	115	266	2.31	48.9
Saganwas	1654	290	480	1.65	48.54
Total population	5601	1024	2062	2.01	–
Total workers	2713	1024	2062	76.00	–

Table 25.8 Comparative wages in agriculture and marble industry in peri-urban area

Type of labour	Wages Agri. work (Rs.)	Working hours in Agri. work	Wages in peri-urban (Rs.)	Working hours in Marble industry
Skilled	200.00	8–10 h	500.00	7 h
Semi-skilled	150.00	8–10 h	300.00	7 h
Casual Labour	120.00	8–10 h	250.00	7 h

of working population is engaged in marble business. Operational holding of the Jetpura Panchaayat is 1.62 hectares for all groups of the farmers.

Comparative wage rate of labours in agriculture and marble business has been shown in the Table 25.8. Table clearly indicate that wage rate in the marble is nearly twice more than the agricultural work. Labours also prefer to work at mines because the working hours and hardness of work is less at mining work for all kind of labours.

25.4.3 Problem of Irrigation Water

It is observed that large number of gangsaw, cutter and crushing plant are being operated in the area needs huge quantity of water. At least one tanker of water for each cutter and 2–3 tanker of water is required for each gangsaw in a day. The increasing demand of water farmers are selling irrigation water to these marble businesses and earning more money as water use efficiency is manyfold more in this business than use for irrigation purpose.

Number of Gangsaw, Marble cutter and godowns are given in the Table 25.9. There are more than 235 Gangsaw and more than 800 marble cutters are functioning in the district. Similarly, more than 1500 godowns and about 50 crusher plant are function in the district, which employees more than 25000 people of the district. This work force was previously depends on the agricultural sector.

Table 25.9 Status of marble Business set-up in peri-urban area of the district

Particulars	Number
Marble Gangsaw	235
Cutter	800
Godowns	1500
Total no. of employees directly engaged	25000

Table 25.10 Status of marble mines and industries in 2011

Particulars	Number
Registered small scale industries	238
Av. Employees in SSI	2263
Large and Medium industries	02
Industrial area	3
Total no. of lease	1341
Sale value of mineral produced (in Crore)	409.40
Got. Revenue through royalty(crore)	72.00
Employees engaged in mines	28682

Table 25.11 Production of Major minerals in peri-urban area of the district

Name of mineral	Production (MT)
Soap stone	20.81
Marble	4261.92
Lime stone (clips)	297.68
Lead and Zinc	797.79
Dolomite	94.88

Revenue earned through royalty and sale value of marble is presented in the Table 25.10. The table shows that sale value of the mineral produced was Rs. 409.40 crore per annum from which govt. of Rajasthan is earning nearly 72 crore rupees per year. Nearly 29000 people are engaged in this business directly or indirectly.

Different kinds of minerals are produced from the district. Table 25.11 revels that 4261.92 MT of marble,797.79 MT of Lead and zinc, 297.79 MT of Lime stone, 94.88 MT of Dolomite and 20.81 MT of Soap Stone has been produced from this district.

25.5 Concluding Remarks

The area under forest was decreasing from 24,663 hectares (5.88 %) in 2001 to 23,214 hectares in 2010, this may be due to development of marble industry in the peri-urban area and conversion of the area into non-forest purpose, similarly the area under non-agricultural use has been decreased from 1,27,697 hectares (38.39 %) in 2001 to 1,75,439 hectares in 2010.Which further strengthen the statement of introduction of marble industry in the peri-urban area of the district. It is important to note that the area under irrigation has been increased from 30971 hectare to 56631 hectare during the said period which is 82.85 % more than the area of year 2001 which shows the economic prosperity in the peri-urban area of the district. Result further shows that productivity of all the crops in the peri-urban area has been increased except pulses and sugarcane over the period may be due to increase in the area under irrigation in Railmagra and Nathdwara Tehsil or changing scenario of technology but area under all the crops is declining which may be due to priority to working in the marble industry set up in the peri-urban area of the district as well as non-availability of agricultural labours. It is further concluded that there was 38,325 total workers available in the tehsil out of which 20132 (52.52 %) were directly engaged in marble business established in the peri-urban areas of the Rajsamand city and nearly 19.22 % workers are indirectly employed in this business shows the migration of farming population into industrial sector of the peri-urban areas. Study clearly indicate that wage rate in the marble industry in the peri-urban area is nearly twice more than the agricultural work. Labours also prefer to work at mines because the working hours and hardness of work is less at mining for all kind of labours. It is observed that large number of gangsaw, cutter and crushing plant are being operated in the peri-urban area needs huge quantity of water. At least one tanker of water for each cutter and 2–3 tanker of water is required for each gangsaw in a day. The increasing demand of water farmers are selling irrigation water to these marble businesses in the peri-urban area and earning more money as water use efficiency is many-fold more in this business than use for irrigation purpose.

In general, rapidly increasing the area under forest into non-forest purpose, similarly the area under agricultural use has been decreased by 10 % during the period of 10 years. Nearly 19.22 % workers are indirectly employed in marble business shows the migration of farming population into industrial sector of the peri-urban areas. Further, the study indicates that wage rate in the marble industry in the peri-urban area is nearly twice more than the agricultural work. Labours also prefer to work at mines because the working hours and hardness of work is less at mining for all kind of labours.

References

Gupta K (1996) Urbanisation and urban growth in India. In: Mohanty SP, Momin AR (eds) Census as social document. Rawat Publications, Jaipur, New Delhi

Kaur G (1996) Migration geography. Anmol Publications, New Delhi

NSSO (2001) Migration in India 1999–2000. Ministry of Statistics and Programme Implementation, Government of India

Singh J, Yadav H, Smarandache F (2013) Rural migration-A significant cause of urbanization: a district level review of census data for Rajasthan. http://vixra.org/pdf/1008.0034v1.pdf. Accessed 12 Dec 2013

Stark O (1978) Economic demographic interactions in agricultural development: the case of rural-to-urban migration. Food and Agriculture Organization of the United Nations (FAO), Rome

Chapter 26
Knowledge Assessment on Climate Change and Urban and Peri-urban Agriculture in Dakar, Senegal

Mamadou Khouma, Yacine Ndour, Marie Sophie Ndong, Youga Niang, Mouhamadou Dial, Idy Niang, Mohamed O. Diagne, Jean Pierre Yvon Fall and Jon Padgham

Abstract This chapter examines the biophysical, socio-economic, environmental and human health dimensions of urban and peri-urban agriculture in Dakar city (Senegal) and identifies structural threats to urban agriculture, including those already induced, or have the potential to be induced, by climate change. Urban agriculture, which provides an important source of fresh vegetables and other fresh products for the city is being increasingly marginalised due to a combination of factors including diminished soil and water quality, increasing temperatures and reduced rainfall, urban encroachment and pollution from industrial sources. A lack of clearly defined roles and responsibilities between local and national governments hinders the ability to protect urban agricultural land from urban encroachment and a lack of access to credit by farmers adds to their ability to cope with the multitude of other pressures. Dakar is bordered by the Atlantic Ocean on the northern, western

M. Khouma (✉) · J. P. Y. Fall
IDEV-ic, Dakar, Senegal
e-mail: khoumamamadou@yahoo.fr

Y. Ndour
ISRA, Dakar, Senegal

M. S. Ndong
IAGU, Dakar, Senegal

Y. Niang
UNDP, Dakar, Senegal

M. Dial
UCAD, Dakar, Senegal

I. Niang
Environment Department, Dakar, Senegal

M. O. Diagne
Dakar, Senegal

J. Padgham
START, Washington D.C., USA

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_26,

and southern sides with no room for expansion, including any potential expansion of urban agriculture. Ground water in this urban zone is steadily deteriorating due to nitrate pollution of shallow groundwater in soil aquifers combined with increasing saltwater intrusion. Recycling of untreated wastewater for use in urban agriculture, a common practice in Dakar and other cities in Africa has increased the incidence of food-borne contamination. For example, recent microbial sampling of water showed a very high proportion of sites (87 %) with contamination levels above World Health Organisation standards for irrigation without restriction. Solid and liquid waste management is one of the biggest problems Dakar is facing as are many other cities of developing countries. Climate change will further impact urban agriculture. Shortening of cold periods favorable to vegetable cropping in semi-arid areas, increasingly hotter summers, more frequent flooding and drought periods, and higher incidence of pest and diseases are among the potential impacts of climate change. Coastal zones of the city are particularly under threat due to the rising sea level with negative consequences of coastal erosion and salt-water intrusion in lowlands. Projection models show a strong warming trend in the region. Conversely, there is no agreed trend of rainfall prediction at present but deficits are anticipated by general circulation models. Adaptation strategies of farmers include lifting the ground surface with landfill in order to better cope with flooding (specifically for flower cultivation), development of soil and soilless micro gardens in boxes, crop diversification and use of hybrid seeds. Urban agriculture has the potential to contribute to climate change adaptation through reinforcement of urban agricultural systems resilience, water recycling, buffering thermal and hydraulic shocks, providing safe and nutritious food, recycling wastes and conserving biodiversity. Despite its huge potential to reduce poverty and make the city more resilient to impacts from climate change, urban agriculture is not high on the urban planning agenda. Recommendations are formulated towards taking into consideration urban agriculture in national and local planning, strengthening capacities of stakeholders and awareness at all levels of society on the economic, social and environmental role of urban agriculture can play in sustainable development and greening of the city and its economy.

Keywords Climate change · Dakar · Urban/peri-urban agriculture · Vegetables · Water · Waste

26.1 Introduction

Urban and peri-urban agriculture (UPA) considerably contributes to food security of cities and provides employment to many people including migrants from the countryside. It also participates in the greening of cities and offers entertainment opportunities where city dwellers can appreciate natural landscapes and biological diversity.

Dakar, where about one quarter of the total population of Senegal is concentrated in only 0.28 % of the total area of the country, UPA is facing strong competition with real state and infrastructure facilities linked to a tremendous population growth rate. In addition to urban pressures, health and environmental problems including those linked to climate change bring additional hazards to this type of agriculture.

Dakar is one of nine cities across Africa and South Asia involved in an assessment on UPA, climate change and urbanisation that is being conducted through a partnership between the System for Analysis, Research and Training, the World Meteorological Organisation, the Intergovernmental Panel on Climate Change, the UN Environment Programme (UNEP), University of Ghana, University of Dar es Salaam and the Bangladesh Centre for Advanced Studies, with support from the European Commission, UNEP and the American Agency for International Development.

The UPA assessment is currently underway and 'to be completed in mid-2014. The paper analyses urban and peri-urban agriculture in Dakar city (Senegal) in aspects related to its biophysical, socio-economic, environmental and human health dimensions, and identifies structural threats to urban agriculture, including those already induced or to be potentially induced by climate change. Each city is a case study articulated on UPA agricultural production systems, in relation to their role in food security, poverty alleviation, and environmental issues in general and climate change specifically.

26.2 Methodology Description

The study was launched in mid-2011 during a workshop with urban agriculture stakeholders that involved researchers, ministry departments, decentralised communities, non-governmental agencies, farmers, researchers and media professionals. During this workshop the objectives of the study were discussed together with its duration, human, technical and financial resources. The study was carried out through a combination of literature reviews with field visits and farmer interviews throughout the Dakar region where urban agriculture is practiced.

26.3 Dakar City Location and Urban Growth

Located in the Cape Vert peninsula, the Dakar region expands 550 km^2 between 17°10 and 17°32 West longitude and 14°53 and 14°35 North latitude. Dakar is bordered on the north, west and south by the Atlantic Ocean; the east is bordered by the Thies region. This location offers few possibilities for spatial expansion of Dakar urban space. Administratively, Dakar is composed of 4 Departments (Dakar, Guediawaye, Pikine and Rufisque), 43 urban districts and 3 rural districts.

The Dakar region concentrates 25 % of the Senegalese population in only 0.28 % of the total country area. In 2007 the total urban population of Dakar was estimated at 2,428,155, representing three times the population of 30 years ago. Dakar is the most urbanised city of the country with an urban percentage increasing from 88.4 in 1976, to 97.2 in 2007 (ANSD 2008). Two main factors contributing to the rapid urbanisation of the region are, natural growth and the hosting of migrants from other regions of the country and from the West African sub-region.

Currently, in the Dakar region, the purchase of a parcel of land for the construction of housing units to be leased is generally more profitable than operating the same land for agricultural purposes. In the peri-urban area (Mbao, Keur Massar, Tivaouane Peul, Rufisque, Sangalkam) where agriculture was prevalent before 2000, a 150 m^2 plot was worth 200,000–300,000 CFA francs. In 2011, the same plot is now worth between 4 and 8 million CFA francs. Competition for land between agricultural and non-agricultural uses affects all types of land as building occurs even in non–constructible areas. Wetlands and good agricultural land (Niayes) is usually confiscated for the development of Technology Parks or transport infrastructure such as the toll road from Dakar to Diamniadio, which attracts further urban development.

In 2010, the region is home to nearly 25 % of the national population. In a period of 20 years, the regional population increased by more than 1 million people, while the regional area is barely 0.3 % of the total country area. While the demand for housing development is high, the extension of the city flows unplanned and uncontrolled in the outskirts. This situation has greatly changed the spatial structure of the Dakar region, which from 1980 to 2001, over an area of 53,640 ha, experienced a population increase from 9.94 to 36.29 %, and a parallel reduction of woodlands, agricultural, flood and vacant area from 78.16 to 50.81 (Figs. 26.1, 26.2).

26.4 Biophysical Aspects

From a general point of view, rainfall at the country level recorded a sharp decrease during the 1970, 1980 and 1990s due to recurrent drought and is illustrated by a south sliding of isohyetal curves (Le Borgne 1988a, b; Ndong 1996; Sagna 2000, 2008). The Dakar region is also affected by this rainfall decrease which characterised the 1970–1998 period. However one should note that since the early 2000, rainfall has significantly improved in this region (Fig. 26.3) though the threat posed by long-term drought persists (CSE 2011).

26.5 Socio-Economic Aspects

At the economic level, activities in the Dakar region remain dominated by secondary and tertiary sectors. Revenues of 26 % of the population come from purely agricultural activities and 6 % of the population is exclusively dependent on the Niayes

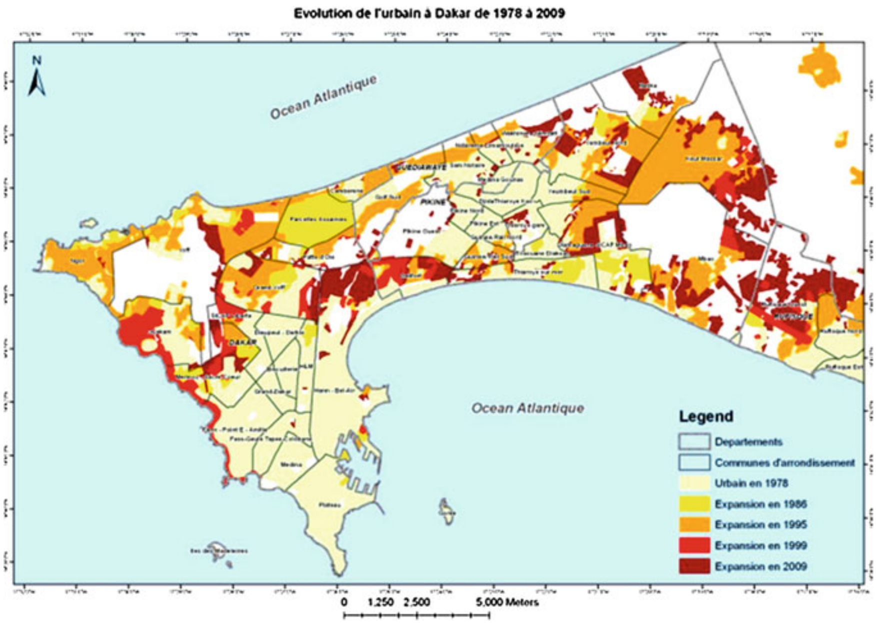


Fig. 26.1 Expansion of urbanized area of Dakar outskirts between 1978 and 2009. *Source* Instituto Agronomico per l'Oltremare et EC-JRS

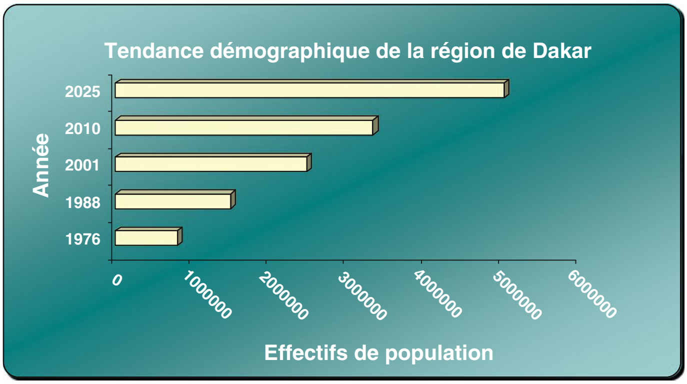


Fig. 26.2 Demographic trends of Dakar region

ecological zone that includes the outskirts of the Dakar department and a large area of Pikine and Guediawaye departments. The rural area of the Rufisque department offers real agricultural potential due to favourable climate and soil conditions. Particularly favourable bioclimatic and water resource conditions for horticulture make the Niayes a privileged location for market gardening and fruit culture.

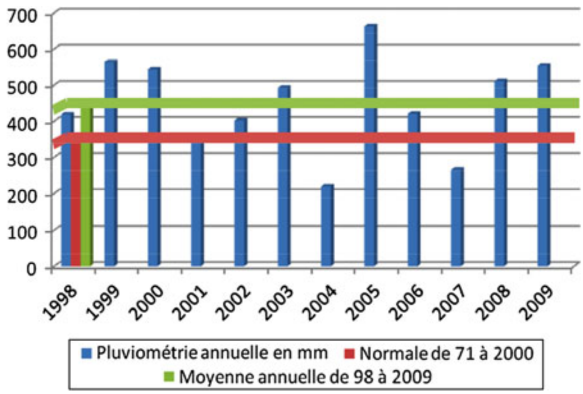


Fig. 26.3 Annual rainfall from 1998 to 2009 and normal from 1971 to 2000 of Dakar

The socio-economic value of UPA in the Dakar region is linked to the fact that 200,000–250,000 people derive their income from market gardening activities (Fall et al. 2003). This key economic and nutritional resource is currently threatened by heavy anthropogenic pressures, which combined with natural dynamics of this sensitive and fragile environment, results in precariousness that in the long run may reduce or potentially destroy the existing capacity for UPA.

Small farms (0.1 ha in average) are dominating in UPA agriculture and they supply the local market (Fall and Fall 2001). Gaye and Niang (2002), cited by Guèye-Girardet 2010; evaluated that vegetable production in urban areas represented 60 % of Dakar city demand in 1998, representing 40,000 tons. The production level is rather stable since the 1990s. The two main UPA production sites are Pikine and Patte d'Oie with a cropped area of 137 ha, intensively cultivated over 15–20 years with 23 % of plots irrigated with untreated wastewater. Lettuce, tomatoes, bitter eggplant, onion and cabbage are the most cultivated crops.

Apart from significantly contributing to food security of cities, UPA also contributes to city landscapes through green spots and flower growing. It also delivers ecosystem services by regulating part of the water cycle and by offering habitats to different animal species. UPA is a main component of poverty alleviation in urban areas.

26.6 Environmental Aspects

Locations where UPA is practiced are generally considered as sites for garbage dumps. Indeed, local residents throw most of their waste in these sites. Where liquid waste is concerned, sewage trucks discharge the raw water coming from septic tanks in these areas. All these practices are a real threat and lead to pollution and environmental degradation.

Urban agriculture is intensively practiced with massive use of mineral fertilizers and pesticides relative to the small size of the plots. The uncontrolled use of

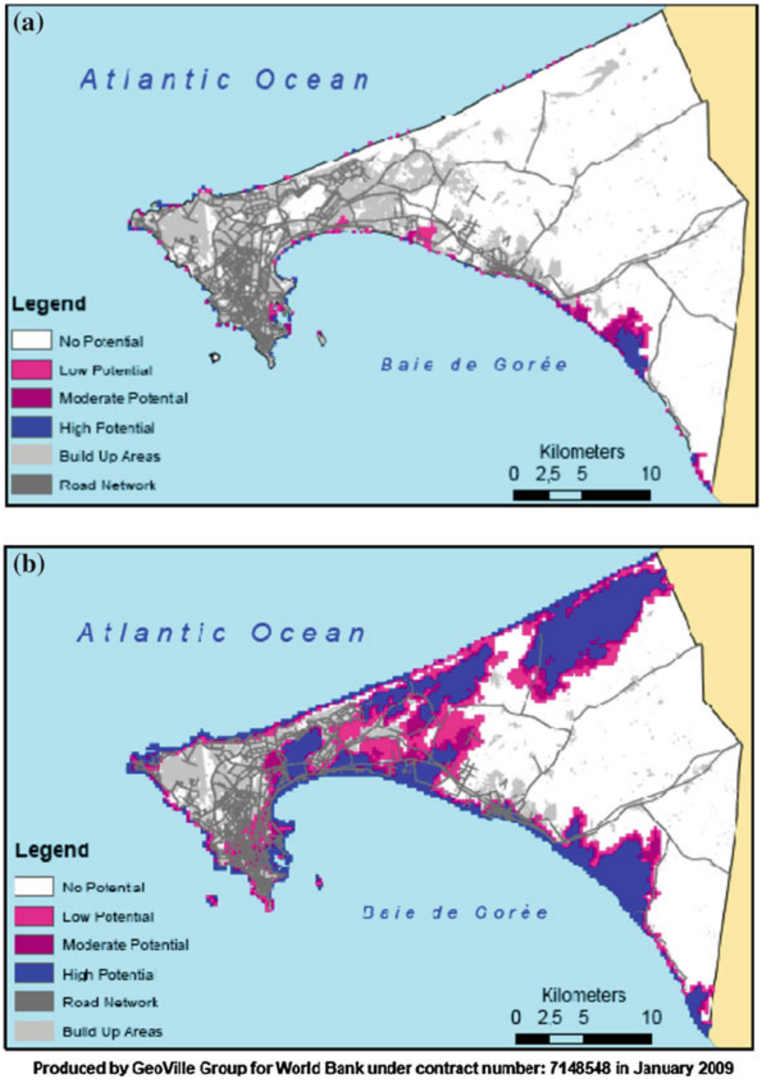


Fig. 26.4 **a** Potential flooding of Dakar (1 m sea level rise), **b** potential flooding of Dakar (5 m sea level rise)

fertilizers and pesticides in UPA remains among the main factors of pollution and land degradation. Indeed we found that farmers often use prohibited products leading to major damage to the entire agricultural chain. Misuse of fertilizers can also contribute to land degradation by modifying some physico-chemical properties of soil (increase in acidity and salinity, for example).

UPA producers are facing known events that may negatively affect their wellbeing and they are in fact facing enormous risks which increase their vulnerability. These risks are primarily health risks and result in a faulty protection during the use of wastewater and pesticides.

The use of fertilizers and pesticides in UPA is a major factor in health deterioration. The vast majority of pesticides sold in Senegal consist of generic pesticides which are cheaper and therefore more accessible to small farmers with low financial means (Diouf, personal communication). They are renamed with exotic local names, synonymous of power and efficiency, repackaged in micro-doses in packages that do not have proper labelling, or sometimes no label at all, making them even more dangerous. Chaudhuri (2009) reported 28 % of vegetable growers were victims of pesticide poisoning in 2003 and 2005 in the Niayes near Dakar.

Pesticides used in the Dakar UPA that are already prohibited by the Interstate Committee to Struggle Against Desertification in the Sahel (CILSS) and topped the ranking of easily leachable substances in soils of Dakar and which in addition exhibit toxicity or eco-toxicity should absolutely be banned. It consists of Carbofuran, Dimethoate, Methomyl, Ethopropos and Fenithrotion.

Farmers often do not comply with the safeguards and put themselves at risk of poisoning. Additionally, vegetables are often harvested and sold without respect for safe waiting times in terms of pesticide persistence.

26.7 Human Health Aspects

The most acute health problems come from the use of raw sewage on irrigated crops. Food production of UPA plays an important role in the current context of population growth and urban poverty in Dakar. However, the way the business is done is facing environmental problems associated with the use of wastewater for irrigation and disposal of waste in addition to the uncontrolled use of chemical fertilizers and pesticides. For example, recent microbial sampling of water showed a very high proportion of sites (87 %) with contamination levels above World Health Organization standards for irrigation without restriction. Solid and liquid wastes management is one of the biggest problems Dakar is facing as are many other cities in developing countries. Recycling of untreated wastewater for use in urban agriculture, a common practice in Dakar and other cities in Africa has increased incidences of food-borne contamination.

The use of wastewater in urban agriculture, due to the large reserves of nutrients it contains, is a fairly common practice and is a response to the scarcity of water for irrigation. However, wastewater also contains large quantities and various forms of pathogenic microorganisms that can withstand more or less time in water, soil or vegetables. These pathogens can infect and cause illness to farmers, traders and consumers.

In Senegal the reuse of wastewater in urban agriculture is one of the factors of pollution and contamination to the environment. Indeed studies have shown the existence of potential hazards associated with their use and these include the presence of bacteria including fecal coliforms around "107 per 1000 ml, and Salmonella at a rate of 11 positive out of 78 samples" (Ndiaye 2009).

In addition, there are different types of parasites in wastewater used in urban agriculture. These include nematode larvae, cysts of *Entamoeba coli*, eggs of *Ascaris Lumbricoides* and Hookworm).

The assessment of health impacts of polluted water in urban agriculture in Dakar showed that 35 percent of irrigation water was contaminated with *Salmonella* spp (Ndiaye 2009). The rate of contamination of shallow water sources (hand-dug well called Ceane) is higher than that of wastewater. Fecal coliforms were detected in groundwater underlying the irrigated fields and water bodies closest to the sites, especially after rain. Analysis of lettuce from the fields and markets has shown that the *E. coli* load exceeds the standards of the I*nternational Commission on Microbiological Specifications for Foods*. The epidemiological study reported a prevalence of 46 % of cases of diarrhoea among children and that the risk factor is attributed to the consumption of water from aquifers.

26.8 Common Threats

UPA, which provides an important source of fresh vegetables and other fresh products for the city, is being increasingly marginalised due to a combination of factors including soil availability due to urban encroachment, water quality and pollution from industrial sources. Groundwater in this urban zone is steadily deteriorating due to nitrate pollution of shallow groundwater aquifers combined with increasing saltwater intrusion.

26.9 Climate Change Threat

The resolution of global climate models do not allow for detailed projections on the scale of this work. Projection models show a strong warming trend in the region as far as temperatures are concerned. Presently there is no agreed trend of rainfall prediction but deficits are anticipated by general circulation models. Thus, a regional model (Regional Climate Model Version 3) has been adapted and used in West Africa and Senegal in particular to simulate the present climate in order to develop climate change scenarios (Gaye and Sylla 2008). The model was forced with the A1B scenario (rapid economic growth, more efficient technologies, balancing sources of energy and non-fossil fuels). The main results of this model are set out in Table 26.1.

Table 26.1 Climate projections

Parameters and climate events	Trends regarding CC
Temperature	Temperatures tend to increase throughout Senegal but the largest increases are predicted in the North by 2100
Rainfall	Rainfall tends to decline over the period (1980–2000). A large deficit is noted for the months of June to July and August. This deficit is even more important for the period 2081–2100
Humidity	The increase in moisture retention capacity in the atmosphere, due to rising temperatures, could result in rainfall events of greater intensity making the region more vulnerable to flooding (Gaye and Sylla 2008)
Extreme events (flooding, drought, storms, heat anomalies)	The regional model, RegCM3, predicts a decrease in wet sequences for Dakar and increased dry spells
Sea level rise	Coastal areas are particularly threatened by rising sea level resulting from climate change with an acceleration of coastal erosion and saltwater intrusion into soil and groundwater of low areas. The elevation of 5 m of sea level will have catastrophic consequences as much of the Dakar region will be flooded with habitat and fishing facilities destruction (Fig. 26.4a, b)

26.10 Responses

Faced with threats to urban farming systems, farmers have developed some coping strategies. These include raising the ground with landfill for growing flowers and infilling the floor of ornamental plant nurseries with gravel to protect against flooding.

Micro gardening, consisting of growing vegetables in wooden crates with liquid nutrients, with or without substrate, is another response to the various threats facing urban food production. This micro gardening is also a way to popularise gardening among urban families. There is also some conversion towards development of fish farming activities in water bodies (water basins, ponds, marshes) around the city. The absence of plant material adapted to the climate warming remains a challenge for agricultural research. It would be useful to have new varieties with good yields in order to adapt to a situation of shorter growing cycles when the temperature is cooler.

26.11 Conclusions

Despite its importance in supplying the city of Dakar with fresh vegetables and its contribution to poverty alleviation in the region, agriculture in urban and suburban areas is still subject to many constraints, including lack of suitable land, uncertainty about property rights, inadequate access to good quality irrigation water, inadequate skills and low investment. Serious health and environmental risks are also associated with agriculture that uses raw sewage and pollution from urban waste. Added to these, impacts of climate change will result in more frequent extreme events such as prolonged droughts and flooding, reduced growth periods favorable to vegetable crops (fewer days with lower temperatures), an increased occurrence of pests, and the threat of salinisation of land closest to the coast resulting in rising sea levels. To face all of these threats to urban agriculture systems, coping strategies have been developed among which are:

- fight against flooding by raising the ground level for growing flowers,
- development of micro gardening consisting of growing vegetables in wooden crates with nutrient liquid with or without substrate. Micro gardening is also a way to popularise gardening in urban families;
- development of inland fisheries;
- expansion of the rice cultivated areas; and
- development of an organic farming sector.

Urban agriculture has the potential to contribute to climate change adaptation through reinforcement of urban agricultural systems resilience, water recycling, buffering thermal and hydraulic shocks, providing safe and nutritious food, recycling wastes and conserving biodiversity. Despite the fact that UPA has a huge potential to reduce poverty and make the city more resilient to impacts of climate change, urban agriculture is not high on the urban planning agenda. Senegal has, from a legislative point of view, a favorable framework, for the integration of urban agriculture in urban development master plans, even though in practice this type of agriculture has been more and more marginalised. The delineation of powers between national and local governments in the allocation of space is not always clear. The survival of urban agriculture will depend on the effectiveness of support that governments and decentralised authorities provide on the ground by protecting it from urban encroachment.

26.12 Recommendations

Recommendations are formulated towards taking into consideration urban agriculture in national and local planning, strengthening capacities of stakeholders and sensitisation at all levels of society about the economic, social and environmental role UPA can play in sustainable development and greening of the city and its economy. These include:

- Strengthening of the inter-urban consultative framework around the Urban Agriculture.
- Capacity building of farmers involved in UPA activities to enhance competitiveness in the market by value adding.

Photo 26.1 Filling in area (flower-growing). Photos Khouma (2011)

- Involvement of local universities, research institutes, organisations, associations and economic interest associations operating in the area.
- Capacity building of civil servants and actors.
- Increased availability of transportation for compost.
- Strengthening financial structures that distribute inputs recycled waste.
- Strengthening financial means of women who buy agricultural products from producers and sell to consumers.
- Strengthening financial processors of agricultural products.

For the attention of the central and decentralised authorities:

- Better urban planning to strengthen the role of urban agriculture.
- Give emphasis to urban agriculture in development planning,
- Educate all stakeholders about the risks of climate change.
- Educate all stakeholders on minimum precautions in food hygiene.
- Strengthen the capacity of stakeholders (farmers, communities and local government, agricultural technicians).

For the attention of agricultural research, conduct or continue research on:

- Development of varieties adaptive to climate change.
- Drafting guidelines on organic farming techniques.
- Continue research on sustainable fertilization practice.
- Continue research on integrated pest management.
- Continue research on valuing treated wastewater for agriculture.

Photo 26.2 a, b Micro gardening in Dakar

For the attention of development partners:

- Give priority to sustainability of urban agriculture activities.
- Support the efforts of local communities in capacity building.
- Encourage visits and exchanges between communities in different countries. (Photos 26.1, 26.2).

References

ANSD (2008) Situation économique et sociale de la région du Dakar en 2007. 187 p

Chaudhuri N (2009) Using participatory education and action research for health risk reduction amongst farmers in Dakar, Senegal. In: Redwood M (ed) Agriculture in urban planning. Generating Livelihoods and Food Security. Earthscan/IRDC, Ottawa

CSE (2011) Rapport sur l'Etat de l'Environnement, Edition 2010. 255 p (à paraître)
Diouf (2008)
Fall ST, Fall AS (eds) (2001) Cités horticoles en sursis? L'agriculture urbaine dans les grandes Niayes du Sénégal. CRDI, Ottawa, 140 p
Gaye M, Niang S (2002) Épuration des eaux usées et l'agriculture urbaine. Dakar : Enda Éditions, 354 p
Guèye-Girardet A (2010) évaluation des pratiques d'irrigation, de fertilisation et d'application de pesticides dans l'agriculture périurbaine de Dakar, Sénégal. thèse de doctorat, Universités de Genève et Lausanne; Faculté des Géosciences et de l'Environnement, Institut de Minéralogie et de Géochimie, 276 p
Gaye AT, Sylla MB (2008) Scenarios climatiques au Sénégal. Laboratoire de Physique de L'Atmosphère et de l'Océan S. F. (LPAO-SF), École Supérieure Polytechnique Université Cheikh Anta Diop, Dakar, Sénégal
Le Borgne J (1988a) La pluviométrie au Sénégal et en Gambie, 86 p
Le Borgne J (1988b). La Dégradation actuelle du climat en Afrique entre Sahara et Equateur. In: La dégradation des paysages en Afrique de l'Ouest : points de vue et perspectives de recherche, Paris Séminaire de Dakar, 21–26 Nov, pp 17–36
Ndiaye ML (2009) Impacts sanitaires des eaux d'arrosage de l'agriculture urbaine de Dakar (Sénégal). Thèse de doctorat: Université de Genève
Ndong J-B (1996) L'évolution du climat du Sénégal et les conséquences de la sécheresse récente sur l'environnement. Th. Doct. Univ. Lyon III, 501 p
Plan Directeur Urbanisme Horizon (2001). Source: Enquête ménage CAUS/2001/PDU
Sagna P, Ndour N, Lake L-A (2000) Bilan climatique. In: Ecographie du Sénégal subsaharien et développement, pp 47–83
Sagna P (2008) L'évolution du climat du Sénégal, Forum régional sur le changement climatique en Afrique de l'Ouest Dakar, 6–7 Nov 2008

Chapter 27
Greenhouse Gas Emissions of Decentralised Water Supply Strategies in Peri-urban Areas of Sydney

Lu Aye, Bandara Nawarathna, Biju George, Sudeep Nair and Hector Malano

Abstract Quantification of greenhouse gas emissions for decentralised water supply systems is essential for water policy development, decision making and implementation of these systems. Two potential water supply strategies 'Effluent Reuse' and 'Stormwater Harvesting' applicable for the planned growth centre development of Western Sydney were developed. The associated energy intensities and operational greenhouse gas emissions of these two strategies were quantified by using the factors and methods prescribed by the Department of Climate Change and Energy Efficiency National Greenhouse Accounts Factors, 2011. It was found that in terms of operational greenhouse gas emissions, stormwater harvesting performs marginally better than effluent reuse while the cost of stormwater harvesting is expected to be about four times cheaper than effluent reuse in Australia.

Keywords GHG · Decentralised water supply · Peri-urban · Sydney

27.1 Introduction

Climate change and population growth put pressure on urban water supply systems in Australia. Energy intensive or greenhouse gas emission intensive water supply systems are not desirable as they have the potential to increase global warming which in turn may further increase climate change effects and reduce water availability.

The Greater Sydney's population is expected to grow from 4.25 to 5.3 million by 2031 (Roads and Traffic Authority 2007) and the majority of this growth is

L. Aye (✉) · B. Nawarathna · B. George · S. Nair · H. Malano
Department of Infrastructure Engineering, Melbourne School of Engineering,
The University of Melbourne, Melbourne, VIC 3010, Australia
e-mail: lua@unimelb.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_27,

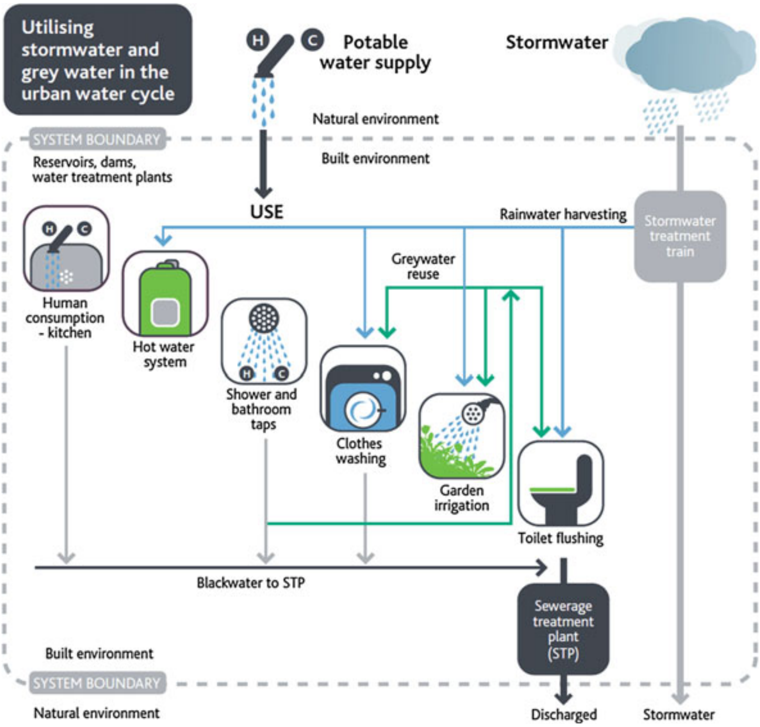


Fig. 27.1 Fit-for-Purpose approach. *Source* City of Melbourne (2011)

expected to take place in the Western Sydney region. Population of the South Creek catchment is projected to reach one million during this period. The expected increase in population is expected to concentrate in the proposed North West and South West growth centres. In this paper, the applicability of decentralised water systems in the proposed growth centre areas within the South Creek catchment is discussed. Mitchell et al. (2008) defined decentralised water systems as "treatment technologies and/or management systems at the scale of multiple buildings e.g. cluster, neighbourhood, precinct, suburb, but not city scale".

There are six potential sources of water available to Western Sydney: surface water, groundwater, recycled water, rainwater, stormwater and desalinated seawater. Currently about 80 % of the water used in Sydney originates in the surrounding catchments and reaches the users through rivers, reservoirs and water distribution systems. The use of non-potable water to meet demands such as toilet flushing, residential outdoor irrigation, washing machines, public open spaces and golf course irrigation and industrial and commercial uses on a fit-for-purpose basis (Fig. 27.1) reduces the potable water requirement which in turn could minimise the energy consumption and greenhouse gas (GHG) emissions depending on the local conditions. Using non-potable water is also an effective mechanism to reduce the pressure on depleting water resources. Decentralised water supply strategies

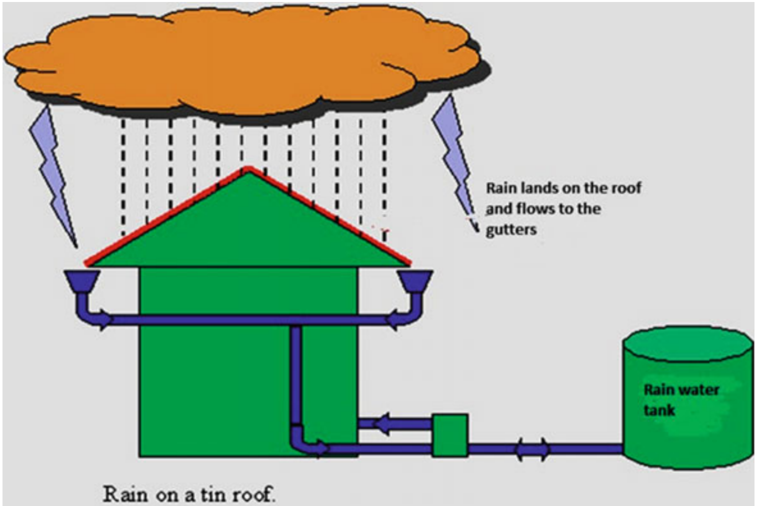


Fig. 27.2 Rainwater harvesting. *Source* Manjusha (2011)

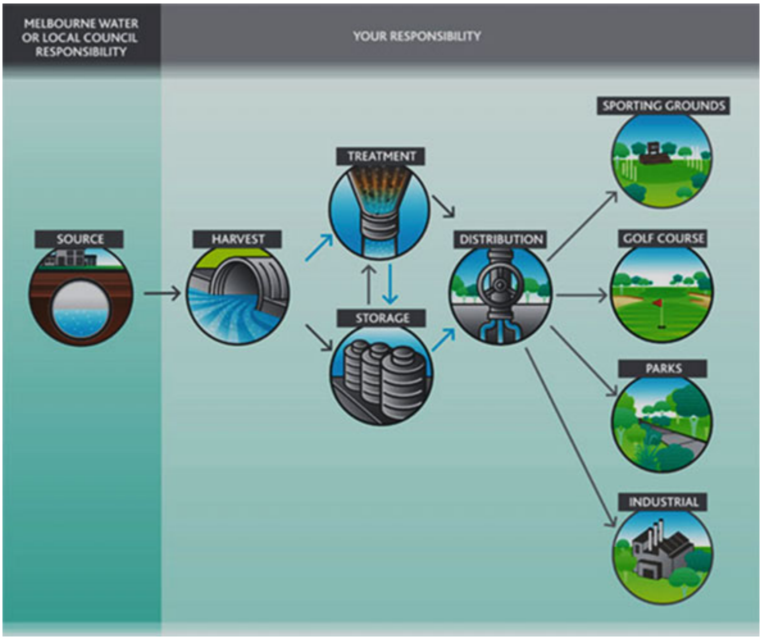


Fig. 27.3 Stages in stormwater harvesting. *Source* Melbourne Water (2011)

such as collection, treatment and use of rainwater (Fig. 27.2), stormwater (Fig. 27.3), groundwater (Fig. 27.4) or wastewater (Fig. 27.5) at different spatial scales are appropriate since they allow a staged development of water resources,

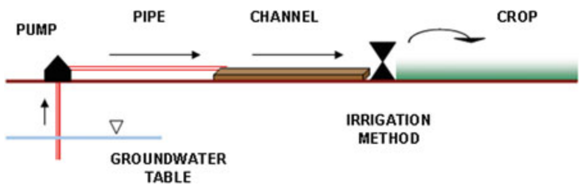


Fig. 27.4 Schematic diagram of typical groundwater irrigation system showing components. *Source* Tyson et al. (2012)

Fig. 27.5 Greywater reuse system. *Source* City of Melbourne (2011)

community involvement and local reuse. The main challenge posed by this type of strategy is to identify the suitable spatial scale and size of the decentralised systems that minimises the environmental impacts associated with the construction and operation of the system without compromising the primary objective of meeting non-potable water requirements of the area.

The aim of this paper is to quantify the greenhouse gas emissions associated with water supply strategies which could be suitable for applications in the planned growth centre development of Western Sydney. The costs of the centralised water systems compared to traditional water supply systems are also reported. The following section discusses the decentralised water supply strategies investigated. The analysis method applied, the results found and conclusions are also presented in subsequent sections.

27.2 Decentralised Water Supply Strategies

This study presents several alternative strategies including business as usual (BAU) water usage in 2030 and other possible ways of using non-potable water via decentralised systems to replace potable water to meet residential outdoor, public open spaces, industrial and agricultural demands (Table 27.1). Two scenarios namely ‘Effluent Reuse’, and ‘Stormwater Harvesting’ were developed considering fit-for-purpose water usage. Resulting GHG emissions are also discussed for these selected scenarios.

Table 27.1 Possible usage of non-potable water to replace potable water supplies (where, 0 = BAU, 1 = Effluent reuse, 2 = Stormwater harvesting)

	Residential indoor	Residential outdoor	Public open space	Industrial	Agriculture
Potable water	0, 1, 2	0, 1, 2	0, 1, 2	0, 1, 2	0, 1, 2
Surface water	–	–	–	–	0, 1, 2
Groundwater	–	–	–	–	0, 1, 2
Treated effluent	–	1	1	1	1
Stormwater	–	2	2	–	2

Contemporary water supply sources in South Creek include potable water, surface water pumped from creeks and deep aquifers in accordance with entitlement based allocation to meet the demand. This study considers treated wastewater and stormwater in addition to the existing sources. Demands include residential indoor, residential outdoor, industrial, public open spaces (parks and golf courses) and agriculture. Surface water and groundwater are generally used for irrigating parks and farms. Treated waste water can be used for all the purposes except indoor use whereas treated stormwater can be used for irrigating public open spaces and agricultural lands.

A detailed hydrological modelling of the catchment was carried out to estimate the stormwater harvesting potentials of the region. The modelling of water allocation and substitution is based on the integration of resource availability and water demand using the Resource Allocation Model (REALM) (Perera et al. 2005) considering quality constraints based on a fit-for-purpose criterion. The allocation of water resources is highly variable due to uncertainty in climatic and land use environments.

Future estimates of urban water demand were projected based on current population, average population growth rate and per capita water demand. The population and number of dwellings in the year 2000 in the study area (South Creek) were 339,105 and 91,650 and are projected to increase to 999,500 and 269,800 respectively by 2030.

Three different water supply scenarios are considered: A BAU scenario assumes that demands from residential indoor, residential outdoor, industrial, public open spaces were met solely from potable supply. The second scenario (Effluent Reuse) assumes that treated effluent is used to supply possible usage demands as listed in Table 27.1. The third scenario (Stormwater Harvesting) assumes that stormwater is used to meet demand in addition to potable, surface water and groundwater. Yearly water allocation from each source to meet different demands is presented in Table 27.2.

The life cycle assessment (LCA) study done by Grant et al. (2006) for specific locations in Melbourne showed that 'capital infrastructure, while not insignificant, is much less important than operational impacts for most environmental indicators. This is because operational impacts are ongoing, while capital infrastructure is long

Table 27.2 Yearly water allocation

Water supply type	Water supply (ML/Yr)			
	2000	2030 BAU	Effluent reuse	Stormwater harvesting
Potable water	40,755	103,328	72,094	84,244
Surface water	3,600	3,103	3,103	3,103
Groundwater	240	234	234	234
Treated effluent	0	0	31,234	0
Stormwater	0	0	0	19,084
Total	44,595	106,665	106,665	106,665

Table 27.3 Energy intensities

Item	Intensity (MJ/kL)	Data source
Centralised water supply pumping	1.022	Sydney, Cook et al. (2012)
Centralised water supply treatment	1.002	
Centralised waste water pumping	0.236	
Centralised waste water treatment	1.530	
Centralised water: others	0.384	
Pumping rainwater in residential settings	5.400	Australia average, Retamal and Turner (2010)

Table 27.4 Energy intensities (MJ/kL) used Method applied to estimate GHG emission in the analysis (adapted from Kenway et al. 2008)

Treatment or pumping component	Lower	Upper
Water treatment and pumping		
Conventional water treatment plant	0.36	1.80
Conventional water pumping	0.25	6.26
Pumping energy for re-use	3.60	7.20
Waste water treatment and pumping		
Primary wastewater treatment plant	0.50	1.00
Secondary wastewater treatment plant	1.00	2.00
Tertiary wastewater treatment plant	2.00	5.00
Conventional wastewater pumping	0.25	1.55

lived and only has to be provided once. Embodied GHG emissions were omitted in this study as embodied energy associated with urban water infrastructure is negligible compared to operating energy (Kenway et al. 2008). Table 27.3 lists the energy intensities of current processes for Sydney. Standard electricity imported from the grid is the main energy source for most water utilities in Sydney, which is over 90 % of their power needs (Kenway et al. 2008). A full fuel cycle emission factor of 1.06 kg $CO_{2\text{-}e}$/kWh for consumption of purchased electricity by end users in New South Wales (DCC and EE 2011) was used for the analysis. Other data and assumptions used in the analysis are presented in Table 27.4.

Table 27.5 Energy intensities (MJ/kL)

Scenario	Lower	Upper	Sydney
BAU	4.17	16.05	4.174
Effluent reuse	4.10	8.20	–
Stormwater harvesting	0.75	7.26	–

Table 27.6 Operational GHG emission intensities (kg $CO_{2\text{-}e}$/kL)

Scenario	Lower	Upper	Sydney
BAU	0.40	6.02	1.23
Effluent reuse	0.38	3.08	–
Stormwater harvesting	0.07	2.72	–

Table 27.7 Costs, $/kL (adapted from Marsden and Pickering 2006)

Scenario	Lower	Upper	Sydney
BAU	0.86	1.59	1.47
Effluent reuse	0.08	6.00	–
Stormwater harvesting	0.10	1.50	–

27.3 Results and Discussion

The estimated ranges of energy intensities and operational GHG emissions for the Effluent Reuse and Stormwater Harvesting scenarios in Australia, together with the data for Sydney, are shown in Tables 27.5 and 27.6. The range of costs found in the literature for Australia is provided in Table 27.7.

The Sydney BAU water supply scenario has lower energy intensity compared to other locations in Australia. This may be due to the demographic distribution of the population thereby causing disparities in the water demand. As the population increases, more pumping energy would be spent for supplying water to new and distant dwellings. The energy use for water supply and treatment also greatly depends on the technology used. The high energy intensity for the upper range of the BAU scenario may be due to the use of advanced technologies in water treatment which are energy intensive.

Stormwater harvesting seems to be a good option considering its lower energy intensity. The energy intensity of both stormwater harvesting and effluent reuse depends on the level of treatment required to meet the desired quality for specific uses. Stormwater harvesting is also a better option in terms of operational GHG emissions and cost. Based on these figures, stormwater harvesting could be used as a potential supplement to the conventional water supply in order to meet additional water demand and incur lower energy and GHG emissions.

27.4 Conclusions

This paper presents the results of quantifying energy consumptions and GHG emission intensities for the Effluent Reuse and Stormwater Harvesting scenarios for the planned growth centre development in Western Sydney. The analysis shows that in terms of operational GHG emissions the Stormwater Harvesting scenario performs marginally better than the Effluent Reuse scenario while the cost of the Stormwater Harvesting is expected to be about four times cheaper than the Effluent Reuse. Quantification of GHG emissions arising from system operation for the two scenarios requires further detailed analyses that consider specific system configurations in Western Sydney.

Acknowledgments The authors gratefully acknowledge the considerable assistance from the members of the Water and Land Management Innovation and Sustainability Enhancement Partnership in Peri-urban Research (WISER) project team. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

References

City of Melbourne (2011) WSUD guidelines: applying the model WSUD guidelines, an Initiative of the inner Melbourne action plan. http://www.melbourne.vic.gov.au/Environment/SavingWater/Documents/WSUD_Guidelines.PDF. Accessed 16 Nov 2011

Cook S, Hall M, Gregory A (2012) Energy use in the provision and consumption of urban water in Australia: an update. CSIRO: Water for a Healthy Country National Research Flagship, CSIRO and Water Services Association of Australia

DCC and EE (2011) National greenhouse accounts factors, July 2011. Commonwealth of Australia, ISBN: 978-1-921299-86-5, p 77

Grant T, Opray L, Grant A, Sharma AK, Mitchell VG, Pamminger, F (2006) Life cycle aspects of alternative water and sewage servicing. In: Deletic A, Fletcher T (eds) Proceedings of 7 UDM and 4WSUD: urban drainage modelling and water sensitive urban design conference 2006, Melbourne, 5–6 Apr 2006, pp 121–128

Kenway SJ, Priestley A, Cook S, Seo S, Inman M, Gregory A, Hall, M (2008) Energy use in the provision and consumption of urban water in Australia and New Zealand. CSIRO: Water for a Healthy Country National Research Flagship, CSIRO and Water Services Association of Australia, ISBN: 978 0 643 09616 5, p x + 50

Manjusha (2011) Rain water collection. http://www.mastanantapur.com/rainwater.html. Accessed 16 Nov 2011

Marsden J, Pickering P (2006) Securing Australia's urban water supplies: opportunities and impediments. Marsden Jacob Associates, Camberwell, Victoria, p xi + 58

Melbourne Water (2011) Urban stormwater harvesting: what does an urban stormwater harvesting scheme look like? http://www.melbournewater.com.au/content/drainage_and_stormwater/stormwater/urban_stormwater_harvesting.asp. Accessed 16 Nov 2011

Mitchell C, Retamal M, Fane S, Willetts J, Davis, C (2008) Decentralised water systems creating conducive institutional arrangements. Paper presented at enviro 08 Australasia's environmental and sustainability conference and exhibition, Melbourne, 5–7 May 2008, pp 1–9

Perera BJ, James B, Kularathna MD (2005) Computer software tool REALM for sustainable water allocation and management. J Environ Manage. doi:10.1016/j.jenvman.2005.06.014

Retamal M, Turner A (2010) Unpacking the energy implications of distributed water infrastructure: how are rainwater systems performing? Water Sci Technol. doi:10.2166/ws.2010.136

Roads and Traffic Authority (2007) Sydney urban corridor strategy: building our national transport future. Department of Transport and Regional Services, Commonwealth of Australia, ISBN: 978-1-921095-49-8, p iii + 29

Tyson A, George BA, Aye L, Nawarathna B, Malano H (2012) Energy and greenhouse gas emission accounting framework for groundwater use in agriculture. Irrig Drainage. doi:10.1002/ird.1645

Chapter 28
Opportunities and Challenges of Urban and Peri-urban Agriculture to Face Climate Change: A Critical Analysis of Policy and Urban Governance of Dhaka City

Shah Mohammad Ashraful Amin and Atiq Rahman

Abstract Dhaka, the capital of Bangladesh, with a current population of 14.64 million, is one of the fastest growing megacities of the world. With already over saturated population density; some 300,000 to 400,000 new migrants, mostly poor, arrive at the city annually from coastal and rural areas after experiencing some kind of environmental hardship. At present, these uprooted people constitute almost one-third of the city's population. Along with the burden of massive population, the problems of Dhaka City are manifold. In the face of additional challenges resulting from the changing climate and increasing intensity and frequency of extreme climatic events; the overall situation is getting worse. On the other hand, poor urban governance and absence of a comprehensive policy on urbanisation have resulted in an unliveable metropolitan area with acute land scarcity and excessively high land prices, poor housing, traffic congestion, water shortages, poor sanitation and drainage, irregular electric supply, unplanned construction and environmental degradation. Now, the biggest challenge is to explore the opportunities to feed the ever-increasing urban population of Dhaka. Hence, with a particular focus on the urban food security situation, this paper has critically analysed the existing policies, strategies, urban governance system and practices; and has eventually identified the loopholes that hinder the promotion and expansion of Urban and Peri-urban Agriculture (UPA). This analysis has also proposed some strategic directions for mainstreaming UPA in the existing policies and urban governance system.

S. M. A. Amin (✉)
UN World Food Programme-Bangladesh, IDB Bhaban, (17th Floor), E/8-A,
Rokeya Sarani, Sher-E-Bangla Nagar, Dhaka 1207, Bangladesh
e-mail: ashu14planner@gmail.com; ashu_planner@yahoo.com; ashraful.amin@wfp.org

A. Rahman
Bangladesh Centre for Advanced Studies (BCAS), House 10, Road16A, Gulshan-1,
Dhaka 1212, Bangladesh
e-mail: atiq.rahman@bcas.net

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_28,

Keywords Climate change · Dhaka · Policy · Urban and peri-urban agriculture (UPA) · Urban governance

28.1 Background-Problematic and Historical Growth of Dhaka

After the liberation war in 1971, Dhaka achieved tremendous growth to meet the needs of the newly independent country's capital. The city's population suddenly rose to 2 million in 1974 and within a decade it shot up to 3 million in an extended area covering 510 km^2 by 1981. Then Dhaka faced its highest rate of physical and population growth during 1981–1991 when its population just doubled and the area expanded from 510 to 1,353 km^2 (Hussain 2010). Figure 28.1; showing the historical growth of Dhaka over 400 years since the Mughal era; eventually reveals the pace of its expansion both in terms of geographical extent and population over different periods of time.

The Bangladesh Bureau of Statistics has officially called this extended metropolitan area a megacity in the 1991 census. Previously it was referred to as a Statistical Metropolitan Area. Megacity Dhaka is an agglomeration of Dhaka City Corporations (North and South), five other municipalities (Gazipur, Tongi, Savar, Narayanganj and Kadamrasul), several cantonments and a large number of rural settlements, stretches of agricultural lands, wetlands, rivers, and even part of the Modhupur forest.

With this current trend of growth, the population of Dhaka city is projected to be 20.93 million by 2025 where the opportunity of geographical extension is very limited (UN-HABITAT 2012). Dewan et al. (2010) has analysed the land use changes in the Dhaka Metropolitan Area (DMA) from 1975 to 2005. Over this period; built up areas increased approximately by 15,049 ha but cultivated land decreased by 5,804 ha. At this backdrop, food security of urban population will be threatened and further aggravated in the face of multidimensional adverse impacts of climate change. Over the last couple of decades, unplanned urbanisation has already created widespread environmental problems that include recurrent events of flooding and drainage congestion, growth of slums, loss of green areas and open spaces, traffic congestion, and air and water pollution.

28.2 Role of Urban/Peri-urban Agriculture

The addition of more and more people to Dhaka is not only creating enormous pressure on the urban infrastructures—water, electricity, sewage and waste management, but also threatening income generating activities, livelihoods and food security. These pressures are likely to multiply in future under climate change and other socio-economic stressors. De Zeeuw et al. (2011), in his analysis on exploring

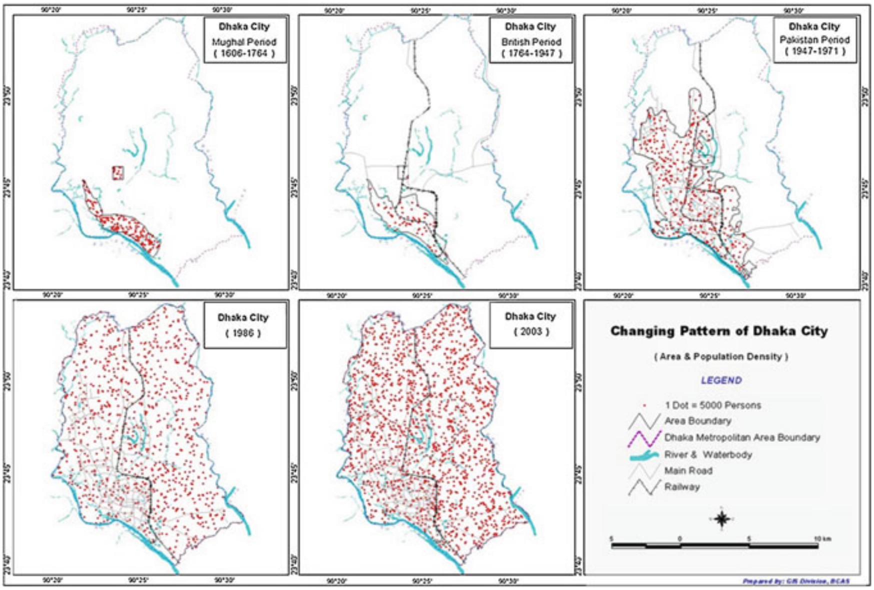


Fig. 28.1 Historical growth of Dhaka

the role of urban agriculture in building resilient cities in developing countries; has concluded that UPA can contribute significantly to food security and nutrition, socio-economy, environment and ecology in the following manners.

Firstly, urban agriculture can be considered as a complementary component of the mainstream strategies to reduce urban poverty and food insecurity. Foods for urban areas are now being transported from rural areas and sources that are sometimes located far away. For example, Dhaka's food (fruit, vegetables, fish, meat, poultry, etc.) supplies come from the coastal and border districts, even from India and Myanmar. There is uncertainty of supply from distant places during natural hazards and civil strife; and rural areas would only export after satisfying their own local demand. Therefore; UPA plays an important role by reducing transportation costs of food as well as guaranteeing supply. FAO (2010) reported that poor urban households spend up to 80 % of their income on food. Nonetheless, UPA can offer survival strategies to the urban poor in various ways; such as; production and consumption; selling the surplus and generate income; or involving in income generating activities like producing compost from organic waste.

Secondly, UPA also contribute to local economic development, poverty alleviation and social inclusion of the urban poor in general, and women in particular by lowering food costs. Besides directly benefitting the producers, UPA also contributes through development of agro-based micro-enterprises like production and supply of necessary agricultural inputs, processing of agro-products, packaging and marketing, animal feed, veterinary service, transportation, waste management, and energy generation from agricultural waste. In addition, UPA can open up new window of economic development for socially excluded and marginalized groups like people with disabilities, unemployed youths and HIV affected people.

Thirdly, as an integral part of urban eco-system, the proper management of UPA can positively contribute to environmental conservation and pollution control in many ways. (1) Urban areas in developing countries generate a huge amount of waste water and most of it is dumped in water bodies. Waste water can be used for irrigation purposes. It will generate higher profits for the producers as well as reduce pollution of water bodies. However, care should be taken regarding the health impact of waste water handling and uses. (2) Open spaces are often used as dumping grounds for household and other wastes. Once they are converted to agriculture plots, such practices will be reduced bringing health and aesthetic benefits to the neighbourhood. (3) Green spaces including urban forestry help to improve the urban micro climate and absorb Greenhouse Gases. On the other hand, rearing animals can contribute to Greenhouse Gas emissions.

28.3 Urban Governance of Dhaka

At present, there are three broad levels of agencies involved in the management of Dhaka, e.g. National, Regional and Local. At national level, the Planning Commission coordinates the urban administration of civic and planning activities. Three ministries, namely Local Government Division of the Ministry of Local Government, Rural Development and Cooperatives, the Ministry of Housing and Public Works and the Ministry of Communication, are largely responsible for urban planning and administration. Some of the agencies that are directly responsible for urban services in the capital are:

- Urban Local Governments
  - Dhaka North City Corporation (DNCC)
  - Dhaka South City Corporation (DSCC)
  - Five Municipalities e.g. Gazipur, Tongi, Savar, Narayanganj and Kadamrasul
  - Dhaka Cantonment Board
  - Savar Cantonment Board
- Planning and Development Authority
  - Rajdhani Unnayan Kartipakkha (RAJUK)
- Single Purpose Authorities
  - Dhaka Water and Sewerage Authority (DWASA)
  - Bangladesh House Building and Finance Corporation (BHBFC)
  - Dhaka Power Distribution Company Limited (DPDC)
  - Dhaka Electric Supply Company (DESCO)

  - Bangladesh Power Development Board (PDB)
  - Bangladesh Telephone and Telegraph Board (T&T)
  - Titas Gas
- Special Government Departments/Directorates
  - Urban Development Directorate (UDD)
  - Public Works Department (PWD)
  - National Housing Authority (NHA)
  - Department of Public Health Engineering (DPHE)
  - Local Government Engineering Department (LGED)
  - Department of Architecture (DoA)
  - Department of Environment (DoE)
  - Roads and Highways Department (RHD)
  - Dhaka Metropolitan Police (DMP).

With the ever increasing urban population and changes in the socio-economic context; the existing urban governance system is quite unable to face the demands and emerging challenges of the mega city. Under the changing circumstances; the central government and urban local government bodies are struggling to provide housing, water, sanitation, electricity and other civic services to city people. And in recent times, the biggest challenge has been maintaining the balance between demand and supply of food for the city people where the changing climatic condition is going to further worsen the food insecurity. Now this is high time for the central government and urban local government bodies to acknowledge this emerging issue.

28.4 Policy Implications

Different National Policies directly address the agriculture sector and the inherent risk of climate change but there is no specific policy document to promote UPA. The national policy documents that should be taken into account for promoting and mainstreaming UPA can be sub-divided into the following five categories:

1. Food security
2. Agriculture
3. Natural resources (Environment, Land and Water) management
4. Housing and urban development; and
5. Climate change.

The National Food Policy (NFP) 2006 is the sole guiding document to ensure dependable food security for all people at all times. In line with the policy, the government has formulated a Plan of Action (PoA) to ensure the effective implementation of the policy over the period of 2008–2015. The PoA covers 26 areas of intervention for achieving the 3 core objectives of NFP. The proposed 26

Table 28.1 Key features of policies related to agriculture sector

	Sub-sector policies	Major goals and policy thrusts	Implementing ministry
A. Crop			
1	National agriculture policy (NAP), 1999	Food security, profitable and sustainable production, land productivity and income gains, IPM, smooth input supplies, fair output prices, improving credit, marketing and agro-based industries, protecting small farmers interest	Ministry of agriculture
2	New agricultural extension policy (NAEP), 1996	Provision of efficient decentralized and demand led extension services to all types of farmers, training extension workers, strengthening research-extension linkage, and helping environmental protection	Ministry of agriculture
3	Department of agricultural extension (DAE)-strategic plan, 1999–2002	Adoption of revised extension approach, assessment of farmers' information needs, supervision, use of low or no cost extension methods, promotion of food and non-food crops, and mainstream gender and social development issues into extension service delivery	Ministry of agriculture
4	Agricultural extension manual, 1999	Annual crop planning, seasonal extension monitoring, participatory technology development and rural approval partnership, technical audit, attitude and practice surveys	Ministry of agriculture
B. Non-crop			
5.	National livestock development policy, 2007	Improvement of small scale poultry and dairy farming, reform of department of livestock, enforcement of law and regulations towards animal feeds, vaccines and privatization of veterinary services adoption of breeding policy, and establishment of livestock insurance development fund and livestock credit food	Ministry of fisheries and livestock
6	National fishery policy, 1998	Development of fishery resources, increasing fish production and self-employment, meeting demand for animal proteins accelerating fish exports, and improvement of public health	Ministry of fisheries and livestock

intervention areas have covered critical issues like agricultural research and extension, use and management of water resources, supply and sustainable use of inputs, agricultural diversification, agricultural credit and insurance, physical market infrastructure development, creation of value chains, agricultural disaster management and enabling environment for private food trade and stock.

The summary (Tables 28.1, 28.2, 28.3, 28.4) accumulate the key features of the policies related to agriculture, natural resources management, housing and urban development, and climate change.

Table 28.2 Key features of policies related to natural resources management

	Sub-sector policies	Major goals and policy thrusts	Implementing ministry
1	Environmental policy and implementation programme (EPIP) 1992	Conservation of environment, wet lands, RAMSAR sites. Prevention of environmental degradation; air, water, soil and noise pollution and conservation of forests	Ministry of environment and forests
2	Land use policy, 2001	The main objectives of the land use policy are prevention of excessive land use due to the ever increasing demand for crop production, maximum utilization of inlands and wetlands, preservation of 'Khas Lands' and helping in reducing the number of landless people in Bangladesh	Ministry of land
3	National water policy 1999	Promote optimum use of water resources across all sectors.	Ministry of water resources

Table 28.3 Key features of policies related to housing and urban development

	Sub-sector policies	Major goals and policy thrusts	Implementing ministry
1	National housing policy 1993 (Amendment 1999)	Ensure housing for all strata of society and to accelerate housing production in urban and rural areas with major emphasis on needs of low and middle-income groups. Make available suitably located land at affordable price for various target groups, especially for the low and middle-income group To provide a quality urban design having aesthetic, functional and flexibility characteristics; To develop a programme for public sector action aiming at the implementation of the plan;	Ministry of housing and public works
2	Detailed area plan (DAP)	To prepare database and disseminate it in professional manner; To provide and guide private sector development; To provide clarity and security to future inhabitants and investors; To prepare guidelines for future infrastructure development	Rajdhani Unnayan Kartripakkhya

Table 28.4 Key features of policies related to climate change

	Sub-sector policies	Major goals and policy thrusts	Implementing ministry
1	National adaptation programme of action (NAPA) 2005; revised in 2009	NAPA document has encouraged investments in better access to agricultural services, social protection measures, i.e. safety-nets, insurance and enhancing awareness, behavioural changes and communication for climate related risks	Ministry of environment and forests
2	Bangladesh climate change strategy and action plan (BCCSAP) 2008, revised in 2009	The BCCSAP is an integral part of national development policies, plans and programmes including the upcoming sixth five year plan. Under 6 thematic areas, BCCSAP has developed 144 action oriented projects where food security has got highest priority	Ministry of environment and forests

28.5 Risks and Challenges

The risks and challenges that hinder the promotion and growth of UPA are mainly 3-fold: poor urban governance, poor policy directions and the adverse impacts of climate change and extreme climatic events.

28.5.1 Problems of Urban Governance

The problems of the existing urban governance system of Dhaka are deep rooted and complex. The following problems have made urban governance most ineffective.

Within the Dhaka Metropolitan Area, there are regulatory authorities such as RAJUK, service providing agencies such as DWASA, DPDC, DESCO and both regulatory and service providing bodies like City Corporations (North and South) in the same horizon. But there is no control of the regulatory authority over the service providing agencies to ensure optimum use of resource and energy. Moreover; no one is responsible for overseeing the balance allocation of water and energy resources across the different sectors of agriculture, industry and households. As a result, the UPA system suffers from irregular supply of water and electricity which eventually halt growth.

Different institutions are quite often created and their boundaries are delineated from exclusively narrow and immediate political considerations rather than through pursuit of objective imperatives. The area under city corporation is less than 10 % of the total metropolitan area and, therefore, the City Mayor cannot exercise his power in all areas under metropolitan jurisdiction. On the other hand, RAJUK has jurisdiction over the metropolitan area, but it can apply only a limited control over the planning and development activities as the Chairman of RAJUK has the rank equivalent to a Joint Secretary where the City Corporation Mayor is equivalent to the rank of a Minister.

The problem of coordination and leadership further aggravated when the Dhaka City Corporation was divided as Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC) in November 2011 through the amendment of the Local Government (City Corporation) Act 2009 (DNCC 2012). Instead of solving the problem, this bifurcation has resulted in poor garbage management, mosquito control and maintenance of city streets.

There is no agency which is capable of exerting strategic policy leadership to maintain the comprehensive city development in a guided way. The absence of such leadership has also, more or less, shuts down the growth of UPA. The situation is further aggravated because none of the local government bodies, development authorities and service providing agencies (listed in Sect. 28.3) has any directive on promoting UPA and there is nothing mentioned about it in their citizen charters.

The involvement of several institutions to decide the development of Dhaka Metropolitan Area has resulted in a gross overlap of functions and problems of coordination. The multiplicity of institutions generates plurality in the planning and development approach and this plurality results in uncoordinated efforts in decision making, planning, implementation and maintenance of services which, in turn, creates more problems rather than solving it.

National level agencies like UDD, NHA, etc. have been created to oversee the urban development and housing issues of the whole country and are usually guided by the National Housing Policy 1993. On the other hand, local planning and development authority RAJUK is guided by its recently developed Detailed Area Plan (DAP). There is absence of synergies between the National Housing Policy and the Detail Area Plan. In addition, UPA has not been addressed in these two guiding documents.

RAJUK is responsible for planning, development and development control through rules and regulations in the Dhaka Metropolitan Area but urban management through municipal services rests with city corporation. There are serious problems of coordination and mutual interaction among RAJUK, DNCC, DSCC and other governmental stakeholders.

Urban local government bodies, planning and development authorities, special purpose authorities and special government departments listed in Sect. 28.3 are neither involved with promoting UPA nor aware of this issue. The overall urban governance structure of Dhaka is a long way from addressing the issues of food availability, access to food, food supply and food utilization. Lack of skilled manpower in those institutions is one of the root causes behind this.

28.5.2 Problems with Policy

National Food Policy 2006 and National Food Policy Plan of Action (2008–2015) were developed considering the needs of both rural and urban farmers. But the adverse impacts of temperature rise, variation in precipitation and increased intensity and frequency of extreme climatic events on crop agriculture, livestock, fisheries and forestry have not been addressed neither explicitly nor implicitly in these documents. The policy directives are far away from the future projection of food production that would be required to feed the additional population.

Despite the recognition of amendment of existing policy documents in order to mainstream climate change issues, to date most of the policies enlisted in summary Tables 28.1, 28.2, 28.3, and 28.4 have not addressed climate change threats. Despite being one of the most vulnerable sectors to climate change, agriculture sector policies should have necessary directions to face the challenges of climate change. National Agriculture Policy (NAP) was formulated with a view to develop and sustain agricultural growth in such a way that it ensures the nation with a self-sufficient reliable food security system. NAP 1999 or the New Agricultural Extension Policy (NAEP) 1996 has no specific statement made on the issue of climate change and its impacts on agriculture. The National Agricultural Policy Draft 2009 specifically mentions the word climate change as an environmental vulnerability. Unfortunate, but true; that the crop sub-sector related policies are directed towards promoting benefits for rural farmers, not for urban farmers.

The National Livestock Development Policy 2007 has promoted incentives for dairy development and meat production, poultry development, veterinary services and animal health, breed development, marketing of livestock product and international trade management for both rural and urban farmers. But it has missed out addressing the adverse impacts of temperature rise on animal health, milk production, reproductive health and disease exposure. In its objectives the National Fisheries Policy 1998 pronounces 'maintenance of ecological balance' and 'conservation of biodiversity', but it does not directly count 'climate change' as a threat to fish resources. But to stimulate the urban fisheries industry, this policy has suggested strong guidelines for stopping the dewatering of lakes, ditches, canals and other water bodies.

The Environmental Policy and Implementation Programme (EPIP) 1992 for Bangladesh neither directly uses the term climate change nor has any direct statement made on the effect and consequences or adaptation procedures related to climate change in the context of agriculture, water and environment. While addressing the demand of water in urban areas, The National Water Policy (NWP) 1999 has just put emphasis on ensuring water supply in households and industries; reducing water logging and waste water treatment. The increasing water demand for UPA with the changing climatic condition has not been covered. No specific statement considering the impact of climate change on the country or its resources is made in the Land Use Policy 2001. And there are no specific guidelines to promote UPA. However, the importance of afforestation, environment and mutual sustainability of land use and forests are focused upon in the policy.

The sole objective of the National Housing Policy (NHP) 1999 is balancing the demand and supply of housing in both urban and rural areas. This policy document failed to retain space for agriculture in urban areas, and eventually not addressed the need of retaining open space, enhance recreational opportunities and conserve wetlands. The recently developed Detailed Area Plan (2010) of RAJUK; the sole guiding document for managing and guiding the growth of Dhaka Metropolitan Area; also missed out to put light on retaining space in urban and peri-urban areas through zoning regulation for promoting agriculture.

Food security has been addressed with a highest priority in the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009. The first pillar encompasses various aspects of food security in Bangladesh in the face of climate change. This pillar has prioritized 9 programmes with a goal to promote food security for the poorest and most vulnerable people of the community. This pillar also highlights an increase of resilience of community people through development of community-level adaptation, livelihood diversification, better access to basic services and social protection (e.g., safety nets, insurance), and scaling up. The nine programmes under pillar 01 include a wider range of activities i.e. research, development of climate resilient cropping systems and production technologies, capacity building, piloting of adaptation measures etc. and although these programmes are equally applicable for rural and urban population, some context specific measures are required to meet the needs of the city's population.

As a response to reduce the risk of agricultural loss and the damage to several crops, fish and livestock, the Government of Bangladesh has intended National Adaptation Programme of Action (NAPA) 2009, as a broad action of several possible adaptive measures. These measures are well aligned with Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009. Food Security, among the others, is one of the most important intents to be addressed by these measures. The first pillar of NAPA i.e. Food Security and Pro-poor Social Safety-Nets, as the name implies, has been devised to address food security directly. This thematic area or pillar consists of 11 adaptive measures. These measures are intended to ensure that the poor people are protected from the climatic upheaval and that they get access to food, employment and basic services. These measures have been devised based on the overall country context. But the socio-economic context and environment of urban areas are completely different from rural areas. Therefore, some context specific adaptation measures are required to address the need of city farmers.

28.5.3 Problems Related to Climate Change

Dhaka is going to be affected primarily by climate change in three ways: floods/drainage congestion; heat stress and water stress. Experts believe that the melting of glaciers and snow in the Himalayas, along with increasing rainfall attributable to climate change, will lead to more flooding in Bangladesh in general, and in cities located near the coast and in the delta region, including Dhaka in particular. Furthermore, Dhaka may also face “heat island” problems from rising levels of vehicle exhaust emissions, increased industrial activity and increased use of air conditioning.

28.5.3.1 Flood

Due to low topography with an average ground elevation of 0.5–12 m and being surrounded by Buriganga on the south–west, Turag on the north–west, Balu on the north–east and Shitalakkhya on the south; Dhaka city is highly susceptible to flood. The city has been affected by flood in 1954, 1955, 1970, 1974, 1980, 1987, 1988, 1998 and 2004 (Yahya et al. 2010). A study of Mirza (2003) based on climate change scenarios from general circulation models stresses that future peak discharges may lead to more serious flooding in Bangladesh, especially in the flood-prone areas of Central and North-Eastern Bangladesh. The Greater Dhaka region, as well as most central parts of the country, will experience increasing problems in terms of depth and spatial extent of flooding due to increases in peak discharges of the rivers Brahmaputra, Ganges and Meghna. In addition to micro level water logging, Dhaka region also has a high risk associated with inland and river flooding (see e.g. Brammer 2004; Braun and Shoeb 2008; Islam 2005; Münchener 2004), which further contributes to the problems faced by the city’s population.

The eastern part of Dhaka, nearly 119 km^2, was completely inundated during the 1998 flood. This devastating flood caused damage to 860,552 households of Dhaka Metropolitan Area, at a cost of Tk. 2.3 billion. More than 600 km of roads were reported to be damaged in this flood. The total loss of large scale industry in Dhaka was equivalent to more than US$30 million while the loss to small and medium size industry including agro-based industries was US$36 million (Alam and Rabbani 2007). Although there was no specific data on damage to crop, livestock, poultry and fisheries in Dhaka during 1998 flood; it can be easily assumed that all of these sub-sectors have faced severe damage.

Along with the Intergovernmental Panel on Climate Change (IPCC), several research findings indicate that the intensity and frequency of flood incidents in the Ganges–Brahmaputra–Meghna river basin will increase as a result of global warming and erratic behaviour of precipitation. Hence, recurring flood is going to be a severe threat to urban agriculture.

28.5.3.2 Heat Stress

Urban area temperatures in Dhaka are consistently 1–2 °C higher compared to the adjacent countryside (EPA 2008). It may be because of Dhaka’s concrete surface conditions, traffic of the city, emissions from industries, cooling systems, air pollutions and presence of aerosols in the lower atmosphere. On the other hand, the peri-urban setting is characterised by agricultural land, green vegetation and a strong presence of water bodies which contribute in absorbing the heat and radiating less heat to lower the air temperature.

28.5.3.3 Water Stress

Bangladesh Agricultural Development Corporation (BADC) has conducted a survey over a period of 5 years (2005–2010) on demand and supply of water in Dhaka City. Over this period, static ground water levels in Dhaka have fallen by nearly 16 m, from 53.92 to 69 m. Another study by Baten and Uddin (2011) projected that at a depletion rate of 2.81 m/year, the groundwater table will go down to 120 m by 2050. According to Dhaka Water Supply and Sewerage Authority (DWASA), there is a gap of 500 Million Litters per Day between demand and supply of water. Increased rate of urbanisation, illegal occupation and encroachment has reduced the amount and volume of surface water bodies around the city and has further aggravated the water stress on city dwellers (Baten and Uddin 2011).

Unfortunately the water supply system in Dhaka and its periphery does not recognise farming as a customer and to promote UPA, water is the most critical input to be ensured. However, the water that urban farming needs can be supplied from wastewater, groundwater, and surface water. The projections and analysis stated above clearly reveal that ensuring a regular supply of water from groundwater sources is going to be a big challenge in the near future. Furthermore, temperature rises and an increasing number of days without rainfall will worsen the situation.

On the other hand, wastewater is usually not readily available to urban farmers because sewage systems are designed to remove sewage from the city, not to reuse it locally. Nor do the authorities of Dhaka City typically make provisions for the reuse of surface water in farming. The lack of access to alternative sources of water sometimes compels urban farmers of Dhaka to use illegal sources. Due to rapid urbanisation and encroachment of water bodies; surface water is also becoming scarce for UPA use.

28.6 Way Forward

28.6.1 Opportunities for Mainstreaming UPA Within the Existing Governance and Policy Domain

Some specific policy directions and structural shifts in the administrative and governance system can open up new vistas of opportunities to mainstream UPA in the overall development endeavours.

28.6.1.1 Promotion of Good Urban Governance

There is an emerging need for an effective strategic plan for the metropolitan area in line with the Detail Area Plan to encourage UPA based on the requirements of projected future population. Legislative support would be essential. In order to bring control and leadership over metropolitan areas; a single apex body on city governance emerges as a better option. It will eventually enhance better horizontal and vertical coordination among different agencies.

A structural reform in the existing city governance system can not only promote good urban governance but also mainstream UPA. Under the leadership of the proposed single apex body, the DNCC, DSCC, RAJUK, single purpose agencies (DWASA, DPDC, DESCO) and special government departments (UDD, NHA) will continue their regular activities. A separate UPA extension wing can be established under the Single Apex Body and this wing can be comprised of four separate cells, i.e. climate change and Disaster Risk Reduction cell, agricultural extension cell, livestock and poultry cell and fisheries cell.

The waste management, street and open space management departments of city corporations and Land Use control regulatory section of RAJUK can be directly linked with the UPA extension wing. This will create opportunities for promoting agricultural practice in the street islands and open spaces and will also ensure proper management of agricultural, livestock and poultry waste. The coordination between land use control regulatory cell and the UPA extension wing will reduce encroachment of urban agricultural lands for housing, industrial or other commercial purpose. The coordination among single purpose agencies, special government departments and other authorities like cantonment board, Border Guard-Bangladesh (BGB), Airport authority with the proposed UPA extension wing through the single apex body will ensure necessary supply of water and electricity for agriculture purpose, reduce bureaucratic entanglement, promote agricultural practice in newly planned urban areas, create opportunities of agricultural practice over the huge amount of land under BGB, cantonment board and old and new airport. The schematic diagram shown in Fig. 28.2 depicts the proposed structural change in the urban governance system to mainstream UPA and climate change (Fig. 28.2).

There is a huge gap between the demand and supply of land in Dhaka. Due to extremely high land prices within the metropolitan area, people are going beyond the outskirts of the city. Furthermore the influence of speculators on the agricultural land owners to sell land to developers has resulted in a decrease of agricultural lands. That is why, there should be a use zoning regulation of land in and around Dhaka city and it should be practiced widely.

Other option may include: (i) The city's government authority can impose restrictions on premature conversion of agricultural land; (ii) A user friendly geospatial database for micro, meso and macro level tasks pertaining to zoning and planning can be generated; (iii) As well as planning; regulation and control are also required. Appropriate legal support can ensure proper guidance and control over the development of the city. There is also a huge capacity building need from

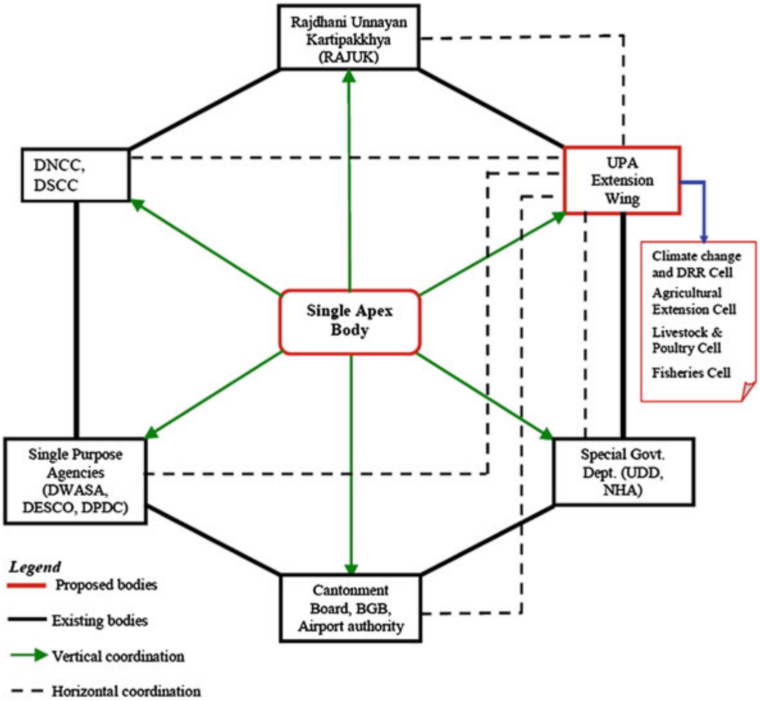


Fig. 28.2 Proposed structural change in the urban governance system

the city government officials and staff on adaptation to and mitigation of climate change.

It may also be important to encourage capacity building of city authorities and making them aware of the urgency to promote urban agriculture. Further, it may be beneficial to encourage the private sector to develop a value chain and market mechanism for urban agriculture sub-sector. The Country Investment Plan 2011 can be the guiding document for creating a value chain and developing a market mechanism. Similarly, encouraging community participation in the process of development activities in metropolitan urban areas may be important.

28.6.1.2 Policy Intervention

At present there is a need of mainstreaming climate change and UPA issues into government policies and development projects. The mapping and review of policy documents revealed that, with the exception of the National Agricultural Policy (2009, Draft Version), the policies; in general; do not pay sufficient attention to potential impacts from climate change. Most of the existing policies do include environmental concerns in relation to agricultural, fish or livestock production. It is clearly a positive finding that environment aspects are being considered to such a large extent in existing policy documents and there seems to be scope for using a similar approach for the projection of climate change risks and opportunities of UPA into these policies.

There is an emerging need to strengthen the linkages between research institutions and farming associations working on urban development issues. A large number of research projects and demonstrations are taking place all over Bangladesh. At present, there is limited coordination and knowledge sharing taking place within and across researchers and farmer groups.

In order to promote UPA, there is a need for more context specific approaches to climate change adaptation. To date the analysing of possible impacts of climate change in Bangladesh has mainly been conceived at the macro level, partly due to data limitations and lack of systematic knowledge of micro level conditions. Such a basis for adaptation work has its limitations, since each of the agro ecosystems hides considerable local variation in the resource; making generalization on technologies and management approaches hazardous. Therefore as of today there is limited knowledge of which adaptation option works best in urban ecosystem. Moreover, much ongoing community based adaptation projects have a rather narrow and short term focus and are mainly based on rural areas. This perspective of adaptation practices should be changed and more research and pilot initiatives on UPA should be encouraged.

There is a need for an integrated and strategic approach to livelihood development at the urban community level, considering the gradual changes in the environment caused by increases in population and climate change. These changes may lead to a need for new innovative and integrated approaches of how to optimize utilization of land and water resources in city areas in future. Such an approach is currently not integrated into the sector policy planning. An explicit Urban Agriculture Policy (UAP) along with a City Adaptation Programme of Action (CAPA) can be formulated in line with the existing BCCSAP and NAPA documents. Some policy decisions are also required to create mass awareness on promoting UPA and to eliminate the socio-cultural bias that hinders involvement in UPA.

The direct benefits and multiplier effects of UPA have not been recognised by the government and policy makers. All of the sectoral policies and strategic guidelines still lack in addressing the adverse impacts of climate change and rationale of promoting UPA. Hence, all of the policy and strategy documents analysed in Sect. 28.5.2 need to be amended based on the changing climatic condition and projection of future climate along with population growth.

Strong political commitment and solid policy guidelines are required to promote alternative approaches of urban agriculture; like roof top gardening. One option can be an amendment of National Housing Policy and the existing building regulations and laws. The Bangladesh National Building Code (BNBC) can be amended with the inclusion of a specific clause on making provision for rooftop gardening to be mandatory on each building. The National Housing Policy can also make provision of retaining spaces for small scale agriculture and open space for recreation in urban setting. The Detailed Area Plan (DAP) of RAJUK can also encourage plantation on street islands and vacant lands through inclusion of necessary provisions in the plan. Conservation of wetlands/ditches/canals can also be encouraged and monitored through DAP.

28.7 Conclusions

Resource poor cities in developing countries like Bangladesh are facing enormous challenges. And if the challenges are seen from climate change lens; then the future of Dhaka looks more appalling. At this juncture, UPA can lay down a pathway for addressing the challenges related to food security and livelihood of urban poor under the changing climatic condition. But poor policy direction and poor urban governance are creating bottlenecks in promoting UPA. Therefore, in order to foster the promotion of UPA in Dhaka; there is an emerging need of structural reform of the existing urban governance system, mainstreaming UPA and climate change issues in the existing policies; developing new policies on UPA and city adaptation; and above all; capacity building and institutional strengthening.

References

Alam M, Rabbani MG (2007) Vulnerabilities and responses to climate change for Dhaka. Environ Urban 19(1):81–97

Baten MA, Uddin AFMA (2011) Water supply of Dhaka City: murky future—the issue of access and inequality. Unnayan Onneshan-the innovators. http://www.unnayan.org/documents/RightsParticipation/water_supply_dhaka.pdf. Accessed 19 Dec 2011

Brammer H (2004) Can Bangladesh be protected from floods? The University Press, Dhaka

Braun B, Shoeb AZM (2008) Naturrisiken und Sozialkatastrophen in Bangladesch—Wirbelstürme und Überschwemmungen. In: Felgentreff C, Glade T (eds) Naturrisiken and Sozialkatastrophen. Spektrum Akademischer Verlag, Berlin and Heidelberg

De Zeeuw H, Van Veenhuizen R, Dubbeling M (2011) The role of urban agriculture in building resilient cities in developing countries. J Agr Sci 49:153–163. doi:10.1017/S0021859610001279. Cambridge University Press

Dewan AM, Yamaguchi Y, Rahman MZ (2010) Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh. GeoJournal 77:315–330. doi:10.1007/s10708-010-9399-x

DNCC (2012) Dhaka North City Corporation. http://www.dncc.gov.bd/dncc-setup/chronological-development-of-dncc.html. Accessed 20 Dec 2012

EPA (2008) US EPA's 2008 report on the environment (final report). US Environmental Protection Agency, Washington, DC, EPA/600/R-07/045F (NTIS PB2008-112484)

FAO (2010) Growing greener cities, (I1610E/1/6.10/1000). http://www.fao.org/ag/agp/greener-cities/pdf/ggc-en.pdf. Accessed 17 Dec 2011

Hussain A (2010) Living in the high-rise flats and apartments in Dhaka City. Anthropol Sci Mag 15:131–148. Jahangirnagar University, Dhaka. http://www.bdresearch.org/home/attachments/article/149/Text0008.PDF. Accessed 01 Dec 2012

Islam N (2005) Dhaka now: contemporary urban development. The Bangladesh Geographical Society, Dhaka

Mirza MMQ (2003) Three recent extreme floods in Bangladesh: a hydro-meteorological analysis. In: Mirza MMQ, Dixit A, Nishat A (eds) Flood problem and management in South Asia (vol 28, issue 1). Kluwer Academic Publishers, Dordrecht/Boston/London

Münchener Rück Munich Re Group (2004) Megacities—mega risks. Trends and challenges for insurance and management, München. http://www.preventionweb.net/files/646_10363.pdf. Accessed 17 Dec 2011

UNHABITAT (2012) State of the world's cities 2012/2013: prosperity of cities. World Urban Forum Edition, 2012. pp 152

Yahya SM, Shams S, Islam AKMS, Mahmud K (2010) Climate change impacts on flood vulnerability for Dhaka City. In: Proceedings of international conference on environmental aspects of Bangladesh (ICEAB 10). http://www.benjapan.org/iceab10/7.pdf. Accessed 20 Dec 2011

Chapter 29
System Harmonisation of Land and Water Resources in Peri-urban Regions: Lessons from Western Sydney, Australia

B. Maheshwari and B. Simmons

Abstract In this study, Western Sydney region was used as the 'laboratory' for understanding issues and options to harmonise rapidly changing peri-urban landscapes and identifying options for regional water security and land use planning. The main focus of the study was to engage and work with a range of stakeholder and government agencies to identify issues that impact on the use of potable water, stormwater, effluent and groundwater. The study involved transdisciplinary research and system harmonisation approach to understand the role of water in primary production, identifying opportunities and constraints as influenced by water quantity and quality, analysing market options and mechanisms to improve water productivity and environmental outcomes, review water policies, institutional barriers and community aspirations and identifying changes needed to improve water security. In this chapter, we discuss how the system harmonisation approach was applied to a peri-urban catchment in the Western Sydney region and a number of lessons that emerged from this study and the relevance of this approach to engaging stakeholders and government agencies and carrying out transdisciplinary research in peri-urban landscapes.

Keywords Stakeholder engagement · Water planning · Water security and system harmonisation

29.1 Introduction

Water in peri-urban landscapes around metropolitan cities and regional centres in Australia is one of the important essential ingredients for producing fresh food locally, keeping parks, gardens and sporting ovals green and sustaining local

B. Maheshwari (✉) · B. Simmons
University of Western Sydney, Locked Bag 1797, Penrith, NSW 2751, Australia
e-mail: b.maheshwari@uws.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_29,

businesses and job opportunities. Land and water availability in peri-urban regions strongly influences the health of the river systems, the supply of fresh fruit and vegetables, operation of water dependent businesses and commercial fishing. Metropolitan cities, particularly Sydney and Melbourne in Australia are now facing complex problems of peri-urban planning. It is now being increasingly realised that without proper land and water planning, we cannot achieve local food security, job security, growth in tourism, adequate opportunities for sport and leisure activities and an overall quality of life.

One significant challenge we face in peri-urban regions is to devise options for using potable water, stormwater, effluent and groundwater in way that will enhance security of water supplies for human consumption while ensuring environmental needs of water. We also need tools and framework that will assist in exploring options for 'integrated water resources planning' and in having meaningful dialogue with stakeholders. This requires understanding the role of water for different uses, water quantity and quality issues, market options and mechanisms, current water policies, institutional barriers and community aspirations. The above aspects are critical for any regional land and water planning, infrastructure development, cost-benefit analysis and implementation strategies in peri-urban regions.

The main aim of this chapter, using the system harmonisation approach, is to understand the complexity of peri-urban issues and challenges and draw out some key lessons from a four year-long study of stakeholder engagement supported by a number of hydrologic, social, economic and institutional analyses.

29.2 Western Sydney Region

The Western Sydney region is part of the Sydney metropolitan area and includes 12 local government areas (LGA). These LGAs are Cities of Auburn, Bankstown, Baulkham Hills, Blacktown, Blue Mountains, Camden, Fairfield, Hawkesbury, Holroyd, Liverpool, Parramatta and Penrith (Fig. 29.1). The region stretches over nearly 9,000 km^2 of residential, industrial and rural lands. The climate in the region is characterised by warm, wet summers and cool, relatively dry winters. Rainfall in summer is typically associated with thunderstorm activity and the region receives less rainfall than the coastal areas of Sydney. There is also significant variations in rainfall across the region, and the average annual value of rainfall is 856 mm while evapotranspiration 1373 mm (UPRCT 2004).

It is projected that the population in Western Sydney would increase significantly over the next 20 years. The proposed North–West and South–West Growth Centres will add about 600,000 people to the 400,000 already living in the South Creek Catchment—a significant area of Western Sydney. It is likely that there will be further population growth in this period, due to the natural increase within existing land use zones, placing additional pressure on water that is available for non-potable uses. This might pose a threat to commerce; industry; and most

Fig. 29.1 The south creek catchment

importantly agriculture as well as recreational sites, such as playing fields and reserves that require significant amounts of water to sustain their user-friendly quality.

The climatic conditions of the region are moderate with warm to hot summers, cool to cold winters and reliable rainfall throughout the year. The average temperature varies from high, around 28–30 °C in January to low, around 2–5 °C in July. On individual days, day temperature may rise up to 40–43 °C in summer months (January–February), and fall lower than or close to 0 °C in winter months (July–August). The average annual rainfall is about 750 mm with fairly uniform distribution over the catchment. The rainfall during summer, which is characterized by thunderstorms, is higher than that occurring over long durations in the winter months.

29.3 Complexity of Land and Water Issues

A large part of the Western Sydney region is part of the Hawkesbury-Nepean River Catchment. The region is currently facing important challenges arising from urbanisation, limitations on water allocation for irrigation, discharge of nutrient runoff from market gardens and other areas into the river system, community issues related to use and reuse of water. Being close to a large metropolitan area, both effluent use and management and urban irrigation play important roles in the overall water use and management in the catchment.

Water and waterway quality of the Hawkesbury-Nepean River system has been considered poor (HMCMA 2007) due to the impacts of increasing urbanisation and other factors. In particular, the river water quality is compromised due to extraction of water on a daily basis to meet the water demands for domestic, industrial and urban and peri-urban irrigation in the region. While the extraction considerably reduces the flow volume, pollutants discharged into the river as sewage effluent and urban and agricultural runoff lower the quality of water in the river. A study by the Hawkesbury-Nepean River Management Forum (2004) concluded that environmental flows need to be managed properly to maintain the health of the river system.

There have been a range of ongoing efforts from different government agencies in New South Wales and specific projects funded by the Federal Government to protect the river system and its dependant activities. So far, most initiatives have been undertaken in isolation and have not adequately taken into account the complex interrelationships between the various biophysical, socio-economic, institutional and policy factors that influence the region's water resource management and the overall liveability. There is need for a holistic and integrated land and water planning to maintain the health of the river system and sustain it as a valuable future asset for the Sydney Metropolitan area.

The population growth and the subsequent urbanisation also had a significant impact on the region's farming land. A large part of this region was originally used for agricultural production, both dryland and irrigated. However, over time the area under agriculture has been reduced as fertile agricultural land has been converted for housing and industry. Market gardens and farms in the region produce more than 1/10th of NSW's agricultural production on 1 % of the state's agricultural lands (Knowd et al. 2005). Therefore, urbanisation is challenging food production and other related activities in a complex manner and need new thinking and research approach to secure sustainable land and water use in peri-urban areas.

The projected changes in rainfall and higher evaporation rates due to climate change are likely to reduce flow in streams (CSIRO 2007), and thereby decrease the sustainable yield of Hawkesbury-Nepean catchment which contributes nearly 80 % of Sydney's Water System. The growing population and reduced rainfall in the region is putting considerable pressure on fresh water resources and is forcing the water authorities to revisit their water use and management strategies. There exists a need for integrating water management approaches that consider system water supply, demands, economic impacts of change, as well as overall effects on social, cultural, institutional and political realms.

29.4 Peri-urban Challenges and Transdisciplinary Approach

Depending upon the complexity and purpose, research approaches can be disciplinary, multi-disciplinary, interdisciplinary or transdisciplinary (Hadorn et al. 2008). In case of peri-urban issues and challenges we face now, the approach taken to solve a problem or improve a situation determines the outcome of research. The complexity of issues related to water recycling and regional water security in peri-urban landscapes is undoubtedly beyond a disciplinary approach and perhaps cannot be handled adequately by multidisciplinary and interdisciplinary approaches.

In multidisciplinary approach, research teams make use of the expertise of individuals from different disciplines, with each discipline approaching the underlying problem from their own perspective. There is generally no clear mechanism or purpose for integration of different disciplines and researchers from each discipline have their own assumptions and methodology. They may work in parallel but do not blend to create a shared knowledge. On the other hand, interdisciplinary approach is based on a collaborative focus and the integration of research between disciplines is embedded in the approach. This means, researchers from different disciplines will work together in teams to share learning about the research problem.

A transdisciplinary approach also involves integration of different disciplines that cut across the boundaries of two or more disciplines but it focusses on 'real world' problems or issues and will inevitably include the interests and involvement of government and non-government agencies, businesses, politicians and community groups. What sets transdisciplinary approach apart from the others, particularly in the context of peri-urban regions, is its emphasis on stakeholder engagement, investigation and team work to deal with some pressing problem that breaks disciplinary boundaries while respecting disciplinary expertise. It is also about bringing the knowledge and learning from different disciplines together, which will most likely result in insights and understanding that is beyond the realms of individual disciplines.

29.5 The WISER Project

The **W**ater and **I**rrigation **S**trategy **E**nhancement through **R**egional Partnership (**WISER**) was a project was one of the four regional projects established by the Cooperative Research Centre for Irrigation Futures (CRC IF) under the System Harmonisation Program. This program was focussed on developing a strategy to improve cross-organisational communication and system-wide management to improve production and environmental outcomes in the context of a whole catchment (Khan et al. 2008). The main objective of the system harmonisation program was to engage key agencies and interest groups and carry out relevant research that will assist in regional planning (Fig. 29.2).

The WISER project was designed to assist water users and water dependent businesses by establishing an integrated water resource management and planning framework, development of business partnerships and implementation process for infrastructure development for Western Sydney. The research in the project focussed on the analysis of the region's water cycle components, water productivity, and environmental, social, cultural, institutional and policy issues and

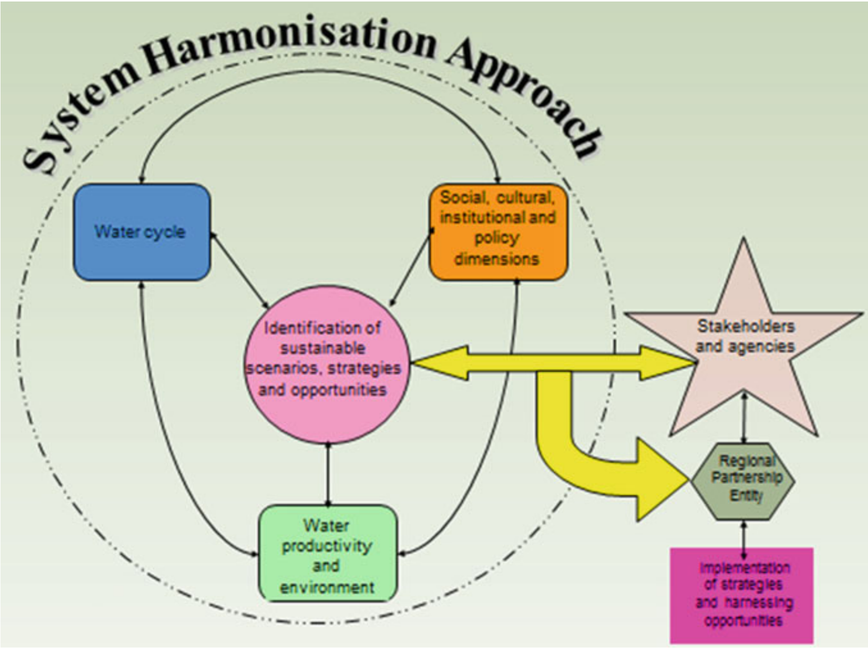


Fig. 29.2 System harmonisation approach in the WISER project

challenges. The analyses helped, in consultation with key stakeholders and government agencies, in identifying and evaluating scenarios, strategies and opportunities for sustainable use of the region's water resources in the longer term. The project was also designed to facilitate the formation of a regional partnership that continues beyond the life of this project. The partnership thus formed provides key input into the implementation of actions identified through this project.

The project involved three major activities: stakeholder engagement; modelling and analysis of hydrologic, environmental, economic, social, institutional and policy aspects. The tasks that were pursued to develop collaboration with stakeholders included undertaking workshops to determine values and water needs in the area. They have also been involved in developing committees to progress and guide the development of regional water business partnership. Stakeholders considered for such workshops were water users and agencies associated with water management.

29.6 Peri-urban Is Different

At the commencement of the WISER project, we realised that in peri-urban context an irrigation-only focus of the system harmonisation was too narrow, especially for peri-urban regions such as Western Sydney where there are so many stakeholders, agencies and users and interest groups that drive the region's water planning and future. Compared to urban or rural water scenarios, the project revealed that, there are numerous natural resources management entities associated with managing or influencing water management and planning in peri-urban regions and there is a limited co-ordination among them. Also, natural resources and other data required for peri-urban water planning are scattered in different agencies and are of variable quality.

29.7 Lessons from the WISER Project

There have been a number of key lessons learnt from the WISER project, and these lessons may have relevance to other peri-urban regions in Australia and overseas. One major lesson was that engagement of stakeholders involved in peri-urban landscapes is not easy. We invited and worked with stakeholders in a series of meetings and workshops during the four years of project to create an ongoing dialogue. In very early during the engagement process, we recognised the complexity and conflicting nature of the peri-urban landscape and engaged a facilitator to steer the process. In spite of a great deal of goodwill and support of the various stakeholders, it was often difficult to have a constructive dialogue among the various parties involved. In particular, governmental agencies sometimes did not see beyond technical details and ministerial directives. Further, they were more concerned with their department's role and responsibility and were not able to adequately appreciate the bigger picture of the water cycle and the needs of the very people they are hoping to serve. This sometime created mutual distrust among local councils, irrigators groups, government agencies and community at large. In this project, we focussed on co-learning to understand the local problematic situation and share information and knowledge for a planned intervention. Further, we found that our persistent efforts and personal approach helped us to keep the motivation of stakeholders, agencies and community and help them to continue with a dialogue with each-other about pressing local peri-urban issues and solutions.

An interesting realisation in this project was that it is unrealistic to expect all stakeholders to start talking and collaborating at the beginning of the project. The most likely reasons for this are related to the lack of a clear understanding of the issues and differences in power and authority. Also, conflicts among the various parties involved in the management of peri-urban water is unavoidable in the stakeholder engagement processes, and therefore it is important to state this point explicitly so that the perceptions and interests are considered appropriately in exploring practical and acceptable solutions (Leeuwis 2000). With this approach, the stakeholder engagement processes therefore become a mix of 'learning and fighting' (Butterworth et al. 2007).

During the WISER project, we observed that when government agencies are the initiator of the process, there was the possibility of mistrust and confusion due to the perception of stakeholders that the agencies have their own agenda and are not neutral. On the other hand, as researchers in WISER project, we were able to play the role of neutral facilitator between government agencies and stakeholders and eventually were able to bring different interests and parties together for a dialogue.

We have learnt that effective and sustained stakeholder engagement requires us to respect the views of stakeholders and provide caring facilitation while not manipulating the process. Water issues in peri-urban regions are multifaceted and so require more holistic thinking, and so it is unrealistic to expect everyone to think the same and reach an agreement on options or point of view at the beginning of the dialogue. Therefore, it is important in the stakeholder engagement process to work in harmony and develop solutions that are jointly owned by government agencies, stakeholders, researchers and community at large.

We have also learnt that the engagement is an ongoing task to keep the momentum and allow development of a deeper relationship among themselves, e.g., by signing of a Memorandum of Understanding and working on joint funding application. Such relationships are of great value at the regional level in building social and networking capital and do help in regular sharing of ideas, getting rid of preconceptions about each-other and providing confidence and positive connections.

29.8 System Harmonisation Approach: Did It Work?

System harmonisation is a powerful concept and involves science, but not science on its own. It is explicitly focussed on bringing all different types of science together with economics, environment and communities to solve wider and practical problems (Bristow and Stubb 2010). For system harmonisation to succeed, it was evident from the WISER project that we need team with strong disciplinary skills and are keen to work collaboratively. Also, for system harmonisation to work properly the science needs to be flexible, not in terms of the rigour of the process or the statement of the findings but rather in the way the issues are approached and communicated to stakeholders. Also, the research that needs to be done, particularly what type of science input is needed and at what point it is needed must be driven by the needs of the stakeholders and a range of environmental, social and economic consideration related to region involved. Further, the science should be allowed evolve as researcher gain deeper understanding of the issue and the community to understand the system more clearly.

We observed that the science made a difference in the process of system harmonisation in the WISER project. The study highlighted that researchers still struggle to connect and communicate their science in way that will enable effective dialogue with stakeholders. The experience in the WISER project indicates that there were significant difficulties in engaging with stakeholder in the beginning. The enthusiasm and persistence of a key people to continually engage with existing and potential stakeholders and community ensured the progress in the project. They were also committed to evolving the program to develop something that was in line with the general direction of system harmonisation approach and that also fitted the local physical and community landscapes (Bristow and Stubb 2010).

The chair of any transdisciplinary project steering committee plays an important role and we learnt that it is important to appoint a person who has deep interest in issues being investigated and who has wide support and respect from the stakeholders. This was possible by attracting a well-known local person as a paid chair. Although the amount paid to the chair was insignificant when compared with the total budget of the project, this helped to get full attention and support for the project from the chair. The leadership and support from different stakeholder groups is equally important, particularly form the four Western Sydney Councils and the Sydney Metro Water Directorate.

Overall, the WISER project was able to define what was important to research with the help of stakeholders and work with stakeholders to make sense of the research done for practical application, and so the project has achieved a level of system harmonisation. Further, the system harmonisation helped people to think different, work out the best ways to work together to address and resolve issues which they would not be able to resolve as individuals (Bristow and Stubb 2010).

29.9 Conclusions

Sydney like all growing cities is expanding into adjacent rural lands (peri-urban areas). The system harmonisation approach could be an important vehicle to establish dialogue among stakeholders for effective and long-term water resources planning at a regional scale. However, the process of system harmonisation is significantly different in peri-urban landscapes, and it is more difficult due to complexity of issues and the range of stakeholders, agencies and interests involved. The most important issues for system harmonisation in peri-urban landscapes include the reuse of water, management of the water cycle for a range of water users (including the environment) in the face of expanding urban needs. For achieving long-term regional water security in peri-urban landscapes, undoubtedly we need effective engagement of stakeholders, regional water managers and land-use planners for developing common vision and long term planning.

References

Bristow KL, Stubb T (2010) Reinventing irrigation catchments—the system harmonisation story. CRC for Irrigation Futures, Toowoomba, 146 p

Butterworth J, Ducrot R, Faysse N, Janakarajan, S. (eds) (2007). Peri-urban water conflicts: supporting dialogue and negotiation, technical paper series no. 50. IRC International Water and Sanitation Centre, Delft, Netherlands, p 128

CSIRO (2007) Climate change in the Hawkesbury-Nepean catchment. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra

Hadorn GH, Hoffmann-Riem H, Biber-Klemm S, Grossenbacher-Mansuy W, Joye D, Pohl C, Wiesmann U, Zemp E (eds) (2008) Handbook of transdisciplinary research. Springer, Dordrecht, 448 p

Hawkesbury-Nepean River Management Forum (2004) Water and Sydney's future—balancing the values of our rivers and economy. Rep. to the NSW Minister of Natural Resources, Department of Infrastructure, Planning and Natural Resources, Sydney

Hawkesbury Nepean Catchment Management Authority (HMCMA) (2007). Hawkesbury Nepean river health strategy, vol 1. Goulburn NSW, Australia

Khan S, Malano HM, Davidson BM (2008) System harmonisation: a framework for applied regional irrigation business planning. Irrig Drainage 57(5):493–506

Knowd I, Mason D, Docking A (2005) Urban agriculture: the new frontier. In: Paper presented at the State of Australian Cities conference, Brisbane. http://www.griffith.edu.au/__data/assets/pdf_file/0015/81222/city-structures-23-knowd.pdf

Leeuwis C (2000) Reconceptualizing participation for sustainable rural development: towards a negotiation approach. Dev Change 31(5):931–959

UPRCT (2004) Water sensitive urban design—technical guidelines for Western Sydney. Upper Parramatta River Catchment Trust, Parramatta 183

Chapter 30
Maintaining Landscape Functionality Under Land Use Change

R. W. Vervoort

Abstract Peri-urban growth can affect local flood and drought risks, which are exacerbated by climate change. Research into optimal planning and arrangement of landscape functions is needed to manage local flood and drought risks. As a first step, simple hydrological models are required to study the range of feedbacks and interactions within the peri-urban areas. A demonstration, using a simple modeling example, indicates how including buffer zones will reduce local flooding and how such models can be used for virtual experiments. Further development of such simple tools into spatial and agent based models will support new field studies and policy development for peri-urban areas.

Keywords Flood risk · Urbanisation · Buffer zones and planning

30.1 Introduction

Cities in many developing regions, such as in India, are undergoing rapid growth with fertile agricultural lands in the peri-urban zone becoming suburbs. Urban growth is unavoidable, given increases in global population (Alberti 2010) and general wealth differences between urban and rural populations. Growth of mega-cities is accelerating faster than the growth of the global population. Peri-urban growth is a global issue and is a serious challenge for policy makers in developing countries (McDonald et al. 2011a), which is further exacerbated by looming climate change. Cities expanding into peri-urban areas in developing countries

R. W. Vervoort (✉)
Hydrology and Geo-Information Sciences Laboratory,
Faculty of Agriculture and Environment, The University of Sydney, Sydney,
NSW 2006, Australia
e-mail: willem.vervoort@sydney.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_30,

create problems of water scarcity, reduced land availability for agriculture and wastewater management (McDonald et al. 2011a).

Urbanisation in turn, results in increased water demand, degradation of waterways, as well as the generation of more stormwater and effluent discharge (Grimm et al. 2008; Jacobson 2011; McDonald et al. 2011b). All of this impacts on water security and therefore livelihoods (Misra 2011). From a governance point of view, well-informed management of urbanisation in peri-urban areas to maximise agricultural productivity, water security and urban functionality is the major challenge (Gordon et al. 2009; Eakin et al. 2010).

Hydrological changes due to land use change are a major focus area for the global hydrological discipline (DeFries and Eshleman 2004). While the general effects of urbanisation on hydrology (increased and faster peak runoff) have been known for decades (Leopold 1968), most of the current literature on the impacts of urban sprawl focuses on ecological and water quality impacts. In this paper, it will be argued that a refocus on landscape hydrological impacts is warranted, as many of the ecological and water quality problems require better understanding of the underlying landscape hydrology. In other words, landscape biodiversity, carbon assimilation and water quality are completely, or in part, driven by hydrology.

Urban development and growth impacts the landscape hydrology in many different ways in both the short and long term. The earlier mentioned increased runoff peak and faster peak runoff are the result of an increase in impervious areas (Bhaduri et al. 2001) which reduces infiltration and changes the evaporation signal (Dagmar 2009; Alberti 2010). Water is routed from impervious surfaces through culverts and drains rather than through natural river beds leading to a disposal problem. This water has to be stored and often cleaned before it can be discharged into the river systems. These are mostly short term hydrological effects that are dealt with by the area of engineering hydrology in terms of drainage, management and recycling.

More extremely and more long term, changes to the hydrological cycle such as the lack of infiltration combined with increased groundwater extraction can exacerbate and cause subsidence, such as is visible in Mexico City or Jakarta (Ortega-Guerrero et al. 1999; Abidin et al. 2001). In addition, over extraction can lead to changes in the groundwater quality by solubilising arsenic and fluoride (Misra 2011). Alternatively, increased concentrated infiltration from runoff and water storage in suburban areas can dissolve salts, raise local groundwater tables and cause salinity problems, such as our research laboratory is currently researching in South Western Sydney. Additionally in past work we have indicated how rainwater harvesting in a catchment in India also shifts the landscape water balance (Glendenning and Vervoort 2011). More vaguely and on a much longer time frame, urban development disrupts the climate feedback effects of vegetation (Bonan 2008), causing changes in the land surface temperature and albedo.

Overall, there is a large amount of literature discussing the different effects of urban land use change (Alberti 2010) but there is limited literature focusing on solutions and ultimately solutions are what we need to manage our urban and peri-urban landscapes. In this paper, suggestions are made about possible solutions to manage these effects.

30.2 Are There Possible Solutions?

Natural landscapes are generally efficient, energy and nutrients is stored and water is recycled. My proposition is that this is mainly due to the large buffering effect in natural systems which allow natural processes to occur, such as evaporation, nutrient cycling and carbon transformation. While urban landscapes cannot be the same as natural landscapes because they need to offer shelter and infrastructure, we can aim to mimic the natural landscape hydrological functionality.

Thus the long term stability of the landscape would depend on re-establishing the buffering capacity. One way to achieve this would be “mix and match” the different land uses within a peri-urban landscape (Brabec 2009). For example (Mejía and Moglen 2010) investigated how the spatial distribution of impervious areas in the landscape affects the runoff properties. More importantly, Alberti (2005) pointed out that specifically the complexity of the functionality of ecological patterns in an urban setting is under-researched. Her research demonstrated how this can be achieved for bird habitats.

There seems to be plenty of research in this area from an ecological perspective, focusing on monitoring habitat, water quality and stream functionality (e.g. Paul and Meyer 2008; Pennington et al. 2010). However, there appears to be little work that has looked at overall landscape hydrological functionality and relating to managing landscape salinity or subsidence. For example, which spatial organisation and combination of land uses would reproduce recharge and runoff at similar levels as natural landscapes? In particular, how would we manage the hydrology using a combination of rainwater harvesting, induced recharge using swales and appropriate water recycling systems?

There is a particular challenge in implementing a landscape functional design, in that there is a conflict between containing urban sprawl by increasing urban density (as is currently occurring in Sydney, New South Wales (NSW)), and increasing the opportunity for natural hydrological processes. The overall complexity with multiple drivers and the spatial diversity of the problem has been highlighted (Alberti 2010). However landscape hydrology is both spatially and temporally variable (Fig. 30.1) and therefore peri-urban landscape design needs to include both of these in the functional similarity. In essence, we need to develop tools to be able to do precision catchment management while minimising impacts through maximising the spatial and temporal organisation opportunities.

Developing robust and reliable knowledge-based evidence and tools for formulating policy and guiding sustainable peri-urban development requires credible science. Spatio-temporal models (for example GIS based models) are useful tools for extracting information, summarising and making predictions. However, prediction models in data scarce regions are particularly challenging and can have high level of uncertainty. As the globalsoilmap.net project is demonstrating in Africa, the collection of legacy data and combining it with modern statistical techniques can deliver good outcomes (Sanchez et al. 2009). Similarly, the recent focus on prediction in ungauged basins from the international hydrological

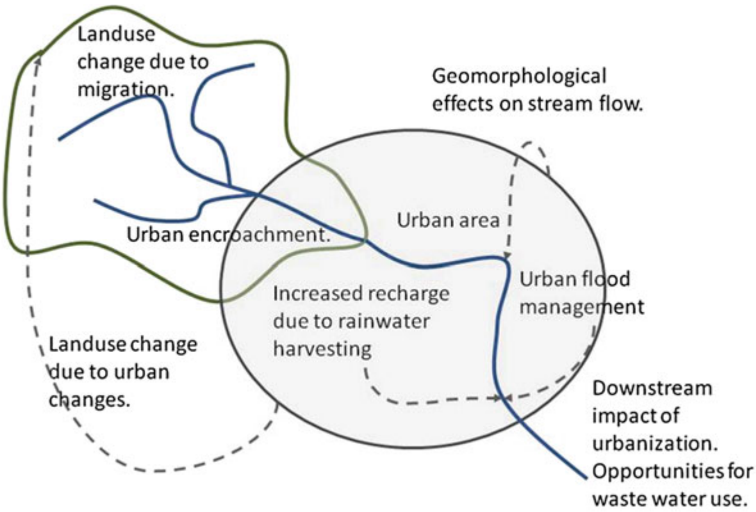


Fig. 30.1 Conceptual diagram of some of the changes and feedbacks between urban and peri-urban as well as upstream and downstream areas

community has highlighted the increased power of using satellite based data (Zhang et al. 2009). However, most of the current work in data scarce regions has not focused on specifically designing models for peri-urban areas, probably because this is particularly challenging work given the mix of urban and rural land uses.

To guide sustainable peri-urban development, policy makers need information and answers that are based on appropriate data and evidence based science for cross-checking. This is currently the missing link to understanding policy impacts.

Given the complexity of the problem in time and space as well as the number of ecological and hydrological feedbacks, new modelling frameworks should be approached with caution. A hydrological modelling framework in hydrology needs to be initially based on simplified modelling, in which all different feedbacks can be strictly controlled. In other words, similar to the "top down" modelling approach in catchment hydrology (Sivapalan et al. 2003), the problem should first be approached theoretically using simplified box models, for example by doing "virtual experiments" (Weiler and McDonnell 2004). These virtual experiments can inform about the behaviour of the combined peri-urban system in both space and time. For example, the research could first investigate behaviour in time, followed by spatial complexity.

Only when we have developed an in-depth understanding of the hydrological complexity and feedbacks in peri-urban systems can science progress to more complex models such as GIS based and 3-D models. This is not to say that the simpler models cannot give in-depth answers, but it does require uncertainties and assumptions about models to be clearly stated.

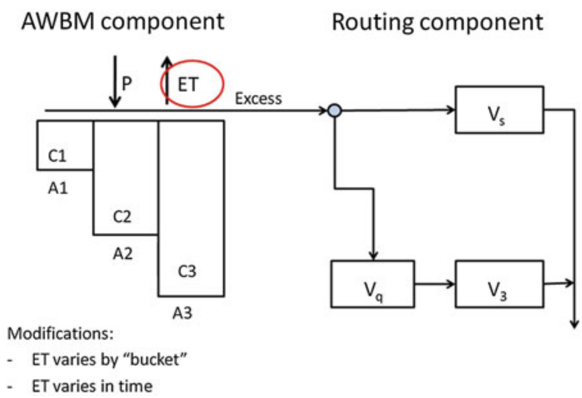


Fig. 30.2 Diagram of the model used in this study, based on components of AWBM (Boughton 2005) and a routing module from IAHCRES (Andrews et al. 2011)

30.3 An Example Modeling Study

To highlight how changes in the landscape functionality can be studied, a simple model, used extensively in Australia for conceptual modeling, AWBM (Fig. 30.2) (Boughton 2005) was applied. In this case the model has been adjusted to include variability in time and space of evapotranspiration. In addition, the AWBM model was coupled to an exponential reservoir routing structure based on the "expuh" routing module in IHACRES contained in the package hydromad in R (Andrews et al. 2011).

The structure allows manipulation of two conceptual processes (apart from varying the climate): (1) the relative areas and capacities of the upstream components (A1–A3 and C1–C3) can be varied to represent different land uses and different areas of land use, while inclusion of a variable Evapotranspiration (ET) strengthens the variation between the land uses and allows temporal analysis (within year variation such as seasonal); and (2) variation of the routing component to allow analysis of different management buffer zones (via V_3) and natural variation between slow flow (V_s) and quick flow (V_q), for each of these components the recession constant can be varied. While the overall model is purely conceptual it mimics the variation in different components of the system and allows more detailed study. The current model does not include any feedbacks, for example through coupling a time variation in V_s and V_q (or their respective recession constants) due to geo-morphological changes in the stream or due to changes in C1–C3.

As a demonstration study, the model was forced with synthetic rainfall and evapotranspiration data generated for a typical semi-arid climate in NSW. The scenarios, based on Fig. 30.1, which were studied are (1) the base scenario; (2) change in urban management to create more space for flooding in the urban area, basically including a buffer zone; (3) land use change in the upper catchment affecting urban flooding; and (4) land use change in the upper catchment with changed flood management.

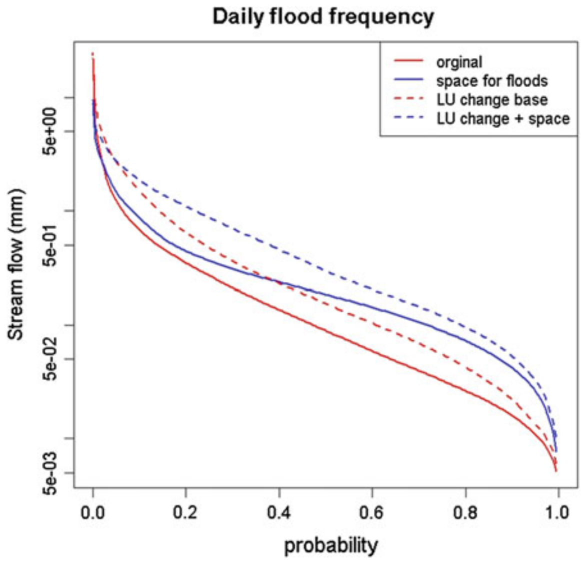


Fig. 30.3 Changes in the daily flood frequency curve as a result of including increased buffer zones (space for floods) in a peri-urban area. Indicated are the impact of the buffer zone and the changes in the flood frequency curve as a result of up stream land use change (an increase in runoff)

30.4 Results

The results of this study show that including a buffer zone to manage flooding clearly has a major effect on the flood frequency curve (Fig. 30.3). The model simulations indicate that slowing and spreading the water results in a flatter flood frequency curve, meaning the probability of extreme floods decreases. These results are of course not very surprising and are the basis of the "Living with Floods" program in the Netherlands (Klijn et al. 2012). The effect of change in landuse (an increase in runoff on one of the partial areas in the model by decreasing actual ET and the storage capacity) shifts the flood frequency curve up, resulting in a higher probability of all floods. This is a common scenario in many peri-urban and urban areas, where an increase in urbanisation results in an increase in impervious areas, which often results in an increase in runoff (Jacobson 2011). Again, increasing the buffer zone decreases the flood severity at the top end and increases the number of medium to low flows.

In model shown in Fig. 30.2, A1–A3 are the relative areas of the buckets with capacities C1–C3 representing different landuse combinations. In the routing module, Vs is the volume of slow flow, while Vq is the volume of fast flow, while V3 represents the buffer zone. Each of the routing module buckets can be specified using a recession constant.

The overall results of this modeling work indicate how simple modeling frameworks can be easily used to develop insights into peri-urban processes. Combining different simple modeling concepts will enable better understanding of the different competing processes. For example, including rain water harvesting effects or food production potential can be included in the model. While this simple model only includes three different land use elements, it is easy to expand to simulate more complex interactions. Hydrological models can also be combined with agent-based economic models to allow multi objective scenario runs. Such simple models can also be easily incorporated into Monte Carlo stochastic frameworks to include analysis of uncertainties (Bennett et al. 2013, Accepted for publication 21/08/2013).

The modeling in this example is purely hypothetical, but even simple models can be calibrated and adjusted to real world scenarios and thus be made more realistic. One issue is that the proposed simple model design can have prediction or simulation errors due to non-stationarity as well as a lack of physical representation (Beven 2006; Milly et al. 2008). However to allow calibration to local conditions and to counter these limitations, it is possible to combine general additive modeling (Wood 2006; van Ogtrop et al. 2011) with the biophysical models. In this way empirical relationships based on flexible statistical modeling of local data and experience can be used to better represent local conditions.

30.5 Conclusions

In the future, we will need to manage the impacts of increasing urban development and hydrology is the major physical process that needs management. This requires innovative re-organisation of landscapes in a way that minimizes ecological disturbance. The peri-urban fringe, in particular, offers opportunities for managing landscape hydrology due to the mix of land uses. To assist with this management, we will need to define research priorities in this area to untangle to complex interactions and feedbacks in the peri-urban landscape. As a first step, there is a need for theoretical modeling work to investigate the different feedbacks between the different components in the peri-urban landscape. This will lead to more complex models and well-designed field studies in the peri-urban landscape.

References

Abidin H, Djaja R, Darmawan D, Hadi S, Akbar A, Rajiyowiryono H et al (2001) Land subsidence of Jakarta (Indonesia) and its geodetic monitoring system. Nat Hazards 23:365–387

Alberti M (2005) The effects of urban patterns on ecosystem function. Int Reg Sci Rev 28:168–192

Alberti M (2010) Maintaining ecological integrity and sustaining ecosystem function in urban areas. Curr Opin Environ Sustain 2:178–184

Andrews FT, Croke BFW, Jakeman AJ (2011) An open software environment for hydrological model assessment and development. Environ Model Softw 26:1171–1185

Bennett SY, Bishop TFA, Vervoort RW (2013) Using SWAP to qantify space and time related uncertainty in deep drainage model estimates: a case study from Northern NSW. Agricultural Water Management, Australia (in press)

Beven K (2006) A manifesto for the equifinality thesis. J Hydrol 320:18–36
Bhaduri B, Minner M, Tatalovich S, Harbor J (2001) Long-term hydrologic impact of urbanization: a tale of two models. J Water Resour Plan Manage 127:13–19
Bonan GB (2008) Forests and climate change: forcings, feedbacks, and the climate benefits of forests. Science 320:1444–1449
Boughton W (2005) Catchment water balance modelling in Australia 1960–2004. Agric Water Manag 71:91–116
Brabec EA (2009) Imperviousness and land-use policy: toward an effective approach to watershed planning. J Hydrol Eng 14:425–433
Dagmar H (2009) Effects of urbanisation on the water balance—a long-term trajectory. Environ Impact Assess Rev 29:211–219
DeFries R, Eshleman KN (2004) Land-use change and hydrologic processes: a major focus for the future. Hydrol Process 18:2183–2186
Eakin H, Lerner AM, Murtinho F (2010) Adaptive capacity in evolving peri-urban spaces: Responses to flood risk in the Upper Lerma River Valley, Mexico. Glob Environ Change 20:14–22
Glendenning CJ, Vervoort RW (2011) Hydrological impacts of rainwater harvesting (RWH) in a case study catchment: the Arvari River, Rajasthan, India: Part 2. Catchment-scale impacts. Agric Water Manag 98:715–730
Gordon A, Simondson D, White M, Moilanen A, Bekessy SA (2009) Integrating conservation planning and landuse planning in urban landscapes. Landscape Urban Plan 91:183–194
Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X et al (2008) Global change and the ecology of cities. Science 319:756–760
Jacobson CR (2011) Identification and quantification of the hydrological impacts of imperviousness in urban catchments: a review. J Environ Manage 92:1438–1448
Klijn F, Bruijn K, Knoop J, Kwadijk J (2012) Assessment of the Netherlands' flood risk management policy under global change. Ambio 41:180–192
Leopold LB (1968) Hydrology for urban land planning—a guidebook on the hydrologic effects of urban land use, circular 554. United States Geological Survey, Washington
McDonald R, Douglas I, Revenga C, Hale R, Grimm N, Grönwall J et al. (2011a) Global urban growth and the geography of water availability, quality, and delivery. Ambio: J Human Environ 40:437–446
McDonald RI, Green P, Balk D, Fekete BM, Revenga C, Todd M et al (2011b) Urban growth, climate change, and freshwater availability. Proc Natl Acad Sci 108:6312–6317
Mejía AI, Moglen GE (2010) Impact of the spatial distribution of imperviousness on the hydrologic response of an urbanizing basin. Hydrol Process 24:3359–3373
Milly PCD, Betancourt J, Falkenmark M, Hirsch RM, Kundzewicz ZW, Lettenmaie DP et al (2008) Stationarity is dead: whither water management? Science 319:573–574
Misra A (2011) Impact of urbanization on the hydrology of Ganga basin (India). Water Resour Manage 25:705–719
Ortega-Guerrero A, Rudolph DL, Cherry JA (1999) Analysis of long-term land subsidence near Mexico city: field investigations and predictive modeling. Water Resour Res 35:3327–3341
Paul MJ, Meyer JL (2008) Streams in the urban landscape. In: Marzluff JM, Shulenberger E, Endlicher W, Alberti M, Bradley G, Ryan C, Simon U, ZumBrunnen C (ed) Urban ecology. Springer, US, pp 207–231
Pennington DN, Hansel JR, Gorchov DL (2010) Urbanization and riparian forest woody communities: diversity, composition, and structure within a metropolitan landscape. Biol Conserv 143:182–194
Sanchez PA, Ahamed S, Carré F, Hartemink AE, Hempel J, Huising J et al (2009) Digital soil map of the world. Science 325:680–681
Sivapalan M, Blöschl G, Zhang L, Vertessy RA (2003) Downward approach to hydrological prediction. Hydrol Process 17:2101–2111
van Ogtrop FF, Vervoort RW, Heller GZ, Stasinopoulos DM, Rigby RA (2011) Long-range forecasting of intermittent streamflow. Hydrol Earth Syst Sci 15:3343–3354

Weiler M, McDonnell JJ (2004) Virtual experiments: a new approach for improving process conceptualization in hillslope hydrology. J Hydrol 285:3–18
Wood S (2006) In generalized additive models: an introduction. CRC Press, Boca Raton
Zhang Y, Chiew FHS, Zhang L, Li H (2009) Use of remotely sensed actual evapotranspiration to improve rainfall–runoff modeling in Southeast Australia. J Hydrometeorol 10:969–980

Chapter 31
Importance of Urban Biodiversity: A Case Study of Udaipur, India

Satya Prakash Mehra, Sarita Mehra and Krishan Kumar Sharma

Abstract Urban ecosystems are complex social-ecological systems with important functions. These man-made ecosystems have certain areas with high biological diversity, including both remnant species and species purposefully or unintentionally introduced by human actions. There can be important habitats and valuable corridors for both common and less common species within the urban sprawl. The main aim of this study is to respond to the call for integrative research by studying relationships between the anthropogenic activities and urban biodiversity of the cities from the southern part of Rajasthan, India. We observed that the local population was interested in biodiversity, especially phenological events, and benefited from it by getting aesthetic pleasure and information on seasonal changes. The cities, such as Udaipur have an artificially developed diversified habitat within urban limits which provides shelter and protection to a variety of flora and fauna species. Urban areas are often rich in species, particularly vascular plants and many groups of animals, especially birds. Further, urban green spaces in the form of artificial parks and agricultural fields have the diversity of flora, whereas artificial lakes are the sites of wetland species. The most eye-catching faunal group of birds was used to understand the importance of biodiversity for Udaipur. Bird diversity and abundance are indicators of the condition of watershed habitats, both terrestrial and wetland. The role of urban areas in functions, such as the provision of ecosystem services will largely be determined by patterns of biodiversity within that area. To keep these biological indicators healthy, watershed conditions should be

S. P. Mehra (✉) · S. Mehra
Rajputana Society of Natural History, Kesar Bhawan, 16/747, P.No.90,
B/d Saraswati Hospital, Ganeshnagar, Pahada,
Udaipur 313 001 Rajasthan, India
e-mail: drspmehra@yahoo.com

K. K. Sharma
Biodiversity Research Laboratory, Department of Zoology,
Maharshi Dayanand Saraswati University,
Ajmer 305 009 Rajasthan, India

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_31,

managed to encourage bird survival and reproduction. Further, to support an integrative approach in urban green planning, both ecological and social research has to be incorporated in the planning process.

Keywords Urban ecosystem · Biodiversity · Urbanisation · Human activity · Bird population

31.1 Introduction

Worldwide urban areas are expanding both in size and number and this rapid urbanization is expected to continue. The beginning of the 21st century can be characterized by the tremendous growth of urban areas and associated processes of globalization and unification of urban environments. Although cities occupy just 2 % of the Earth's surface, their inhabitants use 75 % of the planet's natural resources (UNEP 2008). Urbanization is thus one of the reasons for the loss of global biodiversity (Garden et al. 2006). The decrease in the green cover due to urban invasion is causing fragmentation of the native vegetation resulting in the reduction of associated faunal species in the long term (Beissinger and Osborne 1982; Germain et al. 1998; Marzluff et al. 1998). On the contrary, it is undoubtedly true that urbanisation has introduced new food and habitats to particular sites (Blair 1996) and has developed complex social-ecological systems with important functions in the form of urban ecosystems. These man-made ecosystems have certain areas with high biological diversity and unaltered patterns of diversity, including both remnant species and species purposefully or unintentionally introduced by human actions. There can be important habitats and valuable corridors for both common and less common species within the urban sprawl (Blair 1999, 2004; Crooks et al. 2004; Li et al. 2010). Such characteristics of the urbanized areas have enhanced the approach of the Conservation Science workers to get involved in the studies related to urban biodiversity (McDonell and Pickett 1990; Alvey 2006; Garden et al. 2006) and their dynamics especially avifauna which were otherwise overlooked before the 1990s (Botkin and Beveridge 1997; McDonnell et al. 1997). Cities are dependent on the ecosystems beyond the city limits, but also benefit from internal urban ecosystems (Bolund and Hunhammar 1999). The area of land *within* an urban settlement that is not built upon has been termed as "Greenspaces" which includes nature reserves, original and planted vegetation, river corridors, nature strips, parks and sporting grounds as well as individual trees, residential gardens and vacant land (Smith et al. 2005).

Rajasthan, the largest state of the Republic of India, has a wide variety of habitats due to the diverse range of climatic variations, edaphic characters, physiography, topography and geology. The Aravallis act as a division of the geographical area of the State with the dry western parts and wet eastern parts. These salient features can be seen in areas of human settlements which also may be rural, urban or peri-urban. These diverse habitats, including greenspaces, of the state are home to more than 500 avifaunal species (Islam and Rahmani 2004) with habitats of the eastern and the southern regions harbouring 80 % of these. (Mehra et al. 2009, 2012; Mehra 2011a, b, 2012). As in other parts of the world, aquatic birds have attracted the attention of ornithologists, specialists on hunting management and hunters from the past to the present in the princely state of Rajasthan (Adam 1873; Barnes 1891; Oates 1899; Messurier 1904; Impey 1909; Whistler 1938; Prakash 1960; Kushlan 1993). Surface water plays a major role in providing breeding and resting grounds for aquatic birds depending on its characteristics with respect to the food availability and protection. Approximately 30 % of the total bird species of Rajasthan depend on the wetlands (Ali and Ripley 1968–1999; Grimmett et al. 1999). The surface water resources in Rajasthan are mainly confined to the central and eastwards side of Aravallis, thus providing aquatic habitats for the avifauna.

Known for the wetland ecosystem, “City of Lakes” or “Venice of the East”, Udaipur is one of the dream destinations of international tourists. The water bodies of the ‘lake city’ play an important role in several spheres of human interest: culturally, socially, scientifically and economically. After fish, birds are probably the most important faunal group that attracts people to wetlands. The present investigation was an attempt to highlight the importance of urban avifauna and its value for the community in view of the socio-ecological aspects. It also supports the view that the monitoring of water birds could provide valuable information on the status of wetlands (Custer et al. 1991; Kushlan 1993), and could be a key tool for increasing awareness of the importance of wetlands and conservation values among the local residents of Udaipur.

31.2 Methodology

31.2.1 Avifaunal Surveys

Avifaunal Surveys were conducted periodically on the selected sites with the participation of the trained local volunteers and focusing primarily on the wetlands and associated terrestrial green spaces. Although observations were a regular activity of teams since 1999 the present period included systematic observations for a period from 2004 to 2011. Different field methods were adapted, according to the species or species group in question (Bibby et al. 2000; Javed and Kaul 2002; Urfi et al. 2005). Sometimes, the approach was altered according to field conditions and available resources. Identification of the species was done with the help of field guide books such as Grimmett et al. (1999), Kazmierczak and van Perlo (2000) and Grimmett et al. (2004). Scientific names and classification were used, according to Manakadan and Pittie (2001).

The status of the bird species was assigned according to: R: Resident; R/LM: Resident with Local Movement; LM: Local Movement; R/WM: Resident with Winter Movement; R/WM/LM: Resident with Winter as well as Local Movement; WM: Winter Migrant; WM/PM: Winter Migrant with Passage Migration; WM/R: Winter Migrant with Resident; SM: Summer Migrant.

Urban Habitats and Urban Green Spaces—Urban habitats were broadly divided into—urban terrestrial and urban aquatic habitats. They were further categorized into sub-habitats for the ease of observations, referring to the work of Dunnett et al. (2002) and Manlun (2003) to some extent.

31.2.2 Urban Terrestrial Habitats (T)

These habitats were categorized into the following six sub-habitats:

- Protected Area (TPA)—Sajjangarh Wildlife Sanctuary
- Public Park (TPP)—Sajjan Niwas Garden
- Forest Fragments (TFF)—Baghdara, Khas Odhi and Moti Magri
- Agricultural Field (TAF)—fields of MPAUT and those present on the borders of Udaipur partially representing rural
- Institutional Green Spaces (TIGS)—Administrative campuses of universities (Mohanlal Sukhadia University and Maharana Pratap University of Agriculture and Technology)
- Constructed Areas (TCA)—denotes selected road and buildings within the city.

31.2.3 Urban Aquatic (W) Habitats

These habitats were categorized into the following three sub-habitats:

- Urban Lakes (WUL)—Pichola, Saroop Sagar, Fatehsagar
- Peri-urban Lake (WPUL)—Udaisagar, Baghdarrah Lake
- Other Aquatic bodies (WOA)—Govardhan Sagar, Connecting Links (Ahar), Small temporary pools within terrestrial habitats of Khas Odhi, Sajjan Niwas and constructed areas.

31.2.4 Human Accessibility

Human accessibility was observed for a year (July 2005–June 2006) as adapted from the studies and observations that Mehra et al. (2011a, b, c) made on the different points for particular sites for assessment of the sub-habitats.

31.2.5 Disturbance Level

The disturbance level of the sub-habitats was based on the presence of human or other anthropogenic activities at the times of peak bird activities in the morning hours (the period between half an hour before sunrise to 4 h after sunrise):

- Low Disturbance (Rating-1)—activities or movements of humans for about one-fourth period at all the observation points or transect at a particular site in peak bird activity hours;
- Moderate Disturbance (Rating-2)—activities or movements of humans for about half period at all the observation points or transect at a particular site in peak bird activity hours;
- High Disturbance (Rating-3)—activities or movements of humans for all the observation points or transect at a particular site in peak bird activity hours.

31.2.6 Accessibility Level

The accessibility level for humans denotes the approach of the sub-habitats for general public. The assessment included three points: (a) nearness from residential area, (b) frequency of use by local residents, and (c) ownership of public property and/or permitted site for the common man. Based on these three criteria, a rating on human accessibility was given:

- All the sites of sub-habitat fulfils all the three points (Rating-1)
- All the sites of sub-habitat fulfils either points 'a' and 'c' or 'b' and 'c' (Rating-2)
- All the sites of sub-habitat does not fulfils point 'c' (Rating-3).

31.2.7 Importance Level

The assessment of the importance of the sub-habitats was made through interactions with at least 50 people per season found at particular sites of observation on the issues of direct or indirect benefits related to residence, education, recreation, economic and other:

Based on the use of local community

- Frequently used (Rating-1)
- Occasionally used (Rating-2)
- Rarely used (Rating-3).

Based on the use of global community

- Frequently used (Rating-1)
- Occasionally used (Rating-2)
- Rarely used (Rating-3).

31.2.8 Potential and Scope of Eco-Tourism

Through the analysis of the views of the locals and other parameters of characteristics required for developing tourism sites, potential and scope of the urban habitats for developing sites as eco-tourism, especially related to birding sites, were interpreted. A site was rated as:

- Could be developed as a hotspot for eco-tourism (Rating-1)
- Could be used as an alternative site for ecotourism (Rating-2)
- Least important for eco-tourism (Rating-3).

31.3 Observations and Results

In total, 248 species of birds belonging to 68 families were recorded in the urban habitats of Udaipur during the period July 2004–June 2011. Out of the total species of birds, 143 species, representing 42 families, were recorded in the terrestrial habitats, whereas 103 species, representing 26 families, were recorded in aquatic habitats. Two species, one each from terrestrial and aquatic habitats, were not directly recorded by the authors. Table 31.1 enlists species of global importance, including the two which were not directly sighted in this study, found in the urban habitats of Udaipur. Urban terrestrial habitats were surveyed into six heads, namely, Protected Area (TPA), Public Park (TPP), Forest Fragments (TFF), Agricultural Field (TAF), Institutional Green Spaces (TIGS) and Constructed Areas (TCA).

31.3.1 Terrestrial Bird Species: Occurrence

Around 143 species were recorded from different terrestrial habitats of the urban areas of Udaipur. One species was included due to the authentic information of another worker. Thus, 144 species showed their presence in the terrestrial urban habitats. The highest number of species was 137, recorded from the fragmented forest (TFF) areas lying in and around Udaipur. This was followed by the terrestrial habitats of the protected area (TPA), which harboured 121 species. Interestingly, over 90 bird species were recorded in the institutional campuses (TAF and TIGS). Other urban green spaces, viz., Sajjan Niwas Park (TPP), were home to 84 bird species. Almost 60 species found shelter in the close proximity of human settlements, i.e., constructed structures (TCA). Figure 31.1 presents species recorded from the urban terrestrial habitats.

Table 31.1 Bird species of global importance recorded during study period (2004–2011) from urban habitats of Udaipur

Sr. No.	Common Name Scientific Name	Terrestrial habitats	Aquatic habitats							
		TPA	TPP	TFF	TAF	TIGS	TCA	WUL	WPUL	WOA
	Critically endangered									
1	Indian white-backed Vulture (185) *Gyps bengalensis* (Gmelin 1788)	x	–	–	–	–	–			
2	Long-billed Vulture (182) *Gyps indicus* (Scopoli, 1786)	x	–	–	–	–	–			
3	Cinereous Vulture (179) NT *Aegypius monachus* (Linnaeus 1766)	–	–	x	–	–	–			
4	Red-headed Vulture (178) *Sarcogyps calvus* (Scopoli 1786)	x	–	x	–	–	–	–	–	–
	Endangered									
5	Egyptian Vulture (186–187) *Neophron percnopterus* (Linnaeus, 1758)	x	–	x	x	x	x	–	–	–
	Vulnerable									
6	Lesser Kestrel (221) *Falco naumanni* (Fleischer 1818)	–	–	x	–	–	–	–	–	–
7	Sarus Crane (323–324) *Grus antigone* (Linnaeus 1758)	–	–	–	x	–	–	–	x	–
8	Indian Skimmer (484) *Rynchops albicollis* (Swainson 1838)	–	–	–	–	–	–	x	–	–
9	Pied Tit or White-naped Tit (1798) *Parus nuchalis* (Jerdon 1844)	x	–	x	–	–	–	–	–	–
10	Green Munia (1965) *Amandava formosa* (Latham 1790)	x	–	–	–	–	–	–	–	–
	Near threatened									
11	Darter (29) *Anhinga melanogaster* (Pennant 1769)	–	–	–	–	–	–	x	x	–
12	Painted Stork (60) *Mycteria leucocephala* (Pennant 1769)	–	–	–	–	–	–	x	x	–
13	Black-necked Stork (66) *Ephippiorhynchus asiaticus* (Latham 1790)	–	–	–	–	–	–	–	x	–
14	Oriental White Ibis (69) *Threskiornis melanocephalus* (Latham 1790)	–	–	–	x	–	–	x	x	x
15	Lesser Flamingo (74) *Phoenicopterus minor* (Geoffroy 1798)	–	–	–	–	–	–	–	x	–
16	Ferruginous Pochard (109) *Aythya nyroca* (Guldenstadt 1770)	–	–	–	–	–	–	x	x	–
17	Black-tailed Godwit (389–390) *Limosa limosa* (Linnaeus 1758)	–	–	–	–	–	–	x	x	x
18	Black-bellied Tern (470) *Sterna acuticauda* (Gray 1831)	–	–	–	–	–	–	x	x	–
19	European Roller (754) *Coracias garrulus* (Linnaeus 1758)	–	–	x	x	x	–	–	–	–
	Total	6	–	5	4	2	1	8	10	2

31.3.2 Terrestrial Bird Species: Status

Maximum species (approximately 58 %) of the total recorded terrestrial bird species were local residents (R) of the study area whereas 16 % were resident with local movement (R/LM). Approximately 20 % of the total terrestrial species were winter migratory (WM). They were mainly from the three families, namely, Turdinae, Sylvinae and Muscicapinae. One species of each was showing local movement (LM), resident with winter movement (R/WM) and winter migration with resident (WM/R). Four species were winter migrant with passage migration (WM/PM) and two species were summer migrants (SM) recorded from the study area. Figure 31.2 is a graphical presentation showing the status of the terrestrial bird species recorded from the study area.

31.3.3 Aquatic Bird Species: Occurrence

Urban aquatic habitats were surveyed into three heads, namely, Urban Lakes (WUL), Peri-urban Lake (WPUL), and Other Aquatic bodies (WOA). Aquatic bird species, categorized into wetland species and wetland dependent species, accounted for 103 from the study area. The inclusion of one species (Indian Skimmer) was based on records of other workers. Thus, 104 species showed their presence in the aquatic urban habitats. Eighty six species were wetland species whereas 18 species were wetland dependent. Aquatic habitats from the peri-urban areas (WPUL) harbored 103 aquatic species whereas 89 species were recorded from urban lakes (WUL). Surprisingly, small aquatic bodies and linking canals (WOA) were home for 46 aquatic species. Figure 31.1 presents a picture of the number of species in different aquatic habitats. Twelve aquatic species were also sighted in the terrestrial habitats of the study area.

31.3.4 Aquatic Bird Species: Status

Maximum species (approximately 46 %) of the total recorded aquatic bird species were winter migrants (WM) which showed their presence in the winter season. Approximately 33 % were resident showing local movement (R/LM) due to the decrease or absence of water in main aquatic bodies in summer seasons. The proportion of aquatic resident (R) species was only about 11 % of the total. Eight species were resident which showed winter movement (R/WM) and one species was resident showing both winter and local movement (R/WM/LM). Figure 31.2 is a graphical presentation showing the status of the aquatic bird species recorded in the study area.

31.3.5 Species of Global Interest

Nineteen bird species that are listed in the globally threatened species were recorded during the period of study from investigated habitats (Table 31.1). Eight of the total species are the terrestrial, whereas 11 species are wetland or wetland dependent species.

All the four critically endangered species of vultures, viz., Indian White-backed, Long-billed, Cinereous and Red-headed, showed their presence in the urban green spaces categorized as TPA and TFF, whereas the endangered species of vulture, viz., Egyptian, showed its presence in all types of terrestrial habitats. Two vulture species, namely Indian White-backed and Long-billed, had nesting colonies in Sajjan Niwas Garden and Sajjangarh WLS, whereas Red-headed was nesting in Sajjangarh WLS till the early 2000s. During the study period, the nesting of Long-billed was sighted in the cliffs of Aravallis in peri-urban sites. Records of the Cinereous vulture were rare and the sighting of this species was in the green spaces (Fragmented Forests) in its south and south-western parts of the Udaipur. The Egyptian Vulture was the only species of vulture which was sighted all around the urban habitats with the maximum numbers of individuals and nesting colonies in green spaces around the southern parts of human settlements.

The five vulnerable species were recorded mostly in the urban habitats (both terrestrial and aquatic) in the southern and western parts along with the peri-urban areas on the eastern side of Udaipur. Lesser Kestrel sightings were a rare occurrence, whereas Pied Tit had frequent sightings in Khas Odhi green spaces. Green Munia was a not so commonly found species but could be sighted regularly in Sajjangarh WLS and its adjoining green spaces towards the Bari lake side. Sarus Crane had been occurring in the aquatic habitats in peri-urban sites.

The nine species categorized as near threatened, showed their presence in the urban habitats under study. Eight species were aquatic, whereas one species was terrestrial. Two species, namely, Oriental White Ibis and Black-tailed Godwit, were recorded from all the categorized aquatic habitats and two species, namely, Darter, Painted Stork, Ferruginous Pochard and Black-bellied Tern, were recorded from all the major aquatic habitats, whereas two species, namely, Black-necked Stork and Lesser Flamingo, were only sighted in the peri-urban aquatic habitats. The only near threatened terrestrial species, viz. European Roller, showed its occurrence rarely in the open terrestrial habitats.

31.3.6 Characteristics of the Urban Habitats

On the basis of the importance of the categorized habitats in the local concern, TPP, TCA and WUL were maximally used and TPA, WOUL and WOA were least used by the local public. On the other side of the importance for global concern, TPA, WUL and WPUL were the maximally accepted sites and TPP, TFF, TAF, TIGS,

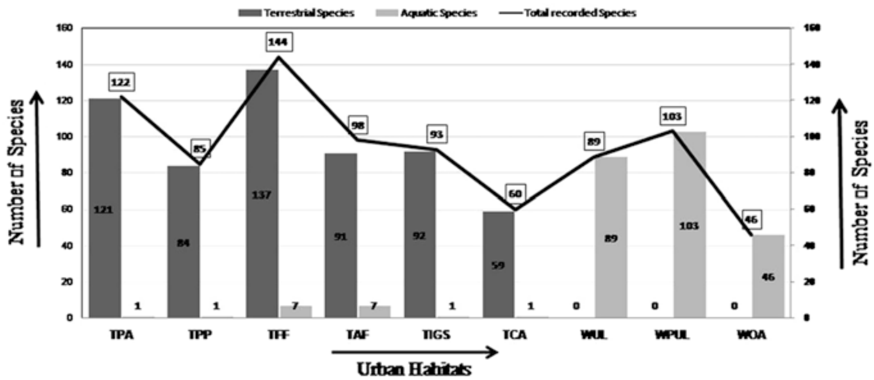


Fig. 31.1 Occurrence of bird species in urban habitats of Udaipur. *Source* Mehra et al. 2011c

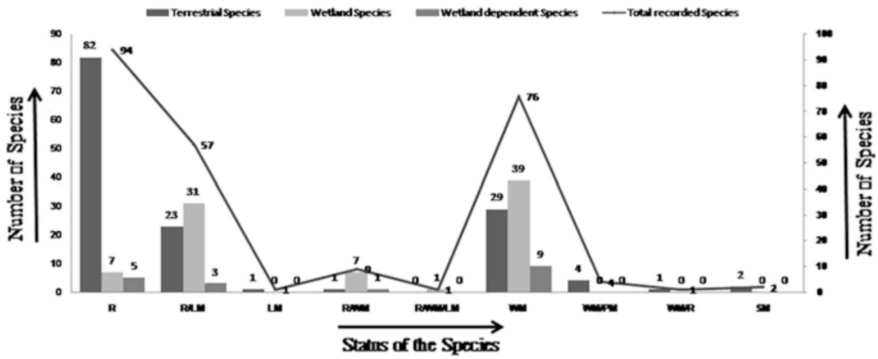


Fig. 31.2 Status of bird species recorded from urban habitats of Udaipur. *Source* Mehra et al. 2011c

TCA and WOA were the least important sites which were generally overlooked. From the above ratings and importance it can be inferred that, based on the potential for developing eco-tourism sites for the local and global communities, habitats such as TPA, TFF, WUL and WPUL can be on the top of the list.

Since the habitats under TPA and WPUL are already on the World Map these can be developed on socio-ecological grounds. The activities, such as Nature Tourism, which include Birding/Bird-watching, Herping/Snakes-Lizard exploring, Frogging/Frogs observations, Buterflying/Butterfly watching along with the local and indigenous vegetation involving local community, can be useful in improving the economic prospects of the locals as well as encouraging community participation. This would also be helpful in achieving the aims and objectives of Conservation Sciences.

Tables 31.2 and 31.3 provide a summary of the assessment of the terrestrial habitats of Udaipur which can be a source of socio-ecological aspects of research and its implementation. The much needed analysis of the inclination of local communities in stepping up for the new global responsibility of employment generation through conservation is a demand of the time for the area.

31.3.7 Discussions

Urban biodiversity is heavily influenced by humans due to land use and construction along with economic, social and cultural dynamics of the area. Amidst the green cover of the Aravallis, human settlements in the form of the city of Udaipur were created in the 16th century by the then rulers (Tod 1920; Shyamaldas 1986). The green forests rich in wildlife was the characteristic feature within and across the city walls (Tod 1920). Until the mid-20th century, urban sprawling was limited within the city walls and after that time it cleared the green cover. Simultaneously, throughout that period there was development of the green space urban sprawls which were used by the faunal species as refuge. In more densely populated areas, biodiversity consists mostly of species that have adapted to the urban environment and live in close proximity to humans. The most important of these species are avifauna, such as pigeons. Less dense sites and those with a shorter history of human impact in the form of alterations of habitats, such as Khas Odhi and Sajjangarh still have important original natural areas and the species which are of global interest.

Mitchell (2006) described the management of urban ecosystems and urban biodiversity. Urban areas and the local human population play a crucial role in this management due to several reasons not only within urban settlements but across the limits of urban areas. Partly because nature in the urban context is accessible nature, and it has been proven that people need access to nature in order to foster concern for nature and support for environmental initiatives. The extent of human influence over urban landscapes means that we also determine the availability and suitability of habitat for other species. From nature reserves to the manicured parks, residential gardens and commercial centres to aquatic bodies, each land use within and around human settlements provides opportunities for some species. Which species and the amount of habitat humans exclude from urban landscapes may play an important role in the ability of cities to provide a liveable habitat for both human and non-human residents into the future. Urban biodiversity is much more than the visibility of animals and plants in our cities. It is becoming the symbol for the dependency of mankind on natural resources. Where landscapes provide habitat for species and their predators, there is a reduced likelihood of species becoming pests because natural predators control their population. The most fascinating and eye catching group of species are important with avifauna being the group which has interested and attracted humans all over globe.

Udaipur also marks its presence on the global map when it refers to avifauna due to the presence of a wide variety of green spaces. The habitats of Udaipur are home to approximately 250 bird species, though, there was a great variation in the avifaunal composition throughout the period of urban sprawling. Hume (1878) pioneered the aquatic avifaunal explorations in southern Rajasthan and documented important species of water birds from Jaisamand (Dhebar) Lake and Kankroli *Talao* from Udaipur. Since then no major work has been done, although a few records of the water birds were found in some books related to hunting of animals by the princely family members (e.g. Tanwar 1956). Such types of documentation only present the group of water birds—not the species—so it is hard to assess the bird species of the respective period.

After a long gap, scientific documentation was done by Tehsin (1989) in which he reported 66 wetland birds from Udaipur Lake Complex. Sharma (1998) documented some of the wetlands birds around Sajjangarh Wildlife Sanctuary. Sharma and Tehsin (1994) then published the avifaunal checklist of southern Rajasthan. With these detailed listings, the reporting of individual species related to wetlands from different parts was also continued (Tehsin 1987, 1997, 1999). The work of Sharma (2002), Mehra et al. (2010), and Mehra (2011a, b, c, 2012) tried to cover and document almost all the birds of southern Rajasthan whereas Islam and Rahmani (2004) made an attempt to document all the sites of southern Rajasthan which are important with respect to birds of global interest listed by Birdlife International (2001). Udaipur Lake Complex, Sei Dam, Jaisamand Lake and Baghdarrah were important sites with respect to birds of international concern and were identified as Important Bird Areas (IBAs) (Islam and Rahmani 2004). Thus, urban lakes and Sajjangarh WLS were marked as important birding sites. Maintaining source habitats and protecting them from human induced threats is the key to ensuring the survival of many regional species.

Remnant species and source habitat cannot be simply replaced by new plantings. The complexity and age of these habitats gives them value far greater than habitats created by humans (Lindenmayer et al. 2003). The agricultural landscapes of Udaipur were home to threatened species such as Green Munia (Banerjee 1996) which was locally extinct from the urban limits (Mehra and Mehra 2008) and reappeared recently in 2011 from urban terrestrial habitats (Sajjangarh WLS and adjoining green patches near Badi). Similarly, urban habitats in the form of fragmented forests, such as scrub forests of Khas Odhi harbored threatened species White-naped Tit (Mehra 2004, 2012) which need immediate attention from the community and concerned departments. By volunteering or supporting environmental groups and programs that act to restore, monitor and maintain both natural and urban habitats, urban communities can make a positive contribution to urban biodiversity now and in the future. It is worth quoting the successful example achieved in urban habitats of Abu Hills where community participation contributed to increasing the population of threatened bird species (Mehra and Sharma 2004; Mehra et al. 2005; Mehra 2012). Despite the fact that urbanisation affects negatively upon the species richness, the study concludes that with effective management and community involvement an urbanized world can be sustainably managed for many of the species, especially birds, on economic grounds.

Table 31.2 Assessment and rating of urban habitats of Udaipur

Habitats → Characteristics ↓	Terrestrial habitats TPA	Aquatic habitats TPP	TFF	TAF	TIGS	TCA	WUL	WPUL	WOA	
Bird species	Terrestrial	121	84	137	91	92	59	0	0	0
	Aquatic	1	1	7	7	1	1	89	103	46
	Total	122	85	144	98	93	60	89	103	46
	Globally threatened	6	0	5	4	2	1	7	10	2
Disturbance level	1	2	1	2	2	3	2	1	2	
Accessibility level	1	1	1/3[a]	3	3	1	1	2	2	
Importance level	Local	3	1	2	2	2	1	1	3	3
	Global	1	3	3	3	3	3	1	1	3
Potential and scope	1	2	1	2	3	3	1	1	2	

Source Mehra et al. 2011c

[a] Represents one of the sites, Khas Odhi, which is private property rich in terrestrial avifauna

Table 31.3 Bird species recorded during study period (2004–2009) from urban habitats of Udaipur

Habitats →	Terrestrial habitats TPA	Aquatic habitats TPP	TFF	TAF	TIGS	TCA	WUL	WPUL	WOA	
Bird species (number)	Terrestrial	118	84	136	91	92	59	0	0	0
	Aquatic	1	1	7	7	1	1	87	102	46
	Total recorded	119	85	143	98	93	60	87	102	46
	Threatened	3	0	5	4	2	1	7	10	2

31.4 Conclusions

There is always a conflict between the protection of habitats and human involvement. Uncontrolled urbanization has forced both wetland habitats and biodiversity into a situation where both are struggling for their existence. There is a need to bring the concept of conserving these habitats as well as biodiversity. Community based nature conservation that is coming up very successfully in many parts of the globe can also be used in Udaipur. This can be an income generating source providing employment to the local residents and the mass involvement to conserve the diversity from an ecological point of view. Udaipur is already on the World Tourism Map due to its scenic beauty and historical importance and the natural heritage of the area is still an unexploited source of income generation in the urban areas. The coordinated and integrated approach of different government departments as well as academic research is required for the sites to achieve their potential for Nature Tourism.

Acknowledgments We are thankful to Rajputana Academy of Natural History, Rajputana Society of Natural History, Udaipur and Laboratory of Biodiversity, M. D. S. University, Ajmer for the help and support provided in the present investigation. We acknowledge all those people who directly and indirectly helped us in providing information on the presence of avifauna of global interest in their nearby habitats. Special thanks to Mr. G. K. Mehra for his comments and inputs in the write up. It is worth mentioning the contribution of Mr. Himmat Ram Kumhar who assisted the authors in carrying out the surveys all around the State.

References

Adam RM (1873) Notes on birds of Sambhar Lake and its vicinity. Stray Feathers 1:361–404

Ali S, Ripley SD (1968–1999) Handbook of the birds of India and Pakistan, vol 10. Oxford University Press, Mumbai

Alvey AA (2006) Promoting and preserving biodiversity in the urban forest. Urban For Urban Green 5(4):195–201

Banerjee A (1996) Some observations on avifauna with respect to habitat in Udaipur District, Rajasthan. Indian Forester 122:1961–1964

Barnes HE (1891) Nesting in western India. J Bombay Nat Hist Soc 6(3):285–317

Beissinger SR, Osborne DR (1982) Effects of urbanization on avian community organization. Condor 84:75–83

Bibby C, Burgess ND, Hill DA, Mustoe SH (2000) Bird census techniques, 2nd edn. Academic Press, London, pp xvii + 302

BirdLife International (2001) Threatened birds of Asia: the birdlife international red data book. BirdLife International, Cambridge

Blair RB (1996) Land use and avian species diversity along an urban gradient. Ecol Appl 6(2):506–519

Blair RB (1999) Birds and butterflies along an urban gradient. Ecol Appl 9(1):164–170

Blair RB (2004) The effect of urban sprawl on birds at multiple levels of biological organization. Ecol Soc 9(5):2

Bolund P, Hunhammar S (1999) Ecosystem services in urban areas. Ecol Econ 29(2):293–301

Botkin DB, Beveridge CE (1997) Cities as environments. Urban Ecosyst 1:3–19

Crooks KR, Suarez AV, Bolger DT (2004) Avian assemblages along a gradient of urbanization in a highly fragmented landscape. Biol Conserv 115:451–462

Custer TW, Rattner BA, Ohlendorf HM, Melancon MJ (1991) Herons and Egrets proposed as indicators of Estuarine contamination in the United States. In: Proceedings of the international ornithological congress, vol 20, pp 2474–2479

Dunnett N, Swanwick C, Woolley H (2002) Improving urban parks, play areas and green spaces. Department of Landscape, University of Sheffield, Department for Transport, Local Government and the Regions, London, pp 214

Garden J, McAlpine C, Peterson A, Jones D, Possingham H (2006) Review of the ecology of Australian urban fauna: a focus on spatially explicit processes. Austral Ecol 31:126–148

Germaine SS, Rosenstock SS, Schweinsburg RE, Richarsdson WS (1998) Relationships among breeding birds, habitat, and residential development in Greater Tucson, Arizona. Ecol Appl 8:680–691

Grimmett R, Inskipp C, Inskipp T (1999) Birds of the Indian subcontinent. Oxford University Press, New Delhi

Grimmett R, Inskipp T, Mehra SP (2004) Uttar Bharat Ke Pakshi. Bombay Natural History Society, Mumbai (in Hindi)

Hume AO (1878) A lake in Oodeypore. Stray Feathers 7(1–2):95–99

Impey L (1909) Duck shooting in Rajputana. J Bombay Nat Hist Soc 19(3):750–751

Islam MZ, Rahmani AR (2004) Important bird areas in India: priority sites for conservation. Indian Bird Conservation Network: Bombay Natural History Society and BirdLife International, UK, pp xviii + 1133

Javed S, Kaul R (2002) Field methods for bird surveys. Bombay Natural History Society, Department of Wildlife Sciences, Aligarh Muslim University, Aligarh and World Pheasant Association, South Asia Regional Office (SARO), New Delhi

Kazmierczak K, van Perlo B (2000) A field guide to the birds of India. New Delhi, Om Book Service

Kushlan JA (1993) Colonial waterbirds as bioindicators of environmental change. Colon Waterbirds 16:223–251

Li P, Ding P, Feeley KJ, Zhang J, Jiang P (2010) Patterns of species diversity and functional diversity of breeding birds in Hangzhou across an urbanization gradient. Chin Birds 1(1):1–8

Lindenmayer D, Claridge A, Hazell D, Michael D, Crane M, MacGregor C, Cunningham R (2003) Wildlife on farms: how to conserve native animals. CSIRO Publishing, Collingwood

Manakadan R, Pittie A (2001) Standardised common and scientific names of the birds of the Indian subcontinent. Buceros 6(1):ix + 37

Manlun Y (2003) Suitability analysis of urban green space system based on GIS. Ph.D. thesis, International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands, p 100

Marzluff JM, Gehlbach FR, Manuwal DA (1998) Urban environments: influences on avifauna and challenges for the avian conservationist. In: Marzluff JM, Sallabanks R (eds) Avian conservation: research and management. Island Press, Washington, DC, pp 283–296

McDonnell MJ, Pickett STA (1990) Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 71:1232–1237

McDonnell MJ, Pickett STA, Groffman P, Bohlen P, Pouyat RV, Zipperer WC (1997) Ecosystem processes along an urban-to-rural gradient. Urban Ecosyst 1:21–36

Mehra S (2012) The avifauna of southern Rajasthan with special emphasis on threatened species and bioacoustic applications in their identifications and monitoring. Ph.D. thesis, M. D. S. University, Ajmer, p 256

Mehra S, Mehra SP, Sharma KK (2012) Importance of aquatic avifauna in southern Rajasthan, India. In: Rawat M, Dookia S (eds) Biodiversity of aquatic resources. Daya Publishing House, Delhi, pp 159–183

Mehra, S, Mehra, SP, Sharma KK (2011a) Aquatic avifauna: its importance for wetland conservation in Rajasthan, India. In: Mathur SM, Shrivastava VK, Purohit RC (eds) Conservation of lakes and water resources management strategies. Himanshu Publications, Udaipur, pp 179–190

Mehra S, Mehra SP, Sharma KK (2011b) Aquatic avifauna of Aravalli Hills Rajasthan, India. In: Gupta VK, Verma AK (eds.) Animal diversity, natural history and conservation, vol I. Daya Publishing House, Delhi, pp 145–167

Mehra SP, Mehra S, Sharma KK (2011c) Urban avifaunal biodiversity in context of Udaipur, Rajasthan, India. In literature (personal observations)

Mehra S, Mehra SP, Sharma KK (2010) Aquatic avifauna: its importance for wetland conservation in Rajasthan, India. In: Proceedings of conservation of lakes and water resources: management strategies, 19–20 February 2010, pp 202–214

Mehra SP, Mehra S, Gautam P (2009) Avifaunal diversity of Keoladeo National Park: a review (Abstract). In: Mathur VB, Sivakumar K, Singh B, Anoop KR (eds) A bibliographical review for identifying research gap areas: Keoladeo Ghana National Park—a world heritage site. Wildlife Institute of India, Dehradun, p 45

Mehra S, Mehra SP (2008) Observations on green munia from Abu Hills. In: Verma A (ed) Conserving biodiversity of Rajasthan. Himanshu Publications, Udaipur

Mehra SP, Mehra S, Mathur R (2005) Munias of Mount Abu (Rajasthan, India) with special emphasis on green avadavat *Amandava formosa*. Indian birds 1(4):77–79

Mehra SP, Sharma S (2004) Additional site records of green avadavat *Amandava formosa* (Latham) from Mt. Abu, Sirohi. Newslett Ornithol 1(6):84–85

Mehra SP (2004) Sighting of White-naped Tit *Parus nuchalis.* Udaipur Newslett Ornithol 1(5):77

Messurier AL (1904) Game, shore, and water birds of India. W. Thacker and Co, London

Mitchell B (2006) Life in the suburbs: urban habitat guidelines for the ACT. Natural Heritage Trust, Government of Australia, Melbourne, p 25

Oates EW (1899) A manual of the game birds of India. In: Water birds, vol 2. Messrs. A.J. Combridge & Co., Bombay, pp 506 (2 vols)

Prakash I (1960) Shikar in Rajasthan. Cheetal 2(2):68–72

Sharma SK (1998) Avian Fauna of Sajjangarh wildlife sanctuary. Newslett Birdwatchers 38(2):25–27

Sharma SK (2002) Preliminary biodiversity survey of protected areas of southern Rajasthan. Unpublished report, pp 1–23

Sharma SK, Tehsin R (1994) Birds of southern Rajasthan. Newslett Birdwatchers 34(5):109–113

Shyamaldas (1986) Veer Vinod (History of Rajputana states up to 1884), Part I–IV. Motilal Banarsidas, Delhi (in Hindi)

Smith R, Gaston K, Warren P, Thompson K (2005) Urban domestic gardens (V): relationships between landcover composition, housing and landscape. Landscape Ecol 20:235

Tanwar DT (1956) Shikari aur Shikar (in Hindi). Udaipur, Mewar

Tehsin R (1987) Migrating demoiselle cranes anthropoides virgo. Tigerpaper 14(4):26

Tehsin R (1989) Faunal history of Fatehsagar Lake. In: Vyas LN, Garg RK (eds) Wetland conservation. Environment Community Centre, Udaipur, pp 109–117

Tehsin RH (1997) Little green Heron *Butorides striatus* and white-eared Bulbul *Pycnonotus leucogenys* sighted in southern Rajasthan. Newslett Birdwatchers 37(5):91

Tehsin RH (1999) Threetoed Kingfisher *Ceyx erithacus* sighted at Panarwa. J Bombay Nat Hist Soc 96(1):142–143

Tod J (1920). Annals and antiquities of Rajasthan, vol I. Motilal Banarsidas Publishers Private Limited, New Delhi (Reprint 1994)

UNEP (2008). www.unep.org/urban_environment/index.asp. Accessed 21 April 2008

Urfi AJ, Sen M, Kalam A, Meganathan T (2005) Counting birds in India: methodologies and trends. Curr Sci 89(12):1997–2003

Whistler H (1938) Ornithological survey of Jodhpur state. J Bombay Nat Hist Soc 40:213–235

Chapter 32
Perspective on Water and Biodiversity Issues in Peri-urban Landscapes: A Case Study of Keoladeo National Park, Bharatpur, India

Satya Prakash Mehra and Sarita Mehra

Abstract Keoladeo National Park (KNP) at Bharatpur, locally known as "Ghana," is acknowledged as one of the most enchanting and outstanding wetland reserves in the world. The wetland ecosystem is a system of small dams, dykes and sluice gates created to control the water level in different blocks. This park became the hunting preserve of the Bharatpur royalty and one of the best duck-shooting wetlands in the world from the 1850s through to the mid-1960s. It was designated as a bird sanctuary in 1956 and recognized as a Ramsar site in 1981. In 1982, it was established as a national park and inscribed on the World Heritage List in 1985. A socio-ecological study was carried out in the adjoining areas of KNP to assess the perception of children towards water and KNP. The paper highlights the historical perspective of water management in Bharatpur and its importance for the betterment of the unique ecosystem that is KNP. Further, change in the perception towards water through community management of water resources is discussed along with resolving local water problems through sustainable natural solutions with the support of Corporate Social Responsibility (CSR) activities. The community participatory works invoke that the wetland management strategies need to be carefully integrated with land use planning and management at catchment and landscape levels.

Keywords Keoladeo · Ramsar site · Bharatpur · Avifauna · Wetland · Socio-ecological

S. P. Mehra (✉) · S. Mehra
Rajputana Society of Natural History, Kesar Bhawan, 16/747, P. No. 90 B/d Saraswati Hospital, Ganeshnagar, Pahada, Udaipur 313001, Rajasthan, India
e-mail: drspmehra@yahoo.com

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_32,

32.1 Introduction

Keoladeo National Park (KNP), formerly known as Bharatpur Ghana Bird Sanctuary, is still referred as "*ghana*" (~dense forest) locally. The name 'Keoladeo' denotes Lord Shiva whose temple is located at the centre of the park. A unique feature of the wetland ecosystem of KNP is its origin from a natural depression, which was an evanescent rainfed wetland (Vijayan 1994). The construction of Ajan Bund (a temporary reservoir, locally known as Kohni Bund) in the 18th century about a kilometre from the park, and the subsequent flooding of the area, marks the beginning of human involvement in the conversion of this natural depression into a permanent waterfowl reserve (Vijayan 1991). Subsequently, several earthen bunds which divide the park into compartments, or blocks, were constructed with sluice gates at various points to regulate the water level. Water from Ajan Bund floods these blocks through the Ghana canal. Excess water passes out through Jatoli and mixes with Bharatpur city's main flood drain. Water remains in the park till it dries naturally in summer.

This extensively modified and man-managed park supports an enormous congregation of migratory waterfowl in winter and in the monsoon season and autumn colonies of breeding, fish-eating birds are commonly seen. The possibility of watching birds from close proximity is the main attraction of the park. KNP is the only wintering ground for the central population of the rare and highly endangered Siberian Crane *Grus leucogeranus* in India (Sauey 1985).

Dr. Ali (1985) in his autobiography, The Fall of Sparrow, described, "What gives to the Ghana its unique distinction as a bird-watchers' haunt is not only the fantastic concentration and diversity of species of both resident and migratory water birds at the appropriate seasons, but the uncommonly extended period of half a year or more at a stretch over which bird watching can be enjoyed here."

The paper reviews the historical perspective and the updated biodiversity of KNP. Further, the paper investigates human's perception towards water and KNP along with CSR initiatives taken for resolving the water issues at one of the sites.

32.2 Methodology

A review of past studies was carried out to document the number of species of different groups with a special focus on the listing of birds, fish and anurans since 1900s. Seasonal observations were recorded from March 2007 to 2010 to record the species in the present scenario with the prime focus on avifaunal and anuran diversity in and around KNP. Line transect methods were employed for the species diversity. Total count method was employed for the waterbirds (Bibby et al. 2000).

A random survey was carried out in the villages around KNP in 2007 as a baseline study. As a sample, a random thousand responses from 50 villages were collected through questionnaire surveys to assess the perceptions of the children of age group 10–15 years. A case study of the village Chak Ramnagar was taken to emphasise the success of community participation in executing works for the improvement of water conditions by NGO with support from the CSR initiative of the corporate sector in 2009–2010.

32.3 Historical Background

The presence of Kadam (*Mitragyna parvifolia*) grooves, which are the climax vegetation of a swamp or river-bed, probably denotes Keoladeo wetland's existence centuries ago (Sankhala 1990). The area of the park is a natural depression which is believed to be part of a river bed, probably that of Yamuna, which subsequently changed its course (Anonymous 1996). This area was developed into a duck shooting reserve by the then Maharaja of Bharatpur at the end of the 19th century.

In the year 1901 this reserve was flooded with water released from Ajan Bund by the then ruler of Bharatpur, Maharaja Suraj Mal (Drake-Brokman 1905; Gasquire 1927; Pandey 1979). Lord Curzon formally inaugurated this reserve with an organised duck shoot in 1902. On November 12, 1938 the world record of duck shooting—4,373 birds in a day was set here by Lord Linlithgow, the then Viceroy of India. The duck shoot record is mentioned in an inscription on a pillar near Keoladeo Temple. Sport of waterfowl hunting was the prime reason for the creation of this reserve. Although there were other reasons, such as grazing facilities for the village cattle and protecting Bharatpur from the floods that frequently occurred. In 1919, its boundaries were notified and from then on the reserve also served as a place for old and infirm cows.

The forest reserve continued to be a hunting preserve for the rulers but simultaneously it was also the primary natural resource for the local economy (Anonymous 1996). At a nominal fee per head people could graze their cattle and use the forest resource for other domestic purposes.

It was in 1925, with the enforcement of Bharatpur Forest Act, management of the reserve was initiated and the erstwhile *Shikar* Department was brought under Forest Department in accordance with the rules for the protection of the wildlife and forests of Rajasthan framed in 1930–1935. Management of the shooting reserve, especially plantation, was taken up according to the working plan of 1944–1964.

After independence, with the consistent efforts of Dr. Sálim Ali, the ruler of Bharatpur, handed Ghana reserve to the Government of Rajasthan which notified it as a Bird Sanctuary on the advice of the National Committee for Bird Preservation, India, in the 1956 (March 13). However the shooting continued till 1965. The rulers retained hunting rights until these were withdrawn in 1972. A brick wall was constructed around the sanctuary perimeter during period of 1977–1981.

When India became a Contracting Party to the Ramsar Convention in 1980, Keoladeo became one of the first two (Chilika Lake, Orissa being the other) wetlands in the country to be listed as Ramsar sites in October 1981. In 1981 (August 26), the site was declared a National Park (an area of 28.723 km^2,) *vide* notification of the Government of Rajasthan F 3(5) (9) Raj 8172 in an effort to raise its conservation status. All forms of biodiversity exploitation inside the park were ended in accordance with the Wildlife (Protection) Act, 1972. It was in 1985 that KNP received the status of a World Heritage site.

32.4 Geographical Features

32.4.1 Location

The Keoladeo National Park, situated at the confluence of the Gambhiri and Banganga Rivers between 27°07′06″–27°12′12″ N latitude and 77°29′05″–77°33′09″ E longitude at an average elevation 174 msl, is 2 km southwest of Bharatpur city. It is flat with a gentle slope towards the centre forming a depression of about 8.5 km^2, which is the submersible area of the park. This 29 km^2 reserve is 50 km away from Agra and 180 km from Delhi (Fig. 32.1).

32.4.2 Climatic Features

KNP experiences extreme climatic conditions. The diurnal temperature varies from 0.5 °C in January to 50 °C in May. Mean relatively humidity ranges from 62 % in March to 83.3 % in December. Rainfall occurs throughout the southwest monsoon, mainly during July-August. The mean annual precipitation is 662 mm, with rain falling on an average of 36 days per year (Vijayan 1994).

32.4.3 Physical and Edaphic Features

The area consists of an artificially created flat patchwork of marshes in the Gangetic plain which is maintained by a system of canals, sluices and dykes. Normally, water is fed into the marshes twice a year from inundations of the Gambhiri and Banganga Rivers, which are impounded on arable land by means of an artificial dam (Ajan Bund). The first inundation is soon after the onset of the monsoon, usually in mid-July and the second is in late September or October when Ajan Bund is drained ready for winter cultivation. It is flooded to a depth of 1–2 m throughout the monsoon (July–September). From February onwards it begins to dry out and by June water remains in only a few pockets. For much of the year the area of wetland is only 1,000 ha. Soils are predominantly alluvial—some clay has formed as a result of the periodic inundations (Vijayan 1994).

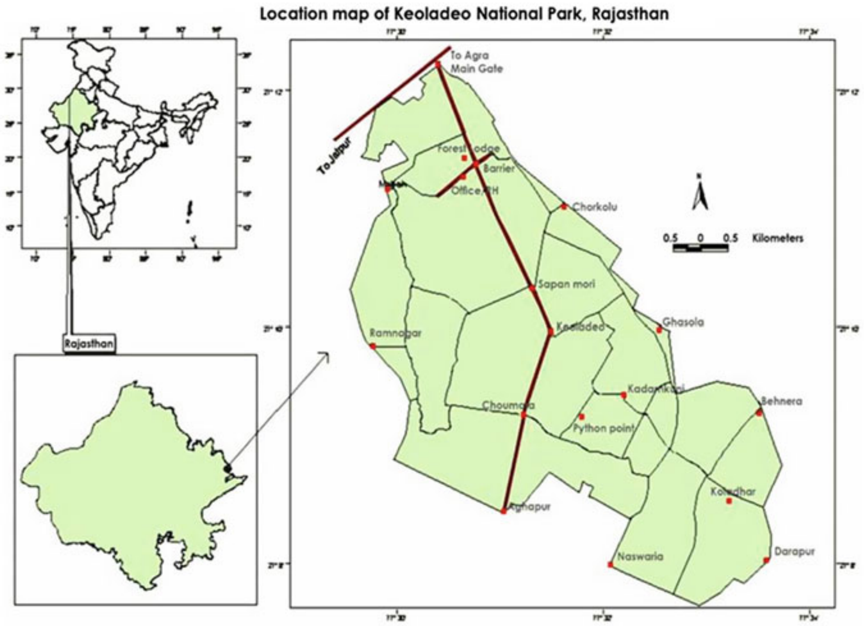


Fig. 32.1 Location of the Keoladeo National Park. *Source* India water portal, http://www.indiawaterportal.org/articles/wetlands-water-quality-management-science-and-technology-paper-current-issues-water. Accessed 12 December 2013

32.5 Biodiversity

32.5.1 Floral Diversity and Habitats

The principal vegetation types are mixed pattern of xerophytic and semi-xerophytic species consisting predominantly of *Acacia nilotica*, *Prosopis cinereria*, *Salvadora oleoides*, *Capparis decidua* and *Capparis seperia* (Prasad et al. 1996). However, *Acacia catechu* and *Anogeissus pendula*, typical of Bharatpur area (Meher-Homji 1970), are conspicuous by their absence.

The Flora of the Park has been studied extensively by Prasad (1988, 1990), Prasad et al. (1991) and Prasad et al. (1996). Its unique mosaic of habitat types range from temporary swamps and potholes which hold water for a few weeks only, to flood plains where water flows for several months. Land types range from land which is wet only during the rains to land which does not even hold raindrops. Woodlands with thickets are distributed in scattered pockets. The physiognomic types recognized are forest, woodland, scrub woodland, savannah woodland, tree savannah, shrub savannah, low grassland with scattered trees and shrubs, plantations and wetlands (Perennou and Ramesh 1987). Each of the major types is further divided into subdivisions according to dominant or characteristic species and based on the density of trees or thickets.

Broadly, the habitats could be classified as wetlands (11 km^2) and terrestrial habitats (18 km^2) which include grasslands (5 km^2) and woodlands (13 km^2). Prasad et al. (1996) detailed vegetation types of these broadly classified habitats which are summarized in subsequent paragraphs. Wetlands constitute one-third of KNP and is the lifeline of the Park due to its unique biodiversity. It is the wetland habitats that attract thousands of migratory waterfowl. The migratory, as well as resident, birds use wetlands for part or all of their life-cycle. Other than the avian variety of species microbes, insects, amphibians, reptiles, fish, and mammals are part of this ecosystem. Grassland habitat is dominated by khus grass (Vetiveria zizanoides), a tall coarse grass whose roots contain oil famous for its aroma interspersed with few trees and/or shrubs. Grasslands provide an excellent habitat for insects, insectivorous birds (rollers, drongos and flycatchers), partridges, quails and mammals, such as spotted deer, blue bull, and wild boars. Other terrestrial habitats, viz., woodlands are frequented by mammalians, such as nilgai, spotted deer and jackals.

32.5.2 Wetland Vegetation

The wetlands of KNP have 90 species of flowering plants, of which *Paspalum distichum*, a perennial grass, is the most dominant species (Prasad 1988). The wetland vegetation includes:

1. Free floating (*Spirodela polyrhiza*, *Lemna perpusilla*, *Eichhornia crassipes*).
2. Rooted with floating leaves (*Nymphaea pubescene*, *Nymphaea nouchali*, *Nymphoides cristatum*).
3. Unanchored submerged (*Ceratophyllum demersum*, *Utricularia aurea*, *Utricularia stellaris*).
4. Rooted submerged (*Hydrilla verticillata*, *Najas minor*, *Potamogeton crispus*).
5. Emergent, amphibious (*Eleocharis dulcis*, *Scirpus littoralis*, *Ipomoea aquatica*).
6. Marshland plants (*Caesulia axillaries*, *Eclipta prostrate*, *Echinochloa colonum*).

Prasad et al. (1996) observed four main plant associations in the KNP wetland which are as follows:

1. *Hydrilla—Najas*: confined to the deepest areas with open water and loose muddy bottoms. Common waterfowl species feeding in this habitat are coot, pochards, pelicans, cormorants and darter.
2. *Spirodela—Wolffia*: occur in open water areas and keep drifting along with the wind. Common waterfowl species in this habitat are cotton teal and coot.
3. *Paspalum—Ipomoea*: shallow water areas with moist soil. Common wetland species are garganey, purple moorhen, egrets, herons and geese.
4. *Corchorus—Melochia*: found near the dykes and bordering areas of wetlands and uplands, the latter being the major habitat for the Siberian crane.

32.5.3 Terrestrial Vegetation

Land vegetation is classified as following:

1. **Mitragyna patch:** few patches of *Mitragyna parviflora* occur in the park.
2. **Woodland:** dominated by *A. nilotica* (upper tree layer) and *Ziziphus mauritiana—Salvadora persica* (under-story).
3. **Scrub woodland:** upper canopy is not continuous, usually formed by trees, such as *M. parviflora*, *A. nilotica* and *Syzygium cumini* whereas undergrowth is prominent, formed by *S. persica*, *Capparis separia* and *Prosopis juliflora*.
4. **Savanna and other grassland:** formed mainly by grasses, such as *Vetiveria zizanioides* and *Desmostachya bipinnata*, mostly in Koladehar area. *Prosopis cineraria*, *A. nilotica*, *Acacia leucophloea*, *Z. mauritiana*, and *Salvadora persica* are common trees and shrubs of this habitat. Low grassland of *Sporobolus helvolus* and *Cynodon dactylon* occurs in some parts with few scattered trees and shrubs, such as *A. nilotica*, *P. cineraria*, *S. persica* and *Kirganelia reticulata*.
5. **Plantation:** *A. nilotica* and *P. juliflora* were planted. *P. juliflora* and have spread all over the park; removal is now being carried out as a part of park management.

Apart from the above, the park has several saline sandy patches where scattered growth of *S. oleoides*, *S. persica* and *P. juliflora* is seen. Sparse growth of *Salsola baryosma*, *Suaeda fruticosa* and *Sporobolus ioclados* are forming the ground cover.

Overall, the flora of park comprises of 375 species of angiosperms (Prasad et al. 1996).

32.5.4 Faunal Diversity

32.5.4.1 Invertebrates

The richness of the varying habitats provides feeding and breeding sites for many invertebrates. Mahajan et al. (1981a, b, c), Mahajan et al. (1982a, b, c) and Vijayan (1991) studied invertebrates of KNP. Venkataraman (1988, 1990, and 1992) reported cladocerans of KNP. The work of Palot and Soniya (2000a, 2001) reported 40 species of butterflies, whereas Trigunayat and Singh (1998) listed 35 butterfly species from KNP. Unpublished work of Mehra and Mehra (2008) reported 52 species of butterflies at KNP. In studies of odonata, Palot and Soniya (2000b) reported 16 species from KNP.

32.5.4.2 Vertebrates

The vertebrate diversity of KNP is detailed under different classes of animals. These are:

1. **Ichthyofauna:** The fish fauna of the park were studied by Moona (1963) and Kumar and Vijayan (1988) and consist of 43 species belonging to 8 orders, 16 families and 31 genera. 37 species enter the park, along with the water, from rivers and six species are breeding residents namely *Channa punctatus*, *Channa striatus*, *Channa marulius*, *Heterpneustes fossilis*, *Clarius batrachus* and *Colisa fasciata*. With these six species, *Labeo* sp. and *Cirrhinus* sp. are also commonly found in KNP.
   Kumar et al. (1995) worked on the sources of fish fauna to KNP which is also important due to its connectivity at the time of the monsoon. The work revealed that out of the total of 46 species collected, 41 species were recorded from Banganga-Gambhiri River system which is the main source of water to KNP.
2. **Herpetofauna:** Vijayan (1991) documentetd 7 species of amphibians and 28 species of reptile. Vijayan (1991) reported six species of frogs (family Ranidae: 4 species, family Microhylidae: 2 species) and one species of toad (family Bufonidae). In a monsoonal assessment in the year 2007 the authors recorded one more species which was identified on the basis of photographs and digitally recorded calls from the park. Thus, out of twelve species in Rajasthan (Sharma and Mehra 2007), the park harbours nine species of anurans (Mehra and Mehra 2012 *in prep*).
   The number of reptile species found in KNP is high considering its size (Bhupathy 1999). KNP has 7 species of turtles, 8 species of lizards and 14 species of snakes (Bhupathy 1999; Vijayan 1991). Rajasthan has only eleven species of turtles (Sharma 1995, 2000) while this park alone has seven species. The absence of Indian Star Tortoise (*Geochelone elegans*) in KNP may be due to the wet conditions and inundation during monsoon, whereas high densities of Indian Rock Python (*Python molurus*) could be mainly due to its protection from hunters and snake charmers along with abundant food (Bhupathy 1999).
3. **Avifauna:** KNP holds a considerable number of birds in its diverse habitat. One of the major conservation values of the park is its role as a wintering habitat for a multitude of migratory waterfowl belonging to 21 species (Bhupathy et al. 1998). The park also acts as a staging ground during immigration and emigration of waterfowl from the Palearctic Region. Avifauna is the most studied component of the park (Vijayan 1991).
   KNP received attention in the latter phase of the 19th century when a plan for an artificial duck shooting reserve arose in the mind of the then ruler of Bharatpur. The very first scientific contribution targeted the information on the duck shooting (Impey 1909) followed by observations from Bates (1925, 1949), and Abdulali (1948). The 1950s and 1960s witnessed intense ringing programmes in KNP (Ali 1962a, b, 1963a, b, c, 1964a, b). Bombay Natural History Society conducted bird migration studies, initiated by Dr. Ali (1959), which

were thereafter carried out during many winters since the 1960s (Mathew 1971; Ali and Hussain 1982). Meanwhile ornithologists regularly observed the birds and contributed towards the avifaunal researches in scientific journals as well as nature magazines (Crum 1964; David 1966; Grubh 1969; Stairmand 1972; Labastille 1974; Aranha 1975; Ali 1979, 1982; Earle 1987; Ewans 1989; Middleton and Mudgal 1989; Sankhala 1991; Bhupathy et al. 1998). The systematic listing (Ali 1953, 1962a; Singh 1958; Donahue 1962a, b, 1964; Shivrajkumar 1962; Rangnathan 1963; Gee 1964; Dharmakumarsinhji 1965; Bora and Saxena 1969; Saxena 1969; Futehally 1972; Abdulali and Panday 1978) and additional records by several workers (Grubh 1968; Grubh et al. 1968a, b; Raju 1970; Harrison and Harrison 1972; Dukes et al. 1975; Kannan 1986a, b; Prakash 1988a, b; Fisher 1990; Norman and Sivasubramanian 1992; Sivasubramanian 1992; Jamdar 1998; Holt 1999) kept on updating KNP's avifaunal checklist which has referenced 350 birds, accounting for approximately 70 % of the avifauna of Rajasthan, the largest state of India (Islam and Rahmani 2004; Mehra et al. 2009a).

KNP was identified as one of the Important BirdAreas (IBA) under the categories A1 (threatened species), A4i (1 % threshold population), and A4iii (≥20,000 waterbirds) (Islam and Rahmani 2004). 15 globally threatened bird species and 12 near threatened species are part of avifaunal composition of KNP. Heronries made by several breeding species of storks, cormorants, herons, egrets, ibises, spoonbills, darters and the number of ducks, coots, and rails, occur well above their 1 % threshold numbers. The large congregation of millions of waterfowl mark it as a birders' paradise.

4. **Mammals:** In all, 28 species of mammals including 6 species of larger herbivores, such as sambhar, cheetal, nilgai, blackbuck, wild boar and feral cattle; and 6 species of carnivores, such as jackal, hyena, jungle cat, fishing cat, civet and otter occur inside the Park (Vijayan 1991). A panther was reported prior to the 1960s (Department of Forest, KNP) and again sighted for a few months during 1987 (September)—1988 (May) (Vijayan 1991). In the year 1999, a tigress and in 2009, a tiger were sighted inside the Park for a few months (Department of Forest, KNP). Blackbucks are now a very rare sighting (only 1–2 in 2008) as compared to hundreds in 1980s. Hanuman Langurs (3–7 individuals) are rarely sighted at Aghapur check-post.

32.6 Water Crises and Alternatives

Around 11 km^2 geographic area of KNP has the spread of water forming an ideal wetland. The presence of water has the major impact on the Keoladeo as it decides the fate of wetland and its floral and faunal diversity especially avifauna. The source of water within Bharatpur, its quantity and quality are major factors affecting the Keoladeo wetland.

Bharatpur lies in the Yamuna flood drain area, situated on the confluence of three rivers, viz. Ruparail, Banganga and Gambhiri. The region has a history of floods and droughts, the frequency of these has changed over the decades, with a decrease in floods and increase in droughts during the 1980s (Bhatnagar et al. 1980; Breeden and Breeden 1982; Singh 1981; Verghese et al. 1982). Banganga and Gambhiri Rivers were the sources of water for Ajan Bund but since the 1980s the Gambhiri has remained the only source. Further, the water flow of the Gambhiri was also reduced due to construction of the upstream Panchana dam which has further worsened with the increased height of the dam and scanty rainfall. In the mid of first decade of 2000s, water influx from all the rivers feeding Bharatpur was checked resulting in an acute shortage of surface water all over the region. The underground water table was lowered from an average ten feet to more than fifty feet. This resulted in a high accumulation of salts increasing the salinity and total dissolved solids of water all over the region. As the mindset of the people was not in accordance to the scarce water conditions, an approach of water conservation through traditional methods, as seen in the people of western Rajasthan, was lacking. For alternative management of water in KNP, options created were the Govardhan Drain along with a subsidiary option of Chiksana Canal. The Dholpur-Bharatpur Chambal Project was undertaken to provide water to the people of Bharatpur and KNP.

32.7 Observations and Case Study

32.7.1 Avifaunal and Anuran Diversity

About 398 species of birds were reported or sighted by the workers since the 1900s. During observations in the years 2007–2010, it was seen that the number of bird species remained around 200 mostly accounted for by the residential birds. During dry conditions at the park, the wetlands around KNP were used as the wintering grounds by the migratory and residential waterfowls. In the satellite wetland surveys, it was observed that these discrete wetlands harbored more than 200 aquatic species which were reported from KNP in the past years. The wetlands in the close proximity to KNP (approximately 50 km of aerial distance) were home for over 150 wetland species. The detailed studies on their occurrence and status are being continued. Other important wetland organisms observed during the three years were anurans. Nine species were recorded from KNP and its surrounding areas (Table 2).

32.7.2 Socio-ecological Assessment

A questionnaire based survey was carried out by Mehra et al. (2009b) in 50 villages around KNP. Out of 1,000 respondents from 50 villages, 112 were not considered due to non-clarity (reasons, such as blank sheets, etc.). Three main populous villages, Uchchain, Pichoona and Kurka contributed approximately 57 % of the responses. Due to a negligible count of children not enrolled for formal education, the section on ‘children with no formal education’ was left out in the analysis. Male proportion was 58.33 % in the selected response. 36.37 % of students were from age group 10–11 years, whereas 42.23 % were from the age group 12–13 years with the highest contribution and 3.15 % were from age group 14–15 years with the lowest contribution in the total correct responses. Only 4.50 % respondents were categorized in category of aware students. 56.64 % respondents were having average awareness, whereas 37.17 % respondents were the category of unaware students. The responses showed that students had only basic information, and lack knowledge about KNP. Thus, this led to the conclusion that there should be a program for children around KNP to provide the information on major aspects of water pollution, water cycle, water conservation and KNP. Further, it was found that to change the attitude of people, one has to provide the long term solution to overcome the local problems of water scarcity.

32.8 Case Study of Village Chak Ramnagar

With the support of the CSR, activities for improvement of water conditions were started in the rural areas of Bharatpur in 2008 (Mehra 2012). In 2009–2010, work on improving water conditions was executed in village Chak Ramnagar (Bharatpur, Rajasthan, India) which is the village of the *Banjara* community (Gypsies of India). To resolve any environmental problems, especially related to water, the scientific community has to think of the traditional options of the particular area which are based on eco-ethics. Thus, natural solutions were explored for resolving water problems after analyzing the natural flow pattern of water both surface and underground. The proportion of the *pucca* constructions (use of cement-contrete) was kept to a minimum. Through *kuccha* constructions (of traditional materials), the deep infiltration of surface water for recharging of ground water to lower the salinity problems was primarily focused. The surface and underground connections were precisely given to the reservoirs as per gradient of water flow to trap every drop of water of rain without checking its downstream movement. The unutilised surface runoff water was trapped from all directions. The work was completely based on traditional approaches and learning from the arid land of Rajasthan. The construction workers were villagers themselves, thus generating extra income for the deprived section of villagers, which was the added importance of the community participatory work.

The models of community involvement and participatory management have been adopted effectively, with *nukkad* plays, screening of films, motivation camps, eco-centric events, and awareness campaigns. Children and women are mainly targetted, as they would not be able to come out due to the existing customs. It was learnt that children of the villages played an important role in encouraging their parents to work for their future and rising above the caste discrimination. Further, women were facing more problems than men; therefore, the availability of water within village was of great benefit to them. The availability of drinking water for the community and the gradual increase in the groundwater table of the region further improved soil moisture conditions resulting in the revival of the local natural environment. The plant species, especially grasses such as *D. bipinnata*, *V. zizanioides*, *Saccharum spontaneum* and *Saccharum munja*, which prefer moisture for larger periods of the year, were planted. These species help bind the soil as well as retain moisture. In addition to their ecological importance these species are of economic value to the local community.

Banjaras are known for their age-old practices of water harvesting, carried out throughout the desert state of Rajasthan. With the passing of time the community has lost the traditional knowledge of its forebears due to a lack of interest from the scientific community and government policies. It is now doubtful whether many water-harvesting structures will provide sustainable, long term solutions. Unplanned structures are worthless in the context of climate change and monsoon failure. On the other hand, age-old structures, like old wells, in Rajasthan are still major sources of water even during drought periods. This work made the villagers from the other areas, in and around the working sites, realise that it is time to revive their eco-centric Indian culture and conserve natural heritage to secure future generations.

32.9 Conclusions

Keoladeo Ghana is illustrative of a wetland where human intervention is important for the wellbeing of the ecosystem. This requires an integrated approach of KNP Forest Management along with the involvement of local communities and stakeholders to achieve the conservation of the ecosystem, especially wetlands, in totality.

Community participation could secure the local resources if a sustainable approach is developed at every level. Furthermore, a large proportion of the rural population realised that they have destroyed their heritage of "Bharatpur Irrigation System" which was scientifically constructed to channel waste water with effective controlling mechanisms and that as a result of such destruction they are now paying a price.

References

Abdulali H (1948) Peculiar behaviour of the Darter (Anhinga melanogaster Pennant). J Bombay Nat Hist Soc 47(3):549

Abdulali H, Panday JD (eds) (1978) Checklist of the birds of Delhi, Agra and Bharatpur with notes on their status in the neighbourhood. Humayun Abdulali, Bombay, iii, 17 p

Ali S (1953) The Keoladeo Ghana of Bharatpur (Rajasthan). J Bombay Nat Hist Soc 51(3):531–536

Ali S (1959) Local movements of resident waterbirds. J Bombay Nat Hist Soc 56(2):346–347
Ali S (1962a) The Bombay natural history society/world health organization bird migration study project. J Bombay Nat Hist Soc 59(1):100–130
Ali S (1962b) Recoveries of ringed birds. Newslett Birdwatchers 2(9):1–2
Ali S (1963a) The BNHS/WHO bird migration study project-3. Activities from 15-10-1962 to 15-4-1963. J Bombay Nat Hist Soc 60(2):410–414
Ali S (1963b) Recoveries of ringed birds. Newslett Birdwatchers 3(6):1–2
Ali S (1963c) Recovery of ringed birds. Newslett Birdwatchers 3(12):1
Ali S (1964a) The BNHS/WHO bird migration study project-4. Activities from 13-9-1963 to 23-3-1964. J Bombay Nat Hist Soc 61(1):99–107
Ali S (1964b) Recovery of birds ringed under the BNHS/WHO bird migraion field study project. Newslett Birdwatchers 4(10):1–2
Ali S (1979) Keoladeo Ghana waterbird sanctuary. Hornbill (Oct–Dec): 27–29
Ali S (1982) Bharatpur: wetland refuge for birds. Sanctuary 2(2):114–129
Ali S (1985) The fall of a sparrow, Oxford University Press, Delhi. pp xiii, 265
Ali S, Hussain SA (1982) Studies on the movement and population structure of Indian avifauna. Annual Report II. Bombay Natural History Society, Bombay
Anonymous (1996) Participatory management planning for the Keoladeo National Park. WWF-India, New Delhi
Aranha DE (1975) The Ghana bird sanctuary: Bharatpur. Newslett Birdwatchers 15(8):1–3
Bates RSP (1925) Birds-nesting with a camera in India, part 3. J Bombay Nat Hist Soc 30(2):306–313
Bates RSP (1949) Peculiar behaviour of the Darter (Anhinga melanogaster Pennant). J Bombay Nat Hist Soc 48(4):810–811
Bhatnagar RK, Verghese A, Chakravarthy AK (1980) Effects of drought on birds: observations from Bharatpur bird sanctuary. Newslett Birdwatchers 20(4):4–6
Bhupathy S (1999) Reptiles of Keoladeo National Park, Bharatpur, Rajasthan. J Bombay Nat Hist Soc 96(3):475–476
Bhupathy S, Vijayan VS, Mathur R (1998) Population ecology of migratory waterfowl in Keoladeo National Park, Bharatpur. J Bombay Nat Hist Soc 95(2):287–294
Bibby CJ, Burgess ND, Hill DA, Mustoe S (2000) Bird census techniques. Academic Press, London
Bora GK, Saxena VS (1969) Birds of Bharatpur Bird Sanctuary. Indian Forester 95(11):753–762
Breeden S, Breeden B (1982) The drought of 1979-1980 at the Keoladeo Ghana Sanctuary, Bharatpur, Rajasthan. J Bombay Nat Hist Soc 79(1):1–37
Crum WDCE (1964) Birds of the Keoladeo Ghana, Bharatpur. Newslett Birdwatchers 4(3):10
David A (1966) Keoladeo Ghana. Newslett Birdwatchers 6(5):6–7
Dharmakumarsinhji RS (1965) List of birds seen in Bharatpur. Peacock 2(3):7–9
Donahue JP (1962a) The search for migratory bird roosts in Delhi and Bharatpur. Newslett Birdwatchers 2(6):1–4
Donahue JP (1962b) Are domestic animals overgrazing the Keoladeo Ghana Sanctuary in Rajasthan. J Bombay Nat Hist Soc 59(2):645–649
Donahue JP (1964) A preliminary list of the birds of the Keoladeo Ghana Sanctuary, Rajasthan. Newslett Birdwatchers 4(2):7–9
Drake-Brokman DL (1905) A gazetteer of Eastern Rajputana, comprising the native states of Bharatpur, Dholpur and Karauli. Scottish Mission Industries Co. Ltd, Ajmer
Dukes PA, Madge SC, Robinson MC, Westwood CW (1975) Whitetailed Eagles [Haliaeetus albicilla (Linn.)] at Bharatpur, Rajasthan. J Bombay Nat Hist Soc 72(1):199
Earle S (1987) A sanctuary for birds. India Magazine 7(5):60
Ewans M (1989) Bharatpur bird paradise. H.F. & G. Witherby, London, 144 p
Fisher D (1990) Olivaceous warblers in Bharatpur. OBC. Bulletin 11:35–36
Futehally Z (1972) A visit to Bharatpur. Newslett Birdwatchers 12(2):7–8
Gasquire HS (1927) Record of Irrigation by bunds and channels in the Bharatpur state: during the years 1896–97 to 1925–26 AD

Gee EP (1964) The breeding birds of Bharatpur. In: Gee EP (ed) The wild life of India. Harper Collins Publishers India Pvt Ltd, New Delhi, pp 35–43

Grubh BR (1968) Greyheaded Lapwing Vanellus cinereus (Blyth): new record for Rajasthan. J Bombay Nat Hist Soc 65(2):484

Grubh RB (1969) Ghana bird sanctuary in january 1969. Newslett Birdwatchers 9(3):1–2

Grubh BR, Panday JD, Shekar PB (1968a) Blackcapped Kingfisher Halcyon pileata (Boddaert) at Bharatpur, Rajasthan. J Bombay Nat Hist Soc 65(2):486–487

Grubh BR, Shekar PB, Panday JD (1968b) Greywinged Blackbird Turdus boulboul (Latham) at Bharatpur, Rajasthan. J Bombay Nat Hist Soc 65(2):490

Harrison J, Harrison J (1972) An example of ‘Paget’s Pochard’ from India. J Bombay Nat Hist Soc 69(2):415–417

Holt P (1999) Long-billed Dowither Limnodromus scolopaceus at Bharatpur, Rajasthan, India: a new species for the Indian subcontinent. Forktail 15:95–96

Impey L (1909) Duck shooting in Rajputana. J Bombay Nat Hist Soc 19(3):750–751

Islam MZ, Rahmani AR (2004) Important bird areas in India: priority sites for conservation. Indian bird conservation network: Bombay Natural History Society and BirdLife International (UK). pp xviii, 1133

Jamdar N (1998) Southern blackheaded Munia Lonchura malacca malacca in Keoladeo National Park, Bharatpur, Rajasthan. J Bombay Nat Hist Soc 95(3):509–510

Kannan R (1986a) The Rufoustailed flycatcher, Muscicapa ruficauda in Bharatpur, Rajasthan. J Bombay Nat Hist Soc 83(1):206

Kannan R (1986b) Searching for the spotted creeper. Newslett Birdwatchers 26(11–12):17–19

Kumar CRA, Vijayan VS (1988) On the fish of Keoladeo National Park, Bharatpur (Rajasthan). J Bombay Nat Hist Soc 85:44–49

Kumar CRA, Ramachandran NK, Asthana A (1995) Composition, abundance and distribution of fish in Banganga-Gambhiri river system and source of fish to the Keoladeo National Park, Bharatpur. J Bombay Nat Hist Soc 92:30–39

Labastille A (1974) Taj Mahal to nature. Audubon 76(3):20–33

Mahajan CL, Sharma SP, Sharma SD, Arora NK (1981a) Protozoan fauna of a wetland ecosystem (Bharatpur Bird Sanctuary) during drought conditions. Int J Ecol Environ Sci 7:131–138

Mahajan CL, Sharma SP, Sharma SD, Arora NK (1981b) Changes in zooplankton populations in a wetland ecosystem due to drought. Int J Ecol Environ Sci 7:139–143

Mahajan CL, Sharma SP, Sharma SD, Arora NK (1981c) Benthic fauna in a wetland ecosystem (Ghana Bird Sanctuary, Bharatpur) subjected to drought stress. Int J Ecol Environ Sci 7:145–148

Mahajan CL, Arora NK, Sharma SD, Sharma SP (1982a) Protozoan fauna of a wetland ecosystem (Bharatpur Bird Sanctuary) during drought conditions. In: Gopal B, Turner RS, Wetzel RG, Whigham DF (eds) Wetlands: ecology and management, International Scientific Publishers and National Institute of Ecology, Jaipur, pp 131–138

Mahajan CL, Sharma SD, Sharma SP, Arora NK (1982b) Benthic fauna in a wetland ecosystem (Ghana Bird Sanctuary, Bharatpur) during drought conditions. In: Gopal B, Turner RS, Wetzel RG, Whigham DF (eds) Wetlands: ecology and management, International Scientific Publishers and National Institute of Ecology, Jaipur, pp 145–148

Mahajan CL, Sharma SP, Sharma SD, Arora NK (1982c) Changes in zooplankton populations in a wetland ecosystem due to drought. In: Gopal B, Turner RS, Wetzel RG, Whigham DF (eds) Wetlands: ecology and management, International Scientific Publishers and National Institute of Ecology, Jaipur, pp 139–143

Mathew DN (1971) A review of the recovery data obtained by the Bombay Natural History Society’s bird migration study project. J Bombay Nat Hist Soc 68(1):65–85

Meher-Homji VM (1970) Some phytogeographic aspects of Rajasthan, India. Vegetatio 12:299–321

Mehra SP (2012) Water conservation through community participation. GRID-Arendal & UNEP’s publication: The Environment Times. Environ Poverty Times 07:12–13

Mehra SP, Mehra S (2008) Annotated checklist of butterflies at Keoladeo National Park. Submitted to KNP Forest Department, Unpublished

Mehra SP, Mehra S, Gautam P (2009a) Avifaunal diversity of Keoladeo National Park: a review (abstract). In: Mathur VB, Sivakumar K, Singh B, Anoop KR (eds) A bibliographical review for identifying research gap areas: Keoladeo Ghana National Park—A World Heritage site. Wildlife Institute of India, Dehradun, p 45

Mehra SP, Mehra S, Saini J, Raina A, Gautam P (2009b) Awareness and knowledge of Keoladeo National Park (KNP) among children of the local terrain: a sample study. In: Mathur VB et al (eds) A bibliographic review for identifying research gap areas: Keoladeo National Park—A World Heritage site, Wildlife Institute of India, Dehradun, pp 56–57

Mehra SP, Mehra S (2012) Anuran diversity of Bharatpur, Rajasthan, India (in prep)

Middleton B, Mudgal LK (1989) Geese of the Keoladeo. Sanctuary 9(3):38–41

Moona JC (1963) Notes on fish from Bharatpur district Rajasthan. Rec Indian Mus 58(2):59–66

Norman D, Sivasubramanian C (1992) Occurrence of longtailed minivet Pericrocotus ethologus Bangs and Phillips in Keoladeo National Park, Bharatpur, Rajasthan. J Bombay Nat Hist Soc 89(2):256

Palot MJ, Soniya VP (2000a) Preliminary report on the butterflies of Keoladeo National Park, Bharatpur, Rajasthan, India. Zoos' Print J 15(6):287–288

Palot MJ, Soniya VP (2000b) Odonata of Keoladeo National Park, Bharatpur, Rajasthan, India. Zoos' Print J 15(8):317–320

Palot MJ, Soniya VP (2001) Additions to the butterflies of Keoladeo National Park, Bharatpur, Rajasthan. Zoos' Print J 16(5):495

Pandey R (1979) Bharatpur up to 1826: a social and political history of Jats. Rama Publishing House, Jaipur

Perennou C, Ramesh BR (1987) Explanatory notes on the vegetation map of Keoladeo National Park. French Institute of Pondicherry, Bombay Natural History Society, Pondicherry, Bombay

Prakash V (1988a) Greater spotted eagle (Aquila clanga) breeding in Keoladeo National Park, Bharatpur. J Bombay Nat Hist Soc 85(2):418

Prakash V (1988b) Lesser spotted eagle (Aquila pomarina hastata) nesting in Keoladeo National Park, Bharatpur. J Bombay Nat Hist Soc 85(3):614

Prasad VP (1988) Wetland angiosperms of Keoladeo National Park, Bharatpur. J Econ Tax Bot 12:457–466

Prasad VP (1990) Flora of Keoladeo National Park, Bharatpur. J Econ Tax Bot 13:729–750

Prasad VP, Mason D, Vijayan L (1991) Additions to the flora of Keoladeo National Park, Bharatpur. J Econ Tax Bot 15:21–29

Prasad VP, Mason D, Marburger JE, Ajith Kumar CR (1996) Illustrated flora of Keoladeo National Park, Bharatpur, Rajasthan. Bombay Natural History Society and Oxford University Press, Mumbai, p 435

Raju KSRK (1970) Pinkheaded duck in Bharatpur. Newslett Birdwatchers 10(5):12–13

Ranganathan S (1963) A weekend at Keoladeo. Newslett Birdwatchers 3(8):8–9

Sankhala K (1990) Garden of Gods: the waterbird sanctuary at Bharatpur. Vikas Publishing House Pvt. Ltd., New Delhi

Sankhala K (1991) The magnificent marsh. Sanctuary 11(6):38–47

Sauey RT (1985) The range, status and wintering ecology of the Siberian Crane Grus leucogeranus. PhD Thesis, Cornell University

Saxena VS (1969) Birds of Bharatpur Sanctuary field check list. Forest Department, Government of Rajasthan, Jaipur, 31 p

Sharma KK, Mehra SP (2007) Need of studies on anuran in habitats of Southern Rajasthan. Frogleg 13:12–16

Sharma SK (1995) An overview of the amphibian and reptilian fauna of Rajasthan. Flora & Fauna 1(1):47–48

Sharma SK (2000) Drought and reptiles: an experience in Rajasthan. Cobra 40:9–10

Shivrajkumar Yuvraj (1962) A visit to Bharatpur, Rajasthan. Newslett Birdwatchers 2(10):2–5

Singh K (1958) Ghana: Rajasthan's bird sanctuary. Indian Forester 84(1):50–56

Singh R (1981) Will Bharatpur die? Indian Wildlifer 1(3):18–21

Sivasubramanian C (1992) Indian Skimmer Rynchops albicollis Swainson and Black Stork Ciconia nigra (Linn.): new additions to the avifauna of Keoladeo National Park, Bharatpur. J Bombay Nat Hist Soc 89(2):252–253

Stairmand DA (1972) A visit to the Ghana. Newslett Birdwatchers 12(9):3–4

Trigunayat MM, Singh NP (1998) Checklist of butterfly fauna of Keoladeo National Park, Bharatpur (Rajasthan). Cheetal 37(3–4):48–51

Venkataraman K (1988) Cladocera of Keoladeo National Park, Bharatpur. Rajasthan. II New Records 1 Moinodaphnia macleayii King, 1853 and 2 Bosminopsis deitersi Richard, 1895. J Bombay Nat Hist Soc 85:229–233

Venkataraman K (1990) New records of Cladoceran of Keoladeo National Park, Bharatpur—III. J Bombay Nat Hist Soc 87(1):166–168

Venkataraman K (1992) Cladocera of Keoladeo National Park, Bharatpur and its environs. J Bombay Nat Hist Soc 89:17–26

Verghese A, Chakravarthy AK, Bhatnagar RK (1982) Bird life in Ghana bird sanctuary, Bharatpur (India), before and after the 1979 drought. Cheetal 23(4):13–23

Vijayan VS (1991) Keoladeo National Park ecology study. Final report 1980–1990. Bombay Natural History Society, Bombay

Vijayan L (1994) Ramsar sites of India, Keoladeo National Park, Rajasthan. WWF-India, New Delhi

Chapter 33
Developing Law and Governance Strategies for Peri-urban Sustainability

Jacqueline Williams and Paul Martin

Abstract Western Sydney is a peri-urban region of Greater Sydney in the state of New South Wales, Australia lying within the Hawkesbury Nepean catchment. This catchment has high environmental, cultural and social significance providing vital ecosystem services such as drinking water, food, fibre, nutrient and water cycling, fauna habitat and cultural diversity. The economic value generated from these services includes $1 billion per annum in agriculture and over $6 million a year in commercial fishing. Western Sydney continues to experience ongoing environmental degradation and water shortages as a result of urban development, population demand and climate change. Land use conflicts, climate change predictions and competition for scarce water resources has placed water and food security as high priority issues, as in many other peri-urban regions across the globe. New law and governance strategies are required for peri-urban regions to harmonise the co-existence of agriculture, urban and other land uses. This paper presents a range of methods developed via a case study in Western Sydney (from 2007 to 2010) to facilitate new law and governance strategies for better legal and institutional protection of peri-urban food security and sustainable production.

Keywords Ecosystem services · Engaged scholarship · Institutions · Policy risk

33.1 Introduction

Food security has become a major issue for Australia in recent years as a result of multiple impacts including recent natural disaster events (in particular significant flooding), ongoing land use conflicts and water scarcity. This is compounded by the global challenges of food security, population growth and energy demands

J. Williams (✉) · P. Martin
University of New England, Armidale, Australia
e-mail: Jacqueline.Williams@une.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_33,

(Australian Bureau of Agricultural Resource Economics and Sciences 2011). Australia, on a national level has begun to respond via the development of policies including the National Food Plan to address national and global food security issues (Department of Agriculture Forestry and Fisheries 2013; the Murray Darling Basin draft plan (Murray Darling Basin Authority 2011)) to address water scarcity and sustainable water use, and various national and state level inquiries (Senate Standing Committee on Rural and Regional Affairs and Transport 2011; New South Wales Government 2011) and policies (New South Wales Department of Infrastructure and Planning 2011; Queensland Department of Environment and Resource Management 2012) concerned with the conflict over resources between mining and agriculture. Whilst these initiatives are largely focused on rural areas of Australia, the peri-urban regions continue to be threatened by housing and other development pressures (Harmon and Low Choy 2011; Carey et al. 2011; Sinclair 2011). Peri-urban agriculture produces almost 25 % of Australia's total gross value of agricultural production (Houston 2005). In particular the Sydney region is particularly prominent producing over 80 % of perishable vegetables within New South Wales (Sinclair 2011). This paper explores the new law and governance strategies required to facilitate improved legal and institutional protection of peri-urban food security and sustainable production with South Creek in Western Sydney, Australia as the case study. This work was undertaken between 2007 and 2010 as part of the CRC for Irrigation Futures *System Harmonisation* Program. South Creek (Fig. 33.1) is a sub-catchment of the Hawkesbury Nepean River, which has significant environmental, social and economic values.

The Western Sydney region has high biodiversity values and is culturally rich. The catchment provides drinking water for over 4 million people of the region; supports 43,000 recreational fishers, and supplies water to produce 70 % of the state's goods and services. Irrigated agriculture has been valued at $1 billion per year to the farmer and $4.5 billion to the industry as a whole. Public open space for Greater Sydney region represents an avoided cost of between $10.6 and $14.6 million per year. Despite these high values the catchment continues to face challenges due to the rapidly growing population, with new growth centres zoned by Government within the region to accommodate up to 1 million new residents. Stakeholders in Western Sydney have identified agriculture, open space, water quality and biodiversity as high priority values (Hawkesbury Nepean Catchment Management Authority 2008; AgEconPlus 2006; Gillespie and Mason 2003; Sydney Urban Parks Education and Research Group 2001; NSW Department of Planning 2005; Allen 2008).

33.2 Law and Governance Strategies

System Harmonisation was a trans-disciplinary program of the CRC for Irrigation Futures involving four research projects addressing water cycle management; markets and productivity; social, cultural, institutional and policy frameworks (SCIP), and integration. Whilst such an approach was initially based on using

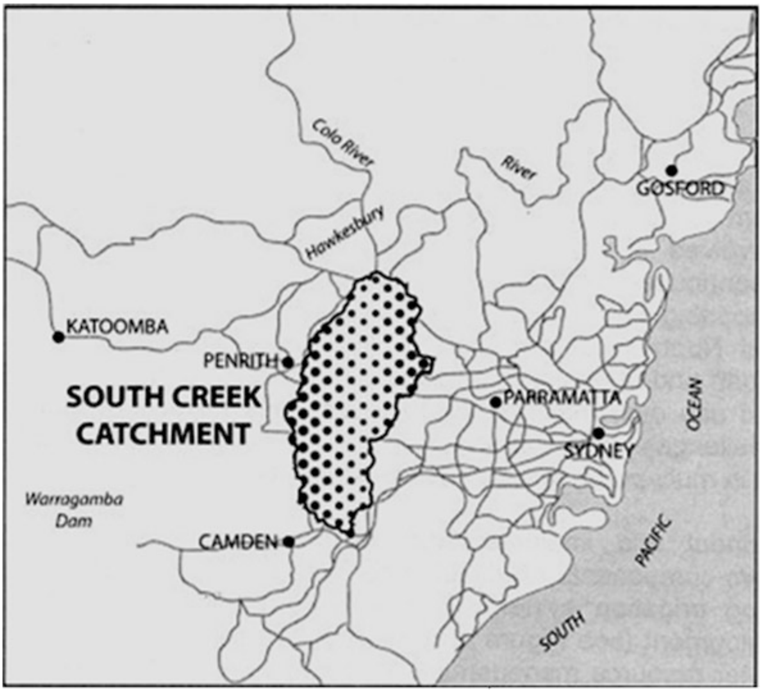


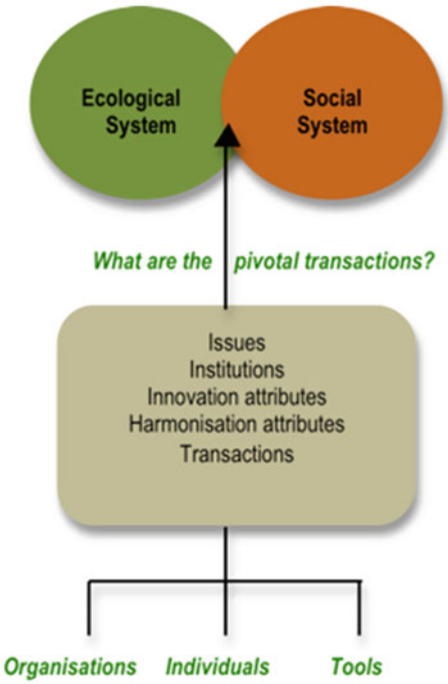
Fig. 33.1 South Creek catchment, Western Sydney (*Source* Rae 2007)

science to improve management of water resources, in reality natural resource consumption takes place within a framework of economic, political and institutional structures, with varied drivers. Peri-urban regions due to their highly politicized nature require law and governance strategies rather than relying solely on scientific recommendations to facilitate protection of peri-urban food security and sustainable production. Our work was focused on developing SCIP strategies, which included four research areas: institutions and transaction costs; ecosystem services framework; policy risk assessment and engaged scholarship. The following discussion provides a brief overview of these methodologies (full electronic copies of the relevant CRC for Irrigation Futures Technical Reports can be downloaded from http://www.irrigationfutures.org.au). These methodologies offer peri-urban regions globally a means to address the political nature of land use conflicts impacting on peri-urban food security and sustainable production.

33.3 Institutions and Transaction Costs

The market economy approach to water reform in Australia relies on the underlying premise that the creation of tradable entitlements to water (coupled with water law and governance reforms) will result in significant improvements in

Fig. 33.2 Methodological approach (*Source* Martin et al. 2008)



water use efficiency and better ecosystem service outcomes. This ideal expectation has been found to be challenging as science-led policies (which rely heavily on economic and hydrological modelling) to facilitate implementation of Australia's water reform agenda intersect with the complex nature of the real world. Our study (Martin et al. 2008) explored this complexity through the lens of institutions and transaction costs focusing on a peri-urban region in Western Sydney (South Creek) where competition for land and water resources has the potential to adversely impact the ecosystem services of the region, in particular the supporting services of irrigated agriculture. Our approach involved understanding the impediments to more socially beneficial uses of scarce water, from a grass-roots perspective reflecting the CRC Irrigation Futures' philosophy of system harmonisation of irrigation systems. Recognising that to achieve harmonised states requires new technologies, production or natural resource management innovations and social innovations, our research also explored the nature of the institutional impediments to innovation.

The following discussion will provide a brief overview of the methodology, findings and recommendations from the institutional and transaction costs analysis undertaken. Our research utilized the concept of 'coupled systems' analysis (see Fig. 33.2) to understand the links between the biophysical, economic and institutional aspects of the system focusing on the pattern of 'transactions' between people and the environment, and between people. Understanding the pattern of 'transactions' (being the flow of resources including money and the flow of information, such as signals or data) provided a lens to better understand the system's behaviour and dynamics (Martin and Verbeek 2006). 'Transactions' occur within the system and are shaped and influenced by power relationships, culture, attitudes, rules, organisations and the dynamic of the system itself.

Sixteen interviews and fourteen stakeholder meetings, forums and workshops were conducted where participants involved in water governance and water use were asked what the transactions that drive outcomes from water were; what would the transacting pattern look like to deliver the desired outcomes; and what matters have to be adjusted to institutionally embed the desired transacting pattern? The findings from our research demonstrated that it is the political economy, rather than the market economy, which drives the system despite the claims of 'market driven' water reform in Australia. Within the political contextual environment of Western Sydney our research suggested that the resulting priority for water allocation is firstly residential (given consumer power is exercised through votes rather than the marketplace), secondly industrial, with irrigation for primary production and other water uses having a much lesser priority. Such a politicized and regulated governance system is likely to have high transaction costs and impediments to production innovation, placing the viability of peri-urban irrigation farming at risk.

Peri-urban irrigation regions are largely underpinned by engineering solutions rather than natural events for water flows and are best characterised as industrial systems from which ecosystem services can be delivered. Because of their industrial nature, peri-urban regions are more dependent upon and subject to social, political and economic transactions and often suffer from institutional complexities including: competing demands; government and private institutional arrangements; significant capital infrastructures, and social and economic dependencies. In such a politically driven system scientific data can be used as justification rather than as a basis for decisions, highlighting the limitations of relying solely on science-led policies in such contested areas. Such contested systems often result in suffering from a lack of adaptability and change as entrenched political actors act to retard any innovations that may threaten their interests. New innovations are frustrated by institutional impediments, generating higher transaction costs, which in turn inhibit innovation. The only innovations that are likely to be adopted are those that are non-threatening to vested interests. Our research found that the reform of transacting systems, rather than limiting the focus of reform to water institutions forming part of those systems, was of key concern. Peri-urban irrigation in Western Sydney can become more politically important when it delivers multiple social, economic and environmental benefits. To facilitate the recognition of these multiple values the development of an ecosystem services framework was proposed for peri-urban regions in Australia as an attempt to reconcile the pressures of urban consumption with the desire for conservation.

Our research demonstrates that resource use optimization is less important in decisions than political satisfaction in peri-urban regions. This reality results in greater institutional barriers to innovations and places peri-urban agriculture at risk. An opportunity for greater innovation is to move from a substantially regulatory-based system to a more market driven system, which expands the range of water-related services that can achieve economic value such as an urban environmental services market. Such a market concept would rely on the cultural and environmental services of water and the riverine system, and a 'multi-attribute' designed system where different environmental values are aggregated for the purpose of purchase by entities with complementary interests.

33.3.1 Ecosystem Services Framework

Our earlier research on institutions and transaction costs in Western Sydney identified the need for greater innovation in natural resource management focusing on moving from the current over-regulated system, which has high transaction costs, to an environmental market system to facilitate commercial innovation in the use and conservation of natural resources. In particular traditional land use planning is considered as failing to include the valuation of public good ecosystem services in Western Sydney. Such an innovative environmental markets approach requires firstly that the ecosystem services be clearly and consistently identified, and secondly the development of a market structure to enable trade of these commodities.

Martin et al. (2007) proposed a business model for ecosystem service trading (see Fig. 33.3) using a multi-attribute, low transaction cost environmental market structure that reflects existing institutional structures with a trust managed by professional funds managers operating three subordinate funds. This model combines philanthropy, commercial markets and taxation arrangements consistent with private ownership and investment focusing on private landholders who manage at least 60 % of the Australian landscape. The model is founded on commercial accountability for conservation outcomes and aims to attract private funds into conservation investments delivering ecosystem services through multiple land-uses, relying on a regional collective of natural resource managers for the delivery of ecosystem services to investors of the trust. To enable such a business model requires the recognition of ecosystem services as viable commodities using a consistent methodology and classification system. Synthesis of the literature on ecosystem services (Williams et al. 2010) demonstrated an ad hoc and inconsistent approach was impeding the recognition and trading of ecosystem services. To progress the environmental market system in Western Sydney a conceptual framework for identifying and valuing ecosystem services was developed with national applicability. Importantly this research aimed to demonstrate how a science-informed market process rather than an unachievable science-led approach can help diffuse political impediments to better natural resource management in a highly politicised environment. The ecosystem services framework was developed to integrate economic, social/cultural; hydrological and markets/production disciplines assisted by models and Geographical Information

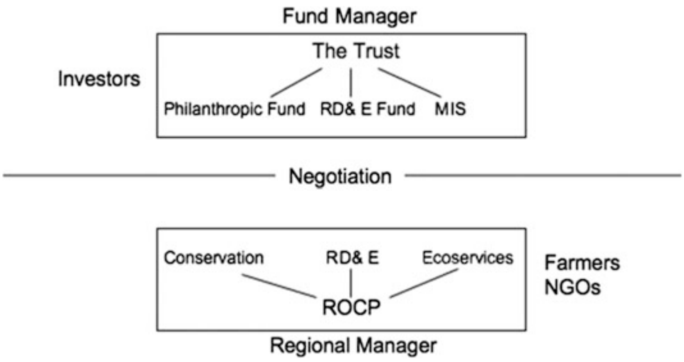
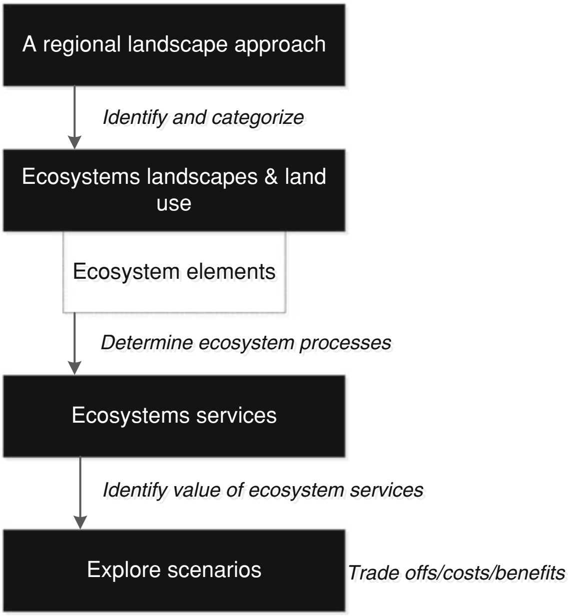


Fig. 33.3 Regional business conservation model (*Source* Martin et al. 2007)

Fig. 33.4 Ecosystem services framework for peri-urban Australia (*Source* Williams et al. 2010)



Systems (GIS) to assist in identifying, categorising and valuing ecosystem services. The classification and identification of ecosystem elements, processes and services proposed are consistent with agreed national and international metrics to ensure legitimate and consistent metric systems for demonstrating and monitoring tradeable ecosystem services. Figure 33.4 provides a brief overview of the framework processes (see Williams et al. 2010 for more detailed information on the methodologies underpinning the framework).

This framework provides an important resource for the stakeholders of Western Sydney who have identified that the evaluations of future land use options for the region have failed to value the non-economic values of agriculture, water quality, open space and biodiversity. The next step required to further this research is to determine the non-economic values of the region through the measurement of the community values of ecosystem services to assist in the establishment of a new environmental market.

33.3.2 Policy Risk Assessment

All policies carry risks of adverse impacts and failure. The riskiness of environmental policy is well illustrated in Australia in particular within water policy. Australia's National Water Initiative (NWI) provides directions for water reform and is an unprecedented policy framework. It aims to reform 200 years of practice using a national approach, with integration of production, environment, science and economics. This innovative initiative, which emphasises the positive attributes of reform, fails to address the vulnerability, hazard and uncertainty associated with its objective. This is well exemplified by the over-extraction of water that occurred when tradable water rights were introduced in Australia resulting in further unsustainable use of water; the opposite of the policy intention. Such lack of consideration of unintended consequences is a common issue as the potential for a policy to fail or carry risks is rarely considered.

A policy, to be fully successful needs to fulfil three criteria: be sufficiently aligned with formal and informal power structures so that it does not encounter difficult political impediments; the strategy design and implementation (institutional arrangements, design of instruments, transacting mechanisms, communications and administration) have to be sufficient to achieve its desired result; and the negative impacts (social, economic and environmental) from implementation of the policy must be within acceptable bounds. Different risks can exist for each of these three requirements. The three main forms of policy risk identified (Martin and Williams 2010) include: the risks of political opposition, the risk of instrument failure and the risk of adverse spillovers. As System Harmonisation involved the development of proposed interventions as a result of integration of water cycle management; markets and productivity; social, cultural, and policy frameworks (SCIP) there was a need for a process to test the risk of these water policy options. The purpose of this research was to: provide a participative risk-framing approach to improved risk sensitivity in the design of policy; use this process to discuss (with a particular emphasis on Australian water policy) some aspects of policy failures and/or spillovers, and from that experience, demonstrate how a disciplined policy risk approach can assist in creating more robust sustainability policy.

The research resulted in the development of a Policy Risk Assessment Manual (Martin and Williams 2010) to guide policy risk assessment in the first stage of analysis of the risks of policy proposals. This manual was used in Western Sydney to assess the policy risks of three possible water supply interventions of: storm-water

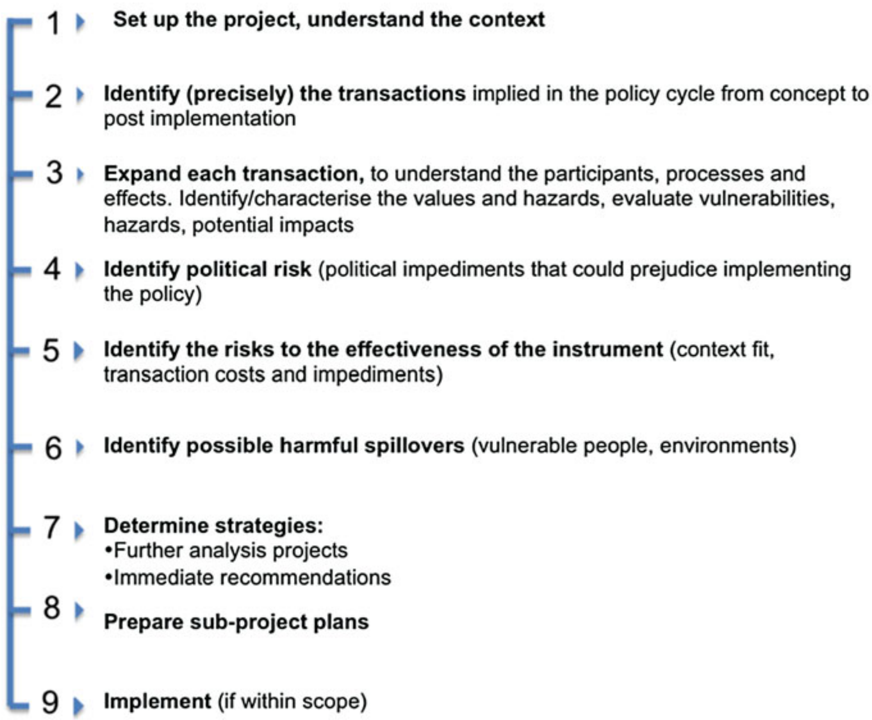


Fig. 33.5 The policy risk assessment process (Martin and Williams 2010)

harvesting and reuse, effluent reuse and smart farms project. Figure 33.5 provides an overview of the process (see Martin and Williams 2010 for more detailed information on the methodologies that underpin the framework).

33.3.3 Engaged Scholarship

Reflections as a group of researchers of the System Harmonisation program in Western Sydney was undertaken so that researcher lessons from the community partnership and trans-disciplinary research in a peri-urban region may be shared and improved upon. Martin et al. (2010) provides a detailed discussion of reflective research including learning’s from the partnered scholarship journey, the literature of partnered research and researcher reflections of a major trans-disciplinary research project. The following discussion will provide a brief overview of some of the key findings from this technical report.

A review of the literatures concerned with elements of trans-disciplinary research and engagement with the community included: adoption/commercialisation; open innovation/fourth generation research and development, engaged scholarship and collaborative governance. Common themes from these literatures were:

- Context factors: strategic fit; established relationships; commitment to the partnered approach and the science enterprise; leadership and facilitation of the partnered approach;
- Shared understandings: clear strategy/vision/plan of both the science and the partnership projects; clearly specified goals/aims/outputs/objectives of both the projects; defined roles and structure for both projects; agreement on information sharing, IP ownership and use; a focus on building common language and common conceptualisations;
- Processes: building and maintaining relationships and trust; effective communication on both a science and relationships basis; assessment/monitoring of measurable outcomes in both projects; managing the flow of information (especially dissemination).

Lessons for deeply engaged scholarship projects conducted by trans-disciplinary teams include the need for: strong balanced leadership; a facilitator/integrator with authority; early scoping of the region (stakeholders/institutional context/political issues); significant funding at the end of the project to finalise integration; differences in researchers understanding of key project concepts and theories identified with common understandings developed between the different disciplines; integration planned and pursued throughout the entire research project, all relevant disciplines to have input into the theoretical framework at the outset of the project and appropriately skilled and committed stakeholders who are also involved in the design of the engagement framework.

33.4 Future Directions

Our research which focused on the social, cultural, institutional and policy aspects of the System Harmonisation program in irrigated agriculture identified the importance of recognising the political nature of land use conflicts impacting on peri-urban food security and sustainable production and the way in which science might inform and intervene in such politically driven systems. Whilst the rhetoric of natural resource management policy in Australia claims to be market-driven, our research indicates that it is politics that is driving natural resource management decisions. There are risks and impediments to achieve true reforms within this contradictory environment. As new policies are developed and implemented in Australia to address food security and sustainable natural resource management, such as the Murray Darling Basin draft plan; Clean Energy Future; Strategic Regional Land Use (to manage the conflict between mining and agriculture), aquifer interference policies and the National Food Plan there appears to be a repetitive pattern occurring. This pattern continues to rely on the development of policy in a highly politicised environment (rather than a true market environment) with a reliance on scientific models to lead policy often lacking a trans-disciplinary foundation and adequate and transparent community engagement. This policy context is often claimed to be a market based system but lacks the true attributes. Such an approach raises the potential of policy failures due to high political and instrumental risks and/or adverse social, economic and environmental impacts.

Our research in Western Sydney developed a number of methodologies to address such risks and impediments to peri-urban food security and sustainable production. Australia, as the most urbanised country in the world holds important lessons for the rest of the globe (which is quickly becoming predominantly urban) of what can occur in a political environment when urban and rural values collide and the role that science can play to assist manage that conflict of values.

33.5 Conclusion

Peri-urban regions are highly politicised due to the industrial nature of these important transition zones between cities and rural land uses. The case study of Western Sydney, where competition between housing development and agriculture is negotiated through a politically dominated land use system demonstrates such institutional challenges. Given this political dynamic, peri-urban regions are more dependent upon, and subject to, social, political and economic transactions, which in turn leads to greater institutional complexity, ongoing entrenched positions and barriers to innovation. Such politically dominated contextual environments require science to 'inform' rather than 'lead' with a focus on reform of the transacting systems themselves and outcomes that have multiple social, economic and environmental benefits. To achieve this, a shift from the current regulatory-based system to a more market-driven system that expands the range of water-related services is required.

Our research found that a science informed market process, such as an ecosystem services framework for peri-urban regions may assist diffuse political impediments to sustainable natural resource management in such highly politicised environments. The framework provides an important resource to value the non-economic values of agriculture, water quality, open space and biodiversity, which are not considered nor valued in the current politicised land use conflict. Any new policy intervention (such as an ecosystem services market) carries risks of adverse impacts and failure, with three main forms of policy risk identified as the risks of political opposition, the risk of instrumental failure and the risk of adverse spillovers. System Harmonisation involved the development of proposed interventions. To test the risk of these various water policy options, a Policy Risk Assessment Manual was developed and tested in Western Sydney. As the complexity of intractable natural resource management conflicts call for trans-disciplinary research and interventions, this new area of research also has its challenges. Lessons learnt from the nature of the System Harmonisation research demonstrate the importance of engaged scholarship and the key attributes required for trans-disciplinary research to succeed. Our research in Western Sydney resulted in the development of four methodologies of importance for research and interventions in peri-urban regions focusing on institutions and transaction costs, ecosystem services framework, policy risk assessment and engaged scholarship.

Acknowledgments We wish to acknowledge the support and participation of the CRC for Irrigation Futures, our partner organisations and the communities of Western Sydney in this research.

References

AgEconPlus (2006) Quantifying the economic value of activities dependent on the Hawkesbury-Nepean River, AgEconPlus Sydney

Allen J (2008) Western Sydney stakeholder workshops'. Cooperative Research Centre for Irrigation Futures

Australian Bureau of Agricultural and Resource Economics and Sciences (2011) Global food security: facts, issues and implications. Science and Economic Insights, Issue 1 (ABARES)

Carey R, Krumholz F, Duignan K, McConell K, Browne JL, Burns C, Lawrence M (2011) Integrating agriculture and food policy to achieve sustainable peri-urban fruit and vegetable production in Victoria. Aust J Agric Food Syst Community Dev, 181–195. http://dx.doi.org/10.5304/jafscd.2011.013.003

Department of Agriculture, Forestry and Fisheries (2013) National food plan. http://www.daff.gov.au/agriculture-food/food/national-food-plan

Gillespie P, Mason D (2003) Sydney basin industry details. NSW Agriculture, Orange

Harman B, Low Choy D (2011) Perspectives on tradable development rights for ecosystem service protection: lessons from an Australian peri-urban region. J Environ Plann Manage 54(5):617–635

Hawkesbury Nepean Catchment Management Authority (2008) Hawkesbury Nepean River health strategy. Hawkesbury Nepean Catchment Management Authority, Goulburn

Houston R (2005) Re-valuing the fringe: some findings on the value of agricultural production in Australia's peri-urban regions. Geogr Res 43(2):209–223

Martin PV, Verbeek M (2006) Sustainability strategies. The Federation Press, Sydney

Martin P, Williams J (2010) Policy risk assessment. CRC for Irrigation Futures Technical Report Series No. 03/10. http://www.irrigationfutures.org.au/news.asp?catID=9&ID=1209. Accessed March 2010

Martin PV, Werren K, Shearing S (2007) Concepts for private sector funded conservation using tax effective instruments. Land and Water, Canberra

Martin P, Williams J, Stone C (2008) Transaction costs and water reform: the devils hiding in the details. Cooperative Research Centre for Irrigation Futures Technical Report UNE CRCIF 9.1. http://www.irrigationfutures.org.au/newsDownload.asp?ID=768&doc=CRCIF-TR0808-web.pdf

Martin P, Williams J, Stone C, Alter T (2010) Researcher lessons from community partnership and trans-disciplinary research in a peri-urban setting: the WISER experience in Western Sydney. CRC for Irrigation Futures Technical Report Series No. 05/10. http://www.irrigationfutures.org.au/news.asp?catID=9&ID=1211. Accessed May 2010

Murray Darling Basin Authority (2011) Murray Darling basin draft plan. http://www.mdba.gov.au/draft-basin-plan

New South Wales Department of Planning (2005) City of cities: a plan for Sydney's future. Department of Planning, Sydney

New South Wales Department of Infrastructure and Planning (2011) Strategic regional landuse Strategy. http://www.planning.nsw.gov.au/StrategicPlanning/StrategicRegionalLandUse/tabid/495/language/en-AU/Default.aspx

New South Wales Government (2011) Coal seam gas inquiry. http://www.parliament.nsw.gov.au/prod/parlment/committee.nsf/0/29AE48525CFAEA7CCA2578E3001ABD1C

Queensland Department of Environment and Resource Management (2012) Strategic cropping land. http://www.derm.qld.gov.au/land/planning/strategic-cropping/index.html

Rae DJ (2007) Water management in South Creek catchment: current state, issues and challenges. Technical Report 12/07 Cooperative Research Centre for Irrigation Futures Australia

Senate Standing Committee on Rural and Regional Affairs and Transport (2011) The management of the Murray Darling basin. http://www.aph.gov.au/senate/committee/rrat_ctte/mdb/index.htm

Sinclair I (2011) Contested landscapes: growing food or growing houses. Cant eat your house: development threatens food bowl conference, Sydney, Sydney Food Fairness Alliance, 26 Oct 2011

Sydney Urban Parks Education and Research Group (2001) The value of public open space for community service provision. Sydney Urban Parks Education and Research Group, Sydney

Williams J, Martin P, Stone C (2010) Using ecosystem services as a means to diffuse political land use decisions in peri-urban regions. CRC for Irrigation Futures Technical Report Series No. 06/10. http://www.irrigationfutures.org.au/news.asp?catID=9&ID=1212. Accessed June 2010

Chapter 34
Adaptive Governance for Extreme Events in Peri-urban Areas: A Case Study of the Greater Western Sydney

Donna Craig and Michael Jeffery

Abstract The sustainable future of peri-urban regions in the face of increased extreme events is dependent upon the development and implementation of adaptive governance models. The case of the Greater Western Sydney region of New South Wales is used here to illustrate the need to improve legal and institutional frameworks for peri-urban governance. This is needed to ensure that decision-making at the regional level is based on science and to effectively address the issues arising in a situation of extreme events that threaten food and water security in the region. Environmental law is relatively well developed in terms of the requirements of "good governance" that should integrate participation in decision-making by stakeholders. Increasingly, the principles of ecologically sustainable development (ESD) are also being elaborated as part of governance systems. The focus of this paper is to elaborate the challenges posed by climate change and variability, and the need to fundamentally re-think the approaches on adaptive governance for food and water security in peri-urban areas. Long term trends may be relatively well understood, but strategic planning and responses must be undertaken in the face of considerable uncertainty about exactly when, and how, extreme events will occur.

Keywords Peri-urban · Climate change · Environmental planning · Governance · Extreme events

34.1 Introduction

The risk of extreme events such as floods and droughts is increasing as a result of the impacts of climate change and climate variability. The increased frequency and intensity of such events has far reaching implications on water food and energy

D. Craig (✉) · M. Jeffery
School of Law, University of Western Sydney, Penrith, Sydney, Australia
e-mail: donna.craig@uws.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_34,

security. Peri-urban areas are particularly vulnerable to the impact of such extreme events. The sustainable future of peri-urban regions in the face of increased frequency of extreme events is dependent upon the development and implementation of adaptive governance models. Despite the attempts in prevalent legal and institutional frameworks to address the risks associated with climate variability in planning, this chapter argues that these frameworks do not effectively constitute an adaptive governance framework for peri-urban regions and thus, in the event of extreme events, such frameworks are unlikely to ensure water and food security. The case of the Greater Western Sydney region of New South Wales (NSW) illustrates how there is a need to improve legal and institutional frameworks for peri-urban governance to ensure decision-making at the regional level is based on science and anticipates and effectively addresses the issues arising in a situation of extreme events that threaten water and food security in the region.

34.2 Water and Food Security in Peri-urban Areas

While appreciating the limitation of prediction models, there is a growing concern that human-induced effects could result in significant climate variability in Australia. In particular, the increase in levels of carbon dioxide released to the atmosphere is predicted to lead to an escalation in the greenhouse effect, which in turn has the potential of disrupting natural resources systems on which communities, economies and ecosystems depend (Pigram 2006). The impacts of climate change in Australia are likely to include shifts in rainfall patterns and increased temperature and climate variability. Normal zones of precipitation are likely to be displaced by the persistent changes in climate patterns resulting in uncertainties in water supply and demand. An increase in the frequency and intensity of natural disasters or extreme events including flooding, bushfires, heat waves, storms, drought, cyclones and storms is predicted, with varying degrees of uncertainty regarding projections of specific hazards (Handmer et al. 2012).

Recent droughts and flood events in Australia seem to confirm these likely impacts of changes in climatic conditions. Rainfall in 2009–2010 for instance was 13 % above the long-term (July 1911–June 2010) average, with evapotranspiration increasing by 4 % of the long-term average and landscape water yield at 40 % above the long-term average (Australia Bureau of Meteorology 2010). Widespread heavy rainfall resulted in significant flooding in the Lake Eyre Basin Region as well as in Murray-Darling Basin region (Australia Bureau of Meteorology 2010).

Although used interchangeably, the terms climate variability and climate change have distinct meanings in scientific literature. Climate variability refers to the variations in the mean state or other statistics (such as standard deviations, the occurrence of risks etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. These variations may be the result of natural internal processes or anthropogenic external forces. In the scientific context, climate change is used to refer to statistically significant variations in the mean state of climate which persist for an extended period of time (Intergovernmental Panel on Climate Change 1995). As is the case with climate variability, climate change may be caused by natural internal processes or external forces including persistent anthropogenic changes, though the use of the term is commonly associated with variations resulting from anthropogenic forces.

Extreme events are features of climate variability under stable or changing climate conditions. The Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) defines an extreme event as the occurrence of a value of a weather or climate variable above or below a threshold value (Intergovernmental Panel on Climate Change 2012). The terms 'climate extremes', 'disaster risk' and 'extreme events' are used to refer to the adverse situations resulting from a combination of climate change, extreme weather and climate events and which have significant implications on society and sustainable development (Intergovernmental Panel on Climate Change 2012).

There is a significant amount of literature providing a scientific basis for assessing the risk arising from the effects of climate change at global and national levels. Nevertheless, the impacts of climate variability on food and water security at local and regional levels are often hard to project with precision. The development of projected scenarios in the event of climate variability at the local level is essential, as it is precisely at these levels that the impact is highest. Further, the effective implementation of climate mitigation and adaptation strategies depends on behavioural changes occurring at these levels. One of the most crucial local contexts where climate variability and associated extreme events are likely to make the greatest impact is in peri-urban regions.

34.2.1 Features of Peri-urban Areas

The notion of peri-urban is associated with landscapes located at the periphery of metropolitan and regional hubs. Peri-urban areas are complex social-ecological systems with multiple land uses and intense land pressures. The regions are characterised by dynamism resulting from their representing a transitory sphere in the evolution to urbanisation.

The Greater Western Sydney (GWS) region is one of the fastest growing peri-urban regions in NSW. Located in the western part of the Sydney metropolitan areas, the region is home to about 1 in 11 Australians, with a population exceeding that of South Australia and of the combined populations of Tasmania, Northern Territory and the Australian Capital Territory (Sydney 2012). The region comprises the area defined by the Western Sydney Regional Organisation of Councils (WSROC) Region, the Macarthur Regional Organisation of Councils (MACROC) Region and The Hills Shire. It also comprises three subregions defined within the NSW State Government's Sydney Metropolitan Strategy: the North West, South West and West Central Subregions. With a total population of 1,923,698 million people and a land area of 894,074 ha, the region has a relatively high population density of 2.15 persons per hectare (Western Sydney Regional Organisation of Councils 2012).

A significant percentage of peri-urban land is used for agricultural purposes, which makes the sustainable use of such land an important aspect of food security, not just for the region but also for the surrounding metropolitan area. In the case of NSW, for instance, approximately 76 % of the land is managed by farmers. Although less than 3 % of the land in peri-urban regions in Australia is used for agriculture, these areas still account for about 25 % of Australia's total agricultural production. This makes these areas an important source of food supply as well as high-consumptive water spots. The adoption of efficient governance frameworks for peri-urban areas, such as the Greater Western Sydney region, is thus critical to food security and the sustainable management of water resources.

Apart from their significance for agriculture, the strategic location of peri-urban regions, close to regional cities, also acts as an incentive for the establishment of primary industries and residential settlements. Mining, manufacturing and construction industries in the Greater Western Sydney region provide employment to many of the residents of the region as well as to others from surrounding regions. Twenty-five per cent of the dwellings in the region are classified as medium to high density which is to be expected given the high population density (Western Sydney Regional Organisation of Councils 2012).

Unlike metropolitan and urbanised regional centres, peri-urban regions maintain significant reserves of habitat and biological diversity, despite having the character of urban landscapes.

Due to their preserved habitat, some of these areas have a high environmental value and thus constituting important tourist and recreational areas. There are numerous parklands, reserves and recreational centres in the Greater Western Sydney Region including the Sydney Olympic Park which is a world class model for integration of built and natural environments. The region is also home to some of the most spectacular native bushland in the State.

Peri-urban regions play an important role in guaranteeing food and water security as they often hold urban water catchments and water storages. Further, as a result of the relative availability of land and proximity to the city, the areas may also contain essential infrastructure including waste disposal facilities, airports, water treatment plants and other important social service industries. This is the case for the Greater Western Sydney region.

Water is considered as perhaps the most critical and vulnerable resource in New South Wales, Australia (Department of Planning and Infrastructure, NSW (2012). One of the fundamental reasons for the choice of the location for settlement by the first fleet was the availability of water resources. Initially freshwater resources for Sydney and the surrounds were sourced from the Tank Stream in the Sydney Cove, then later from swamps near the Centennial Park and ultimately from reservoirs in the ranges to the west and south of the city (Pigram 2006). Today approximately 80 % of Sydney's water supply is from Warragamba Dam, whose capacity to service the needs of the City and surrounding has been tested by periods of prolonged drought. Strategies sought to deal with the strain on the capacity of the dam have included a search for alternative water sources such as the Shoalhaven River and other groundwater sources, recycling plans especially in South West Sydney and a desalination plant. The Hawkesbury Nepean River System located in the region serves Sydney and its surrounds, supporting domestic and commercial needs as well as agricultural and fishing industries. The river is also an important resource for the region given its aesthetic and recreational value.

Multiple uses of water in the Great Western Sydney region range from domestic uses such as drinking water and water for gardening, industrial uses, and recreational uses such as maintenance of parks and sporting fields and river system needs. Commercial farming, particularly of turf, fruit and vegetables is also an important source of demand for water in the region. There are more than 2000 commercial irrigators operating in peri-urban Sydney, most of whom are town water users farming on 2 ha holdings (Department of Planning and Infrastructure, NSW).

34.2.2 Vulnerability of Peri-urban Areas to Climate Change

The features of peri-urban areas discussed above, demonstrate why these areas are particularly susceptible to the adverse impacts associated with climate. Extreme events due to climate change exacerbate these pressures further undermining ecosystem resilience. For instance increased flooding is likely to cause soil loss, while prolonged droughts increase the risk of fires and the ecosystem stress caused by the fires and drought.

As noted above, peri-urban areas are characterised by a fast-growing population and thus represent the crux of the climate change issues that will have impacts on the general population. The adverse effect of extreme events in these regions is likely to result in greater strain on infrastructure requirements and on social-economic requirements such as health services. In the event of extreme events, such as floods or fires, these areas are likely to be most hard hit and also would be most likely targeted in the event of the need for urban evacuation. Due to the multiple land use, the damage resulting from extreme events such as floods or droughts would also have ramifications on food productivity.

In 2011, tangible illustrations of the vulnerability of peri-urban regions in Australia, in the event of extreme events were witnessed. Flooding in South East Queensland (SEQ) resulted in significant loss of lives with peri-urban communities suffering the greatest losses. In some cases, entire townships were affected with many requiring total evacuation. The instances brought to the fore some of the factors exacerbating the adverse effects of catastrophes, such as infrastructure and transport deficiencies. The effect of the crisis was far reaching given that some of the areas affected were vital corridors into, or from, urban areas such as flood-plains, evacuation paths or fire pathways. The risk of significant dam spillage and resulting floods in the event of increased precipitation, is not as great in Western Sydney, due to the high demand for water. However, historically the area has experienced catastrophic floods and this scenario is possible. Experience has also demonstrated that excess rainfall could result in negative effects on the transport and other service infrastructure. For instance, in Windsor, excess rainfall in recent times has caused the closure of roads. The cutting off of areas in the event of extreme climate events would adversely affect the provision of vital resources such as food and water supplies and refugia for species.

Peri-urban areas such as those in the Greater Western Sydney area are the frontiers of population expansion. This often means a substantial presence of vulnerable disjointed communities, whose disadvantage is exacerbated by insufficient infrastructure. The limited availability of services relevant to climate adaptation (e.g. health, public transport, and social infrastructure) is well documented. Often these areas were not originally preferred for settlement because of adverse natural conditions. Areas that are naturally hotter, hillier, less well-drained or more difficult to access face particular challenges with greater climate variability. The interpolation of residential, industrial, farming and undeveloped land uses results in great management complexity and increases vulnerabilities. An example is the perverse cycle of peri-urban bushfires in the region. Proximity creates increased risk to people from fires, at the same time increasing the likelihood that fires will be triggered by human action. Complex 'coupled-system' interactions with the potential for serious consequences typify peri-urban management.

The multiple land and water uses characteristic of peri-urban regions are often the cause of competition among the many users such as farmers, Councils, domestic, commercial and industrial consumers as well as ecosystem needs. Peri-urban water governance thus requires the integration of the multiple uses, conflict resolution and coordination among various users. The challenges associated with integrating the multiple uses and users of water resources in these regions make them particularly susceptible to the adverse effects of climate variability of food and water security.

The features of peri-urban regions thus confirm that these areas are peculiarly exposed to the adverse effects of climate variability including the risk of extreme events. Consequently, governance arrangement for these regions must have the capacity to balance the competing interests of industry, agriculture, residential needs and environmental processes.

The nature and preparedness of peri-urban areas is a significant determinant of how urban areas will be impacted by both chronic and catastrophic impacts. Due to their location and structure, the areas are important for the provision of economic and environmental services to adjacent cities. The task of mitigation of climate variability and the risk of extreme natural events in peri-urban regions is thus a complex task requiring a multi-disciplinary approach. Peri-urban governance frameworks must be evaluated to determine the extent to which they constitute adaptive models capable of dealing with the risks and potential effects of climate variability and extreme events.

34.2.3 Peri-urban Governance Models

Peri-urban governance refers to the institutions and regulatory instruments used for the management of landscapes and resources in the fast-growing areas on the periphery of the metropolitan cities. Law plays an important role in peri-urban governance, as governance systems and sustainability strategies and policies require a legal foundation for their implementation. The success of legal instruments for peri-urban governance depends on their effectiveness in protecting peri-urban environments and ensuring their sustainability.

In Australia, it has been argued that existing regulation has not been sufficiently effective in protecting peri-urban environments as evidenced for example by the persistent clearing of land within farming landscapes (Martin et al. 2012). Some of the shortcomings cited include the high cost of the regulation and the fact that in many cases the costs are not fairly allocated (Martin and Shortle 2009). Recent extreme events such the 2011 SEQ floods and Perth bushfires demonstrated certain deficiencies in governance including inadequate land-release planning and institutional overlaps and gaps in emergency management. The effect of these deficiencies was the realisation of avoidable risks and impacts. While increased climate variability cannot be controlled, its consequences can be mitigated via adequate governance arrangements.

The interactions and activities in peri-urban areas generally results in a governance system characterised by institutional overlap, under-resourcing and fragmentation. As peri-urban areas incorporate industry, urban housing, farmland and environmental assets, they are governed through a mixture of statutory and institutional arrangements that is more complex than for any other type of land use. Research on potential regulatory harmonisation highlights the enormous number of relevant rules at all levels of government, the variety of authoritative, advisory and consultative entities, and the impact that they have upon coordinated realignment of land use for public interest purposes. Institutional complexity is exacerbated by ‘public choice’ contests. It is not abnormal for seemingly simple decisions about land use to engage the political interests of farming, environmentalism, urban development, and industry over the same piece of land. There is thus a need to re-evaluate the prevailing regulatory and institutional framework to enable positive climate adaptation in peri-urban areas.

Legal and institutional frameworks for peri-urban governance need to incorporate pro-active approaches to anticipate the adverse effects of climate change and develop adaptive governance to cope with the resulting changes. Policy makers often face this task by attempting to implement ‘no-regret policies’ that ensure environmental and economic costs of mitigation and adaptive approaches embraced would be justifiable with, or without, the realisation of the risks associated with climate change and variability (Pigram 2006).

34.3 Adaptive Governance Frameworks

The term adaptive governance is used in multiple contexts and disciplines including management, economics and ecology. In the context of socio-ecological systems, adaptive governance has been explored as a means of developing integrated but flexible governance forms to deal with the complexities associated with socio-ecological systems. Adaptive governance requires the coordination of individuals, organisation, agencies and institutions at multiple levels.

34.3.1 Adaptive Governance for Food, Water and Energy Security in Peri-urban Regions

Innovative governance approaches on climate change adaptation need to be incorporated into strategic planning. Effective strategic planning requires the provision of relevant and timely scientific knowledge on the risk and impact of climate variability and extreme natural events. Such information would contribute to improved risk assessment procedures at all levels of governance. The availability of this information would also contribute to increased engagement and capacity building in government processes and policy formulation. In the context of food and water security in peri-urban regions, adaptive governance would require the coordination of government, private sector and civil society and the development of the processes necessary to sustainably manage and use resources for purposes of facilitating resilience and productivity at the local level. Adaptive governance incorporates the use of tools like the *resilience approach* to better understand complex dynamic socio-ecological systems such as are found in an urban or peri-urban context. The essence of the resilience approach is that 'it not only helps to understand the interaction between the system components and how they would co-evolve in the presence of change; but also specifically allows one to identify how far the present state of the system can maintain the structure fulfilling the required functions and services without major changes before moving to other states' (Thapa et al. 2010).

The need for social, economic and institutional research necessary to implement the scientific, technical adaptation responses to climate change and variability is now widely acknowledged (Stokes and Howden 2010). The research further confirms that an improved understanding and management of climate variability at local scales is the most important 'entry point' for climate adaptation and mitigation, although uncertainty in predictions increases at the local and regional level. The identification and management of climate related risk and uncertainty at the local level is crucial for improved food and water security particularly in peri-urban regions. Most analysis of climate change trends rely on output generated from global models.

There is a need for further research geared towards the downscaling of climate change data so as to provide information relevant to local and regional scales including peri-urban areas. Adaptive governance frameworks require the projection of long-term and short-term effects of climate variability risks and extreme events on food and water security. These projections require the down-scaling of data provided under the global climate models. The frameworks should integrate strategies for managing and communicating uncertainty in data and predictions. Effective climate change adaptation and mitigation is dependent on governance frameworks that adopt an anticipatory future oriented approach given the magnitude of potential climate impacts. Such frameworks ought to be based on comparative science and informed and participatory development characterised by public and private sector engagement, capacity building, policy development and adoption, and the development of legal and institutional frameworks incorporating local adaptation strategies.

Risk identification and management models should be included and should form the basis for baseline and alternative scenario strategies for food and water security in peri-urban regions. This is a significant departure from conventional widely used frameworks for planning and regulation in Australia. The discussion below, draws on important theoretical approaches, and research on next generation natural resource governance, that have been pioneered by Professor Paul Martin and the Centre for AgLaw at the University of New England.

Such frameworks identify policy, legal and institutional arrangements required to underpin the necessary transactions and actions of key stakeholders to implement adaptation options. Arrangements that may be required include government actions such as the development of laws, agency activities, plans and subsidies; private arrangements in the form of markets and financing; involvement of cultural and social institutions and industrial, civil society and other non-government organisations.

Some important measures anticipated by adaptive governance frameworks include: prioritisation of desirable reforms of policies, laws and institutions; the design and capacity building of the supporting institutions; identification of key policies, legal and institutional contingencies and identification and prioritisation of policy, legal and institutional coordination requirements for the various adaptation strategies. The frameworks ought to evaluate the adaptation and mitigation options on a cost-benefit analysis so as to determine the options likely to result in least-cost transitions to a more climate resilient environment. Adaptive governance frameworks would thus require the reduction and improved coordination of institutional structures, the reduction of transaction costs of regulation and market instruments, improved incentives for mitigation and adaptation efforts and the development of mechanisms for the transfer of resources to better environmental performers (Martin et al. 2007). These new governance frameworks are unlikely to be adopted, or be politically viable, without participatory engagement with communities and key stakeholders from an early stage. This needs to incorporate the elements of good governance as elaborated in the Aarhus Convention (United Nations Economic Commission for Europe, Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, Aarhus Convention, 2161 UNTS 447; 38 ILM 517) such as transparency, access to information, participation in decision-making and access to justice (with appropriate remedies).

34.3.2 The Role of Law

Law plays an important role in the implementation of policy and governance frameworks including adaptive governance frameworks for climate change adaptation. Law can either play a facilitative role or hinder adaptation efforts. Consequently, there is a need to revise legal regimes and regulatory frameworks in the context of increased risk of extreme events to encourage coping strategies and minimise the social inequities or injustice that may arise from the uneven effects of climate change.

There are various ways through which law can support adaptive peri-urban governance frameworks including the use of traditional command and control measures such as licences and other planning limitations. Alternatively, or in addition to these, soft planning tools may also be used, for instance, by providing information of risk to prospective purchasers through interventionist methods such as zoning exposed areas to restrict or prohibit new developments (Bonyhady et al. 2010).

Successful adaptive governance requires a mix of regulation and market instruments. Effective frameworks incorporate strategies targeting different transactions by various actors and seek to protect or restore multiple ecological assets (Martin and Verbeek 2002). Peri-urban governance frameworks may result in the interaction of state and private rules which do not align with sustainability goals. In the design of governance frameworks, it is important to develop legal rules that do not dis-empower those implementing sustainability initiatives.

34.4 Prevalent Legal and Institutional Frameworks

The development of legal and institutional frameworks that include plans incorporating the increased risks from climate change and extreme events is still in its early stages in Australia's emergency management sectors (Handmer et al. 2012). This is notwithstanding important milestones achieved in the transition to adaptive frameworks such as the National Strategy for Disaster Resilience adopted by the Council of Australian Government (COAG) in 2011. There is a need for further research to provide information on local sector measures of prevention, preparedness, response and recovery particularly in the peri-urban regions.

Planning and development in the Western Sydney Region is regulated under the Environmental Planning and Assessment Act 1979 and the Environmental Planning and Assessment Regulation 2000. The laws include the development of state environmental planning policies, local environmental plans, and regional environmental plans. However, since 2009, all regional environmental plans are now encompassed in state environmental planning policies. Local environmental plans constitute an important tool for peri-urban governance providing criteria for decision-making at the local level. Planning allows decision-makers to control land use through zoning and development controls as well as to achieve other economic, social and environmental objectives. Local environment plans are thus an important instrument for climate change adaptation and mitigation.

The NSW planning framework has undergone, and is undergoing, some changes to improve the timely and cost effective preparation of plans. Some of the plans already require development agencies to consider how the possible effects of climate change may affect a proposed development plan with specific directions including flood planning. Unlike past practices with Environmental Impact Assessment (EIA) processes, planning now requires a consideration of how the environment including extreme weather events may affect the development and whether, given the economic cost, the development is justified. Apart from the inclusion of climate change considerations, the increase in cooperation of volunteers, government, private sector participants, members of the public, irrigation associations and other stakeholders in initiatives seeking to develop climate change strategies provides evidence of steps in the right direction. The following discussion considers whether this goes far enough, as an adaptive governance framework, focusing in peri-urban Sydney in NSW.

Institutional coordination of the various actors in planning and environmental and risk management is essential for purposes of adequately responding to the impacts of climate variability. In the case of the GWS, this would imply integrating and harmonising the mandates of the NSW agencies such as the Department of Planning and Infrastructure, the Local Government Authorities, State Emergency Services and other Non-governmental Organisations.

34.4.1 NSW Legal and Institutional Frameworks for Climate Change Adaptation and Mitigation

The New South Wales planning framework, and in particular the *Environmental Planning and Assessment Act 1979*, does not address the issues arising from the potential effects of climate change such as extreme events. Nor does the framework incorporate directives on adaptation or mitigation. While recognising the importance of climate change, the focus has tended to be the national debate on green-house gas emissions and strategies to reduce these emissions as opposed to the development of legislative and institutional frameworks at a State level for climate change adaptation and mitigation (Ghanem and Ruddock 2011). However, the initiative of local governments in developing climate change adaptation strategies for their local government areas has helped stimulate the state government into action. This is evidenced by the on-going state-level planning legislation reforms most of which incorporate climate change mitigation and adaptation strategies. Some examples of these efforts to incorporate climate change considerations are identified below.

In 2012, the NSW State government released a ten year plan titled the NSW 2021—A Plan to Make NSW Number One. The plan includes a commitment from the government to minimise the impacts of climate change on communities. In the plan the government undertakes to assist local government, business and the community to build resilience to future extreme events and hazards by helping them to understand and minimise the impacts of climate change. The plan sets out the actions to be delivered under this target and these include:

- Complete fine scale climate change projections for NSW and make them available to local councils and the public by 2014.
- Work with government agencies and universities to deliver improved climate projections for NSW and the ACT.

The Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (NSW) also includes references to climate change considerations. The Plan recognises the effects of climate variability on groundwater levels and includes provisions for managing the sharing of water in the groundwater sources within the limits of water availability.

34.4.2 Shortcomings of Present Frameworks

The above efforts are commendable but still insufficient. Despite the inclusion in planning laws of climate change considerations, unacceptable levels of resource degradation and financial loss and unfairness in the distribution of cost and benefit continue to characterise peri-urban areas. Present peri-urban governance frameworks lack the human and financial capital necessary to effectively implement adaptation and mitigation strategies. Research evaluating existing governance models demonstrates how current models combine high cost, inequitable distribution of costs and insufficient behavioural effectiveness (Martin and Shortle 2009). Consequently, extreme events are likely to result in high levels of resource degradation and financial loss and unfairness in the distribution of cost and benefit.

Despite the new generation of planning laws, the potential for land use planning to reduce exposure to climate impacts is more limited in locations which are already heavily developed such as peri-urban areas. The existing long-term infrastructure in such areas may limit the adaptation capacity. There is a need for more specificity in the planning laws as present frameworks tend to be limited to general provisions requiring the consideration of climate change effects with little or no direction on the practical implications of the provisions. There is also a need for more explicit binding requirements to consider the suitability of a site for development in the context of an environment affected by the climate variability including extreme events. Water laws, for instance, could incorporate measures such as water restrictions to control the demand side of water (Bonyhady et al. 2010).

The large number of uncoordinated environmental rules, including environmental property rights constitutes a source of significant transactions costs, the effect of which is to frustrate the effectiveness of regulatory instruments. An adaptive governance framework requires the integration of regulatory and market instruments to facilitate their implementation (Martin et al. 2007). Coordination of incentives and sanctions is necessary so that all actors contribute towards climate change adaptation and mitigation and avoid some of the problems identified above.

One of the main challenges of prevailing peri-urban governance frameworks is their limited incorporation of risk assessment models for evaluating the risks associated with increased climate variability in peri-urban regions. Development of such models requires the alignment between local scale projections of the effect of climate variability and governance arrangements for peri-urban development. Further, there is a need to develop strategies to institutionalise risk assessment into systemic strategic planning processes.

An adaptive governance model would involve the development of local level scenarios for future effects of increased climate variability and extreme natural events using existing large-scale climate science projections. These models would form the basis for generating options for future adaptive governance. An adaptive governance framework should provide for projections on the social, environmental and economic impacts of the proposed options of governance based on qualitative analysis of the risks, the nature and magnitude of losses and the transaction costs. These projections would be used to evaluate on the basis of risk and cost trade-offs the suitability of various governance options.

Participatory and interdisciplinary research, policy making and strategic planning are the starting points for appropriate and resilient adaptive governance that will be necessary to deal with the impact of extreme events in peri-urban areas. This Chapter is not intended to be an exhaustive list of changes that will be necessary in institutions, policies, laws and practices. Rather, it is an attempt to demonstrate that the challenges of extreme events, impacting on peri-urban areas, require new approaches to governance.

34.5 Conclusions

Environmental law is relatively well developed in terms of the requirements of "good governance" that integrates participation in decision-making. Increasingly, the principles of ecologically sustainable development (ESD) are also being elaborated as part of governance systems. It is recognised that the governance of peri-urban areas is often deficient. However, the focus of this paper was to elaborate the challenges posed by climate change and variability and the need to fundamentally re-think our approaches to adaptive governance for food and water security in peri-urban areas. Long term trends may be relatively well understood, but strategic planning and responses must be undertaken in the face of considerable uncertainty about exactly when, and how, extreme events will occur. Adaptive governance will require an understanding of scientifically informed scenarios, risk assessments and strategic planning by all key stakeholders and the development of institutional and legal frameworks that can be rapidly implemented by the public and private sectors.

Acknowledgments The authors gratefully acknowledge the invaluable assistance of their research assistant Elizabeth Gachenga in the preparation of this chapter.

References

Australia Bureau of Meteorology (2010) Australian water resources assessment report (2010 assessment). ABM, Canberra

Bonyhady T, Macintosh A, MacDonald J (eds) (2010) Adaptation to climate change. Law and policy. Federation Press, Sydney

Ghanem R, Ruddock K (2011) Are New South Wales' planning laws climate-change ready? Environ Plann Law J 28(1):EPLJ 17

Handmer J, McKellar R, McLennan B, Whittaker J, Towers B, Duggie J, Woolf M (2012) National climate change adaptation research plan: emergency management, revised 2012 edn. National Climate Change Adaptation Research Facility, Gold Coast, p 60

Intergovernmental Panel on Climate Change (1995) Working group I: the science of climate change

Intergovernmental Panel on Climate Change (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. In: Field CB, Barros V, Stocker TF, Dahe Q (eds) Special report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Martin P, Verbeek M (2002) Property rights and property responsibility in property rights and responsibilities: current Australian thinking. Land & Water Australia, Canberra

Martin P, Bartel RL, Sinden JA, Gunningham N, Hannam I (2007) Developing a good regulatory practice model for environmental regulations impacting on farmers. Land & Water Australia, Canberra. http://products.lwa.gov.au/downloads

Martin P, Shortle J (2009) Transaction costs, risks and policy failure. Paper presented at the 10th annual global conference on environmental taxation, Lisbon

Martin P, Williams J, Kennedy A (2012) Creating next generation rural landscape governance: the challenge for environmental law scholarship environmental governance and sustainability. Edward Elgar, Cheltenham

Pigram JJ (2006) Australia's water resources from use to management. CSIRO, Collingwood

Stokes C, Howden S (2010) National climate change adaptation research plan: social, economic and institutional dimensions, 2009 (ACIAR)

Sydney MoW (2012) Demographics. Accessed 1 Oct 2012

Thapa S, Marshall F, Stagl S (2010). Understanding peri-urban sustainability: the role of the resilience approach. STEPS Centre

United Nations Economic Commission for Europe, Convention on access to information, public participation in decision-making and access to justice in environmental matters, Aarhus convention, 2161 UNTS 447; 38 ILM 517

Western Sydney Regional Organisation of Councils (2012) Greater Western Sydney. About the area. Accessed 1 Oct 2012

Chapter 35
Valuing the Water Used in Peri-urban Regions of Hyderabad, India and in Western Sydney, Australia

Brian Davidson, Hector Malano, Petra Hellegers, Biju George and Bandara Nawarathna

Abstract Economic theory suggests that resources should be employed in different sectors to the point where their marginal values are equal. Yet what has been observed in many instances is that the marginal values of a resource tend to differ, depending on what they are used for. While this occurs for a variety of reasons, it is argued in this paper that the observable relative differences in the marginal values of a resource are a measure of the pressures forcing a reallocation of those resources within a region. This issue is most acute in peri-urban regions (those places where cities and the rural environment meet) as the competition between a declining agricultural sector and the growing domestic and industrial sectors is most intense. The argument arises as to what extent is the pressure to transfer resources between these declining and expanding sectors. To answer that question it is necessary to value the resource in question in a consistent and comprehensive manner across all sectors. Once done, the forces exerted on the resource can be gauged by observing the relative differences in the values placed on it in each use. The purpose of this paper is to present the results of a method that has been used to undertake this task with respect to the allocation of water resources. However, analyzing this question in the water sector has been stymied by the fact that the value of water deployed cannot be compared easily with that allocated to other sectors. The approach taken is an extension of the Residual Method that is used to calculate the marginal value product of water used in each

B. Davidson (✉)
Melbourne School of Land and Environment, University of Melbourne,
Parkville, VIC 3010, Australia
e-mail: b.davidson@unimelb.edu.au

P. Hellegers
Environmental Economics and Natural Resources Group, Wageningen, the Netherlands

B. Nawarathna
Bureau of Meteorology, Melbourne, VIC 3001, Australia

H. Malano · B. George
Melbourne School of Engineering, University of Melbourne, Parkville, VIC 3010, Australia

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_35,

crop and then aggregated to obtain the total value of water allocated to the agricultural sector as a whole. These results are then compared to the more conventionally obtained values of water used in other sectors. The results presented in this paper were drawn from research that has been published on two very different peri-urban sites, in Western Sydney, Australia and in Hyderabad, India. It can be concluded that despite the differences in the circumstances, conditions and concerns of stakeholders, the approach is robust enough to be used in a variety of situations where the competition for water between sectors exists. It was found that the value of water used for domestic purposes is significantly greater than that deployed to the agricultural sector in both peri-urban regions. In addition, it does not matter that the quantities used in the urban areas for domestic and industrial uses are relatively small when compared to those in the agricultural sector (as is the case in Hyderabad) or not (as in the case in Western Sydney). Just like other resources (principally land) it is inevitable that in peri-urban regions water will be and should be allocated to the use that it is most valued; towards urban expansion and away from agriculture.

Keywords Water valuation · Residual method · Water resource redistribution · Australia and India

35.1 Introduction

Peri-urban regions can be defined as those areas which cities grow into. It could be argued that dynamic economic, social and environmental forces at work are greatest in these regions. These forces for change in peri-urban regions appear to be so great because they run in explicit opposition to the existing economic, social and environmental structures. In particular, what is seen in peri-urban regions is the force for an expanding urban sector pushing greatly against a traditional agrarian base.

The strength of the forces interacting in a peri-urban region can be seen in terms of the differences that exist in the values of various resources. For instance, in an urban region the value of land is both high and relatively uniform across the region, because land is scarce. In a mainly rural region the value of land is much lower, because it is relatively plentiful and yet is also somewhat uniform across the region. In both cases, the relatively uniform value for land (within each region) occurs because of the substitutability of the resource use. One piece of land to build a house on, or to farm, is much the same as another within each region.

Peri-urban regions are characterized by non-uniformity amongst the values of land and other resources. The higher valued urban spaces butt up to the lower valued land used for rural pursuits. This difference in value is a measure of the degree of the forces for change at play in peri-urban regions. The greater the difference, the larger the dynamic forces that are at play.

According to economic theory, as resources flow to their highest value use and a single equilibrium value is attained, there should be no difference in the values of these resources used in different uses. Yet great differences have been observed, especially in peri-urban regions. What prevents them being uniform and equalized are the obstacles (including the policies governments impose that protect one sector over another) that prevent a new equilibrium being achieved. As a consequence the size of the difference between the two values should be indicative of the forces that are governing their transfer from a low value use to a high value use. If the difference is relatively high, then it could be argued that the forces acting on the regions to change should also be high.

As is the case with land, the same should be true of water resources. In many cases within a region, the value of water is arguably a better indicator of these forces, given that water can be allocated between uses more seamlessly than land. However, it is only a good indicator if it is possible to measure the value of water across different uses within a peri-urban region. In these situations any measure of value needs to be comparable across uses and over the spatial and temporal limits that define where the water can be distributed. One of the real problems in undertaking the valuation process relates to water used in agriculture, especially if its use competes with the demands for growing urban regions where more water is required for domestic, recreation, environmental and industrial uses.

The purpose in this paper is to present the results of a method of calculating the value, to society as a whole, of regulated water used in agriculture in two very different peri-urban regions: the Musi River downstream from Hyderabad in India and in the South Creek catchment in the Western Sydney region of Australia. Once obtained, these values are compared to the value of using water in different uses, in order to gain some idea of the pressures forcing change in these two very different peri-urban regions. This method was found to be robust enough to be used in a variety of different development situations. Both sites, while at different stages of development with fundamentally different sets circumstances, face the same increased competition for water that arises from a rising level of population and the concomitant increase in aggregate incomes.

35.2 Value of Water Defined and Measured

Value in this study is defined as the difference between what a user is willing to pay for the regulated supplies of water less what is actually paid for it. It should be noted that this definition of value is equivalent to the economic concept of an ‘economic surplus’. It is the difference between the users demand schedule and the supply schedule, over a range from the origin to the quantity provided and consumed, and is expressed in monetary terms ($ or Rs.) as a proportion of a set volumetric quantity (either Ml or Gl or l). It should be noted that the value of water is not necessarily the same as either its cost (which is equal to the area beneath the supply schedule over the quantity axis), or its price. Additionally, in order to calculate the value of water to society, it is necessary exclude the subsidies, taxes and market interventions that plague the sector.

Numerous methods have been used to calculate the value of water (see Young 2005 for a comprehensive review). In attempting to compare the values of different uses of water within a catchment, the problem that has arisen is with respect to agricultural use. With agricultural use the normal practice was to take a programming approach where a hypothetical farm is modelled and assumed to represent all water use within the sector. The approach required to evaluate the forces acting for change in a region need to account for the complexity of use in the agricultural sector and must be compatible with the methods employed to value water used in other sectors. Of all the methods that exist the Residual Method is arguably the best one to apply in valuing the water used in agriculture as water is recognized to be just one input into the production process of a good. In this approach the marginal value product of water is equal to the quantity of the final good produced multiplied by the price it receives, less the summation of the price multiplied by the quantities of all the other inputs used. In other words it is equal to:

$$Price\ of\ Water = \frac{\left(Price_{Output\ Goods}\right)\left(Quantity_{Output\ Goods}\right) - \left(Price_{Input\ Goods}\right)\left(Quantity_{Input\ Goods}\right)}{\left(Quantity\ of\ Water\ Used\right)}$$

An interesting issue that needs to be dealt with is that although the water applied to different uses may well be homogeneous, the uses to which it is put are definitely not. In agriculture alone each crop has different input cost structures, yields, prices and water use rates. In addition, these may well differ across the catchment in question. The Residual Method is sufficiently robust to be used on an individual crop basis, thus yielding the marginal value product of water in each crop produced, or on a crop system basis (such as a vineyard).

Salvatore (2004), amongst many others, argues that the value of the marginal product must lie on an input demand function. Consequently, by ordering the values from highest to lowest it is possible to ascribe a demand function for the water applied to agriculture. The area under this demand schedule for all the water applied is equal to the gross value of water applied and if the cost of providing it is removed, then the net value of water can be obtained. The per unit value is equal to the total net value divided by the quantity deployed. It should be noted that the Residual Method does have a few deficiencies associated with it, most notably that it can result in an over estimate of the value as any unmeasured or unaccounted input accrues to the value of water.

This value for water used in irrigated agriculture is comparable to that determined for any other use. The normal practice in the case of other uses is to determine (by either estimating it or using some other analyst's estimate) the own-price elasticity of demand for each use, to calculate the per unit value (Young 2005).

In order to determine the forces acting to redistribute water amongst uses within a region, these can be measured by calculating the ratio of the expanding sector (the one with the highest value) to the contracting sector (which should have a lower value). In general, as it is in this study, this will be the ratio of the values of water used in the urban sector to that deployed in the agricultural sector. If this ratio is equal to one, then it could be argued that the allocation of water is in equilibrium. If, as expected it is greater than one, then pressure to reallocate water towards the expanding sector will exist. If however it is less than one then the opposite pressure will exist. Finally, it could also be argued that the further the ratio is from one the greater the pressure to reallocate the resource.

35.3 Applying the Method in Peri-urban Regions

Peri-urban regions are those dynamic regions that lie between an established city and its surrounding well established agricultural land; the place where the two adjoin and where the most dynamic changes in society are occurring. The existing residents of a peri-urban region often feel marginalized as they face the considerable costs of societies adjustment and yet they do not have the political clout to influence this change (because the population densities are low, resulting in low levels of political representation). Often the existing industries (principally agriculture) are being replaced by urban growth, which results in the loss of land, water and other resources. With a growing population the provision of services is also inadequate, placing greater pressure on the existing residents, who see their lifestyles changing for the worse. However, there are advantages to the existing residents of a peri-urban region, namely the potential to benefit greatly from the rising property values, as the demands for resources rise.

With respect to water the situation is not usually as dire as it seems, as agriculture uses vast amounts of water in comparison with urban dwellers. Total supply is not much of a problem if urban growth is to replace irrigated agriculture. A far greater problem is that the quality requirements of urban dwellers are much higher than that required from agriculture. In addition, there is a cost of distributing water to dwellings, something that can be quite expensive.

While all cities have a peri-urban region, two of the most interesting are those that surround Hyderabad in India and Sydney in Australia both of which have a set of circumstances that makes them different. Van Rooijen et al. (2005) characterized Hyderabad, which at times only meets 65 % of its water needs, as a 'sponge city'. With a population of over six million and growing rapidly, it can no longer meet its water requirements from the local Musi catchment reservoirs of Himayat Sagar and Osman Sagar (see Fig. 35.1) (George et al. 2011). It draws some of its requirements from distant catchments; most recently taking water from the Nagarjuna Sagar, water that would normally be used in the agricultural sector in its command area. Much of the peri-urban irrigation undertaken around Hyderabad is irrigated from the city's wastewater. So in this case peri-urban agriculture has benefited from the transfer of water from a command area to the 'sponge city'.

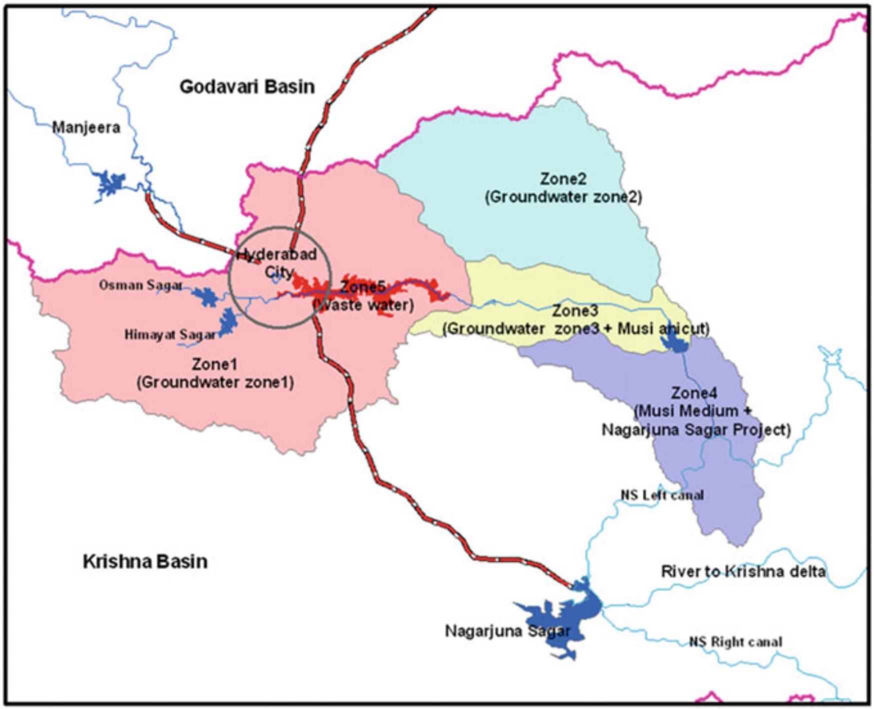


Fig. 35.1 Hyderabad and the Musi catchment, India (George et al. 2011)

The opposite has occurred in Western Sydney where urban growth is replacing the traditional agriculture. The Government has a policy to settle an additional one million people in the South Creek catchment (see Fig. 35.2). Urban requirements already dominate water use and the small quantities used in agriculture are threatened not by the shortage of water but by the loss of land (Rae 2007).

For a comprehensive discussion of the method employed to determine the value of water applied to different uses in the case of the Musi in Hyderabad see George et al. (2011). Hellegers and Davidson (2010) reveal details of how the agricultural value of water is determined in this region and Davidson and Hellegers (2011) show how to link these to an estimation of the own-price elasticity of demand for water used in agriculture. In addition, the same approach has been applied to the South Creek catchment in Western Sydney (Davidson et al. 2013). What is intriguing is that despite the very different circumstances between India and Australia the method outlined above can still be applied to obtain the relevant values, which in turn can then be used to determine the forces acting on the region to reallocate water within the catchment.

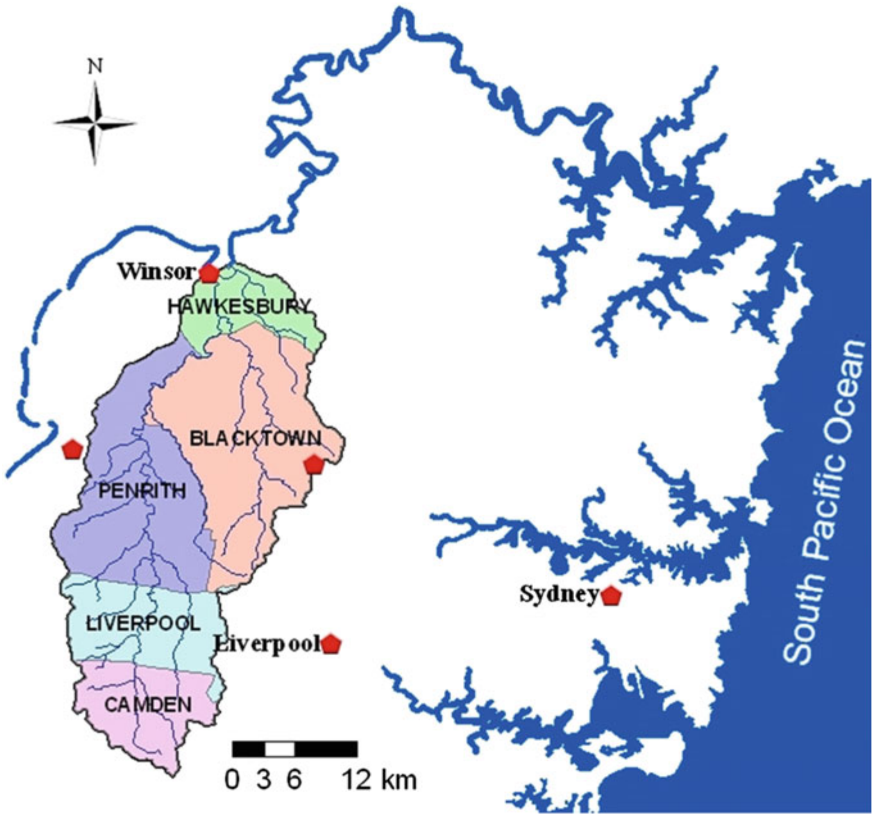


Fig. 35.2 The South-Creek Catchment and its political divisions Western Sydney, Australia (Davidson et al. 2013)

35.4 Results

The results of the estimation of the value of water used in Hyderabad and Western Sydney peri-urban regions, published respectively in Hellegers and Davidson (2010) and Davidson et al. (2013) are presented in Table 35.1. The size of the water system in Western Sydney is approximately only one eighth of that in Hyderabad. In addition, agriculture dominates water use in Hyderabad, whereas in Western Sydney it is domestic use dominating (if one excludes the environmental flow through that system).

What is common between the two is the higher values associated with domestic use. In Western Sydney it is estimated that society gains more than US$272 million from the domestic use of water in 2008, whereas in Hyderabad it was more than US$ 375 million in 2002. The marginal value product in each site was estimated to be US$ 8.89/Kl in Western Sydney and US$ 1.10/Kl, in Hyderabad.

Table 35.1 The value of water deployed in select regions of Hyderabad India and in South Creek Western Sydney Australia

Use	Western Sydney			Hyderabad (2002)		
	Total value	Marginal value	Quantity	Total value	Marginal value	Quantity
Units	$US mil	$US/Kl	Ml	$US mil	$US/Kl	Ml
Agriculture						
Peri-urban	5.38	1.08	4,963	4.44	0.03	148,000
Irrigation NJS	–	–	–	12.79	0.03	456,000
Other						
Domestic	272.56	8.89	30,631	375.37	1.10	324,000
Industrial	1.14	1.79	640	12.48	0.21	60,000
Environmental	6.73	0.07	89,756	0.27	0.03	9,000
Recreation	2.72	2.73	999	–	–	–
Other	–	–	397	–	–	–
Total	289.71	2.27	127,386	405.35	0.41	997,000

Notes All values were converted from local currencies to US dollars, assuming an exchange rate of $A1.02 and Rs. 48 per $US1. These were the annual average exchange rates occurring at the times when the analysis was undertaken (2008 and 2002, respectively)
Sources Davidson and Hellegers (2011), Davidson et al. (2013)

In terms of total and marginal value domestic use could be said to dominate all other uses of water, something that is to be expected in peri-urban regions.

Conversely, water used in agriculture is not valued highly. In Hyderabad it is estimated that for every Kl deployed, society gains only US$ 0.03 of value, regardless of whether it is used in the wastewater region or in a command area like the Nagarjuna Sagar irrigation zone (NJS). This marginal value is seven times less than the value of putting water into industry and 33 times less than the value in domestic use. The total value of water used to produce agricultural products in the peri-urban wastewater and command areas is estimated to be US$ 4.44 million and US$ 12.79 million, respectively, considerably less than the value derived from domestic use. The only reason these total values are as high as they are, is because of the large quantities of water allocated to agriculture.

In Western Sydney a similar situation arises, although the magnitudes are larger. The marginal value is relatively low (at US$ 1.08/Kl) compared to domestic use, resulting in a total value of $US 5.38 million. This low total value is due in part to the small quantities of water (nearly 5,000 Ml) used in agriculture. Yet the marginal values for domestic uses are eight times higher than those for agriculture and are half as great again for industrial use. The value paid for recreational use is more than two and a half times that of agriculture.

In both these cases it is quite clear that the pressure to reallocate water from the agricultural sector to the urban sectors in both these peri-urban regions is great. A measure of that pressure (or the force) to reallocate the water is the relative differences between the values observed. So, in Hyderabad the pressure on reallocating water from agriculture to the domestic and industrial sectors is 33 and seven (respectively), while in Western Sydney it is eight and 1.5 (respectively).

Table 35.2 The individual value of water used in different crops ($US/Kl)

Crop	Western Sydney	Hyderabad wastewater
Dairy	−0.33	–
Market gardens	−0.03	–
Greenhouses	10.58	–
Hydroponics	82.75	–
Turf	0.20	–
Mushrooms	−5.40	–
Nurseries	3.83	–
Orchards	−0.82	–
Vineyards	−0.20	–
Rice	–	0.00
Vegetables	–	0.46
Chili	–	0.04
Gram	–	0.33
Groundnuts	–	0.09
Maize	–	0.08

Notes All values were converted from local currencies to US dollars, assuming an exchange rate of $A 1.02 and Rs. 48 per US$ 1. These were the annual average exchange rates occurring at the times when the analysis was undertaken (2008 and 2002, respectively). The values for these crops were taken from the Blacktown component of Western Sydney and the Wastewater zone in Hyderabad

Sources Davidson and Hellegers (2011), Davidson et al. (2013)

Delving into more detail, Hellegers and Davidson (2010) and Davidson and Hellegers (2011) found that the marginal value product of water deployed in each crop is going to be different (Table 35.2). In other words, the pressure on reallocating water to urban uses across the spectrum of crops produced is going to differ. The greatest pressure is going to be placed on low value crops and it could be the case that in selected instances the value of water used on an irrigated crop may well exceed the value used on other urban pursuits.

In Western Sydney the value of water was determined along farming system lines, whereas in Hyderabad it was determined according to the crops produced. In Hyderabad, the marginal value product varied from US$ 0.46/Kl for producing vegetables through to nothing for producing rice. Interestingly, most water in Hyderabad is used to produce rice, with some of it used for self-sufficiency purposes. It should be noted that it cannot be concluded that farmers are irrational in producing rice over vegetables, as there are many other factors associated with producing a crop, other than the value of water deployed. The point of this analysis is not to determine which crop should be produced. Rather the point is to gain some understanding of the value each use obtains from allocating water at any one point in time. After all farmers have been known to make a loss, hence the value reported in Table 35.2 is occasionally negative. However, what can be suggested from this analysis of Hyderabad is that the greatest pressure on reallocated water to the urban sector will be placed firstly on rice (where its measure could be described as infinite), then on chili production (27.5), then on ground nuts (12.2) and so on until vegetable production (at 2.4 times).

In Western Sydney it was found that the marginal value product of water varied from a loss of US$ 5.40/Kl for mushrooms up to US$ 82.75/Kl for hydroponics (Table 35.2). In this case the greatest pressure will be placed on mushrooms, then orchards, then dairy production and so on. Anything less than the US$ 8.89/Kl value placed on domestic uses and the US$ 1.14/Kl derived for industrial use will face some pressure as was the case with water used for agriculture in Hyderabad. However, in Western Sydney the hydroponics and greenhouse systems derive a value greater than that estimated for domestic use (at US$ 82.75 and 10.58/Kl, respectively). In both these cases the force placed on the need to reallocate water is reversed, it is less than one, at 0.11 and 0.84, respectively.

35.5 Implications and Conclusions

It is quite evident that the results from Hyderabad and Western Sydney (reported above) cannot be directly compared with one another. Besides the fact that they were derived in two entirely different periods (2002 and 2008 respectively), there is no need to compare the two. The situation facing stakeholders and policy makers in each catchment, its underlying conditions and their concerns and desires are entirely different. However, what is required is a comparison between the values derived from different uses of water, within the same catchment.

What is apparent from the results presented above is that the same approach can be used regardless of the state of development or the different concerns of policy makers and stakeholders or by the size of system. Thus, the approach can be considered to be fairly robust.

The approach relies on using the Residual Method to determine the marginal value product of each agricultural product. By multiplying this marginal value product by the quantity of water deployed it is possible to gain the total value society places on the water used for each crop and by summing up each of these values it is possible to determine the value of water used in agriculture as a whole. Knowing these facts is interesting in itself, but of far more interest is the comparisons that can be made between the different marginal value product for each crop and between those and the other uses water is put to. Calculating the ratio between two different marginal value products of water allocated to different uses provides an indicator of the pressures to reallocate water amongst users within a catchment.

In measuring these pressures for reallocating a resource, it can be seen that any figure greater than one can be interpreted as a measure of the force for reallocation from a low valued use to a higher valued use. In addition, any figure less than one, is a force for change in the opposite direction. The strength of the force is determined by the distance between the calculated figure and one. The greater the distance, the greater the force. It is quite evident at both sites that water allocated for domestic use is valued more highly than for any other use; considerably more so than that allocated to agriculture in general and to most crops grown. This is symptomatic of much of the development that occurs in peri-urban regions. The resources move towards and are employed in the sector where they are most valued. One can presume that, like water, the use of land in these circumstances would be subject to similar pressures to be employed in more valuable pursuits. Quite clearly such moves and redeployment of resources can be considered not only to be rational, but also a sign of economic development and progress. To defend agriculture in the peri-urban, by trying to protect it from a resource loss, surely should be considered to be counter to the wellbeing of society. In addition, protecting and quarantining resources within the agricultural sector from other sectors in the rest of the catchment will only increase the relative differences between the values of the resources, thus increasing the pressures to move them out of agriculture. You make the situation worse and increase the pressures faced by policy makers to improve the returns society gets from its resource base.

Of course, it could be argued that while society as a whole gains from moving resources to its highest value use, a redistribution of the resource has also occurred. Those in the agricultural sector might lose while those in the other sectors gain, but those in the other sectors will gain more than the agricultural sectors lose. If something like the Parato criteria is applied (where no action should be undertaken if someone is made worse off) then it is difficult to see how the peri-urban regions will develop. However, if a Kaldor–Hicks (compensation) criterion is used, then development will occur if those who gain have the potential to compensate those who lose. These are the type of difficulties that stakeholders and policymakers will need to concern themselves with, but they can only do so once they measure the marginal values of resources consistently and comprehensively across all sectors.

Finally, it should be asked: where does any reallocation process stop? The amount of a resource that could potentially be reallocated is going to be no greater than that which fulfils the requirements of the sector in which it is destined to go. For instance with water, although the marginal value of the product used for domestic purposes is presently higher that its agricultural value, once the domestic demands are sated (which would occur with an additional 35 % allocated to the domestic sector in the case of Hyderabad or once an additional one million households are supplied in the case of Western Sydney), the marginal value of domestic use will fall to what will be the increased value of that of the agricultural value. In other words, the values of each use will then be the same, they will be in equilibrium and the pressures to reallocate water will disappear. At that point the ratio of the values will equal one and there will be no pressure on policy makers to reallocate water.

Acknowledgment The authors would like to thank the CRC Irrigation Futures and the Australian Centre for International Agricultural Research for funding different parts of this research. In addition the authors would like to acknowledge the helpful comments made by Peter Regan and Mike Reynolds, both of the NSW Department of Primary Industries, and the staff of the International Water Management Institute in Hyderabad. All errors remain the sole responsibility of the authors.

References

Davidson B, Hellegers P (2011) Estimating the own-price elasticity of demand for irrigation water in the Musi catchment of India. J Hydrology 408(3–4):226–234

Davidson B, Malano H, Nawarathna B, Maheshwari B (2013) The hydrology and political economy of the south creek catchment in western Sydney I: model. J Hydrol 499:339–348

George B, Malano H, Davidson B, Hellegers P, Bharati L, Massuel S (2011) An integrated hydro-economic modeling framework to evaluate water allocation strategies I: model development. Agric Water Manag 98(5):733–746

Hellegers P, Davidson B (2010) Determining the disaggregated economic value of irrigation water in the Musi sub-basin in India. Agric Water Manag 97(6):933–938

Rae D (2007) Water management in south creek catchment: current state, issues and challenges. Technical report 12/07, CRC for Irrigation Futures, Penrith

Salvatore D (2004) Theory and problems of microeconomic theory. Tata McGraw-Hill, New Delhi

Van Rooijen D, Turral H, Biggs T (2005) Sponge city: water balance of mega-city water use and wastewater use in Hyderabad, India. Irrigation and Drainage 54(S1):S81–S91

Young R (2005) Determining the economic value of water: concepts and methods. Resources for the future, Washington D.C

Chapter 36
Securing Water, Food, Energy and Liveability of Cities: An Epilogue

Vijay P. Singh and Basant Maheshwari

Abstract This chapter provides the summary of the main points covered in the preceding chapters. The book has six parts, including integrated water cycle modelling, urbanization, water and energy covering aspects of urban agriculture, global warming and climate change, landscape and ecosystem, and governance. The topics covered in different sections of the book are wide ranging and therefore the book illustrates the level of complexity of peri-urban landscapes. The book emphasise the need for integrated planning of future development of peri-urban areas so that our cities sustainable, resilient and liveable.

Keywords Peri-urban planning · Urbanisation · Water and energy security · Urban agriculture · Climate change · Ecosystem and governance

36.1 Introduction

The global demographic landscape has been undergoing a phenomenal change for over half a century, entailing significant annual growth in population, migration from rural areas to urban areas and from developing countries to developed countries, and increase in longevity owing to improved health care and higher standard of living. One of the major consequences of this change is sprawling urbanization. About half a century ago, a majority of people in the world lived in rural areas, comprising small towns and villages. This was especially true in

V. P. Singh
Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering, Texas A&M University, College Station, TX 77843-2117, USA
e-mail: vsingh@tamu.edu

B. Maheshwari (✉)
School of Science and Health, University of Western Sydney, Penrith, NSW 1797, Australia
e-mail: b.maheshwari@uws.edu.au

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6_36,

developing countries, such as China, Egypt, India, and Mexico. What once were small cities or towns have now morphed into huge metropolitan areas. There are many cities in the world now whose population exceeds the population of several European countries. Indeed there are many cities that have more people than Australia has.

Current estimates are that nearly half of the world population now lives in cities and more and more people will be flocking to cities in the years to come. Because cities have limited space, they are growing vertically as well as horizontally to accommodate the burgeoning influx of people, engulfing what once were nearby villages and towns. This urban sprawl is frequently termed as peri-urban or sub-urban. Any major metropolitan area these days is comprised of city and suburbs or peri-urban areas. In developed countries peri-urban areas are more attractive and liveable because there is hardly any pollution, little crime, virtually no traffic jams, and rural environment without being rural, and hence they are growing rapidly. In developing countries, there is a vast difference in the value of land between city and its peri-urban areas. As a result, peri-urban areas are spreading by leaps and bounds.

The unprecedented growth of peri-urban areas brings with it huge and daunting challenges but also offers opportunities for policy makers and inhabitants. Some of the major challenges include providing safe drinking water; supplying affordable energy; developing transport systems and communication systems; constructing needed infrastructure, schools and hospitals, parks and shopping malls; and establishing systems of governance. Because resources are limited and demands for these resources are increasing, there must be an emphasis on sustainability. This book addresses some aspects of sustainable development of urban and peri-urban areas and the challenges that will have to be overcome for such development.

The scope of the book is delineated by six parts, including integrated water cycle modelling, urbanization, water and energy, wastewater, urban agriculture, global warming and climate change, landscape and ecosystem, and governance. Key findings of each section and chapters therein are now summarized.

36.2 Integrated Water Cycle Modelling

The first part of the book is introductory. Discussing the challenges and opportunities for the future of peri-urban areas, it concludes that sustainable planning strategies are fundamental to the development of a sound urban transformation policy. Critical to the policy is the integrated urban water management based on the modelling of the whole water cycle, including water quality. Currently, there are two main constraints to the effective integrated modelling: lack of model integration and lack of data at appropriate time and spatial scales. Frequently, there is a lack of a robust data monitoring program of the entire water cycle for peri-urban catchments.

The merging of rural areas with cities or assimilation of rural-urban spatial fringe is a relatively new concept. The discussion on the geo-social dynamics of this concept, entailing its significance in planning and management of the sustainability of environment and ecology of the area, particularly the socio-economic facet of sanitation and health, concludes that the quantification of geo-social aspect of peri-urban development calls for an interdisciplinary approach. The geo-social buffer zones constitute the basis for the development of peri-urban areas and the strategies for their betterment.

36.3 Urbanisation

This part deals with different aspects of urbanization, including liveability of future cities, impact of expanding urban fringe on peri-urban areas, challenges in urban and peri-urban transition zones and strategies for sustainable cities, managing threats and opportunities of urbanisation for urban and peri-urban agriculture, urbanisation and its effects on water, food security and energy needs. Addressing the issues of sustainable development in landscapes around cities, it is concluded that the ecological cycle should not be disturbed, hence preserving the environment and liveability of future cities. It emphasizes that different options must be developed to meet the future demands of housing around cities, while meeting water needs and producing fresh food and vegetables. Cities that retain the values of their hinterlands may be those which would survive best in this century.

Using as an example of Australian cities that consume land at one of the world's highest per capita rates, continually transforming nearby rural areas with high natural resource values to urban uses, it is argued that unless governments intervene, agricultural land would continue to be subdivided into rural-residential lots and agriculture would move farther away from cities. Therefore, every city must adopt a strategic spatial plan that attempts to limit further outer growth into urban hinterlands through a range of urban containment policies.

Increasing level of urbanisation is altering the environment of peri-urban areas. The conversion of farm lands and watersheds for residential purposes has negative consequences for food security, water supply and public health, both in cities as well as peri-urban areas. Expanding cities are increasing competition over scarce water amongst industry, domestic use, farm houses and recreation parks. Urbanisation brings major changes in demand for agricultural products both from increases in urban population and from changes in dietary habits and demands.

Agriculture within both the built-up and peri-urban areas is being threatened by encroachment upon agricultural land, taxing water resources and enticing rural people away from farming. Increasing climate variability, an indicator of climate change, exacerbates the threat. On the other hand, increased demand for food, the potential for affordable organic manure from urban waste and a need for efficient intensive land use may encourage agricultural production and thereby enhance urban food security. If strategies are nurtured and integrated into policy then they would positively enhance sustainable urban development planning.

Considering the city of Shiraz, located in the Shiraz Plain in southern Iran, as an example, rapid urbanisation has replaced not only large tracts of valuable gardens but has also caused the disappearance of some thousands of hectares of agricultural land, fertile arable land, and rangeland. Due to rapid urbanisation, the demand for water has multiplied and the consumption of energy has grown unreasonably high. Therefore, an in-depth study is needed to understand how urbanisation impacts the availability of water supplies, the security of food production around our cities and the energy needs at the national level and what policy and planning changes are required to achieve sustainable and liveable cities in the future.

36.4 Water and Energy

The part on Water and Energy encompasses urban water footprint and peri-urban interface, analysis of water use, demand and availability, stormwater reuse for sustainable cities, the role of solar energy in urban and peri-urban areas for improving the liveability of cities, and renewable energy policies to shrink the carbon footprint.

Urbanisation is increasingly affecting inter-sectoral water allocations. Virtual flow through the food chain is outpacing actual domestic water consumption. Due to limited wastewater treatment, peri-urban areas are the hot spots for water pollution diminishing their fresh water resources. The fresh water affected by the urban return flow can multiply the overall urban water footprint. Improved on-site sanitation, especially water saving and urine and excreta separating toilets, would have a significant positive impact on the quality and quantity of the urban water footprint, given that actual water availability is limiting large scale sewer connections for final wastewater treatment.

Examination of water use patterns, demand and supply options shows that water demand may more than double in many catchments around the year 2025. Most of this increase would be due to residential and non-residential water use, followed by increases in irrigation requirements for recreational space (parks and golf courses). The potential availability of non-potable water resources is estimated to outpace the potential demand for non-potable water. This provides an opportunity to meet domestic, industrial, agricultural and environmental water demands of a region, provided all water resources are integrated, used and reused in a harmonised fashion. Stormwater and wastewater should be seen as a 'resource' rather than a 'waste' in the new paradigm of integrated water supply management.

Rapid population growth and droughts place increased pressure on urban water resources. Addressing this issue requires consideration of a diverse portfolio of water supply options for non-potable uses, such as alternative non-potable water sources, with stormwater capture and reuse, wastewater recycling and rainwater tank ownership. However, studies have identified public health concerns and a lack of public acceptance as major challenges in implementing water reuse strategies.

Solar energy utilisation is the most important energy resource for bridging the gap between demand and supply of various energy needs in urban and peri-urban areas. The energy consumption is basically in terms of electricity for many appliances and equipment in homes, thermal energy for heating and cooling in homes and passive solar architecture for energy efficient buildings. Conventional energy consumption also induces an ecological imbalance, such as the generation of greenhouse gases. Therefore solar energy may be considered an environmentally friendly alternative energy source for sustainable development.

Renewable energy is gaining importance day by day, particularly in the era of rapid urbanisation. Installing a mix of solar panels, wind mills and biogas plants can make urban and peri-urban areas energy self-sufficient. Increased use of renewable energy sources and thus energy conversation is the main pillar of a sustainable energy supply.

36.5 Wastewater

This part is devoted to issues, challenges and opportunities associated with the management of wastewater, including perspectives on urban sanitation, liveability and peri-urban futures; decentralised wastewater management for improving sanitation; and increasing wastewater treatment capacities for relief for peri-urban farmers.

Peri-urbanisation changes the land use on the margins of growing urban centres (large and small), often displaying a form, structure and interaction across many sectors, that is unique and geared to support the urban centre. Urban sanitation is one of the sectors that face the greatest challenge, where the services are concentrated within municipal limits and disposal activities extend into peri-urban areas. The peri-urban area has often fallen between the cracks of “rural” and “urban” development planning, largely because of low political influence. Therefore, peri-urbanisation needs new perspectives of understanding.

The most challenging characteristics that distinguish urban and rural sectors in developing countries are poor site conditions, unreliable water availability, and high population density, the heterogeneous nature of the population and the lack of legal land tenure. One of the major problems that dwellers in the peri-urban regions have to face every day is sanitation problems. In these peri-urban areas, there are inadequate facilities for waste water disposal and there is a need to improve the water quality through wastewater treatment processes. Studied have shown that conventional centralised approaches to wastewater management have generally failed to address the needs of communities for the collection and disposal of domestic wastewater and faecal sludge from on-site sanitation. Waste stabilisation ponds can be used for fish culture. The importance of building the capacity of local organisations in all aspects of decentralised wastewater management deserves emphasis. The choice of technology is limited by the need to ensure that the operation and maintenance requirements of the chosen technology are compatible with the levels of knowledge and skills available at the local level.

Large volumes of fresh water are extracted from sources often located increasingly further away from the city, while investments in wastewater disposal often lag behind. The resulting environmental impact in peri-urban areas can have multiple consequences for public health, in particular through the use of untreated or poorly treated wastewater in irrigated agriculture. Despite significant efforts to increase wastewater treatment, substantial volumes of untreated wastewater are applied in irrigated agriculture in many developing countries, such as Ethiopia, Ghana, and India. More options for safeguarding public health are required to allow the cities to maintain the benefits from already existing, but largely informal, wastewater reuse.

36.6 Urban Agriculture

The focus of this part of the book is to understand how urban agriculture can play an important role in future food security of cities, particularly examining response to food supply crisis; assessing the importance of the city's peri-urban farms; comparison of urban, peri-urban and rural food flows; sustaining agriculture around cities; protecting horticulture in peri-urban areas, urban and peri-urban dairy production; recycling excreta for peri-urban agriculture; and nutrient recycling from organic wastes through viable business models in peri-urban areas.

There have been sharp increases in the prices of basic food commodities in recent years, and major factors contributing to this trend include rapid growth in the demand for food due to an increase in population, urbanisation, drought and climate changes impacts on agricultural areas and a sharp increase in the cost of living driven by inflation. In response, urban and peri-urban agriculture is making an important contribution to the general food supply of the city. Besides making a significant contribution to the food basket, urban and peri-urban agriculture represents an important economic activity. Emerging policy and planning frameworks support the continued positive contribution of urban and peri-urban agriculture.

Large cities depend on the availability of fresh food products and traditionally these have been supplied competitively by small scale farmers located on the fringes of cities. A peri-urban location gives access to urban markets as well as the opportunity to tap into urban water infrastructure and temporarily idle land. These opportunities mean, however, that peri-urban farmers are displaced by urban expansion. It is found that there is much uncertainty as to the future of these farmers.

While the majority of calorie rich food derives from rural areas, urban and peri-urban farms cover significant shares of certain, usually more perishable but vitamin rich, commodities. With every harvest, the soils in the production areas export parts of their nutrients or soil fertility. Thus the "urban nutrient footprint" is significant and calls for options to close the rural-urban nutrient loop.

In peri-urban regions agriculture tends to suffer as the process of urbanisation occurs. However, it tends to survive because of its proximity to urban centres provide the farmers with all the advantages of a natural monopoly in selected products. However, this natural protection is being eroded by the improvements in transport systems, amongst other factors, resulting in the likelihood of traditional agriculture succumbing to development pressures. Therefore, there is a need to manage the process of change in an ever changing environment for the farmers and acts as a template for other regions suffering from similar pressures.

Among myriad challenges that rapid urbanisation faces is food and nutritional security to feed the millions in these new urban hubs. In a country like India where the majority of people are vegetarian, fresh fruits and vegetables are needed to meet their dietary needs. Growing fruits and vegetables in and around cities increases the supply of fresh, nutritious produce and improves the economic access of urban poor to food. Cultivation of vegetables offers distinct advantages in quality, productivity and a favourable market price to growers. Vegetable growers can substantially increase their income by protected cultivation of vegetables in the off-season as the vegetables produced during their normal season generally do not fetch good returns due to large supplies in the market.

Food shortage and inadequate land are ranked as the first and second order constraints in urban and peri-urban areas in many developing countries, respectively. Diseases followed by waste disposal are rated as the third and fourth order constraints in urban areas, whereas a lack of exotic breeds ranked third in peri-urban areas. The problem of availability of food and land are significant both in urban and peri-urban areas.

Management of human excreta from on-site sanitation facilities continues to endanger public health and degrades the environment through soil and water pollution. Yet much of the excreta consist of organic matter and nutrients that are valuable inputs for agriculture. Recycling in agriculture has often neglected the recovery of nutrients and organic matter in faecal sludge collected from on-site sanitation facilities in developing countries. Exploring the high proportion of resources in excreta can provide a win-win strategy by reducing the environmental pollution, enhancing soil fertility and therefore improving livelihoods. Challenges to maximising these benefits include type of sanitation facility used in developing countries, nature of faecal materials, prevailing treatment technologies which are usually designed for waste disposal not for reuse, institutional and market factors as well as negative perceptions regarding the excreta use in agriculture.

A major challenge of urbanisation is the provision of sufficient food and water for the emerging mega-cities and appropriate peri-urban sanitation management. A decision support system is needed for nutrient recycling from organic waste in peri-urban areas through waste composting or co-composting with night soil. Studies show that from a city perspective cost savings are only possible if large volumes of waste can be composted to reduce waste transport costs, while compost sale (and agricultural use) is not a necessity from the perspective of cost savings.

Closing the rural-urban nutrient cycle appears unrealistic, given the increasing transport distance at least as long as smallholder farmers are targeted. However, consideration of alternative customer segments and implementation of innovative business models can help reach different scales.

36.7 Future of Peri-urban Landscapes

36.7.1 Global Warming and Climate Change

Global warming and climate change are receiving a lot of attention these days. Some aspects of this important topic are dealt with in this section, including assessment of knowledge of climate change and urban and peri-urban agriculture, greenhouse gas emissions of decentralised water supply strategies in peri-urban areas, and coping with the effect of climate change on urban and peri-urban agriculture.

Examination of biophysical, socio-economic, environmental and human health dimensions of urban and peri-urban agriculture can identify structural threats to urban agriculture, including those already induced, or have the potential to be induced, by climate change. Urban agriculture provides an important source of fresh vegetables and other fresh products for the city but is being increasingly marginalised due to a combination of factors, including diminished soil and water quality, increasing temperatures and reduced rainfall, urban encroachment and pollution from industrial sources. A lack of clearly defined roles and responsibilities between local and national governments hinders the ability to protect urban agricultural land from urban encroachment and a lack of access to credit by farmers adds to their inability to cope with the multitude of other pressures.

Ground water in urban and peri-urban areas is steadily deteriorating due to the nitrate pollution of shallow groundwater in aquifers combined with increasing saltwater intrusion. Recycling of untreated wastewater for use in urban agriculture has increased the incidence of food-borne contamination. Solid and liquid waste management is one of the biggest problems that many cities of developing countries are facing.

Climate change will further impact urban agriculture. Shortening of cold periods favourable to vegetable cropping in semi-arid areas, increasingly hotter summers, more frequent flooding and drought periods, and higher incidences of pest and diseases are among the expected impacts of climate change. Coastal zones of the city are particularly under threat due to the rising sea level with negative consequences of coastal erosion and salt-water intrusion in lowlands. Atmospheric projection models show a strong warming trend in many regions of the world. Conversely, there is no agreed trend of rainfall prediction at present but deficits are anticipated by general circulation models.

Adaptation strategies of farmers include lifting the ground surface with landfill in order to better cope with flooding (specifically for flower cultivation), development of soil and soilless micro gardens in boxes, crop diversification, and use of hybrid seeds. Urban agriculture has the potential to contribute to climate change adaptation through reinforcement of urban agricultural systems resilience, water recycling, buffering thermal and hydraulic shocks, providing safe and nutritious food, recycling wastes, and conserving biodiversity. Despite its huge potential to reduce poverty and make the city more resilient to impacts from climate change, urban agriculture is not high on the urban planning agenda.

Quantification of greenhouse gas emissions for decentralised water supply systems is essential for water policy development, decision making and implementation of these systems. Two potential water supply strategies, including effluent reuse and stormwater harvesting, applicable for the planned growth development can be developed. It is found that in terms of operational greenhouse gas emissions, stormwater harvesting performs marginally better than effluent reuse, while the cost of stormwater harvesting is expected to be much cheaper than the effluent reuse, say in Australia.

In the face of additional challenges resulting from the changing climate and increasing intensity and frequency of extreme climatic events, the overall situation is getting worse. Poor urban governance and absence of a comprehensive policy on urbanisation in developing countries have resulted in unliveable metropolitan areas with acute land scarcity and excessively high land prices, poor housing, traffic congestion, water shortages, poor sanitation and drainage, irregular electric supply, unplanned construction and environmental degradation. Now, the biggest challenge is to explore the opportunities to feed the ever-increasing urban population of large cities, such as Dhaka.

36.7.2 Landscape and Ecosystem

Peri-urban growth can affect local flood and drought risks, which are exacerbated by climate change. Research into optimal planning and arrangement of landscape functions is needed to manage local flood and drought risks. As a first step, simple hydrological models are required to study the range of feedbacks and interactions within peri-urban areas. Studies, using simple models, show how the inclusion of buffer zones can reduce local flooding and how such models can be used for virtual experiments. Further development of such simple tools into spatial and agent based models can support new field studies and policy development for peri-urban areas.

Urban ecosystems are complex social-ecological systems with important functions. These man-made ecosystems may have certain areas with high biological diversity, including both remnant species and species purposefully or unintentionally introduced by human actions. There can be important habitats and valuable corridors for both common and less common species within the urban sprawl. Studies show that the local population is interested in biodiversity, especially phenological events, and gets benefited from it by getting aesthetic pleasure and information on seasonal changes. Urban areas are rich in species, particularly vascular plants, and many groups of animals, especially birds. Urban green spaces in the form of artificial parks and agricultural fields have the diversity of flora, whereas artificial lakes are the sites of wetland species. The most eye-catching faunal group of birds has been used to understand the importance of biodiversity. Bird diversity and abundance are indicators of the condition of watershed habitats, both terrestrial and wetland. The role of urban areas in functions, such as the provision of ecosystem services, will largely be determined by patterns of biodiversity within the areas. To keep these biological indicators healthy, watershed conditions should be managed to encourage bird survival and reproduction. To support an integrative approach in urban green planning, both ecological and social research should be incorporated in the planning process.

Despite the fact that wetlands have great economic importance, they are barely considered under land management practices. The wetlands in dry-land regions are under particularly serious pressures from environmental degradation, including the loss of biodiversity. The community participatory works invoke that the wetland management strategies need to be carefully integrated with land use planning and management at the catchment and landscape levels.

36.7.3 Governance

A catchment has high environmental, cultural and social significance providing vital ecosystem services, such as drinking water, food, fibre, nutrient and water cycling, fauna habitat and cultural diversity. The economic value generated from these services is significant. Western Sydney continues to experience ongoing environmental degradation and water shortages as a result of urban development, population demand and climate change. Land use conflicts, climate change predictions and competition for scarce water resources have assigned water and food security high priority in many peri-urban regions across the globe. New law and governance strategies are required for peri-urban regions to harmonise the co-existence of agriculture, urban and other land uses.

The sustainable future of peri-urban regions in the face of increased extreme events is dependent upon the development and implementation of adaptive governance models. The improvement of legal and institutional frameworks for peri-urban governance is needed in order to ensure that decision-making at the regional level is based on science and to effectively address the issues arising in a situation of extreme events that threaten food and water security in the region. In the developed world, environmental law is relatively well developed in terms of the requirements of “good governance” that should integrate participation in decision-making by stakeholders but that is not the case in the developing countries. Increasingly, the principles of ecologically sustainable development are being elaborated as part of governance systems. There is a need to fundamentally re-think the approaches on adaptive governance for food, water and energy security in peri-urban areas. Long term trends may be relatively well understood, but strategic planning and responses must be undertaken in the face of considerable uncertainty about exactly when, where and how extreme events will occur.

Editors Biography

Professor Basant Maheshwari has wide ranging research experience in urban and peri-urban water management and planning. He was a Program Leader for Urban Water in CRC for Irrigation Futures that operated during 2003–2010. Over the years, his work has involved trans-disciplinary approach to water research and has focussed on understanding how water, landscape and people at the interface of urban and rural fringe (peri-urban) interact and influence the environment and sustainability. His work in recent years focussed on modelling and analysing the water cycle for long-term water resource planning at regional level and examining the implications of social, economic, cultural, policy and institutional aspects of water cycle management. He has over 160 publications, including more than 65 journal articles in peer reviewed, international journals. He was recipient of the 2010 Collaboration and Leadership Award from CRC for Irrigation Futures.

B. Maheshwari et al. (eds.), *The Security of Water, Food, Energy and Liveability of Cities*, Water Science and Technology Library 71,
DOI: 10.1007/978-94-017-8878-6,

Professor Ramesh Purohit has over 30 years research, teaching and extension experience in the area of irrigation management, soil and water conservation, applied hydrology and stakeholder engagement. He has led several collaborative research projects that involved multiple research partners and disciplines. Currently he is involved in a significant research work related to managed aquifer recharge in Rajasthan. He has published widely at the national and international levels and has received national awards for his service to the profession.

Professor Hector Malano works in the Department of Infrastructure Engineering at the University of Melbourne. He has extensive experience in water resource management and has carried out research in river basin management, water allocation and operation and management of irrigation systems. He has conducted extensive research with strong focus on basins with extensive irrigation development including among others the Murray-Darling Basin, Australia and the Krishna River Basin, India. In recent years, his current research interests are focused on the impact of climate change on water security and climate change adaptation processes and the management of the urban water cycle including the optimal use of variable quality water to meet demand under conditions of scarcity and climate change. He has published authored and co-authored over 180 refereed papers. He has received various awards including a fellowship from the Fulbright Commission (USA) and the Biennale Medal from the Modelling and Simulation Society of Australia and New Zealand (MSSANZ). He is also a Fellow of this society.

Professor Vijay P. Singh, Ph.D., D.Sc., P.E., P.H., Hon. D.WRE, is Distinguished Professor and Caroline and William N. Lehrer Distinguished Chair in Water Engineering at Texas A&M University. Professor Singh has been recognized for four decades of leadership in research, teaching and service to the hydrologic and water resources engineering profession. He has published his research in more than 710 refereed journal articles, 300 conference proceedings papers, 80 book chapters, and 70 technical reports. He has authored or co-authored 21 books and has edited another fifty four reference books. He has been the recipient of 63 national/international awards from professional organizations. He is a recipient of the Arid Land Hydraulic Engineering Award, Ven Te Chow Award, Torrens Award, Norma Medal, and Lifetime Achievement Award all given by ASCE; and Ray K. Linsley Award and the Founders Award given by the American Institute of Hydrology. He has been awarded two honorary doctorates one by University of Waterloo, Canada; and the other by the University of Basilicata, Italy. He is a fellow of ASCE, EWRI, AWRA, IE, ISAE, IWRS, IASWC, and IAH; a member of AGU, IAHR, IAHS and WASER. He is member/fellow of 10 engineering/science academies.

Dr. Priyanie Amerasinghe is a Senior Researcher and Head of the International Water Management Institute (IWMI), Hyderabad Office, India. She is a public health specialist by training and has over 30 years of teaching and research experience in the broad area of environmental and community public health. She has led multidisciplinary research studies in a number of countries and has provided academic supervision and guidance to a large number of undergraduate and postgraduate students. Her recent interests have been in the areas of health impacts of wastewater use, safe use of wastewater in agriculture and, policy advocacy and action planning in urban/peri-urban agriculture, including adaptive strategies to climate change. She has over 60 peer-reviewed journal articles; around 90 conference abstracts, proceedings, book chapters and technical reports. Her current work is supported by the International Water Management Institute (http://www.iwmi.cgiar.org/) led CGIAR research program on Water Land and Ecosystems (http://wle.cgiar.org).