Rukhsana
Asraful Alam *Editors*

Agriculture, Food and Nutrition Security

A Study of Availability and Sustainability in India

Springer

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Foreword

The agriculture sector has received a lot of attention in discussions on sustainable development, with a priority to ensure production of sufficient food, feed and fibre to meet the rising demands of the world's growing population without compromising the needs of future generations. However, a large section of the world's population still suffers from food insecurity in spite of rapid economic growth in many developing nations including India. There is an urgent need to recognise and revitalise agricultural systems in a way that fulfils the nutritional needs of the people and also raises the economic status of those employed in the agricultural sector. The latest available estimates indicate that around 795 million people in the world, or just over one in nine, were undernourished in 2014–2016. The contribution of undernourished people in the population has declined from 18.6% in 1990–1992 to 10.9% in 2014–2016, reflecting underserved people in a growing population. Thus, rising food demands have to be complemented with an increase in farmers' income in an efficient and sustainable manner.

In a developing country like India, agriculture is dominated by small and marginal farmers, with about 86% landholding being less than 2 ha. The income from such small farms is not enough to maintain a healthy life. Moreover, India has 1.3 billion people, and it will most likely overtake China to become the most populous country in the world. Producing food for such a huge population is an imperative issue for the nation.

I am, therefore, very pleased to introduce this book titled *Agriculture, Food and Nutrition Security: Case Study of Availability and Sustainability in India* edited by Dr. Rukhsana of the Department of Geography, Aliah University, Kolkata, and Dr. Asarful Alam, Department of Geography, Serampore Girls College. The editors have collected a stimulating series of contributions, giving a new dimension to the discussion of issues, challenges and strategies to address the problems of agricultural sustainability in India. This book explores the significant issues about food production and consumption in the past and present periods of climate change. The book uses geospatial tools and statistical methods to present innovative approaches for sustainable agriculture and management. The book is arranged in three broad parts, namely, Part I—Climate and Agricultural Productivity for Availability; Part II—Changes and Trends of Cropping Pattern and Food Security; and Part III—Food and Nutrition Security for Sustainable Development. The volume includes 15 chapters under three major parts beginning with an introductory note.

In conclusion, the challenges of sustainable agriculture are highly diverse and therefore need multidisciplinary thinking and application. This book brings together a wide range of contributions to address the pressing agriculture, food and nutrition security challenges. The book will be helpful for students, researchers, teachers and policy makers particularly interested in various aspects of agriculture, food and nutritional security.

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Preface

Food and nutrition security is fundamental to leading a healthy and productive life and essential for socio-economic development. The system of food production and consumption has formed human society and the environment for millennia. Thus, food and nutrition security is important for any society and a top priority in regional, national and global development. Food security is a tedious process, subject to the risk of various changes that can directly affect dimensions such as agricultural production, food access utilisation and sustainability. As per the United Nations, more than 836 million people in the world are still living in extreme poverty. The fight against the progress of hunger continues; yet, there are unacceptably large numbers of people with a shortage of food, and they need an active, healthy and prosperous life. The latest available estimates indicate that around 795 million people in the world, just over one in nine, were undernourished in the period 2014–2016. The proportion of undernourished people in the population has declined from 18.6% in 1990–1992 to 10.9% in 2014–2016, reflecting under-served people in a growing population. This volume discusses interdisciplinary agriculture, climate and productivity, crop diversification, unemployment, child nutrition, the problems and prospects of food and nutrition security, and the availability and sustainability of agriculture from various perspectives, including philosophy, transformation and economics, as well as the natural sciences. This book argues the significant issues regarding food production and consumption in the past and present periods of climate change. All these threats pose significant challenges to food security, particularly for the poorer segment of society, where malnutrition and famine have been the norm over several decades. Reducing productivity gaps in grain yields, investing in agricultural research and development, improving food security measures and paying special attention to the rural poor, all to reduce sector dependence on food imports and much more equitable incentives, can contribute to and balance economic development. The book focuses on the importance and power of spatial thinking and planning by applying various statistical methods and geospatial technologies to solve past and current problems such as soil fertility, the composite agriculture drought index, agriculture productivity, the food security model, climate change, land suitability evolution, environmental management for sustainable agriculture, as well as food and nutrition security, and consists of a wide range of case studies from various regions of developing countries that address the challenge of developing countries to mainstream a sustainable development paradigm into their economy to improve food and nutrition security in a sustainable manner. This volume is aimed at focusing on the use of geospatial knowledge, methods, tools and an innovative approach to the significance of agriculture, food, nutrition, climate change, environment, socio-economic and social planning to promote sustainable agriculture, food and nutrition security from a local and global perspective.

Part I of three consists of five chapters and logically depicts the different issues of agriculture, food and nutrition security. The first chapter 'Agriculture, Food, and Nutritional Security: An Overview', contributed to by the editors, is an overview of agriculture, food and nutrition security worldwide, followed by a more detailed analysis along various dimensions of food security, such as food availability, food utilisation and sustainability in food supplies and access to food.

Ujjal Senapati, Shrinwantu Raha, Tapan Kumar Das and Shasanka Kumar Gayen (Cooch Behar, West Bengal, India) looked into 'A Composite Assessment of Agricultural Drought Susceptibility Using Analytic Hierarchy Process: Case Study of Western Region of West Bengal' (Chapter 2). This research chapter shows the demarcated agricultural drought susceptibility zone in the Bankura and Purulia districts by using the analytic hierarchy process (AHP) and weighted overlay techniques. First, different agricultural drought indices are estimated using remote sensing-based satellite imagery. From MODIS (1 km spatial resolution), evapotranspiration (ET) and the land surface temperature (LST) are estimated. In the next step, LST data are utilised to produce the Temperature Condition Index (TCI). From LANDSAT satellite data (30 m spatial resolution), the Normalized Difference Vegetation Index (NDVI), the Normalized Difference Water Index (NDWI) and the Enhanced Vegetation Index (EVI) are constructed. From the NDVI, the Vegetation Condition Index (VCI) is estimated. The VCI and TCI are again utilised to create the Vegetation Health Index (VHI). From ERA INTERIM and SWAT data, the Soil Moisture Condition Index (SMCI) and the Standardized Precipitation Index (SPI) respectively are estimated. ET, the VHI, the NDWI, the EVI, the SMCI and the SPI are finally utilised to achieve drought susceptibility zonation using the AHP.

Chapter 3, entitled 'Impact of Microclimate on Agriculture in India: Transformation and Adaptation' by Rukhsana, Asraful Alam and Ishita Mandal (Kolkata, India) is another important contribution to this book. Their study focuses on the vulnerability of agriculture to climate risks and the impact on food security and farm livelihoods. Different types of scientific methods and literature were used to recognise the crop choices and diversifications that are practiced to counter the irreversible effect of microclimate and also to shed light on future agricultural practices in India.

The work of Tapash Mandal, Jayanta Das, Debapriya Poddar and Snehasish Saha (Siliguri, India), 'Characterization of Spatial Variability of Soil Properties of Malda District, in West Bengal, India' (Chapter 4), addresses the nutrient status of surface soil. A total of 45 composite surface soil samples were collected at a depth of 15 cm and the actual location of the sampling sites was detected by GPS. The soil fertility parameters such as soil pH, available nitrogen (N), available phosphorus (P), available potassium (K), organic carbon (OC), electrical conductivity (EC), available boron (B), available zinc (Zn), available iron (Fe), available manganese (Mn), available copper (Cu) and available sulphur (S) were analysed and categorised as low, medium and high using the nutrient index. The spatial distribution of parameters was mapped by use of the inverse distance weightage interpolation method.

The fifth chapter, 'Land Suitability Evaluation for Agricultural Crops in Selected Blocks of South 24 Parganas District, West Bengal', contributed by Rukhsana and Sabir Hossain Molla (Kolkata, India), states that selected crop suitability assessment is a prerequisite for achieving optimal use of available land resources for sustainable agricultural production to increase food security. Various environmental parameters, i.e., for the delimitation of potential and suitable land for crop cultivation, climatic factors (temperature and precipitation) and the physico-chemical properties of various alluvial soils (e.g., soil texture, pH, electrical conductivity, organic carbon content) were used. This study was carried out in three blocks; namely, Patharpratima, Kakdwip and Mathurapur-II of South 24 Parganas district, which is situated in the Sundarbans region of West Bengal.

Part II of the book combines description and analysis in six chapters (Chapters 6, 7, 8, 9, 10 and 11) relating to changes in cropping patterns and food security. The study by Rukhsana (Kolkata, India) on 'Levels of Agriculture Development and Estimated Growth and Pattern of Area, Production and Yield of Major Crops in Selected Region of Uttar Pradesh' (Chapter 6), looks at the changing patterns in agriculture, area, production and productivity of major crops in western Uttar Pradesh for the years 1970–1973, 1980–1983, 1990–1993 and 2000–2003. It occupies the top position in the production of wheat, barley, sugarcane, potato and lentil crops.

Chapter 7 consists of a 'Household Analysis of Crop Diversification and Socio-economic Classifications of Agriculture Practitioner' and was carried out by Rukhsana and Asraful Alam (Kolkata, India) based on both primary and secondary data. This chapter provides an important method for evaluating and examining the status of crop diversification and the effects on smallholders. The results of the study show that the agricultural sector of West Bengal is gradually diversifying toward high-value commodities.

The study (Chapter 8) by Asraful Alam, Rukhsana and L. N. Satpati (Kolkata, India) on 'Assessment of Food Security Using Geospatial Techniques in Rural India: A Study from Koch Bihar, West Bengal' shows the methods that were applied to assess the risk and likelihood of food insecurity based on an assessment of food security status. The FSA model was based on the geospatial analysis of factors ranging from topography, land use, climate and agricultural activities. The study resulted in the ability to illustrate regions at risk within the Koch Bihar district.

'Problems and Prospects of Food Security in India' (Chapter 9) by Asraful Alam, Rukhsana and Sabir Hossain Molla (Kolkata, India) focuses on the future prospects of food security in India. The study additionally concludes by suggesting measures to ensure national food security.

'Dietary Diversity is Associated with Child Nutrition and Food Security Status: Empirical Evidence from Rural India' (Chapter 10), authored by Asraful Alam, Rukhsana and Nilanjana Ghosal (Kolkata, India), is another important contribution to this book. The study focused on child nutrition and food security from perspective of the family diet recorded at grass roots level in rural India. The overall goal of the research was to determine whether there is an association between child dietary diversity and nutritional status in the selected households of the study area. The study is based on both primary and secondary data. Primary data were collected from direct field observation and a proper interview process. As locals largely depend on agricultural production for their living, investments in agriculture are being made to increase food security in the sample households so that no child goes to bed hungry and that the physical and mental capabilities of the children should not be stunted by malnutrition.

The work of Asraful Alam and L. N. Satpati (Kolkata, India) on 'Resource Availability and Socio-economic Profile Scheduled Caste (SC) Community in Agrarian Society: Approach Towards Sustainability' (Chapter 11) is based on field work from different villages in Koch Bihar District, West Bengal. Both primary and secondary sources of data to were used to examine the resource availability and its sustainable utilisation by the inhabitants of Koch Bihar district. The extensive household survey also focuses on the socio-economic background of the schedule caste population residing within the district, which largely belongs to the farming community, and they are directly dependent on the primary economic activity and natural resources.

Part III of the book contains four chapters and shows the underlying facts or ideas relating to sustainable food and nutrition security. The study by Sanjit Sarkar (Karnataka, India) on 'Understanding the Multidimensions of Food and Nutrition Security in Odisha: An Integrated Approach of Availability, Accessibility, and Utilization' (Chapter 12) is an attempt to provide an idea to understand food security in Odisha by integrating its multiple components of food availability, accessibility and utilisation. Using a set of 21 indicators collected from multiple sources of secondary data, the study is aimed at understanding multi-dimensions of food and nutrition security in Odisha. A composite food security index was constructed using principal component analysis to summarise the indicators.

Chapter 13 is entitled 'Determinants of Childhood Stunting in India: Comparative Evidence from Bihar', and is authored by Sumela Ajmer, Samarul Islam, Md Juel Rana, Margubur Rahaman, Moslem Hossain and Babul Hossain (Pune, India). They discuss the issues of a comparative assessment of socio-economic determinants of stunting in India and Bihar displayed in this study. The data from National Family Health Survey-4 was used in this study to examine the comparative scenario of stunting in Bihar and India. Further, primary evidence for childhood stunting was given from Bhagalpur district, representing the eastern Bihar. The bivariate and binary logistic regression model was used to accomplish the study objectives. A comparison of child growth between the WHO standard and the sample from the Bhagalpur district of Biharhas was also made. There is an difference in stunting prevalence of more than 10% between India and Bihar.

Nowaj Sharif and Bhaswati Das (Delhi, India) authored 'Sibling Effect on Intra-Household Child Malnutrition in India: An Analysis among Different

Sociodemographic Groups from the National Family Health Survey' (Chapter 14). This study examines the effect of the number and composition of boys and girls and the socio-economic group on malnutrition in households with two siblings or fewer. Bivariate analysis was used on National Family and Health Survey (NFHS-IV) data on families with two or fewer children age under 5 in India ($N = 53{,}599$). Data were pooled at a national level, and multinomial logistic regression was used to assess the relationship between composite bio-demographic, socio-economic characteristics and malnutrition outcomes (stunting, wasting, underweight).

Chapter 15 consists of the study 'Does Immunization Coverage Influence on Childhood Dual Burden of Malnutrition in India?: What Does Demographic Health Survey Tell?' and was carried out by Md Illias Kanchan Sk, Babul Hossain, Mausam Kumar Garg and Kabir Pal (Pune, India) based on secondary sources of data. This chapter provides an important method for evaluating the patterns of the dual burden of malnutrition among children aged <5 years, including its determinants and multilevel variations in the context of immunisation coverage in India. All four rounds of the NFHS were employed to accomplish the analyses. Overall undernutrition and stunting vulnerability were observed in states with low immunisation, whereas the prevalence of high overweight was found in states with a high level of full immunisation.

Kolkata, West Bengal, India
November, 2020

Rukhsana
Asraful Alam

Acknowledgments

The completion of a work is often a result of the direct or indirect contributions of many individuals. The task editing this book has resulted in a great source of learning process and experiences.

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We are pleased to express our gratitude to all our intellectual contributors for their valuable contributions, which made it possible to complete this book.

We are immensely grateful to the publishing house company, Springer Nature Switzerland AG and all team members for enabling us to publish this edited book. The completion of this work would have been impossible without the publisher's support and guidance.

Kolkata, India Dr. Rukhsana and Dr. Asraful Alam

About the Book

Description

As the largest producer and consumer, India plays an important role in the global agriculture economy. The proposed book entitled '*Agriculture, Food and Nutrition Security: Case Study of Availability and Sustainability in India*' is a collected work of selected papers that are interdisciplinary, covering trends and patterns of agriculture, climate and productivity, food and nutrition security, and the availability and sustainability of agriculture from different perspectives, including philosophy, transformation and economics, as well as the natural sciences. This book discusses a broad range of vital issues encompassing the production and consumption of food in the past and current period of climate change. All of these add up to threatening, significant challenges to food security, especially for poor sectors of society where malnutrition and famine have been the norm for many decades. The book is arranged in three broad sections. Part I Climate and Agricultural Productivity for Availability; Part II Changes of Cropping Patterns and Food Security, Part III Sustainable Food and Nutrition Security. Considering all these points, this book has been prepared to discuss and provide insights to generate awareness of agriculture, climate, food and nutrition security, and focuses on perspectives of sustainable food production and security with regard to human society. It should attract the attention of students, researchers, academicians, policymakers. and other inquisitive readers interested in different aspects of agriculture, food and nutrition security, particularly in the Indian context. The papers are organised into three sub-themes, each part includes a set of articles dealing with a particular issue of agriculture, food and nutrition security. The volume includes 15 chapters divided into three major sections preceded by an introductory note.

Key Features

- The book presents an exhaustive read that includes a methodological and innovative approach, focusing on overall food security, agriculture and sustainable development that will usher in sustainability, from both the local and the global perspective.
- The focal themes elaborate on the essential components of the climate, of agriculture, food and nutrition security, and of management techniques through research innovations. The book is aimed at starting new approaches and ideas to various issues of agriculture, food and nutrition security with regard to sustainable development. This has been formulated on a comprehensive philosophical and theoretical basis, clearly linking the conceptual to the practical.
- The chapters offer a new dimension for discussing the issues, challenges and strategies of food and nutrition security and agricultural sustainability in a comprehensive way. They are aimed at educating students, as well as advanced and budding researchers, in developing novel approaches to sustainability with environmentally sound practices.
- This book provides a comprehensive overview of the key aspects of agriculture, food, and nutrition security, including definitional and conceptual issues, information systems and data sources, indicators and policies. The aim is to equip readers with a sound understanding of the subject, which will help in the recognition of agriculturally low regions, food and nutrition insecurity and the design of suitable responses. This book is an informative and stimulating resource for both students and professionals.
- The book features almost 190 pages and more than 100 figures, coloured photographs, diagrams and maps using machine learning tools and new applied statistics to highlight major themes and to clarify the concepts introduced in the chapters.

Contents

Editors and Contributors

About the Editors

Rukhsana is currently serving as an Assistant Professor in the Department of Geography at Aliah University, Kolkata. She obtained her doctoral degree in Geography from Aligarh Muslim University. Dr. Rukhsana has published more than 35 research papers in reputed journals and four books at national and international levels. She has presented a number of research papers and she was also conferred with the International Young Geographer Award. She has attended XXV FIG International Congress 2014, Malaysia, and ICGGS-2018, Bangkok, Thailand. Her research interests include agriculture development, urban planning, population pressure, environment justice and rural development in geography. She has supervised three scholars leading to the award of Ph.D. degrees in Geography. Dr. Rukhsana has successfully completed one major research project sponsored by ICSSR, New Delhi. She has been the Head of the Department of Geography at Aliah University.

Asraful Alam is an Assistant Professor at the Department of Geography, Serampore Girls' College, University of Calcutta, West Bengal, India. He received his M.A. and Ph.D. degrees in Geography from Aligarh Muslim University, Aligarh and Aliah University, Kolkata, India respectively and also completed a PG Diploma in Remote Sensing & GIS. Dr. Alam completed his Post Doctorate (PDF) from the Department of Geography, University of Calcutta, Kolkata, India. Previously, he was an Assistant Coordinator in the PG Department of Geography, Calcutta Women's College, University of Calcutta, Kolkata, India. His research interests include Population Geography, Agricultural Geography, Climatology and Remote Sensing & GIS and Developmental Studies. He has published two books (one published by Springer) and more than 25 papers in peer-reviewed journals. Dr. Alam has served as a reviewer for many international journals.

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Part I
Climate and Agricultural Productivity for Availability

Chapter 1
Agriculture, Food, and Nutritional Security: An Overview

Rukhsana and Asraful Alam

Abstract Priority in developing countries is achieving food and nutritional security (FNS). A flexible global food system, and one of the critical routes to achieving better FNS, requires the reorganization of relevant policies. Among them, policies and strategies related to the creation and adaptation of technologies, innovations, and their associated institutional adjustments are significant factors to counteract the complex and growing challenges of the global food system. During the last decades, food and nutritional security (FNS) has developed greatly in practice. This overview provides some basic information about current understanding on agriculture, food, and nutritional security. It introduces the concepts of food and nutritional security and separately introduces the part of this book. It focuses on the overview of agriculture, food, and nutritional security worldwide, followed by a more detailed analysis along various dimensions of food security, such as food availability, food utilization, and sustainability in food supplies and access to food. This observation emphasizes the interdisciplinary nature of food insecurity concerns, which have to be addressed through an effective cross-sectoral approach.

Keywords Food and nutritional security · Developing countries and agriculture

1.1 Introduction

Agriculture plays a central role in food availability and accessibility, income, livelihoods, and sharing to the overall economy (World Bank 2007) and is thus a major factor in efforts to improve food and nutritional security. The development of the agricultural sector is particularly important for reducing poverty in developing

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countries, where a large proportion of GDP is generated by small shareholders within the primary sector. For example, agricultural development has been shown to be four times more effective at reducing poverty relative to development in other regions, and increasing smallholder agricultural productivity has a positive impact on both urban and rural populations in three ways: for consumers, low food prices; for producers, high income; and for the rest of the economy, manifold increase in economic growth as a result of increased demand for other goods and services (FAO 2004). Agriculture is diverse and full of contradictions. In 2012, an estimated 1.3 billion (19%) of the world's 7.1 billion people were directly engaged in farming, but agriculture (including the relatively small hunting/fishing and forestry sectors) accounted for only 2.8% of total income (World Bank 2012). However, most farmers in the world today are to be found in middle- and low-income countries, where the agricultural income constitutes a large proportion of national income and employment.

The significant increase in global food production over the last four decades has been a major achievement, but they have also caused serious environmental problems. These contain the cumulative effects of salinization on land productivity and soil erosion, pesticide hazards and chemical fertilizer, desertification, and accelerated conversion of crops to nonagricultural uses. Large-scale industrial agriculture is also the cause of genetic degradation, species loss, and wildlife habitat erosion; over 4000 plant and animal species are endangered by agricultural intensification (FAO 2010). Improvement of the industrial livestock sector is an essential part of sustainable food security (FAO 2010). From various studies, it is found that much improvement has been made to minimize the poverty and hunger and to improve food and nutritional security. Improvement in productivity and technological advancement has shared to more efficient resource utilization and better food security. But major concerns remain. Seven hundred ninety-five million people still endure from hunger, and more than two billion people suffer from micronutrient deficiency. In addition, global food security may be threatened, due to increasing pressure on natural resources and climate change, both of which threaten the sustainability of large-scale food systems. If the current trend continues, planetary boundaries may cross well.

Despite the many successes of development worldwide, including major advances in food production, the persistence and scale of world hunger are astounding. As per latest State of Food Security and Nutrition in the World report (FAO 2019), more than 820 million people endure from daily hunger, and this number has been increasing gradually over the last 3 years. And nearly two billion people face some form of food insecurity—no access to safe, nutritious, and adequate food. Women, children, and indigenous groups are particularly vulnerable to starvation. Under nutrition, the world is also facing an increasing risk of overweight and obesity, growing rapidly in all world regions and assuming epidemic proportions. Hunger remains a silent emergency—drawing attention primarily when a large number of people die during a sensational and highly visible famine. In contrast, chronic hunger remains in the headlines. As the world struggles to accomplish better developmental outcomes in the face of climate disruption, the political, economic, and social implications of this silent emergency are enormous. Hunger and food insecurity are the products of a complex set of factors, including climate-related triggers (such as droughts, floods, cyclones), often exacerbated by economic tightness and conflict.

Food security exists when all people, at all times, have physical and economic access to adequate, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (1996 World Food Summit Plan of Action, UN FAO; FAO 1998). India can attain food security only through measured active steps with population of 1.35 billion. The United Nations Declaration of Human Rights states that "everyone has the right to an adequate standard of living for the health and well-being of himself and his family, including food" and mandatory food as a human right. A flexible global One of the important routes to achieving the food system and better food and nutritional security (FNS) is the need for recombination of relevant policies. Among them, policies related with the adoption, knowledge, creation, and adaptation of technologies and innovations (Juma and Yee-Cheong 2005) are key factors for countering the complex and developing challenges of the global food system.

Food and nutritional security is essential to leading a healthy and productive life and for socioeconomic development. The system of food production and consumption has wrought human society and the environment for millennia (Desor 2017). Food insecurity historically refers to a decrease in overall regional, national, or global food supplies compared to requirements. However, by some groups increasing inadequate food intake, the term has recently been applied at a local, household, community, or individual level (Foster 1992). In addition, the term has been used beyond the notion of food supply, which contains the elements of access (Sen 1981), vulnerability (Watts and Bohle 1993), and sustainability (Chambers 1989; Maxwell 1995).

Food security is attained when it is ensured that "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO 2000). Food is essential to maintain life and growth of people to drink and eat food which results; safe and clean water is a vital part of food commodities. The need to also include nutrition in food security developed over time. The focus of nutrition links care practices and aspects of health services and healthy environments to this definition and concept. It is intended to be more accurately termed "nutritional security," which can be defined as an adequate nutritional status in terms of protein, energy, vitamins, and minerals for all household members at all times (Quisumbing et al. 1995, 12).

The FAO estimates that a total of 925 million people were undernourished in 2010, compared to the 2009 figure of 1.023 billion. This decline is largely due to a more favorable economic environment in developing countries and a decline in both international and domestic food prices since 2008. However, 2010 estimates were higher than they were before the 2008–2009 food and economic crisis. In addition, the recent increase in food prices, if it persists, will create additional barriers to further reduce hunger. The fact that nearly a billion people are still hungry due to the recent food and financial crisis largely points to a deep structural problem that confers the ability to achieve internationally agreed goals on hunger reduction and supports (FAO 2010).

Global FNS has a history of more than 50 years and has been developed through a sequence of definitions and paradigms including “Food for Development” in 1960, “Food Assurance” in 1970, “Broadened Food Security” in 1980, “Freedom from Hunger and Malnutrition” in 1990, and “Food and Nutrition for Poverty Reduction and Development” in 2000. The concept of “safe, adequate, and appropriate supply of food for all” was accepted internationally in Hot Spring Conference on Food and Agriculture in 1943, in which bilateral agencies from donor countries such as the United States or Canada Was made in the 1950s and abroad began to dispose of its agricultural surplus goods. In the 1960s, when it was accepted that food aid could be an obstacle to developing self-sufficiency, the concept of food for development was introduced and institutionalized. The creation of the World Food Programme (WFP) in 1963 is a prime example.

During 1972–1974, food crisis marked a dramatic turn from the previous era of food abundance of contributor countries to highly volatile food supplies and prices on the world market. As a result, food security insurance schemes that assured international access to physical food supplies were developed in the 1970s. Improved food safety assurance was to be achieved through better coordination between donor organizations and agencies and through food availability monitoring in recipient countries. In the 1980s, following the success of the Green Revolution, which helped increase food production (food availability), it was recognized that food emergencies and even famines were not the cause of the catastrophic shortages in food production, because there was a sharp decline in purchasing power. Therefore, food security was broadened to include both physical and economic access to food supplies. In this decade, the role of women in poverty alleviation and development was promoted. In the 1990s, concrete plans were defined to reduce at least hunger and malnutrition. In addition, the human right to adequate food and nutrition was reaffirmed internationally and by committed national governments to a more active role. Finally, international public support from donor agencies reduced food aid for crisis management and prevention. In the 2000s, the reduction of hunger and malnutrition has been seen in terms of overall development, poverty reduction, and attainment of the Millennium Development Goals (SCN 2004).

“Food and nutritional security is achieved if a person has enough food (quantity, quality, safety, socio-cultural acceptance) available and accessible at all times to lead a healthy and active life.” This definition combines food and nutritional security and emphasizes many aspects, namely, availability, access, and use of food. Food security developed from the “Freedom from Hunger” in the 1940s to a broader concept in four dimensions including availability of food, accessibility to food, utilization, and stability. Nutritional security evolved in the 1970s from a “multi-sectoral nutrition planning” approach and UNICEF conceptual framework with three determinants, i.e., access to adequate food, hygiene and health, and care and feeding practices Marzella w. 2013.

Food security is the fundamental foundation of the right to adequate food, which was adopted by the Food and Agriculture Organization (FAO) Council in the 127th session held in November 2004. In that session, governments had agreed to some voluntary guidelines so that they could cooperate in this direction. For the recognition of the economic, social, and cultural rights to food and the right to food, it is recommended to pursue some practical work during the coming decade. In October 2012, the FAO's "Committee on World Food Security" endeavored to define food and nutritional security as the condition when all people at all times have physical, social, and economic access to food, safe and adequate, and it is supported by adequate sanitation, health services, and care environments, which allow for quality and to meet their dietary needs and food preferences to stay healthy and active (FAO 2012). Inadequate food insecurity is a condition where calorie intake is less than the minimum dietary energy requirement (Jones et al. 2013).

Nutritional security exists when food security, coupled with a hygienic environment, adequate health services, and proper care and feeding practices, ensures a healthy life for its household members (Shakir 2006a). The undernourishment measures aspects of food safety and is present when energy intake is less than the minimum dietary energy requirement, which is the amount of energy required for light activity and the minimum acceptable for attained height (Food and Agricultural Organization of The United Nations (FAO) 2009) is the weight. Although undernourishment is based on national-level data, it can be used as a substitute for food consumption in circumstances where regional- or household-level data is not available. It varies from country to country and year to year depending on the gender and age composition of the population. Undernutrition is present when inadequate food intake and repeated infections result in one or more of the following including low weight for age, low vision for age (blurred), thin for height (wasted), and vitamin-deficient and/or functionally deficient in minerals (micronutrient malnutrition). Malnutrition is a broad term that refers to poor nutrition in all forms. Malnutrition is caused by a complex collection of factors including dietary deficiency (deficiency in energy, protein, and micronutrients, overeating, or imbalanced eating), infection, and sociocultural factors. Malnutrition includes underweight as well as overweight and obesity (Shakir 2006a).

"Food security exists when all people, at all times, have physical and economic access to adequate and safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996). There are four dimensions to food security: availability, access, utilization, and stability (FAO 2008b). Food availability refers to the physical availability of sufficient levels of food in a particular area. Cultural suitability of food is also an important aspect as dissimilar cultures have different food preferences (Jones et al. 2013; Hussain and Routray 2012). Access to food refers to physical and economic access to food. Food use refers to food quality, absorption, and safety, supported by a sufficient health status. Food availability, access, and use ensure food stability throughout the year and over a long period of time.

The concept of food security also needs to be unstated from both national and domestic standpoint. Although national food security is significant as providing a basis, it cannot guarantee domestic food security. It is therefore important that every household and every member within it has safe, nutritionally sufficient, and culturally suitable food available (Gillespie and Mason 1991). Hunger and food insecurity may exist at the domestic level even when there is sufficient food at the national level. Food security is a multidimensional concept involving (a) physical availability, including food production, stocks, and reserves on multiple scales; (b) physical and economic access, which depends on purchasing power, income, food prices, transportation, and market infrastructure; (c) the use of food, or the ability to absorb nutrition according to health, dietary diversity, and intra-household distribution; and (d) timely food supply stability and accessibility in cases of weather variability, price fluctuations, and other transitory shocks or periodic stresses (FAO 2008a).

1.2 Climate and Agricultural Productivity

Agriculture is the economic sector most susceptible to climate change. Climate characteristics that have the most direct impact on agricultural productivity include increases in temperature, changes in frequency and intensity of rainfall, and extreme weather events and increased CO_2 levels available for photosynthesis. Agriculture mostly depends on climate change (Mendelsohn and Dinar 2009); the choice of the optimal crops and planting and harvesting times depends directly on the weather conditions prevailing in every region. The imminent climate change due to the increase in greenhouse gases will have a direct impact on agricultural productivity and production and, as a result, on farmers' incomes. Climate change is happening very fast; compared to the gradual change in temperature during the last ice age, it has been 5.0 °C lower in today's temperature (Duncan 2009). The predictions of the current century reflect the urgency of the case. Therefore, urgent actions are needed to mitigate the effects of climate change as well as the adoption of climate change mitigation measures by the agricultural sector.

Since climate affects production and current findings suggest that climate change can positively or negatively alter crop yields (IPCC 2007), it is not a big leap to hypothesize that increased productivity may be influenced by climate change. For example, climate change depicted in the IPCC (2007) is a possible explanation for the decline in the rate of increase in productivity of agriculture (Pardey et al. 2007).

According to the most widely considered climate change scenario (A2), as per recent estimate of the impact of climate change on agricultural productivity, global food production is not threatened by expected climate change, unlike previous forecasts (IPCC 2007). However, due to climate change, the regional agricultural productivity gap will increase the percentage of world population which will become more vulnerable to hunger. The recent estimates from the IPCC forecast state that there will be both positive and negative impacts in agricultural productivity based on climate change and type of farming (IPCC 2007). Thus, there will be different effects at regional, national, and international levels. However, losses in the arid tropical regions of the world can be expected through international trade (European

Commission 2009). Increasing atmospheric concentration of CO_2 will positively impact agricultural productivity (Taub 2010).

The growth rate of agricultural production is usually measured by the recital of food and non-food production. The agricultural product of food production from these two is more important for two reasons. First, it provides the basis for subsistence by offering basic foods, and second, it is the only cluster of agricultural produce where Green Revolution was first introduced. Its importance has also increased due to the establishment of the World Trade Organization (WTO) in 1995, and hence in the present study, we will focus our attention on production (Sharma 2005).

1.3 Changes and Trend of Cropping Pattern and Food Security

The concept of food security is based on three main pillars including availability of food, access to food, and sustainability of food. Agriculture is a creator of food using available natural resources, containing water, soil, and weather resources. Food production and availability, as well as reduced food insecurity, can be achieved by increasing the efficiency of using the said resources. To assist meet the world demand for food, many crops must be put into practice, namely, technology and gradual harvest. Intercropping technology can achieve all of the above benefits. In addition, a consistent crop production can have many benefits, such as improving and maintaining soil fertility, as well as increasing farmers' income (Sheha et al. 2014). Both solutions occur when land is limited; thus intensive harvesting can adequately utilize available water and labor (Gallaher 2009). Intercropping provides year-to-year ground cover, or at least longer than monoculture, to protect the soil from erosion (Gebru 2015). By growing more than one crop at a time on a single farm, farmers achieve maximum water use efficiency and maintain soil fertility, where the soil profile has high roots. In today's world, cereal grains have been considered a major component of the human diet for thousands of years and have played a vital role in shaping human civilization. Around the world, wheat, rice, and corn, and to a lesser extent, millet and sorbet, are important staples for the daily survival of millions. More than 50% of the world's daily calorie intake is taken directly from cereal consumption. Most grains used for human food are bran (pericarp), and some are milled to remove bran and germs, mainly to meet consumers' sensory expectations (Awika 2011).

Today, cereal grains are the most important source of calories for most of the world's population. Developing countries are more dependent on grain for needs than developed countries. Approximately 60% of calories in developing countries are derived directly from cereals, with more than 80% of the value in the poorest countries. In comparison, about 30% of calories in the developed world are derived directly from grains. However, even in these more wealthy societies that rely less on direct grain consumption, grains are the most important foods, as they supply most of the nutrients for livestock that make up a large portion of the diet in these regions (Anon 2003). The three most important food crops in the world are rice, wheat, and maize (maize). These three cereal grains directly contribute more than half of all calories consumed by humans. In addition, other small grains such as sorghum and millet are major contributors to overall calorie intake in some regions of the world, particularly in the semiarid parts of Africa and India. For example, sorbet and millet contribute up to 85% of daily calories in Burkina Faso and Niger. A large part of cereal grain production (especially corn, barley, sorbet, and oats) also goes to livestock feeds, thus contributing indirectly to human nutrition (FAO 2014). The three most edible foods in the world are rice, wheat, and maize (maize) crops which directly share more than half of all calories consumed by people. In addition, other small grains such as sorghum and millet are major contributors to overall calorie intake in some regions of the world, particularly in the semiarid parts of Africa and India. A large part of cereal grain production (especially corn, barley, sorbet, and oats) also goes to livestock feeds, thus contributing indirectly to human nutrition (FAO 2014).

1.4 Food and Nutritional Security for Sustainable Development

Food security exists when all people, at all times, have physical and economic access to adequate, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1998). The World Food Summit, after much deliberation, promised to reduce the number of malnourished people during 1996, compared to 2015. Sixth report on humanity was “malnourished” by the United Nations Food and Agriculture Organization (UNFAO) on June 19, 2009, after 12 years (UNFAO 1999). Severe shortages in food supplies and huge increases in the prices of basic food items were identified as the primary cause of malnutrition (Timmer 2010). The final report released by UNFAO on the timeframe interval for achieving the Millennium Development Goals in 2015 indicated that the proportion of undernourished people in developing regions has fallen by almost half since 1990, down from 23.3% in 1990–1992 to 12.9% in 2014–2016 (UN Report 2015). Despite such a claim, the World Food Price Index was found to be higher from 201.4 in 2008 to 229.9 in 2011, and it was 163.5 in October 2018. Food prices remain volatile over the years, and India, the world’s highest exporter of rice, grapples still with food insecurity (Pogge 2015). The promise made in 1996 has been resumed as one of the Sustainable Development Goals (SDGs) to be achieved by the year 2030 (UN 1996). New policies and regulatory measures were designed to achieve the goal of zero hunger. It is worth considering whether this goal-shifting will help solve the hunger problem or at least make it manageable for countries like India.

Despite numerous developmental successes around the world, including major strides in food production, the persistence and scale of world hunger are astonishing. According to the latest State of Food Security and Nutrition in the World report (FAO 2019), more than 820 million people suffer from daily hunger, and this number has been slowly increasing in the past 3 years. And almost two billion people face some form of food insecurity—i.e., without access to safe, nutritious, and sufficient food. Women, children, and indigenous groups remain particularly vulnerable to hunger. In addition to undernutrition, the world is also facing the growing threat of overweight and obesity, which continue to rise fast in all world regions and are assuming epidemic proportions. Increasing food production to meet growing demands is a major global challenge, particularly in a population-dense and poor South Asia, where smallholder agriculture is dominant (Fischer et al. 2009). Sustainable intensification has been widely proposed as an important agricultural development policy goal (Godfray et al. 2010). Availability, access, and adequacy are recurring concerns when developing policies to achieve "zero hunger." Climate change and land boundaries are also emerging as important factors that increase the problem of food insecurity globally. In particular, "[i] is likely to intensify the debate about the preservation of seeds and plant diversity due to food insecurity, which mandates licensing provisions used to provide access to life-saving drugs in developing countries Refuel for life" (Leidwein 2011).

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Chapter 2
A Composite Assessment of Agricultural Drought Susceptibility Using Analytic Hierarchy Process: Case Study of Western Region of West Bengal

Ujjal Senapati, Shrinwantu Raha, Tapan Kumar Das, and Shasanka Kumar Gayen

Abstract Agricultural drought is a recurrent natural phenomenon that needs to be addressed with care and attention. The Purulia and Bankura districts of West Bengal faced severe agricultural drought several times in the recent decade. But the agricultural drought-related scenario in these area is far from the conclusive statement till date. This research has shown the demarcated agricultural drought susceptibility zone in Bankura and Purulia districts by using analytic hierarchy process and weighted overlay techniques. At first, different agricultural drought indices are estimated using remote sensing-based satellite imagery. From MODIS (1 km spatial resolution), evapotranspiration (ET) and land surface temperature (LST) are estimated. In the next step, land surface temperature data is utilized to make Temperature Condition Index (TCI). From Landsat satellite data (30 m spatial resolution), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Enhanced Vegetation Index (EVI) are constructed. From Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI) is estimated. The VCI and TCI are again utilized to make Vegetation Health Index (VHI). From ERA-Interim and SWAT data, respectively, Soil Moisture Condition Index (SMCI) and Standardized Precipitation Index (SPI) are estimated. ET, VHI, NDWI, EVI, SMCI, and SPI are finally utilized to make drought susceptibility zonation using analytic hierarchy process (AHP). The northwestern portions of Bankura and northeastern portions of Purulia are prone to extreme drought (39% area). The rest portions are affected by the mild to moderate drought (41% area). The study uses a unique methodological framework that can be applicable in any region of the world.

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Keywords Vegetation Health Index (VHI) · Vegetation Condition Index (VCI) Analytic hierarchy process (AHP)

2.1 Introduction

Drought affects near about all climatic regions with varying intensity, duration, and trend (Wilhelmi and Wilhite 2002; Rhee et al. 2010; Narasimhan and Srinivasan 2005). It is one of the major natural hazards with a significant impact on environment, society, agriculture, and economy (Van Dijk et al. 2013; Kanellou et al. 2008; Minamiguchi 2005). It originates from the deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector (Raha and Gayen 2020; Murthy et al. 2007). Information on agricultural drought is useful for the seasonal management of crops, estimation of seasonal crop production, and the assessment of crop loss (Murthy et al. 2011). In the pre-monsoon phase, drought may lead to delay in the crop sowing activities or reduction in the cropped area or both (Das et al. 2013a; Samra 2006). Agricultural season was delayed about 31 days due to rainfall anomaly in the year 2009 in different parts of India (Das et al. 2013b). Agricultural drought becomes fatal in association with meteorological drought in India (Murthy et al. 2015; Agutu et al. 2017). According to Alam et al. (2013), agricultural drought is a dynamic phenomenon which changes over space and time, and it is more fatal than other types of drought as it directly degrades the agricultural activity of a particular region (Dalezios et al. 2014, 2017). Agricultural production is highly dependent on climate, and it is adversely affected by anthropogenic climate change and increasing climate variability (Sivakumar et al. 2005; Dalezios et al. 2014). Agriculture faces many challenges in the LPG (Liberalization, Privatization, and Globalization) era due to increasing competition in the international markets. Agriculture production risks have become the issue in India especially in West Bengal (Ghosh 2019). According to Salinger et al. (2005), agriculture will gain further importance as the environmental and ecosystem services are in the era of global warming and climate change. Thus assessment of agricultural drought and demarcation of agricultural drought-vulnerable zone become crucial for efficient planning and management of agricultural drought (Patel et al. 2012; Jain et al. 2009).

Current scientific projections point out that drought will be more fatal in upcoming times of climate change (IPCC 2012; Kiem et al. 2016). Vulnerability in agriculture due to climate change can be reduced by adaptation measures and proper monitoring systems (Farrell et al. 2010; Donaire et al. 2020). Climate change especially drought will affect West Bengal, and it will be one of the most challenging issues for Bankura and Purulia (Raha and Gayen 2020). Lohar and Pal (1995) showed that the mean monthly pre-monsoonal rainfall has decreased and the temperature has increased significantly in the last decades of the twentieth century. According to Ghosh (2016), the western part of West Bengal is expected to receive less rain in monsoonal season. That is why they are prone to both agricultural and meteorological drought. Bankura and Purulia are likely to experience a 1 °C rise in average temperature during 2025–2099 (Ghosh 2016, 2018). Over the past few years, the impact of climate change has felt severely in this region (Bhave et al. 2013; Vass et al. 2009). Delay in arrival of monsoon season is observed in Bankura, Purulia, and its associated tract. It is also noticed that summer becomes long and drought has become more frequent. The problems are further being compounded with the growing population, lack of water resources, and adaptation with water-intensive commercial crops. The Bankura and Purulia, including Gangetic West Bengal (GWB), are less experienced in coping with drought. In such a pandemonium, agricultural drought susceptibility zone identification is a good attempt.

Figure 2.1 determines the location map of the study area. Bankura and Purulia are two western districts of West Bengal. The study region is also known as the *Rarh* tract predominantly dominated by drought. Purulia District is bordered in the east by Bankura and Paschim Medinipur districts, on the north by the Bardhaman District of West Bengal State and Dhanbad District of the Jharkhand State, on the west by the Bokaro and Ranchi districts of the Jharkhand State, and on the south by the West

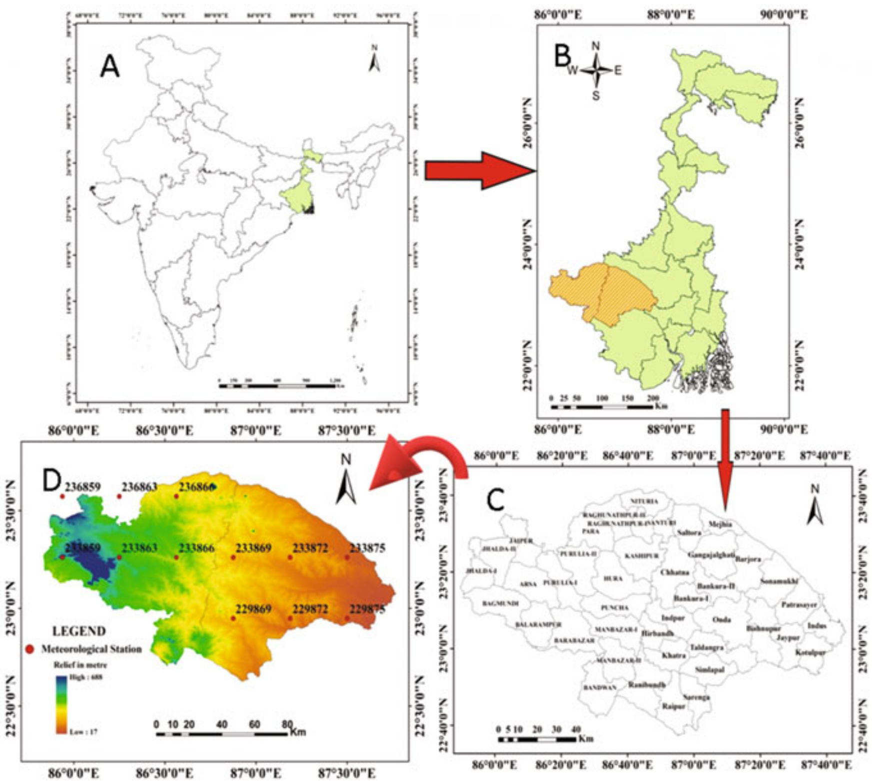

Fig. 2.1 Location map of the study area: (**a**) India, (**b**) West Bengal, (**c**) block boundary of Purulia and Bankura districts, (**d**) spatial distribution of SWAT meteorological station of Purulia and Bankura districts

Singhbhum and East Singhbhum districts of the Jharkhand State. Purulia acts like a gateway between the developed industrial belt of West Bengal and the hinterlands in Orissa, Jharkhand, Madhya Pradesh, and Uttar Pradesh. Bankura is an administrative division surrounded by Purba Bardhaman and Paschim Bardhaman districts in the north, Purulia District in the west, and Jhargram and Paschim Medinipur in the south. The average rainfall of Bankura and Purulia is 1600mm but the rainfall is not wel distributed over the study region (Ghosh 2019). Hot westerly winds prevail in Bankura from March to June in the study area (Ghosh 2018). The study region becomes geographer's attraction for the last 5–7 years due to excessive drought proneness, poverty, and migration-related scenarios (Raha and Gayen 2020).

2.2 Methodology

2.2.1 Data Sources, Framework, and Indices

In recent decades satellite images have been increasingly used for agricultural purposes (Bokusheva et al. 2016). In this research satellite images play the key role for data acquisition and assimilation. Figure 2.2 is identified as the methodological framework of this research. For this research the Moderate Resolution Imaging Spectroradiometer (MODIS), Landsat, ERA-Interim, and SWAT data have been used (Table 2.1). From MODIS and Landsat satellite data, evapotranspiration (ET) and Vegetation Health Index (VHI) are estimated. Evapotranspiration is the process in which the stored water in the vegetation is converted into vapor and is transferred into the atmosphere (Maes and Steppe 2012). The MOD16A2 Version 6 Evapotranspiration/Latent Heat Flux product is used here, and it is an 8-day composite product produced at 500 m pixel resolution. The algorithm used for the MOD16 data product collection is based on the logic of the Penman-Monteith

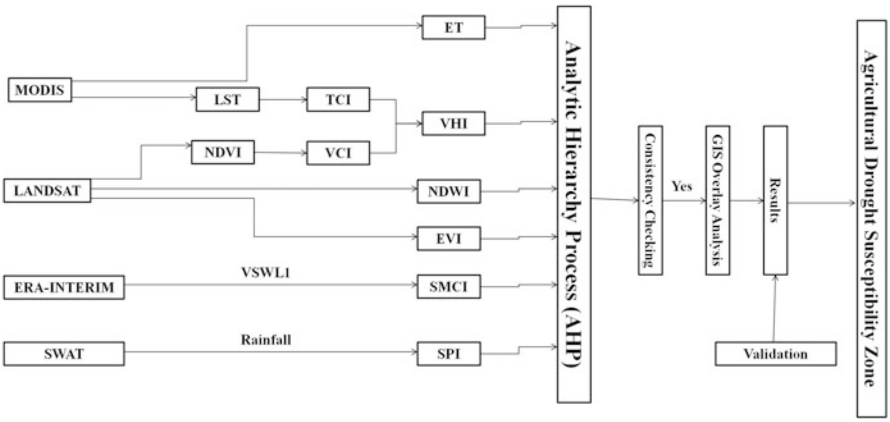

Fig. 2.2 Methodological framework for agricultural drought susceptibility zone mapping

Table 2.1 Location of meteorological stations with latitude, longitude, elevation

Station Id associated to Bankura	Longitude	Latitude	Elevation (m)
229869	86.875	22.9488	133
229872	87.1875	22.9488	61
229875	87.5	22.9488	34
233869	86.875	23.261	127
233872	87.1875	23.261	95
233875	87.5	23.261	46
236859	85.9375	23.573	481
236863	86.25	23.573	193
236866	86.5625	23.573	159
233859	85.9375	23.2609	307
233863	86.25	23.26	286
233866	86.5626	23.261	182

equation, which includes inputs of daily meteorological reanalysis data along with MODIS remotely sensed data products such as vegetation property dynamics, albedo, and land cover (https://lpdaac.usgs.gov/products/mod16a2v006/).

First of all, from MODIS, land surface temperature (LST) is estimated. In the next step, land surface temperature data is utilized to make Temperature Condition Index (TCI). From Landsat satellite data (30 m spatial resolution), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Enhanced Vegetation Index (EVI) are constructed. The NDVI is calculated using the following formula (Rouse et al. 1974):

$$\mathrm{NDVI} = \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{RED}}}{\rho_{\mathrm{NIR}} + \rho_{\mathrm{RED}}} \tag{1}$$

According to Jensen (2016), the seasonal and interannual vegetation growth can be monitored by NDVI. The NDVI ranges between −1 and +1. Negative NDVI denotes severe drought proneness, and if NDVI becomes positive, it denotes wet condition. From NDVI, Vegetation Condition Index (VCI) is formed. The Vegetation Condition Index (VCI) is constructed using the following formula:

$$\mathrm{VCI} = \frac{\left(\mathrm{NDVI}_j - \mathrm{NDVI}_{\mathrm{min}}\right)}{\left(\mathrm{NDVI}_{\mathrm{max}} - \mathrm{NDVI}_{\mathrm{min}}\right)} * 100 \tag{2}$$

Here, $\mathrm{NDVI}_{\mathrm{max}}$ and $\mathrm{NDVI}_{\mathrm{min}}$ represent maximum and minimum NDVI of each pixel calculated for each month, and j represents the index of current month. VCI ranges between 0 and 100 (Dutta et al. 2015; Palchaudhuri and Biswas 2019). The range between 50% and 100% indicates above normal condition of vegetation, whereas the values ranging from 50% to 35% indicate the drought condition and below 35% indicate severe drought condition (Kogan 1995). This index normalizes NDVI and short-term signal of agricultural drought is clearly portrayed by it (Kogan and Sullivan 1993). The resulted images of Vegetation Condition Index (VCI) were classified on the basis of drought severity classification proposed by Kogan (1995). Further, VCI and TCI are linearly combined (Bhuiyan et al. 2006; Bento et al. 2018; Singh et al. 2003) to build Vegetation Health Index (VHI). Finally, the VHI is estimated by the following equation (Yoon et al. 2020):

$$\mathrm{VHI} = \alpha \mathrm{VCI} + (1 - \alpha)\mathrm{TCI} \tag{3}$$

The rationale behind the formulation of VHI rests over the following assumptions (Quiring and Ganesh 2010):

1. VHI is defined such that the lower the NDVI and the higher the LST, the poorer is vegetation health.
2. Since there is no a priori knowledge about vegetation and temperature contributions to vegetation health, the latter index is commonly computed by simply averaging VCI and TCI.

Temperature Condition Index (TCI) is a very important index to determine drought proneness. Further TCI can be expressed as (Tran et al. 2017)

$$\mathrm{TCI} = 100 * \frac{\mathrm{LST_{max}} - \mathrm{LST}}{\mathrm{LST_{max}} - \mathrm{LST_{min}}} \tag{4}$$

where LST is land surface temperature. $\mathrm{LST_{max}}$ determines maximum land surface temperature and $\mathrm{LST_{min}}$ is minimum land surface temperature.

The Normalized Difference Water Index (NDWI) is a satellite-derived index from near-infrared and shortwave infrared channels. SWIR changes with the vegetation water content and mesophyll structure of vegetation canopies, while NIR is affected by leaf internal structure, leaf dry matter, and water content. According to Gu et al. (2007), Berry et al. (2007), and Ceccato et al. (2002), NDWI is vital for agricultural drought monitoring and early warning systems. In this research NDWI is estimated using the following formula:

$$\mathrm{NDWI} = \frac{\mathrm{NIR}_t - \mathrm{SWIR}_t}{\mathrm{NIR}_t + \mathrm{SWIR}_t} \tag{5}$$

Soil Moisture Condition Index (SMCI) is developed using the Volumetric Soil Water Layer 1 (VSWL1) data which is downloaded from the ERA-Interim daily website. Value of SMCI will vary from 0 for wet condition and 1 for very dry condition. The SMCI is computed based on the soil characteristics and soil moisture conditions, and the parameters include soil moisture (SM) (Sridhar et al. 2008; Sánchez et al. 2017; Baik et al. 2019). The equation is given as

$$\mathrm{SMCI} = \frac{\mathrm{SM}_i - \mathrm{SM_{min}}}{\mathrm{SM_{max}} - \mathrm{SM_{min}}} \tag{6}$$

Enhanced Vegetation Index (EVI) is often used for vegetation condition monitoring (Bajgain et al. 2015; Diodato and Bellocchi 2008). The index is particularly useful in vegetation condition monitoring and assessment. The condition of canopy is particularly revealed by this index as it is a unique composition of NIR, red and blue band:

$$\mathrm{EVI} = \frac{\delta \mathrm{NIR}_1 - \delta \mathrm{RED}}{\delta \mathrm{NIR}_1 + 6 * \delta \mathrm{RED} + 7.5 * \delta \mathrm{BLUE} + 1} \tag{7}$$

Rainfall data associated with 12 meteorological stations are extracted from the Soil and Water Assessment Tool (SWAT) developed from Climate Forecast System Reanalysis (CFSR) gridded dataset. From the rainfall data, Standardized Precipitation Index (SPI) is developed. SPI was developed by Mckee et al. (1993) to monitor drought. The responsiveness of precipitation deficits of SPI was found more reliable within shorter and longer time steps (Wu et al. 2001). Because of simple calculation and its' ability to address different drought related issues at a glance, SPI is found most suitable and reliable can be applicable in different parts of the world (Durdu 2010; Turkis and Tatli 2009; Lana and Burgueno 2000). Using the input data, deviation of total rainfall (X) from long-term rainfall mean $\left(\overline{X}\right)$ is estimated. After completion of the process, that total deviation is divided by the standard deviation of rainfall (δ) which is basically as follows (Salehnia et al. 2017; Sonmez et al. 2005):

$$\mathrm{SPI} = \frac{X_i - \overline{X}}{\delta} \tag{8}$$

The long-term rainfall is then fitted to the probability distribution function (Here gamma distribution) and then transformed into the normal distribution so that the mean SPI for thelocation and the desired period is zero,

$$\mathrm{SPI} = \frac{a - M}{\delta} \tag{9}$$

where a is the individual gamma distribution, M is mean, and δ is the standard deviation of rainfall.

According to Mckee et al. (1993), negative SPI values denote more drought risk. If SPI value is < -2.0, it will be considered as extreme drought. The SPI value -1.5 to -1.99 is denoted as severe drought. -1.0 to -1.49 SPI value is denoted as moderate drought. For each dataset average value of 2014 (considering all season) is considered.

2.2.2 Analytic Hierarchy Process (AHP) Method

Analytic hierarchy process is a multiple decision-making tool based on eigenvalue approach to the pair-wise comparisons (Vaidya and Kumar 2006). It is widely used in evaluation, cost-benefit analysis, allocations, planning and development, priority and ranking, and decision-making (Braglia et al. 2001). According to Saaty (2001), AHP is an objective mathematical process where subjective preferences may be incorporated for accurate generalization. The wide applicability of AHP is due to its simplicity, ready to use nature, and great flexibility (Ho 2008; Bhushan and Rai 2007). In this present study, the analytic hierarchy process (AHP) (Saaty 1980) method is used to analyze the weight values of each thematic layer involved in the agricultural drought susceptibility zone identification. Relative rating values of each thematic layer have been assigned for the subclasses based on their causative factor on the agricultural drought triggers. The classes of various thematic layers are further being rated on a scale of 1–7, where higher rating value indicates higher influence for agricultural drought. All thematic maps of causative factors have been stored in raster format with a pixel size of 80 m × 80 m. Final agricultural drought susceptibility map is prepared by spatial overlay analysis between each of the thematic layers.

In multiple-criteria decision analysis (MCDA) method, analytic hierarchy process (AHP) (Saaty 1980) is often applied for the determination of weighted values of each factor. AHP methods show the hierarchical structure of multiple criteria into a pair-wise comparison method for decision-making (Bera et al. 2019). The AHP comparison matrix consists of an equal number of rows and columns, where scores are recorded on one side of the diagonal, while values of 1 are placed in the diagonal of the matrix (Gorsevski et al. 2006). For the construction of a pair-wise comparison matrix, each criterion was rated against every other criterion by assigning a relative dominant scale between 1 and 9 (Table 2.2). The relative scale of all these parameters is given based on different criteria and preferences (1, equally important; 3, moderately important; 5, strongly important; 7, very strong importance; 9, extremely important; 2, 4, 6 and 8, intermediate values). Thereafter, the weighted values of each criterion have been determined using AHP pair-wise comparison matrix (Table 2.3). Each row of pair-wise comparison matrix values describes the relative importance between two criteria. For instance, the first row represents the

Table 2.2 Description of scales for pair comparison with AHP (Source: Saaty 1990)

Scales	Degree of preferences	Descriptions
1	Equally important	The contributions of two factors are equally important
3	Moderate importance	Experiences and judgment slightly tend to certain factor
5	Strong importance	Experiences and judgment strongly tend to certain factor
7	Very strong importance	Experiences and judgment tend to certain factor with Extreme Strong
9	Extreme importance	There is sufficient evidence for absolutely tending to certain factor
2, 4, 6, 8	Intermediate values	In between two judgments

significance of slop in comparison with other six criteria positioned in the column. In this matrix, the rows follow the inverse value of each criterion and its significance with others (e.g., the Vegetation Health Index (VHI) is little more important than the evapotranspiration (ET); hence, the value of VHI is 1 and value of evapotranspiration is 2; thus in the next row, ET is having a value of ½ and so on). In Table 2.3 weights are normalized, and a standardized pair-wise comparison matrix is formed, and criteria weights are obtained. VHI obtains highest weightage (about 38%) as it has highest influence in the agricultural susceptibility zone estimation. ET achieves second place and it obtains 25% weightage. At the successive level, NDWI (16% weightage), EVI (10% weightage), SMCI (6% weightage), and SPI (4% weightage) are taken into consideration (Table 2.4). Every raster variables is divided into five subclasses, and individual weightage of those classes is also determined (Table 2.5).

Consistency ratio (CR) was calculated in order to determine whether the pair-wise comparisons were consistent or not (Kolat et al. 2012). One of the strengths of the AHP method is that it allows for inconsistent relationships while providing a CR as an indicator of the degree of consistency or inconsistency (Chen et al. 2010; Feizizadeh and Blaschke 2013). If the CR < 0.10, it indicates a good level of consistency to recognize the class weights.

$$\text{Consistency ratio} = \frac{\text{Consistency Index (C.I.)}}{\text{Random Consistency Index (RI)}}$$

where

Table 2.3 Comparison matrix of each parameter index

Parameter index	VHI	ET	NDWI	EVI	SMCI	SPI
VHI	1	2	3	4	5	6
ET	1/2	1	2	3	4	5
NDWI	1/3	1/2	1	2	3	4
EVI	1/4	1/3	1/2	1	2	3
SMCI	1/5	1/4	1/3	1/2	1	2
SPI	1/6	1/5	1/4	1/3	1/2	1

Table 2.4 Normalized and the weight values in the standardized pair-wise comparison matrix

Index	VHI	ET	NDWI	EVI	SMCI	SPI	Weights (Wi)
VHI	0.166597	0.10901	0.059792	0.034083	0.020812	0.013605	0.379357
ET	0.083299	0.054505	0.039862	0.025562	0.016649	0.011338	0.24883
NDWI	0.055532	0.027252	0.019931	0.017041	0.012487	0.00907	0.160434
EVI	0.041649	0.018168	0.009965	0.008521	0.008325	0.006803	0.102441
SMCI	0.033319	0.013626	0.006644	0.00426	0.004162	0.004535	0.065494
SPI	0.027766	0.010901	0.004983	0.00284	0.002081	0.002268	0.043443

Table 2.5 Subclasses of each parameter and the pair-wise comparison matrix and their weights

Factors	Classes	A	B	C	D	E	CR	Weight
ET	28–74.3	1	2	3	4	5	0.015881	0.420326
	74–87.5	0.5	1	2	3	4		0.264588
	87.6–106	0.333333	0.5	1	1	3		0.140376
	107–132	0.25	0.333333	1	1	2		0.112508
	133–197	0.2	0.25	0.333333	0.5	1		0.062203
VHI	0.22–0.42	1	2	3	4	5	0.015881	0.420326
	0.43–0.48	0.5	1	2	3	4		0.264588
	0.49–0.55	0.333333	0.5	1	1	3		0.140376
	0.56–0.65	0.25	0.333333	1	1	2		0.112508
	0.66–0.87	0.2	0.25	0.333333	0.5	1		0.062203
NDWI	−0.024 to 0.07	1	2	4	5	7	0.016312	0.457232
	0.071–0.11	0.5	1	2	4	5		0.266641
	0.12–0.15	0.25	0.5	1	2	4		0.147535
	0.16–0.19	0.2	0.25	0.5	1	2		0.080526
	0.2–0.35	0.142857	0.2	0.25	0.5	1		0.048066
EVI	0.24–0.33	1	2	3	5	7	0.006237	0.444648
	0.34–0.37	0.5	1	2	3	5		0.261921
	0.38–0.43	0.333333	0.5	1	2	3		0.152359
	0.44–0.6	0.2	0.333333	0.5	1	2		0.08868
	−0.27 to 0.23	0.142857	0.2	0.333333	0.5	1		0.052392
SMCI	0.63–1	1	2	3	4	5	0.015881	0.420326
	0.45–0.62	0.5	1	2	3	4		0.264588
	0.29–0.44	0.333333	0.5	1	1	3		0.140376
	0.16–0.28	0.25	0.333333	1	1	2		0.112508
	0–0.15	0.2	0.25	0.333333	0.5	1		0.062203
SPI	−0.57 to −0.28	1	2	3			0.009608	0.539613
	−0.27 to 0	0.5	1	2				0.296962
	0.01–0.56	0.333333	0.5	1				0.163425

Table 2.6 Random Index (RI) value (Source: Saaty 1990)

n	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

$$\text{Consistency Index} = (\lambda_{\max} - n)/(n - 1)$$

where $\lambda_{\max}$ is the principal eigenvalue and n is the number of factors.

Random Consistency Index (Table 2.6) is derived from the randomly generated reciprocal matrices. Those numbers are utilized from the study of Saaty (1980). According to Saaty (1980), if consistency ratio is below 0.1, the matrix becomes consistent. In our study, consistency ratio is 0.019768 which is <0.1, and principal eigenvalue is 6.122. So, here matrix (Table 2.4) is consistent, and the estimated criteria weights can be utilized for agricultural susceptibility zone identification. Pair-wise comparison matrix for each subclass (for each raster layer) is also consistent (Table 2.5).

2.3 Results

Evapotranspiration is an important parameter to denote the agricultural drought. In this study area, the range of evapotranspiration is between 28 and 197 kg/m^2. The amount of evapotranspiration is low in the southeast and northeast portions of Purulia (28–74.3). The low evapotranspiration (28–74.3) is confined to northern and northwestern portions of Bankura. Lowest average evapotranspiration is noticed in the southwestern and western portions of the study region in a pocket form. Remaining portions of Purulia are in the condition of moderate evapotranspiration (74.4–106). In case of Bankura, relatively high rate evapotranspiration (107–197 kg/m^2) is found at the eastern portions. Southern and northeastern sections of Bankura are affected by moderate evapotranspiration rate (74.4–106 kg/m^2). Figure 2.3 denotes average evapotranspiration of the study area.

High average land surface temperature (LST) (31.82–35.18 °C) is observed at the western and northwestern portions of the Purulia. The northern, southern, and

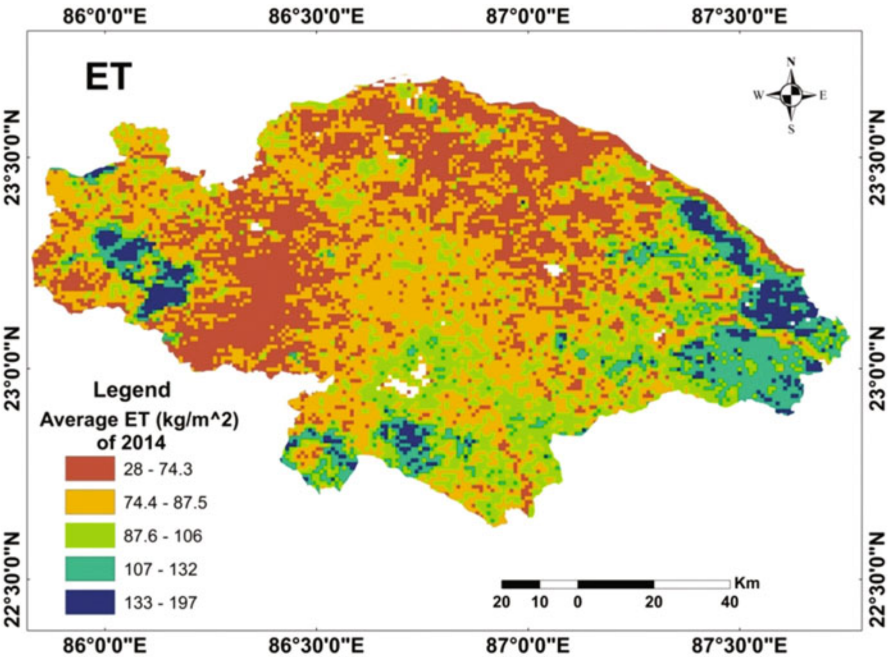

Fig. 2.3 Average evapotranspiration (ET) of study area (2014)

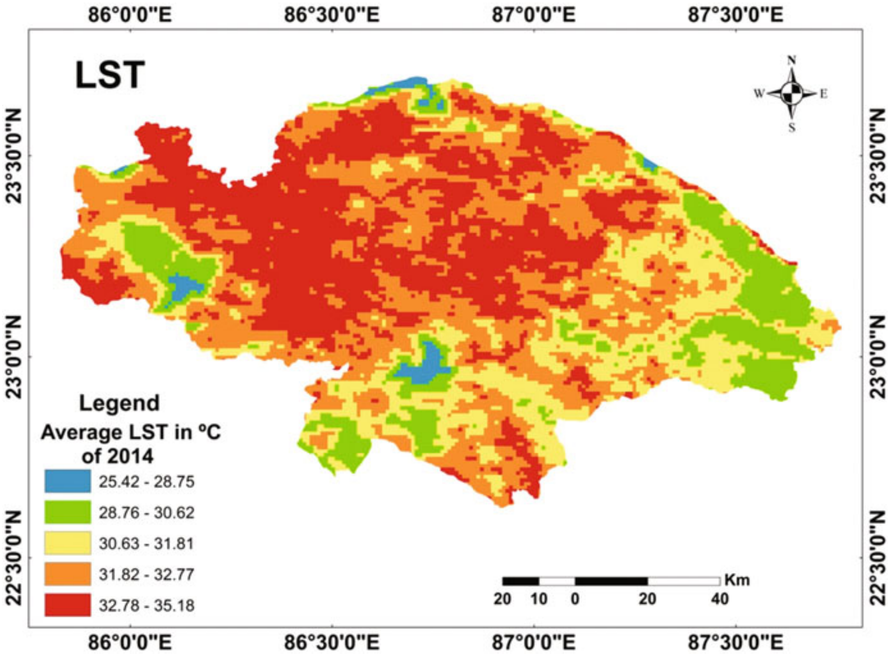

Fig. 2.4 Average land surface temperature (LST) of study area in 2014

western tip of Purulia experience low to moderate surface temperature (25.42–30.62 °C). The northwestern sector of Bankura experiences high land surface temperature (LST) (31.82–35.18 °C). Low average LST (28.76–30.62 °C) is noticed in the eastern and northeastern portions of Bankura. Figure 2.4 denotes average LST of the study area.

Overall for the region, northern portions are noticed with 0.093–0.3 NDVI value. Remaining portions of the study area are characterized with 0.31–0.53 NDVI value (Fig. 2.5). High TCI (0.47–1) (Fig. 2.6) is noticed in northern portions of the study area.

Purulia experiences better condition of vegetation, and southwestern portion of Purulia is noticed with 0.8–1 Vegetation Condition Index (VCI) value. However for both Purulia and Bankura, southern portions are noticed with relatively moderate to high condition of vegetation (VCI value 0.6–0.8). The northwestern portions of Bankura and southeastern portions of Purulia are noticed with moderate to low condition of vegetation (VCI value 0.2–0.6). Figure 2.7 denotes Vegetation Condition Index (VCI) of our study area. Similar nature is observed for spatially distributed Vegetation Health Index (VHI) (Fig. 2.8).

The southern sections of the study region are noticed with healthy vegetative growth (0.56–0.87 VHI value), and northern and northeastern sections of the study area are observed with relatively little growth of vegetation (0.22–0.48 VHI value). The scenario slightly changes for Enhanced Vegetation Index (EVI) (Fig. 2.9).

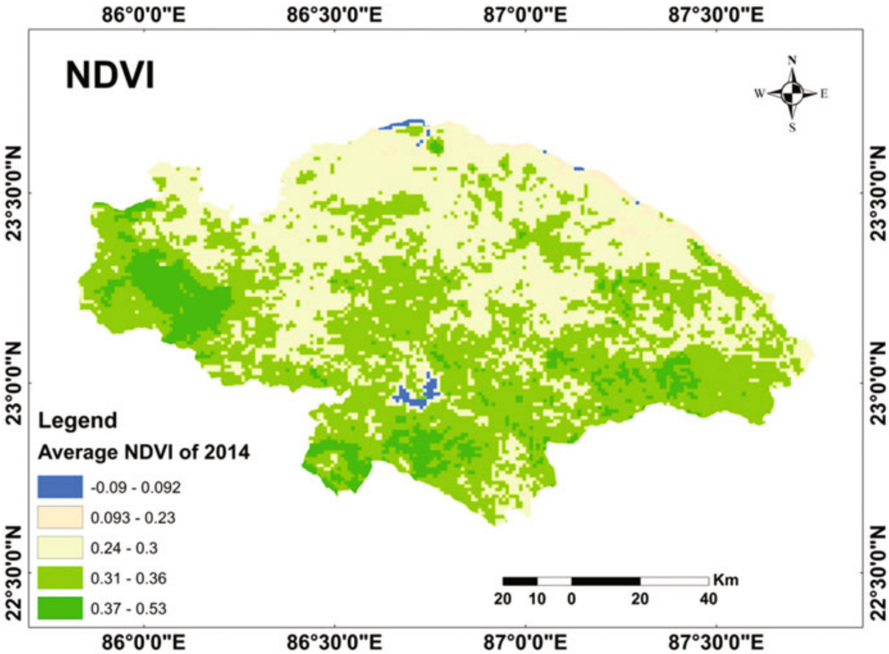

Fig. 2.5 Average Normalized Difference Vegetation Index (NDVI) of the study area (2014)

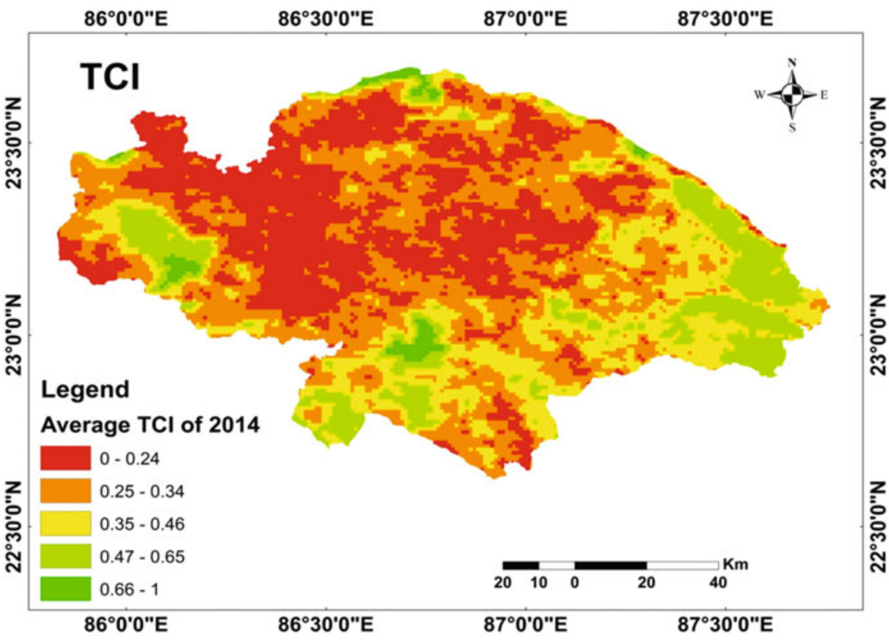

Fig. 2.6 Average Temperature Condition Index (TCI) of the study area (2014)

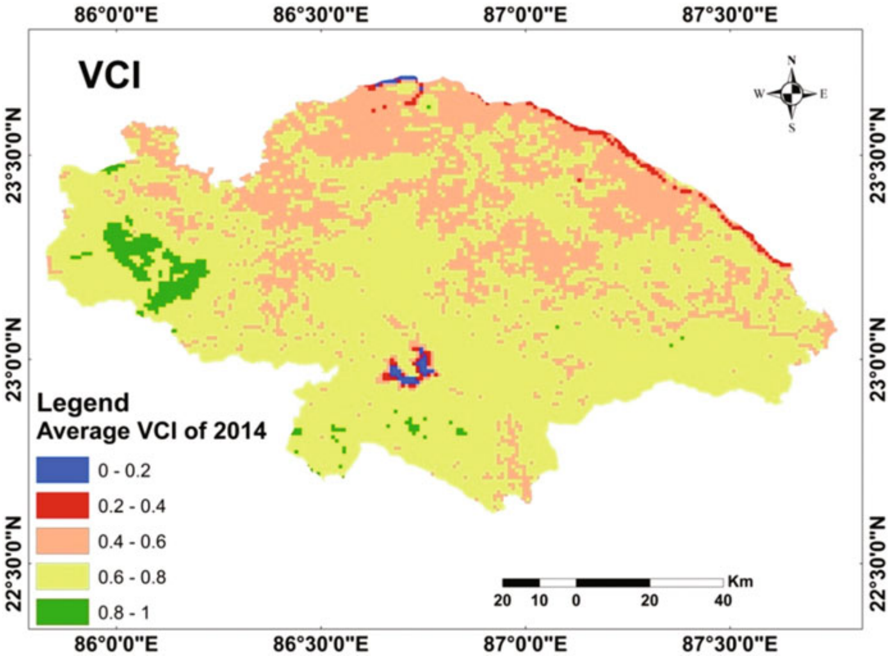

Fig. 2.7 Average Vegetation Condition Index (VCI) of the study area (2014)

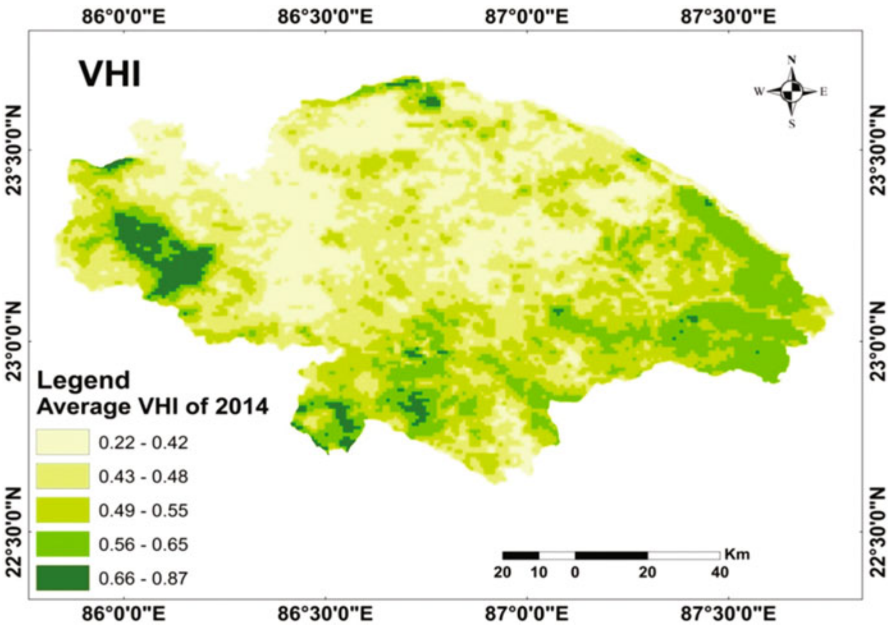

Fig. 2.8 Average Vegetation Health Index (VHI) of the study area (2014)

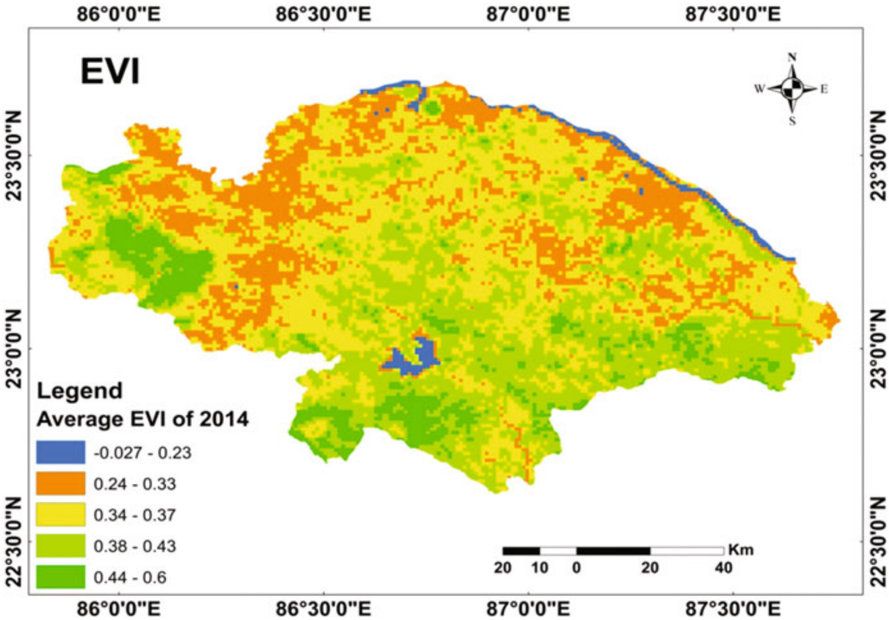

Fig. 2.9 Average Enhanced Vegetation Index (EVI) of 2014

The southwestern and southeastern sections of Purulia and Bankura are observed with the highest EVI value. The northern and northwestern portions are identified with 0.24–0.33 EVI value. Almost all portions of Purulia are identified with low NDWI (−0.024 to 0.11). Only some portions of western and southwestern patch of Purulia are identified with high average NDWI value (0.2–0.35). On the contrary, about 90% area of Bankura experiences about 0.16–0.35 NDWI value. Only northwestern portions of Bankura are characterized with low NDWI value (−0.024 to 0.11) (Fig. 2.10).

Soil moisture condition is better in the western portions of Purulia and eastern and southeastern portions of Bankura. However the eastern segment of Purulia and western segment of Bankura are noticed with relatively poor condition of soil moisture (low SMCI value; Fig. 2.11). The southeastern portions of Bankura are characterized with relatively high SPI value (0.01–0.56 SPI value). Average SPI (Fig. 2.12) is low at the northwestern portions of Bankura and Purulia.

2.3.1 Delineation of Agricultural Drought Susceptibility Map

All thematic layers are incorporated and agricultural drought susceptibility map has been prepared. According to AHP-based drought susceptibility zone marked in Fig. 2.13, northwestern part of Bankura and northeastern part of Purulia are

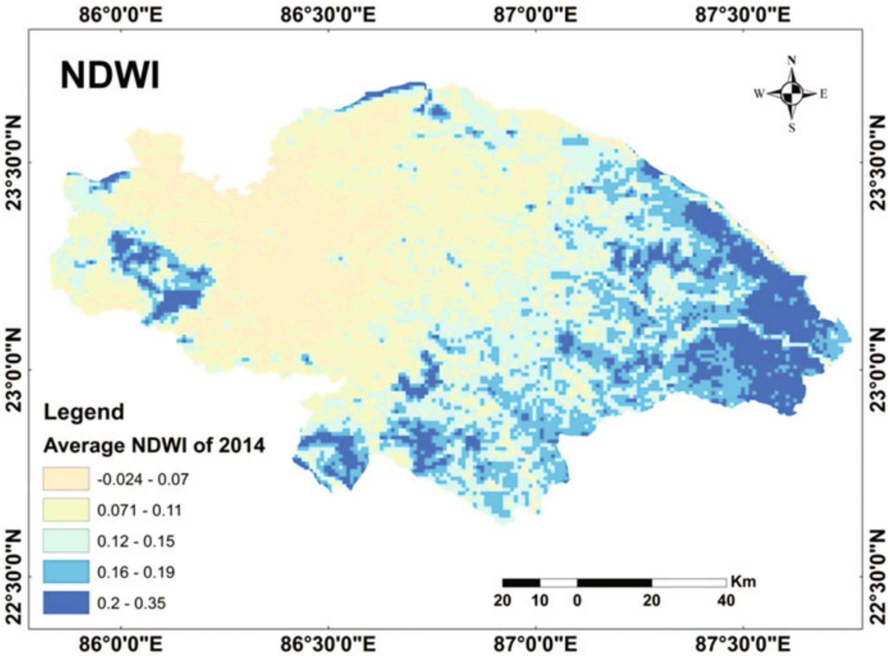

Fig. 2.10 Average Normalized Difference Water Index (NDWI) of 2014 in the study area

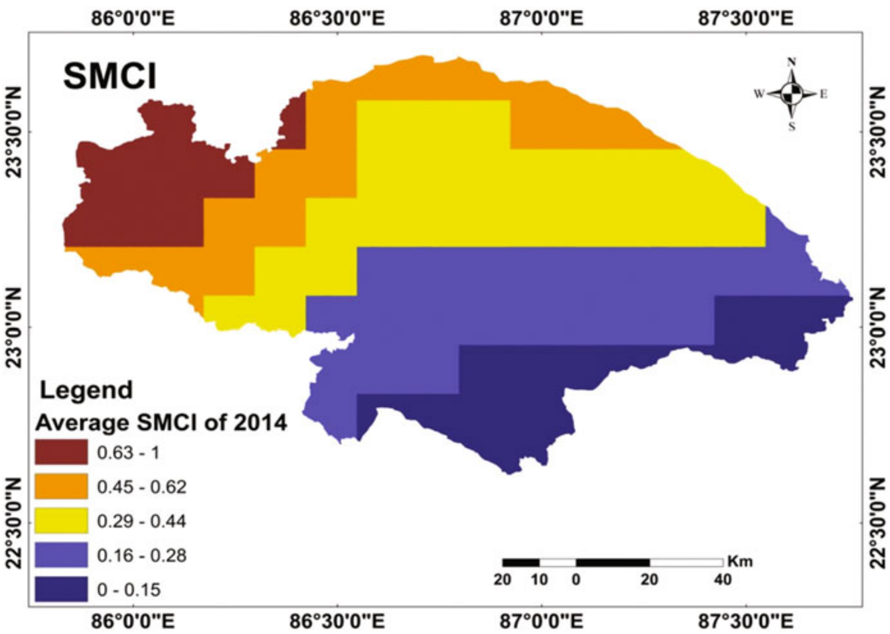

Fig. 2.11 Average Soil Moisture Condition Index (SMCI) of 2014

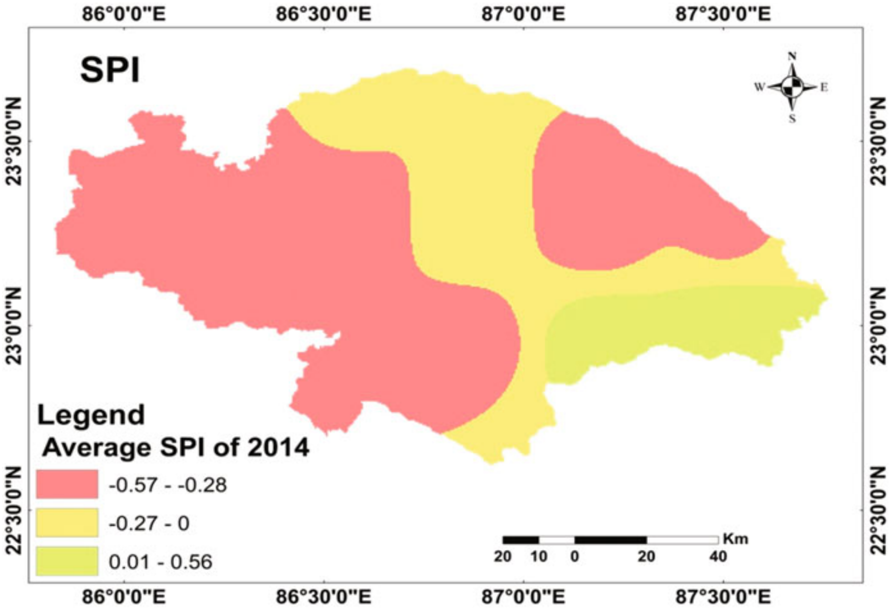

Fig. 2.12 Average Standardized Precipitation Index (SPI) of 2014

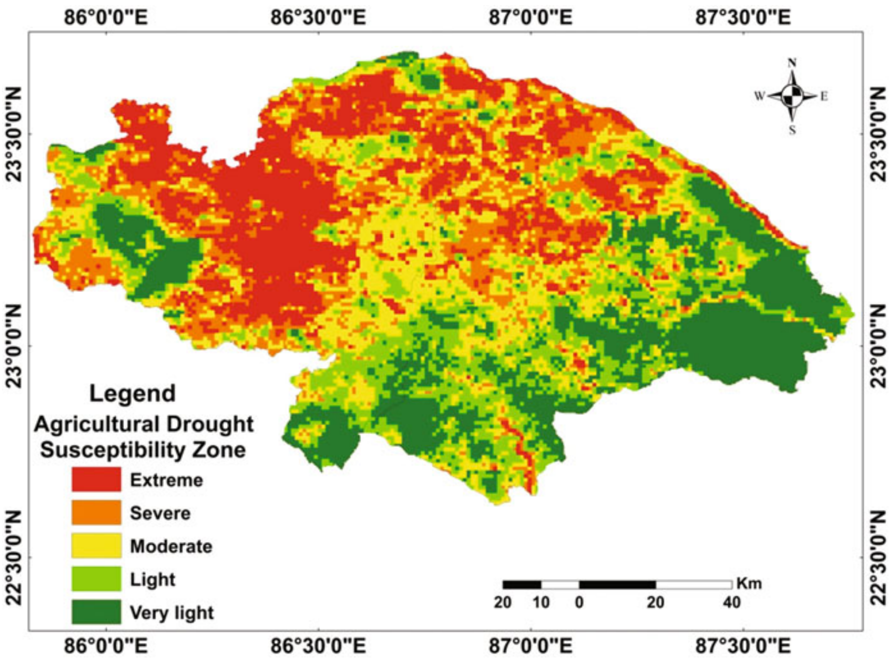

Fig. 2.13 Agricultural drought susceptibility zone

Table 2.7 Percentage area of agricultural drought susceptibility zone

Ranges	Pixel count	Area (sq km)	Percentage (%)
7007–15,112	3,195,305	2876	22
15,112.00001–21,330	2,528,017	2275	17
21,330.00001–27,448	3,119,012	2807	21
27,448.00001–34,258	2,916,663	2625	20
34,258.00001–43,322	2,872,803	2586	20

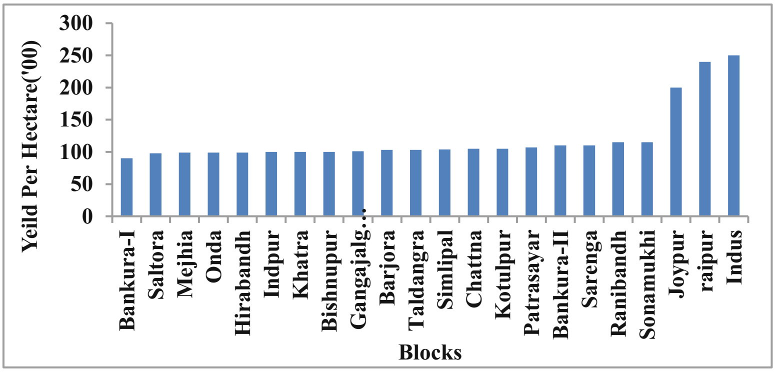

Fig. 2.14 Agricultural productivity of Bankura in 2014 (Source: District Annual Plan for Agriculture 2014, WB)

recognized as extreme to severe (ES) drought-prone region. Eastern portions of Purulia and Bankura are noticed with light and very light drought proneness. The remaining portions are moderate drought-affected region. Overall 22% of the study region is under extreme drought; 17% area of the study region is under severe drought. Light and very light drought-affected portions cover almost 40% of the total area of the region. The remaining portion (almost 21%) is at the condition of moderate drought. Table 2.7 denotes the respective pixel count and percentage area under different agricultural susceptibility zone.

2.3.2 Validation of the Results

To validate the AHP-based susceptibility zone map, the block-wise productivity data of 2014 has been utilized. The dataset was collected from the District Annual Plan for Agriculture (2014). This dataset is authentic and also utilized in a research paper by Patra et al. (2020). The eastern and southeastern blocks of Bankura are noted with higher rate of productivity (200–300 yield/hectare), whereas the northwestern and western blocks are identified with low productivity rate (50–100 yield/hectare) (Fig. 2.14). Similarly, the northeastern blocks of Purulia are identified with relatively

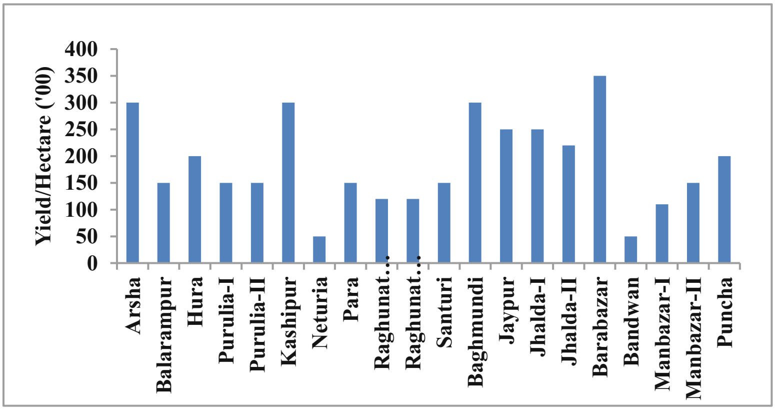

Fig. 2.15 Agricultural productivity of Purulia in 2014 (Source: District Annual Plan for Agriculture 2014, WB)

lower productivity rate (50–250 yield/hectare), and the remaining blocks are noted with relatively higher rate of productivity (250–400 yield/hectare) (Fig. 2.15). The visual cross-correlation study between the input variables with productivity shows that almost in all cases, over 70% correlation coefficient value is observed (Fig. 2.16). In all cases of agricultural drought indices, if indices value is less, it suggests drought, and vice versa. In all cases (as depicted in Fig. 2.16), agricultural productivity decreases with decreasing NDVI, NDWI, EVI, SPI, and VHI value. So, it is quite eviTable 2. that productivity is directly reflected by the agricultural drought. The portions which are highly drought-affected are identified with relatively lower rate of productivity.

2.4 Discussion and Conclusion

By utilizing different satellite-based indices, the research is able to demarcate agricultural drought susceptibility zone which is comparable with all India pattern. The possible causes of such agricultural drought susceptibility pattern are deeply rooted in the existing geo-environmental condition as well as global climate change (Chatterjee et al. 2016). The relationship with agricultural drought with ENSO (i.e., warm ENSO event represents weak Indian monsoon) has altered around 1990, and it experiences maximum positive relationship with the weakening of Indian monsoon (Kundu and Mondal 2019) which in turn affects the agricultural drought susceptibility. The changing relationship has been attributed by global warming induced southward shift in the Walker circulation anomalies and higher surface temperatures of Eurasia (Kumar et al. 1999). Alone ENSO event cannot truly express the variability of agricultural drought susceptibility pattern. The study of agricultural

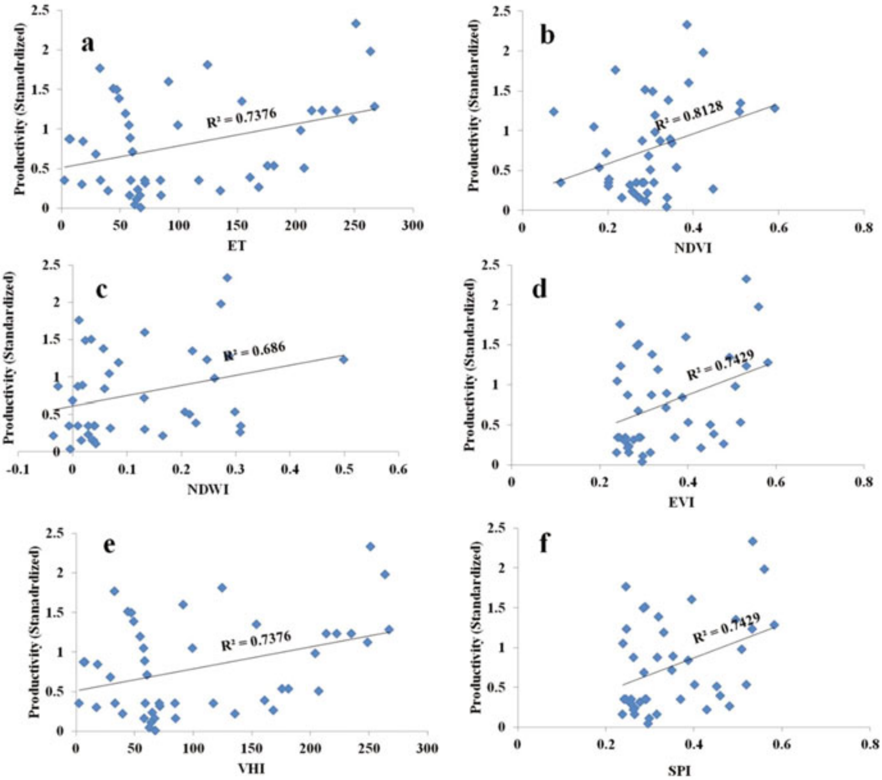

Fig. 2.16 (**a–f**) Cross-correlation with input variables with productivity

drought susceptibility in western region of West Bengal is devoted to the micro-level variability. The local-level factors such as occurrence of tropical disturbances (Dhar et al. 1981); topographic variables, i.e. elevation, slope, orientation, exposure, etc. (Basist et al. 1994); increasing concentration of aerosol resulting from higher level of urbanization; and air pollution (Ramanathan et al. 2005) lead to rapid changes in agricultural land use by means of initiation of irrigated agriculture (Douglas et al. 2006). The unplanned unsustainable use of pesticides as well as the rapid climate change induces the agricultural drought in India and also in Bankura and Purulia (Nair et al. 2003). The western and northwestern portions of Bankura and eastern and northeastern portions of Purulia are the extended portions of Deccan Traps which experience relatively low SPI, high evapotranspiration (ET), low Vegetation Health Index (VHI), and low Soil Moisture Condition Index (SMCI), and thus these portions of the study region face extreme to severe drought condition. The remaining portions are observed with relatively low drought proneness. Unplanned reduction of forest cover, as well as steep sloppy granitic terrain, makes the northwestern portions of Bankura and northeastern portions of Purulia more sensitive to drought. Steep sloppy granitic terrain is having fracture zones which cannot store sufficient quantity of groundwater (Sharma and Baranwal 2005). According to Ray and Shekhar (2009), the groundwater of Purulia and Bankura is restricted due to weathered fracture zone which is having secondary porosity. Secondary porosity is indicating a thick profile of in situ soft porous material developed as a disintegration product on the upper most part of the hard, consolidated rock due to weathering. The inconsistent monsoon as well as restricted groundwater haunts the agricultural production of Bankura and Purulia, and these phenomena simulate the agricultural drought in these regions.

A quick identification of different agricultural drought indices at a glance makes the study interesting and unique. The composite micro-level assessment of agricultural drought is recognizable for its unique spatial assessment. This research may also be useful to take actions for improved resiliency of the agricultural and water management infrastructure of Bankura and Purulia. The observed agricultural drought susceptibility zones demonstrate a potential risk to agrarian agricultural practices which is prevalent in the present study area. If necessary action is not taken immediately, drought will be the cause of less production which will ultimately affect the financial condition of farmers. Therefore, this study is an essential step to enhance drought risk management strategy and review of agricultural practices and water use in the study area.

Note: All tables and figures are prepared by authors themselves. No third party material was used.

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Chapter 3
Impact of Microclimate on Agriculture in India: Transformation and Adaptation

Rukhsana, Asraful Alam, and Ishita Mandal

Abstract Agriculture vulnerability to climate risks and its results on food security and farm livelihoods are well-known. Normally climate adaptation into policy landscape is necessary for achieving the pathway to sustainable development. Agriculture is highly dependent on prevailing weather conditions. Increased frequency of extreme weather events including droughts, cold waves, heat and cyclones, floods, hailstorms, strong winds, etc. has made agriculture more susceptible to climatic risks. Global warming and climate change are expected to have severe impact on agricultural production predominantly in the tropical and subtropical regions. Decreased crop productivity is affected by rising in temperature which caused shortened crop duration and increased respiratory losses. Agricultural production in India shows that production of Kharif crops suffers more. The annual mean, maximum, and minimum temperature rise since 1901–2019 were 0.61 °C/100 year, 1.0 °C/100 year, and 0.22 °C/100 year, respectively. On the contrary, annual precipitation was deviated about −20% from normal since 2000. Rising of winter temperature also squeezes the time span of grain filling for Rabi crops. Thus, both the crops lose their nutritional value to some extent. The irreversible microclimatic effects call forth the need of diversified cropping pattern with greater sustainability. Different policies and measures are already taken to secure sustainable, profit-maximizing agriculture. The agricultural system of India is deliberately driven toward the climate-smart agriculture to cope with the adverse effects of changing climate. Microclimatic modifications assist to rectify the unfavorable conditions prevailing in vicinity of the plants making it favorable for the better development, yield, and crop growth. In the present scenario of global warming and augmented extreme weather events, implementation of such microclimatic alterations in crop

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production is necessary to manage extreme weather risks and improve crop productivity to increase the food security and sustainability of agriculture under this changing climatic condition. This article aims to recognize the crop choices and diversifications that are practiced to counter the irreversible effect of microclimate and also to throw light on future agricultural practices in India.

Keywords Microclimate · Kharif crops · Rabi crops · Microclimatic effects Sustainable and profit-maximizing agriculture · Climate-smart agriculture

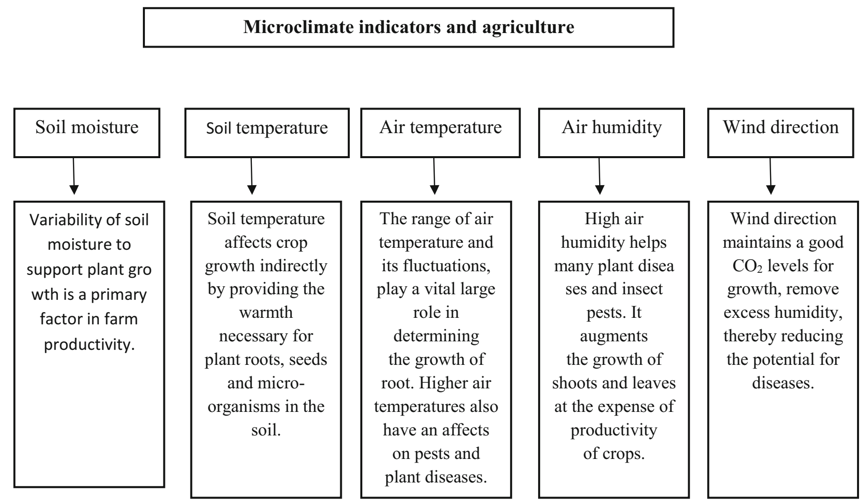
3.1 Introduction

Microclimate is a climatic condition examined in local areas near the surface of the Earth with environmental variables, temperature, humidity, wind speed, and light, which can give meaningful parameters for ecological activities and habitat selection (Naiman et al. 2005). The microclimate is very much closely associated with habitat and significant for organisms on a microscale. Nowadays, microclimate becomes an indispensable component in current research field because it influences ecological processes such as soil respiration, plant regeneration, selection of wildlife habitat, and nutrient cycle (Chen et al. 1999). The microclimate factors such as soil moisture, soil temperature, light intensity, soil acidity, air temperature, wind direction, and CO_2 level are very significant in aquaculture productivity. These factors can be constricted unnaturally to increase quality of crop cultivation and productivity (Bramer et al. 2018). The elevation of few meters from the surface is so vital for the climatic processes to get the sound potencies. The climatic pattern in this elevation is known as microclimate. Broadly the Earth can be divided into three zones; torrid, temperate, and frigid, based on insolation, pressure system, and wind regime. Within these broad zones, there are several micro-regions, which are unique in some of a kind. They provide a basis to a particular set of flora and fauna to flourish and determine the size of a community, growth, and survival of it in adjustable situation. Microclimate is not limited to only over-surface, but it can penetrate to subsurface also. Organisms live anywhere and everywhere where they make their own favorable microclimatic regions and can interact (Mislan and Helmuth 2008).

The rising of global temperatures with climate change does not only impact human health, but also it is a disaster for agriculture production and food security. Farming sectors become the most unbalanced sector because its production stability depends closely on the water sufficiency. The association between human activities and natural procedure in agricultural landscapes is required in order to progress and reinforce the adaptive capability in response to the climate change (Farina 1998). Increasing climatic risks on agriculture, human, food, and livelihood security emphasize the transformational pathway toward sustainable development. It is confirmed from the evidences that agricultural sector is much effected by changing climatic conditions (Auffhammer and Schlenker 2014; Lobell et al. 2011; Campbell et al. 2016; Khanal and Mishra 2017) austerity of which is expected to augment in the near future especially in developing nations being the most affected (IPCC 2012, 2014). Irregularity of weather and sudden arrival of weather extremes such as droughts, floods, etc. affect crop productivity through outburst of pest and diseases (Gornall et al. 2010; Easterling et al. 2007), soil productivity (Tang et al. 2008; Clair and Lynch 2010), water quality, moisture content, and resources (FAO 2011; Misra 2014; Malek et al. 2018). In the stage of urban revolution, rapid urbanization, injudicious use of land, and deforestation create man-induced change in climate (Abu Hatab et al. 2019). The microclimatic change is rather a negative change over cities. It shows the spread of many negative effects all over the world. If to consider Indian cities, the heat stress spreads over the urban areas (Agrawal et al. 2003; Pathirana et al. 2014; Vailshery et al. 2013). Gradual temperature rise, deficiency in rainfall, etc. are the common characteristics of this change. Besides human health, plants and animals are being affected by this change. The most alarming effect of it could be seen on agriculture because it puts question mark on a developing country's capability to carry a huge population with low production (Kang et al. 2009). Agricultural sector in India shares its only 14% in gross domestic product (GDP) and remains a major livelihood assist to more than 50% of the total workforce. In India, mostly agricultural system depends on southwest monsoon from June to September, with loss of huge food production for more than half of the year. Indian farmers are highly vulnerable to weather aberration due to high dependence on rainfall for irrigation, small land holdings, limited financial resource, and technology (Acharya 2006; Jain et al. 2015; Khan et al. 2009; Patnaik and Das 2017). It has been observed that over the years protracted breaks in southwest monsoon have augmented the frequency of droughts (Choudhury and Sindhi 2017; Udmale et al. 2015; Zhang et al. 2017). Spatial trend and variability of droughts that a move in droughts towards agriculturally important coastal south-India, Indo-Gangetic Plain and central Maharashtra (Mallya et al. 2016). Different studies related temperature and precipitation to a significant fall in the productivity of major crops like rice, wheat, millets, and maize in the country (Auffhammer et al. 2012; Guiteras 2009; Gupta et al. 2014; Kumar et al. 2014; Lobell et al. 2012; Sanghi and Mendelsohn 2008). As every organism has its own favorable environmental setting, therefore, it is natural to have different microclimate for various crops. It is necessary to know the role of the variables of microclimate on plant to further assess the impact of microclimate on Indian agriculture, to mitigate the ongoing problems, and to foster the crop production. Fall in crop productivity affects to food availability, prices, and farm revenues, which destabilize to socioeconomic progress in the rural economy. It has been seen that in India, there is an annual loss of agricultural income because of climate change which is estimated in the range of 15–18%, rising to 20–25% for unirrigated areas (GOI 2017a). Such disaster of climate change not only risks production, food security, and nutrition but also deteriorates the socioeconomic stability of rural economies which result to the social conflict, migration, poverty, and unemployment in the region (FAO 2016; Singh et al. 2014).

3.2 Concept of Microclimate

The microclimate that prevails just few meters over the ground can be accused for potential heat and moisture exchange to the upper macroclimatic systems. There is a difference between macro- and microclimate. Macroclimate is the homogenous layer of air mass over the ground where no or little change of characteristics happens horizontally. On the other hand, microclimate is that climate near the ground which is being modified by the terrestrial properties, be it a bare ground or vegetated. Climate that surrounds an organism or a region, influences and is influenced by the features of it (Holmes and Dingle 1964). Microclimate is the complex system of many variables (Rosenberg et al. 1983). These variables together in horizontal and vertical dimension form different microclimatic conditions and microhabitats and hence support major proportion of life forms (Mislan and Helmuth 2008). This system of variables includes radiation, air temperature, surface temperature, humidity, wind, CO_2 concentration, etc. (Behera et al. 2012; Jones 1993). Every living being requires a particular setting of these variables coupled with morphological variables like relief, orientation, aspect, etc. forming a certain ambience to grow. The extent of any microclimate is based on perspectives; it could be 1 m to several hundreds of kilometers according to the distribution of a certain life form in consideration (Mislan and Helmuth 2008). For example, a tropical forest has a definite situation, so also a desert, grassland, rural and urban region, etc. have their own microclimatic conditions (Behera et al. 2012; Rao 2009).



These five indicators of micro climate promote the crop growth, hereafter agriculture.

3.3 Impact of Microclimate on Agriculture

Crop production is highly sensitive to climate, which is affected by long-term trends in average temperature and rainfall variability and extreme weather events (IPCC 2012). Microclimate is that system which influences that particular environment both directly and indirectly. The phenomenon that climatic variables influence agriculture is not unknown. However, it is high time to assess the climatic modifications and subsequent effect on agriculture. In this era of global warming, the climate changes itself and the impact of that on agriculture is noteworthy.

Since the Green Revolution, mainstreamed agriculture has principally concerned on controlling crop varieties, pests with chemical pesticides, and soil fertility by application of chemical fertilizers, but the impact of this type of agriculture on the environment has been severe. Wheat, rice, maize, and barley, which were once rare plants, have become the leading crops on Earth (FAOSTAT 2014). In agriculture depleted of soil organic carbon, which is difficult to increase yields for higher produce. Soil erosion destroys the 10 million hectares of cropland each year; 40% of this loss is due to tillage erosion (Pimentel 2006). The increasing frequency of extreme weather events due to global warming causing climate changes has resulted climatic risks in agriculture. Inter- and intra-seasonal weather variability and extreme weather events such as floods, heat, cyclones, hailstorms, cold waves, strong winds, droughts, etc. have augmented over the recent decades (Singh and Kalra 2016). Burning of fossil fuels, deforestation, agriculture, and industrial processes are major processes, which contribute toward climate change. Among various greenhouse gases, carbon dioxide shares by 76%, methane by 16%, nitrous oxides by 6%, and chlorofluorocarbons by 2% (IPCC 2014). Agriculture shares 28% of the Indian greenhouse gas emissions through methane emission from paddy fields, enteric fermentation in ruminant animals, and nitrous oxides from application of manures and fertilizers to the soil (Aggarwal 2008). Global temperature that increased by 0.85 °C during the last 100 years has been recorded, and average precipitation has been noticed over different regions of the Earth, which result in melting of polar ice and glaciers leading to increase in sea levels and floods over various regions (IPCC 2014). Global circulation models expected a rise of about 2 °C in global average temperature by 2100. Although total precipitation is also projected to be increased during Kharif season, trends may vary at local level. Similarly, atmospheric CO_2 concentration is predicted to increase from 478 to 1100 ppm by the end of the twenty-first century. Global warming and climatic changes are anticipated to rise in future (IPCC 2007).

Based on the global annual mean temperature of the period 1951–1980, the global land-ocean temperature trend has been presented by Goddard Institute for Space Studies Surface Temperature product version 4 (GISTEMP v4), in black line. According to which the global temperature is rising definitely (Lenssen et al. 2019) (Fig. 3.1). The southern hemisphere also becoming hot but due to large water mass and differential specific heat of water, although southern hemisphere is less warm than northern hemisphere (Fig. 3.2).

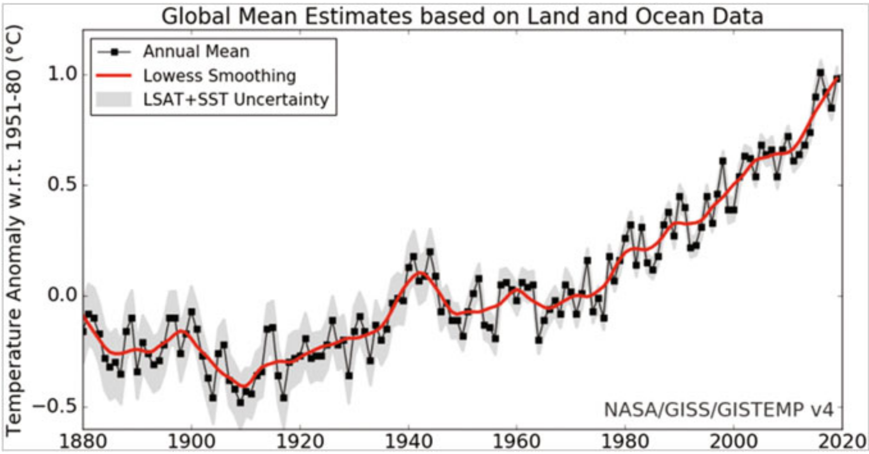


Fig. 3.1 Global mean estimates based on land and ocean data. The graph is showing Land-Ocean Temperature Index from 1980 to 2020 based on the period of 1951–1980. The solid black line shows global annual mean, and the solid red line shows the 5-year LOWESS. The gray zone signifies the total annual uncertainty of land surface air temperature and sea surface temperature data at 95% confidence interval. (Source: NASA, https://data.giss.nasa.gov/gistemp/graphs_v4/#, NASA 2020)

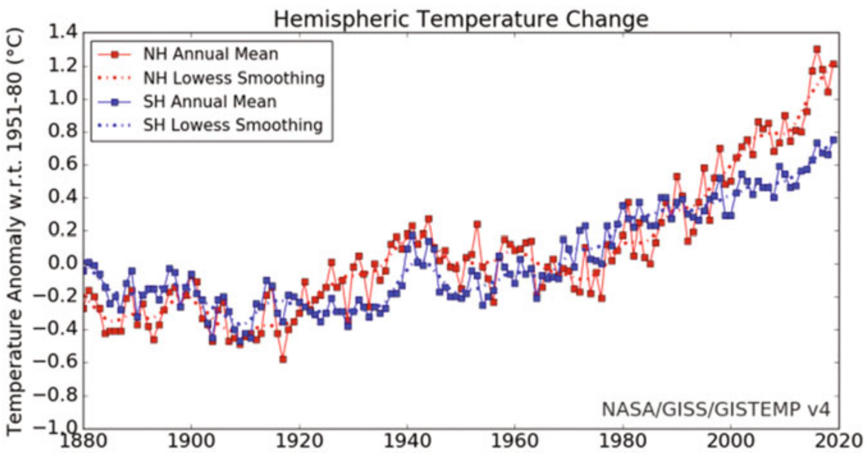


Fig. 3.2 Hemispheric temperature change. Trend of hemispherical temperature anomaly is shown for northern hemisphere (in red continuous line) and southern hemisphere (in blue continuous line) with respect to the 1951–1980 level. The dotted lines (red for northern hemisphere and blue for southern hemisphere) show 5-year LOWESS to find out the best fit for the time plot depicting the rising trend of temperature of both hemispheres based on land and ocean data. (Source: NASA, https://data.giss.nasa.gov/gistemp/graphs_v4/#, NASA 2020)

Table 3.1 Climate impacts on selected crop yields, globally and in tropical areas, under warming of 1.5 and 2 °C above pre-industrial levels over the twenty-first century

Crop	Region	Increase over pre-industrial temperatures (%)	
		1.5 °C	2.0 °C
Wheat	Global	2 (−6 to +17)	0 (−8 to +21)
	Tropical	−9 (−25 to +12)	−16 (−42 to +14)
Maize	Global	−1 (−26 to +8)	−6 (−38 to +2)
	Tropical	−3 (−16 to +2)	−6 (−19 to +2)
Soybean	Global	7 (−3 to +28)	1 (−12 to +34)
	Tropical	6 (−3 to +23)	7 (−5 to +27)
Rice	Global	7 (−17 to +24)	7 (−14 to +27)
	Tropical	6 (0 to +20)	6 (0 to +24)

Note: The figures in parentheses indicate a likely (66%) confidence interval
Source: FAO (2016), Table no: 1

If the temperature continues to increase in such a manner, it will cross the 1.5 °C level soon. In 2016, the temperature anomaly had reached to 1.01 °C. Under the warming of 1.5 °C, the main cereals will be highly affected and will lose their yield. The tropical regions would be more vulnerable in this sense. Table 3.1 shows the decrease in yield with increase in temperature by 1.5 and 2.0 °C. Strikingly, the production and yield of soybean seem to increase in totality, and rice production as it is largely dependent on rainfall amount will be more or less same (FAO 2016).

According to IPCC (2018), the global mean surface temperature is increased to 0.87 °C in 2006–2015, relative to 1850–1900, and the human-induced warming, in 2018, has reached to 1 °C, which is an alarming threat to crop production in all scales. Also, the greenhouse gases have made a record in 2018: for CO_2 level it is approximately at 407.8 ± 0.1 ppm, 1869 ± 2 ppb for methane, and 331.1 ± 0.1 ppb for nitrous oxide. These three influential greenhouse gases have reached to 147%, 259%, and 123%, respectively, in 2018 of pre-industrial level (WMO 2019). The positive impact on agriculture is high growth and productivity of crops due to high CO_2 concentration. This phenomenon is called carbon fertilization effect (Kimball 1983; Kumar and Parikh 2001). But the temperature rise in warmer months or in tropical region may lead to dwindling crop duration, which may affect crop phenology, increased evapotranspiration, occurrence of heat waves, agricultural drought, soil degradation, etc., and on the other hand, the global sea level rise would lessen the coastal arable land area; hence coastal agricultural microclimate would be in danger (Aggarwal 2008; Teixeira et al. 2013). Not only that, simple agrarian practices such as leaving crop residuals on the field or shading can also modify the microclimate of a crop which in turn puts a control over crop growth. Crop residuals increase the temperature of the soil surface during night and make it less warm and humid during daytime. Thus, it helps in lowering the evapotranspiration and wind speed and eventually in saving the soil moisture. While it makes positive imprints on winter crops or dry farming, it puts negative impact on cropping region as the optimal temperature of soil for seedlings to come up is reduced (Hatfield and Prueger 1996; Tanny 2013). All these changes are likely to have severe insinuations on agricultural production especially in the tropical and subtropical regions including India. Hatfield and Prueger (2015) recorded that more extreme temperature events will significantly affect plant productivity (Barlow et al. 2015). Crop production in India is likely to be reduced by 10–40% in spite of the valuable effects of higher CO_2 on crop growth. Wheat production of India can be decreased by 4–5 million tons due to every 10 °C increase in temperature; however, timely planting can reduce these losses to 1–2 million tons (Aggarwal 2008).

The global change in climate and agriculture may also be reduced to regional level. The mean land surface air temperature for India in 2019 was 0.36 °C above average (1981–2010), which set another record for one of the warmest years since 2005. The annual mean, maximum, and minimum temperature rise since 1901–2019 were 0.61 °C/100 year, 1.0 °C/100 year, and 0.22 °C/100 year, respectively. In addition, annual precipitation departed about −20% from normal since 2000 (IMD 2020). Moreover, long rainy spells across the country except northeast have been replaced by prolonged dry spells with drought condition and short-duration extreme rain events over number the moderate precipitation events since 1951 (Dash et al. 2009). This kind of intensified short-lived weather extremes and drought may cause the lower yield of Kharif crops (Auffhammer et al. 2012). The yield of Kharif crops is largely dependent on the nature of various agroclimatic zones. Many studies revealed a positive correlation between temperature rise along with precipitation and rice yield. It is evident that Kharif crops are more sensitive to annual and seasonal departure from the normal climatic condition than the Rabi or winter crops (Barnwal and Kotani 2013; Mall et al. 2006). Increased CO_2 concentrations can contribute to stabilize and to increase the plant growth and production near about 10% with doubling of CO_2, but sharp rise in temperature of about 2 or 3 °C may suppress it, and that can be vulnerable to crop duration and biomass accumulation, especially in arid and semiarid regions of northwestern India (Lal et al. 1998). Similar study done in selected areas in Kerala also reveals the same (Saseendran et al. 2000). Not only rice yield, production of other Kharif crops like maize, sorghum, etc. would have to face the difficulty, depending upon regions. In contrast to these, coconut farming would increase as coconut trees produce one leaf and inflorescence in 1-month interval, hence having enough time to accumulate biomass in rising temperature through photosynthesis (Naresh Kumar et al. 2011). Most of the Rabi crops are sown as intercrop in India; after harvesting a Kharif crop, the field also needs to be prepared for a crop with less water requirement. That is why Rabi crops are lately sown in India, which pushes the whole cycle to warmer climate. Crops like wheat, which are exposed to temperature >34 °C, are accelerated toward early senescence, or it can be said that they matured in short time span. Simulations show that about +2 °C temperature rise can lower the yield about 50% (Lobell et al. 2012), especially in growth stage (Pramanik et al. 2018). Again, in vegetative phase, low temperature than optimal inhibits seedlings to grow properly. As the moderate rain events are about to limit in number, there would be a chance to have water stress also in future (Kohli and Saini 2003; Lal et al. 1998). Results are also similar for other crops like maize (Byjesh et al. 2010), chickpea (Chakrabarti et al. 2013; Pal et al. 2008), sorghum, oilseeds, etc. (Krishna Kumar et al. 2004).

Thus, agriculture is highly dependent on climatic conditions, but noteworthy fluctuations and increased frequency of extreme weather conditions have made it more vulnerable by augmenting climatic risks in crop production. Under such conditions, there is awful need to administer climate change impacts on crop production to ensure food security along with sustainability of natural resources. Since rise in temperatures reduces crop yield, it is essential that suitable adaptation strategies should be developed to reduce the adverse impacts (Rao and Rao 2016).

3.4 Crop Choices Based on Various Microclimate Regions in India

Variability of climate affects crop yields at global level, and yield is characterized as highly dependent on crop type, irrigation, and location. Under the early mentioned warming circumstances over Indian subcontinent, the agricultural sector is likely to be affected much unless that effect is checked to some extent through some adaptations. Crop portfolio choice or crop choice is one of those adaptations. Depending on the prevailing and upcoming change of temperature and moisture content of a region, farmers choose to harvest some crops over some risky crops that are not climate resilient enough. For example, for an area (arid or semiarid) experiencing higher temperature than normal associated with recurrent drought, the farmers would have to choose drought-resistant, faster-maturing crops like sorghum. Although the choice of crops does not solely depend upon climate, there are some other factors behind it including soil characteristics, topography, wealth of farmers to bear risk, economy, etc. (Burke and Lobell 2010). To cope with the adverse climatic condition or to be benefitted by the condition, farmers in developing countries often do this through intercropping and mixed cropping system.

The poor rural farmers in India might choose less risky crop choices that would lessen their production and income but would save from huge loss. In contrast, the wealthier farmers would seek for risky crop choices as they have enough capacity to investment in capital-intensive agriculture (Dercon 1996; Lamb 2002). Not only in India, South American farmers also switch from maize, wheat, and potatoes to fruits and vegetables due to the advent of warmer climate (Seo and Mendelsohn 2008). In a study over semiarid region of India (Khanal and Mishra 2017), authors found out riskiness of each crop (beta coefficient) harvested there along with food crop portfolio index or crop choice on the basis of beta coefficients. According to that, the smaller the coefficients, the more neutralizing effect on revenue can be seen, and vice versa. Food crop portfolio index (calculated by averaging the beta coefficients) also follows the same manner. That means the higher the index value, the more prone that crop or group of crops is to risk of climate change, and poor farmers cannot afford that uncertainty. This will surely be imprinted on global subsistence agriculture also (Morton 2007).

India is divided into five agricultural regions based on climate, soil, topography, natural vegetation, crops, etc. by ICAR. These are temperate Himalayan region (eastern region where tea and paddy cultivation is prominent and western region where horticulture including fruits, potatoes, maize, and in some places paddy is cultivated), dry northern wheat region (comprises of parts of Punjab, Rajasthan, western U.P., western M.P. where barley, gram, maize, and cotton are chief crops), eastern rice region (comprises most of the eastern states of India where aside from rice, jute, and sugarcane, tea is also cultivated), Malabar coconut region (coconut, spices, and rice are the main crops), and southern millet region (comprises southern U.P., southern M.P., parts of Andhra Pradesh, Karnataka, and Tamil Nadu where millet, cotton, groundnut, sorghum, etc. are main crops). These regions are named after the dominant crop (Randhawa 1958). In a recent study (Mittal and Hariharan 2016), Indian states are grouped into some agroecological regions based on same factors in changing platform. It is observed that the share of cropped area by the dominant crops is reducing and occupied by high-value crops like potatoes, onions, cotton, and fruits and vegetables. On the other side, maize is introduced to the rice-producing states; strikingly the area covered by sugarcane in low irrigated arid region increases. From the temporal analysis, it is found that arid and semiarid areas are likely to diversify crop choices than humid areas (Ramasundaram et al. 2012), though another study reveals the high level of diversified crop choices in humid regions of West Bengal (Bhattacharyya 2008; De and Chattopadhyay 2010), Karnataka, Andhra Pradesh, and Maharashtra toward cash crops than arid and semiarid regions (Mukherjee 2012). In Assam, this picture is same as the recurrent flood-prone areas having more crop choices, mainly Rabi crops. That might owe to vagaries of monsoon, weather extremes, relief, and other factors (Mandal and Bezbaruah 2013). It is clear from the above discussion that the entire country is experiencing a climate change, and therefore to avoid that risk at different regional levels, farmers diversify their choices to have a certain amount of yield and income.

3.5 Transformation and Adaptation in Indian Agriculture

Green Revolution technologies, high-yielding grain varieties, fertilizer, pesticides, and irrigation facilities, have been introduced in India during the early 1960s. India succeeded in appreciably minimizing the number of poor populations living in poverty. By the early 1990s, India achieved being self-sufficient in food grain production, but not everyone has enough access to the food produced. India is still the country with the poorest population in the world which shows that India has 300 million poor people of its 1028 million people in 2001. Indian agriculture covers 37% or as much as 40–50% of the Earth's land surface which is very much significant, but it is presently facing many major defies such as declining net sown area, degrading soil quality, declining of per capita land availability, stagnating productivity levels, and the adverse effects of climate change. Climate change is a major issue in agriculture all over the world, but developing countries like India are more vulnerable due to pressure of huge population dependent on agriculture, poor coping mechanisms, and excessive pressure on natural resources.

After independence, India has gone through many changes starting from the land reform. High-yielding crops replaced our previous crop varieties. Mainly wheat, rice, millets, and maize were those crops, which brought Green Revolution in India. Afterward, many multipurpose projects, agricultural institutes, seed banks, credit system to farmers, and other planning were implemented (Randhawa 1986). However, that created regional inequality in terms of production and income generation. Population explosion added further fuel to it leading to pseudo unemployment, large number of marginal workers, and so on. Opportunity in nonagricultural sector in rural India provokes people to change occupation. In 1951, there were 69.7% workers engaged in agriculture, whereas in 2011, there were only 54.6%. Some economists and policy makers thought that release of pressure from agriculture would be beneficial for it (Dev 2018).

To minimize the adverse climatic effect, ICAR launched a project named National Innovations in Climate Resilient Agriculture (previously named National Initiative on Climate Resilient Agriculture). Under this project, Free Air Temperature Environment, Carbon dioxide Temperature Gradient, Automatic Weather Stations, etc. are some achievements. Planning for different sowing dates to deal with pest attacks, android applications to disseminate advices, simulation studies for crops which are likely to adapt changing climate, crop improvement, improvement and management of microclimatic environment, etc. have been done in this context (ICAR 2018). The area under Kharif crops is reduced in contrast with Rabi crops, and the interesting thing is that the productions of both the types are almost same (125.09 million tons and 126.47 million tons in 2015 and 2016, respectively). More area is engaged to diversified crop choices, mostly among Rabi crops. High-value cash crops such as fruits and vegetables and plantation crops are getting more importance in today's life, and the area production of those crops shoot up. Climate-resilient crops like soybean, maize, and millets are introduced in humid regions. Government is aiming for doubling the farm income by 2022 by shifting the focus on high-value crops (Ministry of Agriculture & Farmers Welfare & Agriculture 2017). For this purpose, the government launched a program named "Sankalp Se Siddhi" to spread awareness to people (ICAR 2018). According to Dev (2018), about 86% of total agricultural holding is small sized and marginal in nature. That can be a reason for low production and yield. In addition, these farmers avoid high-technology and management practices for very low accumulation of wealth. For that, the Government of India adopted credit system, seed banks, and institutes for spreading technical know-how and other facilities everywhere. As income-generating sector, it helps rural people to cope with unemployment. It constitutes about 8.6% share of GDP in 2015–2016. The poverty alleviation effect of agriculture opens up the door for inclusion of any kind and equity (Chand 2019; Ministry of Agriculture & Farmers Welfare & Agriculture 2017).

Fragmentation of holdings, unbalanced use of fertilizers, climate change, rapid urbanization, fast-growing nonagricultural sector, etc. exert pressure. The deterioration of ecological balance in agricultural microclimate calls for sustainable practices.

According to Khan et al. (2009), the evergreen farming can only be the way to sustainability. It takes care of all the spheres of biotic and abiotic world and makes it environmentally sound and ethical. The conservation agriculture works based on minimum mechanical soil disturbances, permanent soil cover, and crop rotation. Minimum or zero tillage reduces mechanical soil disturbance, and the soil manages water and air circulation within it by its own biological tillage. It also helps in accretion of soil preventing soil erosion. Diversified crop rotation process promotes food security and enriched biodiversity in a concerned microclimate, recycles soil nutrient, and inhibits pest attacks through life cycle disruption. It also increases soil organic carbon, which can be done efficiently by leaving crop residue on the field. In India conservation agriculture achieves a certain position in wheat production (Bhan and Behera 2014; Srivastava et al. 2016). This agriculture is termed as climate-smart agriculture by FAO in the context of food security in Hague Conference 2010. It comprises six major components (energy smart, carbon smart, knowledge smart, weather smart, nitrogen smart, water smart) to conserve and maintain the environment and microclimate, reduce greenhouse gas emission, make people adapt to the change, and to take precautionary measures for extreme weather events through forecasting (Pal et al. 2019).

To ensure producers against crop market fluctuations, our country has come up with minimum support price (MSP), which guarantees to give minimum money for production. This MSP is fixed based on market demand and supply. Besides this tariff rate, insurance (Pradhan Mantri Fasal Bima Yojana), warehouses, market policies (Dalwai 2018), conservation of water by rainwater harvesting (Gupta et al. 2011), and other measures are adopted based on regional need (Khatri-chhetri et al. 2017). Adaptation of potential policies contains efficient use of natural resource like water which is highly critical for adaptation to climate change, along with developing strategies for cultivars tolerant to heat and resistant to flood, drought, and salinity stresses and improving water management, enhanced crop management practices, modified pest management, better weather forecasts, and enhanced technological knowledge of farmers. Diversification of crops is needed to grow more cultivation for farmers' betterment to increase income and exert less pressure to the natural resource base. Adaptation strategies can alternative from short-term coping to longer-term aim to meet more than climate change targets and be successful in modifying harm (Moser and Ekstrom 2010).

3.6 Future of Indian Agricultural Practices Due to Climate Change

The rising temperature, heat waves, and drought conditions associated with prolonged dry spells over Indian subcontinent could hamper agricultural sector. As a developing country, India needs the stability in agriculture to feed its citizens. Different simulation studies show that the country is experiencing climate change and the arid and semiarid regions will be affected more (Rao 2009). Eastern region is also about to face more rainfall; hence flooding will not be an occasional phenomenon (Bandyopadhyay et al. 2016). Intensive and injudicious use of land, water, and other resources puts a question mark on the future of agriculture, whether it could provide food for all. In this context, conservation agriculture or climate-smart agriculture is the only way to secure environment and crop production. In India, there is a little open up for conservation agriculture till now (within Indo-Gangetic Plain), but the facilities given by and awareness programs held by the government created an impetus toward it (Bhan and Behera 2014). Kharif crops especially rice dominated the country in the past years. The abnormality and regional inequality in rainfall may induce unequal rice production throughout a year (Naresh Kumar et al. 2014; Yadav et al. 2017). Moreover, the decelerating growth in terms of area and production gives a clue that the whole system is tending toward Rabi crops. Late sowing Rabi crop like wheat gives low yield while exposed to higher minimum temperature than normal. So preparation of proper crop calendar synchronized with new climate is needed (Naresh Kumar et al. 2014). Among the Rabi crops, drought-tolerant crops and varieties stood higher in queue. On the other perspective, cereal crops are cultivated most (Mittal and Hariharan 2016) than the non-cereal crops. In 2016–2017, horticulture crops set a new revolutionary record (Dev 2018). Besides cash crops (Birthal et al. 2020), there is need to look after the production of pulses, oilseeds, etc. also, since they help in nitrogen fixation to improve soil and plant health (GOI 2017b). The areas, which are vulnerable to drought in recent climate change scenario, should be covered with irrigation facilities with judicious water and power management. The recurrent flood-prone areas of eastern region require diversification and intensive cultivation within limited flood-free season (Baishya et al. 2019; Mandal and Bezbaruah 2013). Therefore, it is clear that our agriculture is shifting with climate, and that is necessary to cope with adverse effects of climate. Through sustainable practice a balance between biotic and abiotic components of nature can be done. Research and technologies will support for the cause.

3.7 Conclusion

India is bestowed with diversified topography, climate, and biosphere comprising different regions. In agricultural perspective, relief, soil, availability of water, climate, crop choices, etc. make a region beneficial for a certain crop. Thus, India is divided into some agricultural regions by ICAR. However, dividing the country into various microclimatic regions is troublesome as there is no clear-cut demarcation of region for all crops. The changing climate compels farmers to shift from monoculture to diversified agriculture. Through different technologies, facilities, and adaptations, every region wants to be self-sufficient in food and income generation. There is an urgent need for sustainable thinking in addition to doubling the farmer's income. Global warming drives us at that stage where most of the low-lying areas of our country will submerge under water and a reduction of arable land is about to happen. Not only that, vagaries of monsoon and extreme events will make natural resources difficult to utilize ubiquitously (Swaminathan and Rengalakshmi 2016). That change cannot be reversed back, so adaptation and conservation in new setting need to be done. For that, people's participation is needed. There is a scope for further study to find out the microclimatic regions for each crop first to know which crop thrives well in a particular setting. The impact of climate on each crop should be assessed in current condition and in changed environment. The diversification will be based on crop choices, which are suitable for climate-smart agriculture across the country. There is also a gap of how agricultural practices modify each zonal microclimate and that in return promotes yield. These fields will be the further development in this context.

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Chapter 4
Characterization of Spatial Variability of Soil Properties of Malda District in West Bengal, India

Tapash Mandal, Jayanta Das, Debapriya Poddar, and Snehasish Saha

Abstract Understanding soil fertility status is crucial for fertilizer management and sustainable crop production. A study was conducted in the Malda district of West Bengal in 2019 to evaluate the nutrient status of surface soil. A total of 45 composite surface soil samples were collected at a depth of 15 cm, and the actual location of the sampling sites was detected by GPS. The soil fertility parameters such as soil pH, available nitrogen (N), available phosphorus (P), available potassium (K), organic carbon (OC), electrical conductivity (EC), available boron (B), available zinc (Zn), available iron (Fe), available manganese (Mn), available copper (Cu), and available sulfur (S) were analyzed and categorized as low, medium, and high using nutrient index (NI). The spatial distribution of parameters was mapped by inverse distance weighted (IDW) interpolation method. The coefficient of variation (CV) showed that P, K, EC, B, and Cu were highly heterogeneous (CV > 33%). The soil pH reveals that most of the surface soil samples of the study area are neutral and slightly acidic. Available phosphorus, potassium, iron, manganese, and sulfur are more or less satisfactory, whereas widespread deficiencies were observed for nitrogen (54.25%), organic carbon (65.76%), boron (100%), zinc (64.31%), and copper (7.5%) in the study area. More precisely, multinutrient deficiencies were observed in Barind region of the study area that noticeably influenced the productivity of crops.

Keywords Soil fertility · Nutrient index · Sustainable crop production · Malda

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4.1 Introduction

Soil is an important natural resource for the production of crops, plant growth, subsistence of life, and the socioeconomic development of human beings (Mandal et al. 2020). It is dynamic in nature, and its trend is determined by the interaction between chemical, biological, physical, and anthropogenic processes (Salgado-Velázquez et al. 2020). Knowledge of soil characteristics, soil fertility, distribution, and potential is extremely important for the strategic setting of irrigation, agricultural management, and optimum land use planning (Das and Bhattacharya 2015). However, for normal growth and accomplishment of their life cycle, plants require more or less 18 essential elements. Among these, 15 are taken from the soil as mineral form by plants or supplementary as fertilizers. Soil nitrogen (N), phosphorus (P), and potash (K) are the primary macronutrients of the soil and are used in great quantities, which set the fertility status of a soil. Available calcium (Ca), magnesium (Mg), and sulfur (S) are the secondary elements, required in smaller amounts than the primary nutrients, whereas boron (B), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) are micronutrient elements that normally occur in very small amounts in both soils and plants, but their role is equally important as the primary or secondary nutrients (Khadka et al. 2019). A deficiency of one or more of the above nutrients can lead to severe retardation toward growth, yield, and crop quality. Hence, for a better understanding of plant growth and the present soil fertility status and trend, wide-ranging knowledge of soil nutrients is mandatory (Dafonte et al. 2010).

However, the fertility of soil may vary from place to place to a bigger regional scale, probably due to the variation in soil-forming factors, which can be termed as intensive and external factors. Precipitation, crop rotation, soil management practices, slopes, soil characteristics, etc. are such soil-forming intensive and external factors that create varied soil fertility from one region to another (Cambardella and Karlen 1999). This may impact on the crop productivity and agricultural practices of any region in different ways. Soil survey helps to identify such extent of problems and potentials, which in turn help to work out the suitability of land for agricultural and non-agricultural uses (Aandahl 1958; Sehgal 1996). Thus, assessment of soil fertility may be the most elementary decision-making tool to plan effective land use systems (Havlin et al. 2010) to maintain soil dynamics to increase agricultural production and crop management performance (MacCarthy et al. 2013). Moreover, several parts of the district are experiencing the problems of arsenification, overuse of chemical fertilizers, intensive farming with traditional plus modern technology, and waterlogging. Therefore, it is very indispensable to evaluate the spatial variation and distribution of soil fertility properties of the district.

There are various methods available for evaluating the soil quality status and the spatial variability of soil fertility parameters in a region; among these, soil testing is most popular (Panda 2010). But the technique normally follows merged soil samples collectively forming into one mean sample collected from the field of proximal geographic locations. Hence, the results of such soil testing are not appreciated for site-specific recommendations and successive monitoring (Pulakeshi et al. 2012).

Maull's Griddle method, nutrient index, soil quality index, etc. are also being used by some researchers to identify soil fertility status where the specific soil nutrient status has been categorized into three groups, e.g., low, medium, and high (Mitchel 1977). However, for soil and water resources, improvement and management of some modern geospatial technologies, e.g., Global Positioning System (GPS) and Geographic Information System (GIS) have played an important role due to its immense potential (Rao et al. 1997; Das 2004; Majhi 2018). Geospatial techniques are very useful for acquiring the knowledge of distribution, characteristics, and variability of soil fertility for sustainable farming practices in an appropriate and precise manner (Liu et al. 2014; Desavathu et al. 2018). For agricultural productivity, enhancement, and management, it also plays an important role by site-specific management practices. Several researchers have more popularly assessed the soil fertility distribution using *inverse distance* weighted (IDW) *method*. Its simplicity and robustness make it the best interpolation methods (Goovaerts 1997, 2000; Cressie 2015).

4.2 Study Area

The study is conducted in Malda district covering 15 community development blocks from both the subdivisions, Chanchal and Malda Sadar. Malda, the gateway of North Bengal, lies between latitudes of 24°40′20″N to 25°32′08″N and longitudes of 87°45′50″E to 88°28′10″E. The district is surrounded by Murshidabad district in the south; North and South Dinajpur districts in the north; international border of Bangladesh in the east; Santhal Parganas of Jharkhand and Purnia of Bihar in the west; and the river Ganga in the southwestern boundary. The total geographical area of Malda district is 373,300 ha, out of which 283,714 ha (76.00%) is under net sown area. The main crops are grown in the summer monsoon season (June–September) which include rice (*Oryza sativa*), maize (*Zea mays*), jute (*Corchorus* species), sugarcane (*Saccharum officinarum*), and maskalai (*Vigna mungo*). In winter or retreat monsoon season (November–February), wheat (*Triticum aestivum*), gram (*Cicer arietinum*), masoor (*Lens culinaris*), khesari (*Lathyrus sativus*), rapeseeds (*Brassica juncea*), mustard (*Brassica campestris*), and potato (*Solanum tuberosum*) are the major crops of the district. The average annual rainfall of the district is 1485.2 mm for the period of 2000–2015, and the mean annual temperature varies from 27.2 to 30.6 °C (2000–2015). The cropping intensity of the district is very high (196%) and, therefore, dependency on the nutrient status of the soil is seriously concerned.

Based on relief characters, the district can be divided into three physiographic zones *Barind*, *Tal*, and *Diara*. *Barind* tract is rising and falling in nature, covering the district's 34.45% cultivable land. *Tal* is a low-lying region subject to seasonal deluge by the rivers, mostly during the rainy season, covering 32.34% of cultivable land. Diara is the result of fluvial actions maximum of the river Ganga, partially by Fulahar, Kalindri, Mahananda, etc. occupying 30.21% of the total cultivable land.

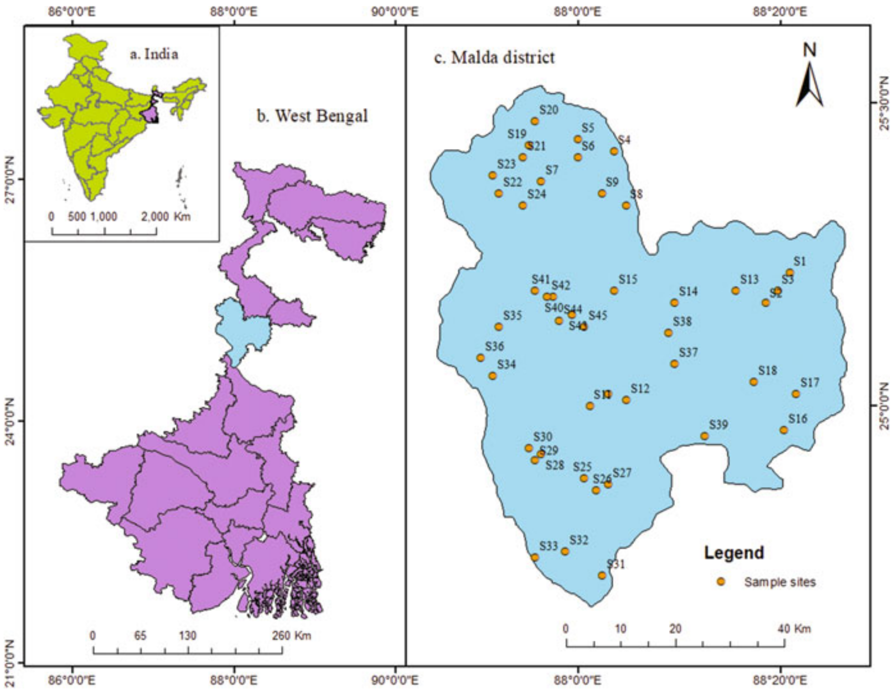

Fig. 4.1 Location map of the study area. (**a**) India, (**b**) West Bengal, and (**c**) Malda district with location of sample sites

Since the study area is located on the western portion of the alluvium-filled cracks in between the Rajmahal Hills on the west and the Garo Hills on the east, the entire area is covered by alluvium soil, which is of two different ages displaying different physical and physiographic characteristics (Sengupta 1969). *Barind* region is dominated by older alluvium, and Tal and Diara are dominated by newer alluvium. The district is divided into three different soil groups, i.e., (1) old alluvium soils (77,700 ha), (2) Vindhyan alluvial soils (17,130 ha), and (3) Ganga alluvial soils (243,540 ha). On the other hand, the district is receiving the major agricultural tracts of char lands of Ganga, i.e., parts of bars and flood plains associated with Mahananda-Tangan, Tangan-Punarbhava, and Fulahar-Ganga interfluves (Fig. 4.1).

4.3 Material and Methods

4.3.1 Collection of Soil Samples

A systematic survey has been conducted over the study area, and composite surface soil samples (0–15 cm depth) were collected from 15 community development blocks of Malda district. A composite soil sample of 8 to 10 core fixtures was followed and mixed for specific mean sampling. A total of 45 soil samples were incorporated from the various mouzas based on cluster sampling according to the variability of the crop production. Soil samples of high agricultural lands on an observation basis were considered as intake sites. The sample locations were tagged on the base map using a handheld GPS receiver during the autumn and winter since 2017–2019. After collecting, the samples were air-dried under the shade, processed and passed through a 2 mm sieve to get a homogeneous and uni-representative grade of solum, and sent to the laboratory.

4.3.2 Soil Sampling Analysis

The composite soil samples were tested in the District Soil Testing Laboratory, Malda, and Pedological Laboratory, Department of Geography and Applied Geography, NBU. The test results were used after simplification to maintain the association of degree of homogeneity in data character. However, the different soil parameters were tested using the following methods (Table 4.1).

Afterward, descriptive statistical computations on simplified and rounded off datasets were performed to assess the degree of variability for detailed study. The main objective of the study was to characterize the spatial variability of the soil properties in Malda district based on nutrient elements. The *nutrient index* (NI) method has been applied to evaluate soil characteristics. In this method, the individual nutrient status has been categorized into three groups: low, medium, and high. The basic and central theme of this method is constructed better by Parker et al. (1951) and is represented below:

Table 4.1 Soil properties and their measuring methods

Soil parameter	Methods	Reference
Soil pH	pH meter	Eckert and Sims (1995)
Available N	Kjeldahl	Bremner and Mulvaney (1982)
Available P_2O_5	Byer's method	Byers et al. (2005)
Available K_2O	Ammonium acetate	Jackson (1967)
Organic carbon	Walkley and Black method	Walkley and Black (1934)
Electrical conductivity	Electrical conductivity meter	Rhoades and Corwin (1981)
Available B	Hot water	Berger and Truog (1939)
Available Zn	DTPA	Lindsay and Norvell (1978)
Available Fe	DTPA	Lindsay and Norvell (1978)
Available Mn	DTPA	Lindsay and Norvell (1978)
Available Cu	DTPA	Lindsay and Norvell (1978)
Available S	Turbidimetric	Verma et al. (1977)

$$NI = \frac{(N_l \times 1) + (N_m \times 2) + (N_h \times 3)}{N_t}$$

where:

NI: Nutrient index
N_l: Number of samples of low nutrient category
N_m: Number of samples of medium nutrient category
N_h: Number of samples of high nutrient category
N_t: Total number of sample

On the other hand, the IDW interpolation method was used to generate the spatial variability maps of the different soil properties. The R 3.5.1 and Arc 10.3 software for Windows have been used for statistical analysis and mapping purposes.

4.4 Results and Discussion

4.4.1 Descriptive Statistics of the Soil Properties

Table 4.2 depicts some statistical analysis parameters of different soil parameters, such as maximum, minimum, mean, range, first quartile, third quartile, mean, median, standard deviation (SD), standard error, variance, coefficient of variation (CV), skewness (C_S), and kurtosis (C_K) of 45 soil samples. According to the criteria recommended by Wilding (1985), there are three variable classes, i.e., most (>35%), moderate (15–35%), and least (<15%) in the district. The analysis of variability reveals the phosphorus, potassium, and electrical conductivity are extremely variable, whereas pH is least variable. The rest of the fertility parameters are moderately variable in the district (Table 4.2). In general, soil pH and organic carbon (OC) are considered as the stable parameters of soil (Bouma and Pinke 1993). Skewness is a measure of the degree of symmetry or asymmetry in any given dataset. As per results, the skewness of the different soil fertility parameters of the study area varied from −0.64 (boron) to 1.16 (electrical conductivity). So, it can be inferred that the data are skewed in nature since the value of the skewness coefficient (Karl Pearson's) is not smaller than zero and the majority of the soil parameters are positively skewed. Additionally, most of the parameter's mean is greater than the median of the datasets, enough provision as skewed. Comparable results are obtained from the kurtosis of the time series data and varied from −1.35 for nitrogen to 1.99 for copper. Since the values are lesser and greater than zero, the kurtosis is not mesokurtic (normal distribution).

Table 4.2 Descriptive statistical analysis of the sample soil properties of Malda district

Statistic	pH	N	P	K	OC	EC	B	Zn	Fe	Mn	Cu	S
Data size	45	45	45	45	45	45	45	45	45	45	45	45
Maximum	8.30	372.40	222	549	0.84	0.79	0.12	0.81	9.30	4.20	0.52	5.10
Minimum	5.20	131.30	16	18	0.25	0.07	0	0.28	5.20	2.30	0.09	2.20
Range	3.10	241.10	206	531	0.59	0.72	0.12	0.53	4.10	1.90	0.43	2.90
First quartile	6.10	231.30	64	188	0.42	0.17	0.07	0.42	6.30	2.60	0.18	3.20
Third quartile	7.60	348.60	125	281	0.55	0.33	0.11	0.61	7.8	3.40	0.28	4.20
Mean	6.88	280.39	92.60	244.58	0.49	0.29	0.08	0.51	7.08	3.10	0.24	3.76
Median	6.90	241.60	80	228	0.46	0.26	0.08	0.52	6.8	3.10	0.23	3.8
Standard deviation	0.93	66.16	45.53	100.06	0.14	0.16	0.03	0.14	1.16	0.57	0.08	0.74
Standard error	0.14	9.86	6.79	14.92	0.02	0.02	0.01	0.02	0.17	0.09	0.01	0.11
Variance	0.85	4279.98	2026.55	9790.02	0.02	0.02	0.01	0.02	1.31	0.32	0.01	0.53
Coefficient of variation (%)	0.13	0.23	0.49	0.41	0.27	0.53	0.31	0.28	0.16	0.18	0.33	0.19
Skewness	−0.15	0.11	0.75	0.95	0.5	1.16	−0.64	0.03	0.6	0.45	0.97	0.11
Kurtosis	−1.21	−1.35	0.20	1.57	−0.03	1.12	0.65	−0.73	−0.75	−0.82	1.99	−0.64

4.4.2 Spatial Distribution of the Soil Properties

The widespread variability of the soil fertility parameters is categorized into different classes to determine and demarcate the regions with their deficiency for their better management. The soil fertility parameters are grouped into different categories with the help of the nutrition index range, representing their amount in soil, and the area of each class.

4.4.2.1 Soil Reaction (pH)

The NI of sample soils for soil pH and their spatial variability are presented in Table 4.3 and Fig. 4.2a. The obtained results reveal the soil pH of the study area is ranged from moderately acidic (5.20) to slightly alkaline (8.30), which slightly differ from the standard limit for majority of the crops. From the agrarian point of view, soil pH ranging between 6.5 and 7.5 is optimum to maintain soil fertility (Daji et al. 1996; Dhale and Prasad 2009). From the areal coverage, it is observed that the majority of the soils in this area are neutral (48.75%) in character, followed by slightly acidic (33.54%), slightly alkaline (17.16%), and moderately acidic (0.55%) (Table 4.3). The neutral soils are mainly found in the middle-western and north-western part of the district covering parts of Gazole, Chanchal I, Chanchal II, Ratua II, Kaliachak II, and English Bazar and a little portion of Old Malda, Habibpur, Manikchak, and Kaliachak I and II blocks (Fig. 4.2a). Due to heavy rainfall in the monsoon season and high temperature in the summer, washing of soil has resulted in deacidification with increasing neutrality. Neutral to slightly acidic, and slightly alkaline, soil in the study area is quite prevalent. However, slightly acidic soil is comparatively higher than the other two types in the study area due to agroforestry and agricultural practices. Kaliachak II and III are having slightly alkaline soil owing to bank erosion and prolonged agri-practices and rainwash effects. However, Vasu et al. (2017) emphasize the nature of parent material, use of fertilizer, and microtopography for spatial variation of pH in an area.

4.4.2.2 Available Nitrogen (N)

From the analysis of available N content in the study area, it is found that there are two classes as low and medium are exist, and they are summarized in Table 4.3 and Fig. 4.2b. The estimated value of the available N content in the district varies from 130 to 370 kg/ha on average. It is also inferred from the results that the available N is low or deficit in the major portion (54.25%) of the study area with values <280 kg/ha, covering vast parts of Bamangola, Gazole, Habibpur, Kaliachak I, and Old Malda and a little part of English Bazar, Manikchak, Ratua I, Harishchandrapur I, and Chanchal I (Fig. 4.2b). The severe scarcity of nitrogen in the study area is observed mainly due to insufficiency of organic carbon content and increased rate of

Table 4.3 Parameter-wise soil nutrient index classes and their salient features

Parameter	Value	Rating	Area (sq km)	Percentage of area
Soil pH (%)	5.2–5.5	Moderately acidic	20.47	0.55
	5.5–6.5	Slightly acidic	1251.98	33.54
	6.5–7.5	**Neutral**	**1819.98**	48.75
	7.5–8.30	Slightly alkaline	640.57	17.16
Available nitrogen (kg/ha)	131–280	**Low**	**2025.23**	54.25
	280–372	Medium	1707.76	45.75
Available phosphorus (kg/ha)	<45	Low	58.33	1.56
	45–90	Medium	1607.4	43.06
	>90	**High**	**2067.28**	55.38
Available potassium (kg/ha)	<500	Low	362.33	9.71
	500–750	**Medium**	**3298.79**	88.37
	>750	High	71.89	1.93
Organic carbon (%)	<0.50	**Low**	**2454.76**	65.76
	0.50–0.75	Medium	1270.4	34.03
	>0.75	High	7.85	0.21
Electrical conductivity (dS/m)	<0.28	**Low**	**2157.41**	57.79
	0.28–0.40	Medium	1328.3	35.58
	>0.40	High	247.29	6.62
Boron (mg/kg)	<0.03	Low	12.96	0.35
	0.03–0.06	Medium	117.85	3.16
	0.06–0.09	**High**	**3236.28**	86.69
	>0.09	Very high	365.91	9.8
Zinc (mg/kg)	<0.41	Very low	337.77	9.05
	0.41–0.54	**Low**	**2400.86**	64.31
	0.54–0.67	Medium	963.07	25.8
	>0.67	High	31.3	0.84
Iron (mg/kg)	<6.23	Low	437.11	11.71
	6.23–7.25	**Medium**	**1747.76**	46.82
	7.25–8.27	High	1410.76	37.79
	>8.27	Very high	137.37	3.68
Manganese (mg/kg)	<2.77	Low	292.91	7.85
	2.77–3.25	**Medium**	**2706.74**	72.51
	3.25–3.72	High	673.91	18.05
	>3.72	Very high	59.44	1.59
Copper (mg/kg)	<0.20	Low	280.12	7.5
	0.20–0.30	**Medium**	**3347.65**	89.68
	0.30–0.40	High	94.82	2.54
	>0.40	Very high	10.4	0.28
Sulfur (mg/kg)	<2.93	Low	54.23	1.45
	2.93–3.65	Medium	1166.37	31.24
	3.65–4.37	**High**	**2382.36**	63.82
	>4.37	Very high	130.04	3.48

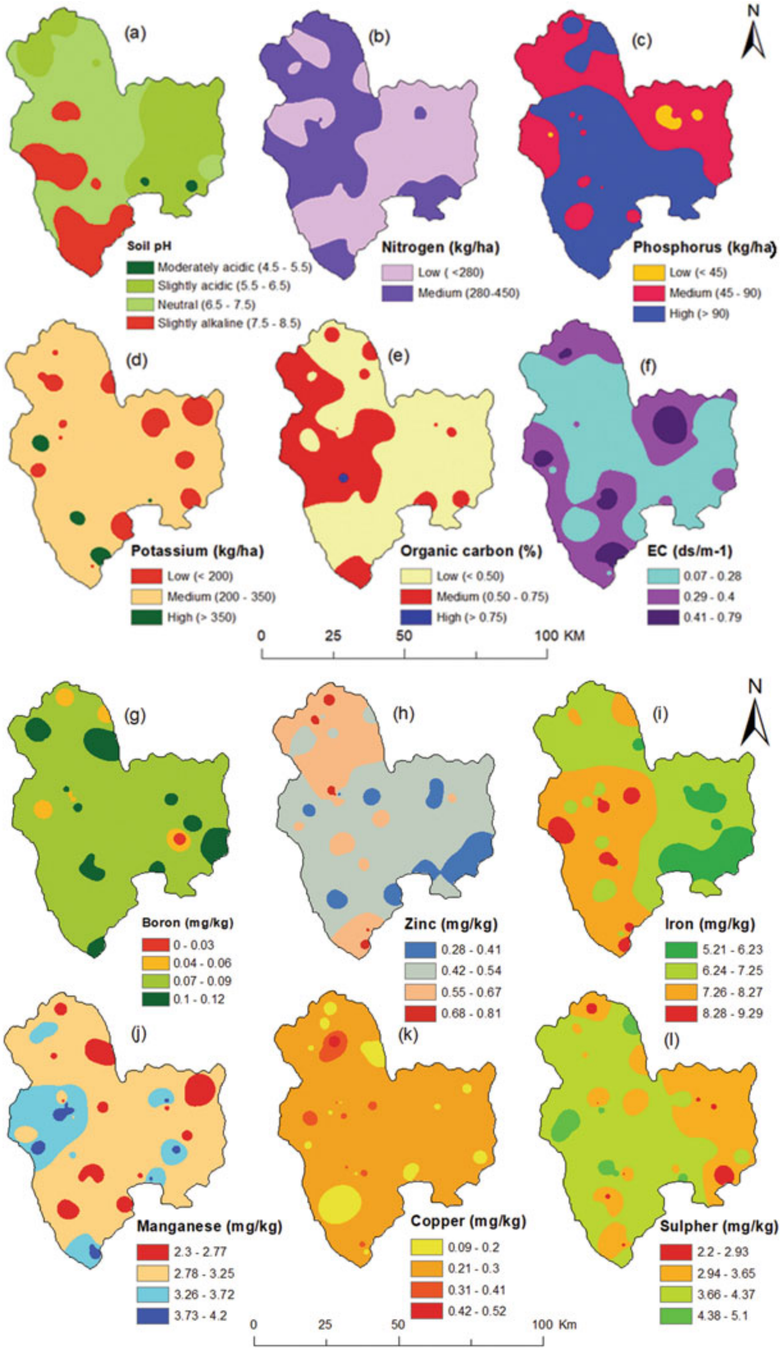

Fig. 4.2 Soil fertility parameters and their spatial distribution in Malda district. (**a**) Soil pH, (**b**) nitrogen, (**c**) phosphorus, (**d**) potassium, (**e**) organic carbon, and (**f**) electrical conductivity, (**g**) boron, (**h**) zinc, (**i**) iron, (**j**) manganese, (**k**) copper, and (**l**) sulfur

mineralization; however, lack of nitrogen fertilizer application to comprehensive nutrient crops especially maize and existence of high sulfur in the soil are considered as the reason of N deficiency (Vasu et al. 2017). On the other hand, medium available N is found in all the areas except the parts mentioned above, whereas low nitrogen content is expected to be more coinvestigated. The areal coverage of medium available N is 45.75%, and surprisingly, there is no portion in this district with a high level of available N (expectedly 400 kg/ha), and thereby yield rate is hampered to produce healthy and nutritious crops.

4.4.2.3 Available Phosphorus (P)

The results of the P availability obtained from NI are presented in Table 4.3 and Fig. 4.2c. The estimated value of the availability of P content in this region varies from 16 to 222 kg/ha (Table 4.2). From the spatial distribution, it is found that 55.38% are covered by high concentration of available P observed at the middle and southern part of the district and 43.06% are covered by a medium concentration especially found at north-eastern, north-western, and western part of the district. The comparatively healthier availability of P is mainly due to dissolution of Ca-P in the soil with deep-rooted crops under neutral soil reaction (Pal et al. 2012). Simultaneously, only 1.56% area of the total district is observed with a low concentration of available P found in the middle part of the Gazole and western part of Bamangola block (Fig. 4.2c).

4.4.2.4 Available Potassium (K)

The NI of available K and its spatial distribution are summarized in Table 4.3 and Fig. 4.2d. The assessed value reveals the available K in the study area ranges from 18 to 549 kg/ha (Table 4.2). It is also experienced from the results that the major soils (88.37%) have a medium available K content, observed at almost every block of the district, except some pockets of Gazole, Bamangola, Habibpur, English Bazar, Manikchak, Chanchal II, and Harishchandrapur II. High potassium availability is found only at 1.93% of the region, scattered over the district. However, a tiny part of Kaliachak I and Kaliachak III, located in the southern part of the district, and Manikchak, located in the western part, is included in this group. Whereas 9.71% area has been observed with low available K, scattered over the district especially in the north-western part including Gazole, Bamangola, and Chanchal II blocks. On the other hand, Habibpur, English Bazar, Harishchandrapur II, and Manikchak blocks are also considered potassium-deficit blocks (Fig. 4.2d). The poor cation exchange capacity may be the one causing factor of the deficiency of K (Srinivasarao et al. 2014).

4.4.2.5 Organic Carbon (OC)

The estimated value of the organic carbon in the district varies from 0.25% to 0.84%, summarized in Table 4.2. The magnitude of the average OC reveals the study area is dominated very low contention is the case of commonality. Organic carbon in the soil of the whole of India is very poor (Venkanna et al. 2014). Most of the area (65.76%) of the district has low organic carbon content, located in the northern, eastern, and southern part of the district covering blocks of Harishchandrapur I, Chanchal I and II, Gazole, Bamangola, Habibpur, Old Malda, English Bazar, and Kaliachak I and III (Fig. 4.2e). Heavy showers are responsible for washing out the surface and subsurface organic compounds creating further deficits.

4.4.2.6 Electrical Conductivity (EC)

The results show that the average value of EC in this region is 0.29 dS/m and ranged from 0.07 to 0.79 dS/m (Table 4.1). It is also found from the estimated results that most soils of the district are with low (57.79%) electrical conductivity, and a very little parts are with high electrical conductivity (6.62%). The low level of electrical conductivity is prevalent in the north-western to the south-eastern part of the district, and high EC has been observed in very little portions of Gazole, Kaliachak II and III, Manikchak, and Harishchandrapur I blocks (Fig. 4.2f). The fluctuation of soil electrical conductivity depends on the amount of soil moisture detained by particles of soils. However, the soils of the study area are free from strong salinity as all the collected sample values of EC are <1. It is so typical that if the EC is high in the substrate flushing, the soil with irrigation water is necessary. Similarly, if it is low, it indicates that some supplementary inputs especially salts and other nutrients are necessary.

4.4.2.7 Available Boron (B)

Boron is another typical and essential trace element of the soil. The concentration of boron in the study area ranges from 0.00 to 0.12 mg/kg, with an average of 0.08 mg/kg. However, the outcome of areal exposure shows a large quantity of the soil (86.69%) of the district has the optimum availability of boron content, experienced at every block of the district. The highest level of boron is concentrated in the north-eastern, north-western, eastern, and some middle part of the study area in a scattered manner, whereas the rest of the part of the district are observed with medium (3.16%) and low (0.35%) available boron. This is a key element for agriculture as soil pH, calcium, soil texture, organic matter, and moisture content are influenced by the availability of boron in soil (Orlov 1992).

4.4.2.8 Available Zinc (Zn)

The NI of available Zn and its spatial distribution are summarized in Table 4.3 and Fig. 4.2h. The assessed value clearly reveals the proportion of the available Zn in this region varies from 0.28 to 0.81 mg/kg. Except for the northern and southern parts of the study area, the entire region is enclosed with the soil of low (57.79%) share of zinc content. Medium concentration (25.80%) has been found in all the areas except the parts mentioned above, where low zinc content is observed. The yield of flowers and fruits is considerably reduced and delayed if Zn deficiency persists.

4.4.2.9 Available Iron (Fe)

The results of the NI of available Fe and its spatial distribution are presented in Table 4.3 and Fig. 4.2i. In the study area, the availability of iron ranges from 5.20 to 9.30 mg/kg (Table 4.2). Nearly half (46.82%) of the study area is enclosed with the medium concentration of iron, observed mainly at the northern and eastern part of the district. On the other hand, approximately one third (37.79%) of the area experienced high concentration of Fe, mainly observed in the west and southwestern part of the district. In contrast, only 3.86% of the area is observed with a very high concentration of iron found in the western part of the study area but in a scattered manner.

4.4.2.10 Available Manganese (Mn)

The existing Mn content in the study area varies from 2.30 to 4.20 mg/kg (Table 4.2); however, the results of NI and its spatial variation are presented in Table 4.3 and Fig. 4.2j. The assessed results show the medium quantity of available Mn is experienced for the majority of the portion (72.5%) of the district covering a vast part of Bamangola, Gazole, Habibpur, Kaliachak I and II, English Bazar, Old Malda, Harishchandrapur I and II, and Chanchal I and II. On the other hand, high available manganese (18.5%) is found in the little part of the western, southern, and eastern portion of the study area. The areal coverage of a very high concentration of Mn (1.59%) is significantly less than others.

4.4.2.11 Available Copper (Cu)

The analysis results of Cu and its spatial distribution in the study area are presented in Tables 4.2 and 4.3 and Fig. 4.2k. The estimated results reveal most of the area (89.68%) of the district is covered with the medium quantity of the copper blend soil. However, very high absorption of copper in the soil occupied merely 0.28% of the region, located only in the very little proportion of the northern part of the study area.

A very low (7.50%) concentration of the nutrient is found in the eastern, south-western, and northern parts of the district in a diffused manner. In the present study, the availability of copper has varied from 0.09 to 0.52 mg/kg with an average of 0.24 mg/kg.

4.4.2.12 Available Sulfur (S)

Sulfur in the study area ranges from 2.20 to 5.10 mg/kg, with an average of 3.76 mg/kg (Table 4.2). More than half (63.82%) of the study area is covered with the soil of good absorption of S except the eastern part of the study area. On the other hand, the medium quantity of sulfur is associated with 31.24% of the whole study area (Fig. 4.21l). The rest of the area is covered with the soil of a very high percentage of sulfur content. Surprisingly, there is hardly any evidence of existing soil with a low and very low concentration of sulfur in this district. The possible reason behind poor availability of S content in the study area is low organic matter and acidic soil pH (Hareesh et al. 2014).

4.5 Conclusion

This study explored the characterization of the soil properties and its spatial variability in Malda the district. The assessment revealed most of the soils (49%) of the district are neutral, followed by slightly acidic (34%). The low status of organic carbon is noticed in 65.76% of the area. The available nitrogen and potassium in the soils are of low to medium category. However, higher content of phosphorus has been observed in 55.38% of soils. A deficiency was observed in boron in the whole study area and zinc in about 75% of areas. The availability of iron, copper, and manganese in soils was observed almost permissible. Precise inspection proves that Tal and Diara regions are comparatively more fertile than the Barind tract. Fertilizer recommendations can be made for maximum crop yields. Improper agriculture practices, intensive farming, monoculture, cropping pattern, and over-irrigation are responsible for the deterioration of soil quality in some portion of the study area. To overcome the adverse effect of the chemical fertilizers in cultivation, efforts should be made to probe ahead for integrated nutrient management (INM). Under this approach, the best available option lies in the complementary use of biofertilizers, organic manures in suitable combinations for chemical fertilizers. "Organic agriculture" system should be inculcated which begins to consider potential environmental and social impacts by eliminating the use of synthetic inputs such as synthetic fertilizers, pesticides, etc. The camps, rallies, and training programs for the farmers should be arranged for increasing awareness regarding the benefits of organic agriculture, biofertilizers, etc. in better crop production and thereby improving soil fertility and nutrient status.

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Chapter 5
Land Suitability Evaluation for Agricultural Crops in Selected Blocks of South 24 Parganas District, West Bengal

Rukhsana and Sabir Hossain Molla

Abstract Cropland development evolution is necessary to achieve optimal use of existing land resources for sustainable agricultural production. In India, agriculture is the backbone of national economic development. But the productivity of the land is found to be low due to mismanagement of the land which results to land degradation. Therefore, land suitability analysis for matching crop requirement with resource available has become a vital need to sustain the agricultural development and productivity in the study area. The present study has been done in three blocks, namely, Patharpratima, Kakdwip, and Mathurapur II, of South 24 Parganas district which lie in Sundarbans region of West Bengal. Various environmental parameters, i.e., for the delimitation of potential and suitable land for crop cultivation, climatic factors (temperature and precipitation), and physicochemical properties of various alluvial soils (e.g., soil texture, pH, electrical conductivity, organic carbon content) have been used. This chapter assesses land suitability for the cultivation of selected dominated crops using multi-criteria evaluation (MCE) and GIS approaches and compares potential land use to current land use. The findings revealed that the largest area under moderately suitable category in paddy, potato, betelvine, and mung bean was 22,619.52 ha (33.67%), 15,240.04 ha (22.53%), 23,379.55 ha (34.60%), and 23,504.35 ha (34.71%), respectively, and this category land has insignificant limitations. A fairly noticeable area under each crop was found under marginally suitable class which could be made suitable through modifying land quality parameters. Overall, the outcomes indicate that study area has an enormous potential for agricultural production.

Keywords Environment factors · Crop suitability · Agriculture · Soil nutrients · Geospatial · AHP

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5.1 Introduction

The present study is an attempt to assess the suitability of land as part of a rational cropping system to optimize land use for a specific use (Sys et al. 1991). The cropping system is essentially based on the availability of climate, soil, topography, and water which are the most important categories of environmental information required to identify crop suitability. Land suitability is the ability of a tract of land to tolerate the production of crops in a sustainable method. Suitability is a function of crop requirements and land characteristics and is a measure of how the properties of a land unit correspond to the requirements of a particular form of land use according to the FAO explanation. The main restriction factors of a particular crop production have been found which allows decision-makers to generate a crop management to increase land productivity (FAO 1976). There is a need for cropland suitability analysis to achieve optimum utilization of available land resource for sustainable agricultural production (Khush 1997). The suitability or development of land is a function of crop requirements and land characteristics (Mustafa et al. 2011), given suitability, for matching land characteristics with crop requirements. Appropriateness is thus a measure of how the properties of a land unit match the requirements of a particular form of land use (FAO 1976). The suitability of the land should be analyzed in such a way that local requirements and circumstances can be well simulated in the final decisions (Prakash 2003).

Land suitability analysis is a method of land assessment, which measures the degree of suitability of land for a certain use. The analysis allows identifying the main limiting factors of crop production and enables decision-makers to develop crop management systems (Halder 2013). Land and soil have different characteristics from one place to another because soils have a variety of physical, chemical, and biological processes that work proportion-temporally and with varying intensities (Widiatmaka et al. 2016; Jenny 1941; Goovaerts 1998; Tripathi et al. 2015; Ferguson et al. 2002). Some growth-promoting factors, including temperature, pressure, humidity, soil type, soil drainage, pH level, and soil electrical conductivity, affect plant growth (Maddahi et al. 2014). The productivity per acre can be increased up to double considering these properties. Due to lack of awareness, local farmers avoid these factors, so it is the responsibility of the state to establish research centers at the local level which can guide the farmers to take preventive measures to improve the productivity of crops (Raza et al. 2017). Optimization of crop production can be achieved through sustainable agriculture which includes quality of environmentally appropriate, economically efficient, and socially acceptable products (Addeo et al. 2001) and making optimal use of available natural resources for efficient agricultural production. To accomplish sustainable agriculture, crops have to be grown in the most suitable land, and for this the land suitability has to be analyzed (Ahamed et al. 2000).

Geographic information systems (GIS) are a powerful set of tools that can incorporate local production variables (temperature, humidity and soil type, soil drainage, EC, and soil pH) and achieve a favorable output of multi-criteria evaluation (MCE) approach as per their importance (Perveen et al. 2007). Overlay techniques in GIS do not enable comparisons between the underlying production variables (Janssen et al. 1990). MCE is a modern and emerging technology in GIS to handle such limitations for GIS-based decision-making (Pereira and Duckstein 1993). MCE helps in deciding several options for evaluating decision criteria (Jankowski 1995). Thus, the use of MCE and GIS techniques becomes quite concrete in crop suitability analysis. Many researchers have used this approach in different parts of the world including Tana Delta (Kuria et al. 2011) and great Mwea (Kihoro et al. 2013) of Kenya, Central Anatolia Region of Turkey (Dengiz 2013), inland valley wetlands of Ghana (Gumma et al. 2009), and Morobe Province in Papua New Guinea (Samanta et al. 2011).

Paddy, potato, betelvine, and mung bean (mainly summer moong) are the main crops grown in the experimental site. More than half of the available agricultural land in the study area is under paddy cultivation. Agricultural production and productivity have drastically improved due to the inclusion of high-yielding varieties of seeds, fertilizers, irrigation and pesticides. But at the same time, agricultural land has come under the grip of many environmental challenges. This is why land suitability assessment for various agricultural crops becomes essential to ensure long-term agricultural sustainability, along with human needs.

5.2 Objectives

The purpose of this study is to determine physical land suitability for the cultivation of major crops using a multi-criteria assessment and GIS approach and a comparison of current land use versus potential land use based on selected physical and climatic parameters of production according to FAO guidelines. Relevant biophysical variables of soil and topography were considered for suitability analysis (FAO 1978, 1994, 1996), and selected production was expanded in the experimental site. The current examination will be most useful, especially to encourage farmers to grow the proper crop in their fields.

5.3 Materials and Methods

5.3.1 Study Area

Three blocks, namely, Patharpratima, Kakdwip, and Mathurapur II, of South 24 Parganas district which lie in a part of the Sundarbans region of West Bengal (Fig. 5.1) have been chosen for the study. The study is located between 21°35′N and 22°05′N latitude and 88°09′E to 88°32′E longitude and is bounded on the north by the Dampier-Hodges line (an imaginary line formed in 1831), Bay of Bengal in the south, Ichamati-Raimangal rivers in the east, and the Hooghly River in the west.

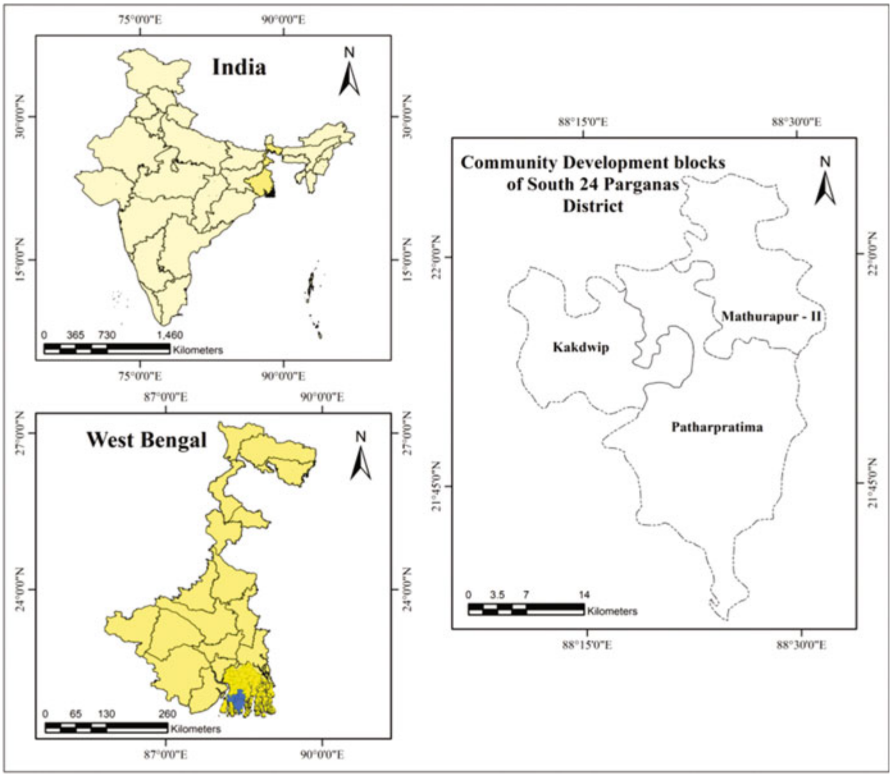

Fig. 5.1 Location of the study area

The soil in this region is mostly heavily textured, which varies from silt clay to clay. The pH of the top (0–15 cm) soil was found to be 6.85–7.68, and the average organic carbon was 0.62%, available as N, P, and K, concentrations in the topsoil being 243 kg/ha, 10.5 kg/ha, and 482 kg/ha, respectively (Burman et al. 2018). Tropical climate, high monsoon rainfall in a hot and humid summer and a dry-mild winter found here. Most of the rainfall is received during the months of May to October. The economy of the study area is directly dependent on agriculture. Paddy is the most cultivated crop (50,756 ha) and is grown in more than half of the agricultural area. Other important crops include potato, sunflower, mustard, and wheat.

5.3.2 Satellite and Supplementary Data

This research work has used different sources of data including secondary, primary, and site visit for field investigation which has been collected through various sources (Table 5.1). The current study of crop suitability analysis was conducted based on the last 18 years' (2001–2018) average temperature and mean rainfall, soil

Table 5.1 Sources and methods of collected data to prepare suitability map

Sources	Method	Maps generated
SOI (toposheets)	On-screen digitization	Study area map
Landsat 8 OLI	Supervised classification	Agricultural land
ICAR-CSSRI-RRS station, Canning; Deputy Director of Agriculture (admin), South 24 Parganas	Interpolation (IDW)	Rainfall map
Deputy Director of Agriculture (admin), South 24 Parganas	Interpolation (IDW)	Temperature map
Soil Testing Lab, RAKVK, Nimpith (ICAR)	Geo-referencing/on-screen digitization	Soil texture map, pH map, electrical conductivity map, and organic carbon map
District Census Handbook, 2011	Proximity analysis	Spatial proximity to closest market
District Disaster Management Plan, South 24 (PGS), 2018–2019	Geo-referencing/on-screen digitization	Flood susceptibility

physicochemical properties (soil texture, pH, electrical conductivity, and organic carbon content) of 2011, flood susceptibility, and distance to market (km), which were collected from different sources (Table 5.1). Landsat 8 OLI satellite data (6 May 2019) were acquired from USGS website, keeping in view the agricultural land (Table 5.1). Frequent interviews with local agronomists and Additional Directors of Agriculture (ADA) for each CD block, literature review, and various references to crop experts' opinions help in identifying key requirements for appropriate crop cultivation areas. Therefore, in modifying the appropriate land area for various agricultural crops, software such as ERDAS IMAGINE 14.0 and ArcGIS 10.1 is employed.

5.3.3 Generation of Thematic Maps

The study selected temperature, rainfall, soil texture, soil pH, soil electrical conductivity, organic carbon content, flood susceptibility, and distance from the market to create various suitable areas for agricultural crops. Thematic map of temperature and rainfall was generated with the help of IDW process in ArcGIS 10.1 software based on the last 18 years' (2011–2018) mean rainfall and average temperature. In order to prepare the thematic layers of temperature and rainfall, the values and station coordinates are entered into Excel, imported into ArcGIS as comma-separated values (.csv) files, and interpolated using inverse distance weighting (IDW) techniques in GIS environment.

The data of soil suitability parameters (soil texture, pH, electrical conductivity, and organic carbon) for selected crop has been taken from the Soil Testing Lab, RAKVK, Nimpith (ICAR), as vector polygon layers. The thematic layer for each of the parameters has been prepared from this polygon with digitized procedure and reclassified based on their value fields in ArcGIS 10.1 platform. Spatial proximity to the nearest market significantly affects cost efficiency, which then influences farmers' decisions. Therefore, spatial proximity to the nearest market is an influencing factor on crop suitability. This map was generated by the point buffer feature in ArcGIS 10.1 software. Criteria for flood susceptibility were created through on-screen digitization of the map prepared by the District Disaster Management Plan (2018–2019), South 24 (PGS). Figure 5.2 shows the flow diagram of the methodology applied.

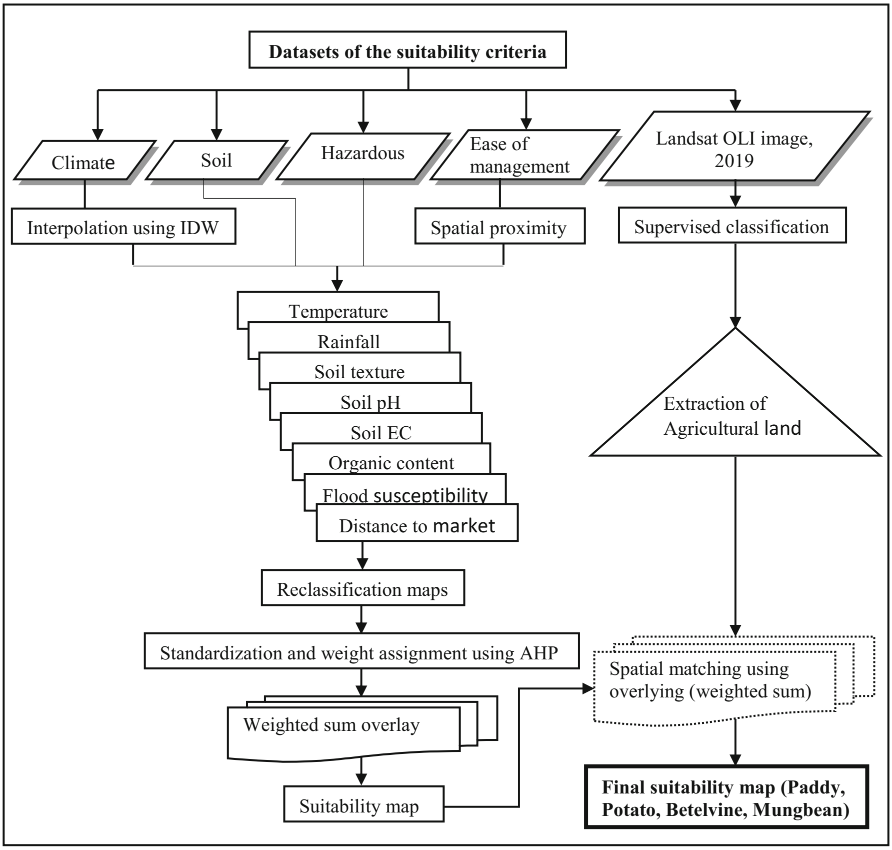

Fig. 5.2 Flowchart of the methodology

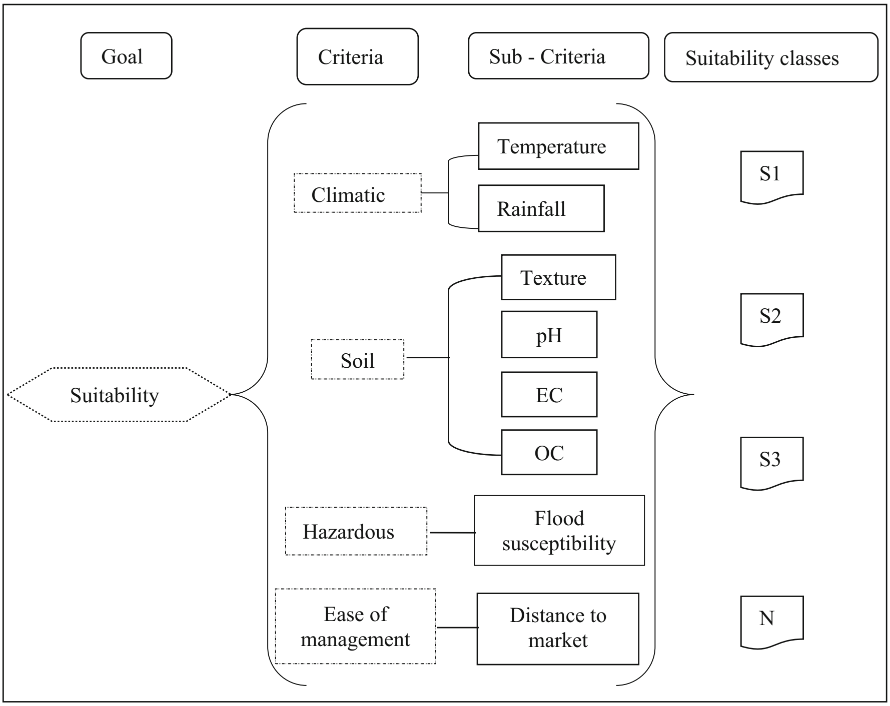

Fig. 5.3 Hierarchical organization for the criteria considered in the study

5.3.4 *Applying of MCE Using Spatial AHP Procedure*

To give relative importance of criteria, sub-criteria, and suitability classes, AHP procedure was used. It consists of several main stages:

Generating a Hierarchy Structure Malczewski (1999) stated that the relationship between objectives and their characteristics is a hierarchical structure. At the highest level, one can distinguish the objectives, and at the lower level, characteristics can be broken. Figure 5.3 shows the hierarchical structure used in the study.

5.3.5 *Development of a Comparison Matrix at Each Level of Hierarchy*

The pairwise comparison matrix (PWCM) was implemented using a scale with values from 9 to 1/9 initiated by Saaty (1980), shown in Table 5.2. The pairwise comparison matrix is a rating of the relative importance of the two factors regarding the suitability of the cropland. To determine the relative importance/weight of the

Table 5.2 Fundamental scale used for pairwise AHP comparison (Saaty 1980)

Less important					More important			
Extremely	Very strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very strongly	Extremely
1/9	1/7	1/5	1/3	1	1/3	1/5	1/7	1/9

criteria, sub-criteria, and suitability classes, the PWCM was implemented using a scale with values 9 to 1/9 initiated by Saaty (1980).

A rating of 9 indicates that in relation to the column factor, the row factor is more important. On the other hand, a rating of 1/9 indicates that the row factor is less significant, relative to the column factor. For example, the rating of precipitation relative to temperature is 3, and the rating of temperature relative to precipitation would be 1/3. In cases where the column and row factors are equally important, they have a one rating value. Pairwise matrices were constructed to examine the effect of each factor on land suitability for farming systems (Table 5.5).

5.3.6 Rating the Suitability Classes of Sub-criteria

In land suitability analysis, a map represents each of the evaluation criteria with ordinal values (like S1, S2, S3, N1, and N2) indicating degree of suitability in relation to a sub-criterion based on crop requirements (Sehgal 1999). These classes are to be evaluated—how important is class S1 in relation to a particular sub-criterion to contribute to the end goal. This process is called standardization which obtains a normalized score for each suitability class. Than assigning a score on a scale of 1–4 in increasing order of suitability (4, highly suitable (S1); 3, moderately suitable (S2); 2, marginally suitable (S3); 1, not suitable (N)). The ranking system was assigned following (Yalew et al. 2016) the WOA, and the criteria layers were standardized based on the FAO land suitability classification. Table 5.4 presents the standardization criteria used for the suitability assessment of various crops.

In the application of the AHP method, it is important that the weights obtained from a pairwise comparison matrix are consistent. CR is used to account for the probability that matrix decisions were randomly generated (Saaty 1977).

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{5.1}$$

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{5.2}$$

where:

Lambda ($\lambda_{\max}$): The maximum eigenvalue
CI: Consistency index
CR: Consistency ratio
RI: Random index, which is the average of the resulting consistency (index depending on the order of the matrix given by Saaty (1977) (see Table 5.3))
n: The numbers of criteria or sub-criteria in each pairwise comparison matrix

A consistency ratio (CR) of 0.10 or less indicates a reasonable level of consistency (Saaty 1977). The homogeneity of the factors within each group, a smaller number of factors in the group, and a better understanding of the decision problem

Table 5.3 Values of random index (RI)

Order matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

improve the stability index (Saaty 1993). The resulting CR in land suitability analysis, particularly for agricultural crops, is 0.04 indicating that the comparison of land characteristics was completely consistent and the relative weight was appropriately chosen in this particular study.

5.4 Analytic Hierarchy Process (AHP)

For the present study, the use of AHP is assigned to the weights of the various data layers of this study area, in order to ascertain the appropriate land assessment for different crop cultivation. The analytic hierarchy process is a tool that is used in the decision-making process with multi-criteria which is presented by Saaty (1970). The AHP assigned the weight of different data layers to determine the appropriate land assessment. The weight of the assignment is to illustrate the relative importance of each single parameter to another parameter that impacts crop suitability. The pair-wise comparisons of different parameters were standardized into a square matrix that was given in Table 5.5. The level of suitability for each factor used as a basis for developing the criterion map (each single factor) is classified into four categories that include highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N) based on FAO land suitability classification to find out the degree of suitability of every single factor (Table 5.4).

5.5 Multi-criteria Assessment and Weighted Overlay Analysis

The MCA model was used to find suitable land for cultivation of the selected crop based on the selected parameters of climate (mean temperature and mean rainfall), soil physicochemical properties (soil texture, pH, electrical conductivity, and organic carbon), flood susceptibility, and distance to market; discussed the study in detail with local agronomists and consulted some literature such as by Raza et al. (2018), Dengiz et al. (2015), Kihoro et al. (2013), Ayehu and Besufekad (2015), Roy and Saha (2018), Rath et al. (2017), and FAO (1983, 1985).

After standardizing and calculating the weight of each parameter using AHP, WOA was performed. Each criterion raster layer was assigned a weight in the suitability analysis. Dissimilar weighted layers were reclassified on a common suitability scale from 1 to 4. These layers were then overlaid, where the product of each sub-criterion layer and the weight assigned to each criterion were calculated

Table 5.4 Standardization criteria used, data range, and suitability class for crop suitability

Parameters	Suitability class	Paddy	Potato	Betelvine	Mung bean
Temperature	S1	24–26	16–24	16–24	12–24
	S2	18–24	24–27	24–26	24–27, 10–12
	S3	26–30	27–30	26–30	27–30, 8–10
	N	<18 and >30	<16 and >30	<16 and >30	>30 and <8
Rainfall	S1	>1400	>1000	1000–1400	400–600
	S2	1000–1400	800–1000	800–1000	600–800
	S3	800–1000	600–800	600–800	800–100
	N	<800	<600	<600	>1000
Soil texture	S1	Clayey, clayey loam	Loamy	Loamy	Loamy, sandy loam
	S2	Silty clayey loam, silty loam	Sandy loam	Silty loam	Silty clayey
	S3	Sandy loam, loamy sandy	Clayey	Clayey loam	Clayey
	N	Coarse sandy loam	Heavy clayey	Heavy clayey	Heavy sandy, heavy clayey
Soil pH	S1	5.5–7.5	5.5–6.5	6.5–7.5	6.2–7.2
	S2	7.5–8.5	6.5–7.5	5–6.5	5–6.2
	S3	4.5–5.5	7.5–8.5	7.5–8.2	7.2–8
	N	<4.5 and >8.5	<5.5 and >8.5	<5 and >8.2	<5 and >8
Soil EC (dS/m)	S1	0.75–1.50	<0.25	<0.25	<0.25
	S2	0.25–0.75	0.25–0.50	0.25–0.50	0.25–0.50
	S3	<0.25	0.50–1.00	0.50–1.00	0.50–1.00
	N	>1.50	>1.00	>1.00	>1.00
Soil OC	S1	>0.75	>0.75	>0.75	>0.75
	S2	0.50–0.75	0.50–0.75	0.50–0.75	0.50–0.75
	S3	0.25–0.50	0.25–0.50	0.25–0.50	0.25–0.50
	N	<0.25	<0.25	<0.25	<0.25
Risk of flooding	S1	Low	None	Low	Very low
	S2	Moderate	Low	Moderate	Low
	S3	High	Moderate	High	Moderate
	N	Very high	High	Very high	High
Distance to market (km)	S1	0–5	0–5	0–5	0–5
	S2	5–10	5–10	5–10	5–10
	S3	10–15	10–15	10–15	10–15
	N	>15	>15	>15	>15

Sources: FAO (1976), Ali (2010), Dengiz et al. (2010), Ayehu et al. (2015), Ayoade (2017), Silva and Blanco (2003), Kamau et al. (2015), Mugo et al. (2016)

Table 5.5 Pairwise comparison matrix of crop suitability parameters

Criteria	Temperature	Rainfall	Soil texture	Soil pH	Electrical. conductivity	Organic content	Flood susceptibility	Distance to market	Weight
Temperature	1	1/3	1/5	1/5	1/2	3	2	5	0.0739
Rainfall	3	1	1/3	1/2	2	5	5	6	0.1580
Soil texture	5	3	1	2	5	7	6	7	0.3268
Soil pH	5	2	1/2	1	3	6	5	7	0.2290
Electrical conductivity	2	1/2	1/5	1/3	1	5	3	5	0.1068
Organic content	1/3	1/5	1/7	1/6	1/5	1	1/2	2	0.0330
Flood susceptibility	1/2	1/5	1/6	1/5	1/3	2	1	3	0.0481
Distance to market	1/5	1/6	1/7	1/7	1/5	1/2	1/3	1	0.0243
CR = 0.04									$\sum = 1$

and a sum of the products to be obtained. Final Suitability Map (Eq. 5.3). Assigning a weight to each raster layer in the overlay process allows controlling the effect of different criteria in the suitability model.

$$\mathrm{SI} = \sum (W_i \times X_i) \tag{5.3}$$

where SI is the suitability index for each map pixel, W_i weight value of parameter ith, and X_i sub-criterion score of parameter ith. The above formula is applied to each thematic layer. The analysis was carried out using weighted sum overlay techniques in ArcGIS 10.1. In the overall outcome, the higher SI value is the higher suitability of land use for stated land use type.

5.6 Extraction of Agricultural Land and Overlay with Suitability Map

We carried out land use/land cover (LULC) supervised classification in ERDAS IMAGINE 14.0 to improve the outcome. Current agricultural land was extracted and mapped in Fig. 5.4. The accuracy of the current cultivation map was 84.5% based on kappa statistics. Weighted sum overlay techniques have been applied in the purpose of overlay analysis. A weighted overlay is a technique for applying a common scale of values to diverse and diffuse input data to create a unified analysis (Kuria et al. 2011). In this study, agricultural land and crop suitability maps were overlaid to determine potential crop suitability zones.

5.7 Results and Discussion

Descriptions of the Factor Maps Temperature and rainfall are two major climatic factors on crop cultivation. Average annual temperature values are varying from 26.49 to 26.55 °C (Fig. 5.5a), which influence factors on crop cultivation and increase soil productivity, which are essential for successful crop growth. The rainfall map (Fig. 5.5b) based on data from three rainfall stations of the region ranged from 1781 to 1805 mm which created a very favorable environment for crop cultivation. Both thematic layers are assigned weights using the AHP method.

The low flood susceptibility zone is located in the northern part (Kakdwip block) in relation to the study area, while the high flood susceptibility zone due to extreme climatic rainfall events, poor drainage, and river embankment breakdown is mainly occupied by the Patharpratima block (Fig. 5.5c). Spatial proximity to the nearest market played an important role in crop suitability as well as agricultural development. Here, the Kakdwip block has the highest spatial proximity to the market, and the Patharpratima block has the lowest spatial proximity to the market (Fig. 5.5d).

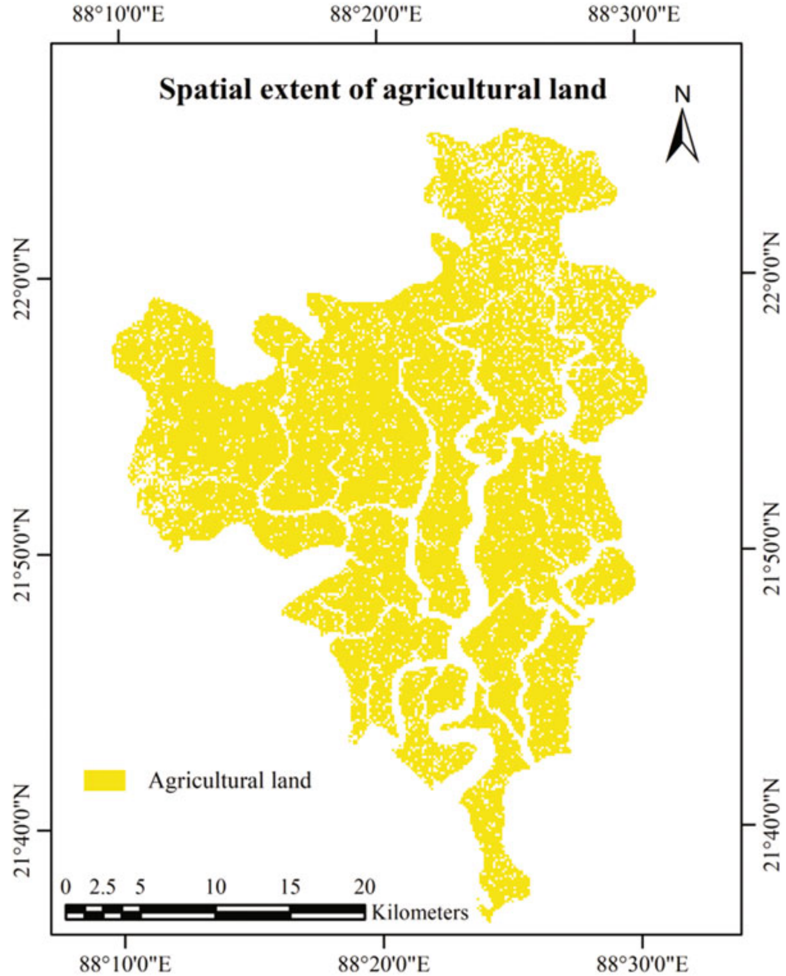

Fig. 5.4 Extraction of agricultural land from Landsat 8 OLI image

Being a part of the vast Ganges-Brahmaputra delta complex, this coast is believed to have been formed during the late quaternary period through the deposition of silt, mud, and non-cohesive sand brought by rivers flowing through (Allison et al. 2003). The initial soil factors identified in this research were soil texture, pH, electrical conductivity, and organic carbon (Fig. 5.6a–d).

Based on the classification of the soil texture, the experimental site is mainly divided into course loamy (sandy loamy, loamy, and silty loamy), fine loamy (sandy clayey loamy, clayey loamy, and silty clayey loamy), and fine (sandy clayey, silty clayey, and clayey). Most experimental sites were characterized by fine soil (sandy soil, silty clay, and clay). Soil response or pH is an important factor in soil productivity and plant growth. The pH of the surface soil varied from 5.5 to 7.5

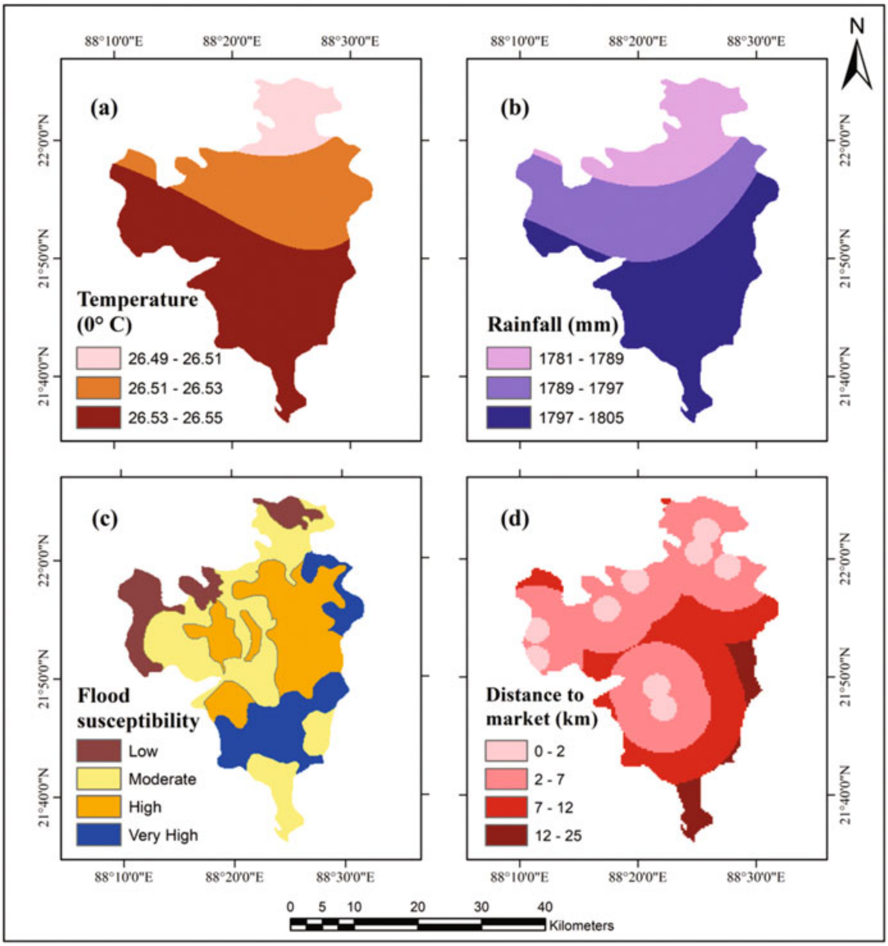

Fig. 5.5 Criteria map for land suitability assessment: (**a**) temperature, (**b**) rainfall, (**c**) flood susceptibility, (**d**) distance to market

which was considered as highly suitable and not suitable value categorized as <4.5 or >8.5. Almost none of the crops prefer high pH; thus soil response is considered as one of the limitations that damage the crop grown in the study area. Salt-affected soil negatively affected plant growth in many ways, in addition to specific ion toxicities such as Na, Cl, and B, causing direct injury to the plants. However, a large number of agricultural land in this study area is occupied by EC values ranging from 0.75 to 1.50 dS/m. Soil OC indicates organic matter content in the soil which often forms the basis for successful use of mineral fertilizers. The spatial distribution of the organic carbon (%) value of this study above 0.75 was considered highly appropriate and was moderately appropriate below 0.50.

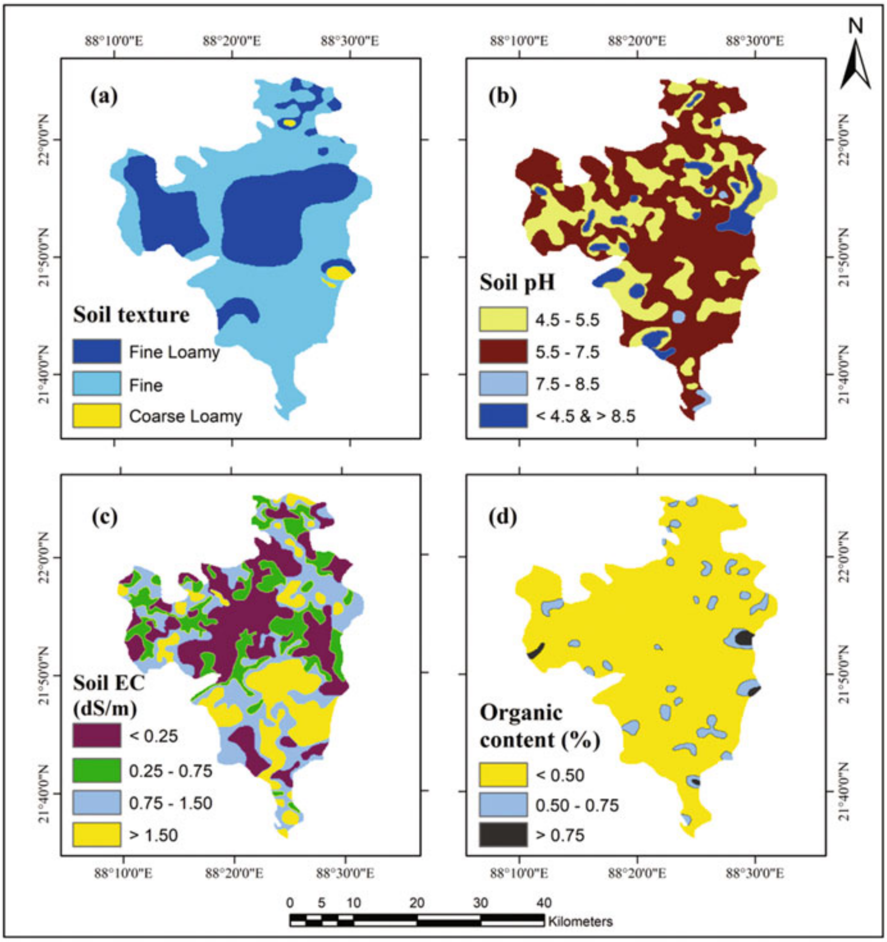

Fig. 5.6 Criteria map for land suitability assessment: (**a**) soil texture, (**b**) soil pH, (**c**) electrical conductivity, (**d**) organic content

Analytic hierarchy process (AHP) was applied to calculate the weight parameters of crop suitability. Results are listed in Table 5.5. The highest weighted value was 0.3268 corresponding to soil texture, and its smallest value was 0.0243, and this value corresponded to the distance from the market. Therefore, soil texture is the most influential factor in crop suitability, and market distance had less impact on crop suitability. The same weighted techniques were applied in Raza et al. (2018), and the soil type or texture was weighed as the highest value of 0.3555 due to its water retention capacity, preserving nutrients and causing no damage to crop growth.

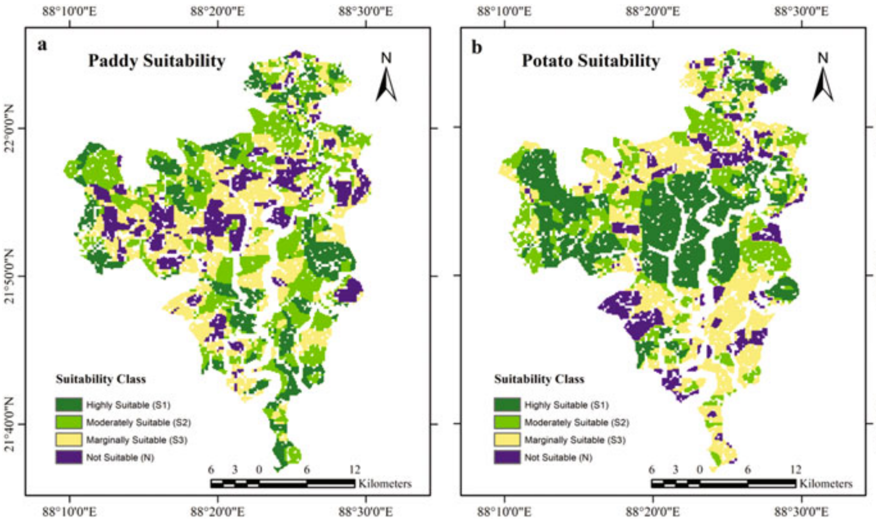

Fig. 5.7 Spatial variation in land suitability classes for (**a**) paddy and (**b**) potato cultivation

5.7.1 Suitability of Crops

Land suitability for agricultural crops is very important for agricultural development and future planning. The land suitability map of the experimental site was prepared by integrating selected site-specific parameters using the analytic hierarchy process (Figs. 5.7a, b and 5.8a, b). Thematic layers are presented in Figs. 5.5 and 5.6. Land suitability specifically indicates the potential of the land for crop cultivation. Its classification evaluated suitability classes for cultivation of various crops. Four categories of land suitability, viz., highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N), were recognized based on FAO land suitability classification.

Paddy and Potato Crop Suitability The suitability map for paddy and potato crop has been generated with integration of all thematic layers based on Eq. (5.3) and then overlaid (weighted sum overlay) with present agricultural land (Fig. 5.4) that has been shown in Fig. 5.7.

Paddy productivity is the highest among all cultivated crops and is also grown extensively in the study area. Results showed that 13,032.93 ha (19.40%) of the agricultural area under paddy cultivation was highly suitable, 22,619.52 ha (33.67%) moderately suitable, 20,315.09 ha (30.34%) marginally suitable, and 11,206.43 ha (16.68%) not suitable.

Block-wise variation in land suitability for paddy crop cultivation is presented in Table 5.6 and Fig. 5.7a. Patharpratima (23.39%) found the largest area in the most suitable category after Kakdwip (17.51%) and Mathurapur II (13.12%). High suitability of the area in all the aforesaid blocks is attributed to temperature of 24–26 °C,

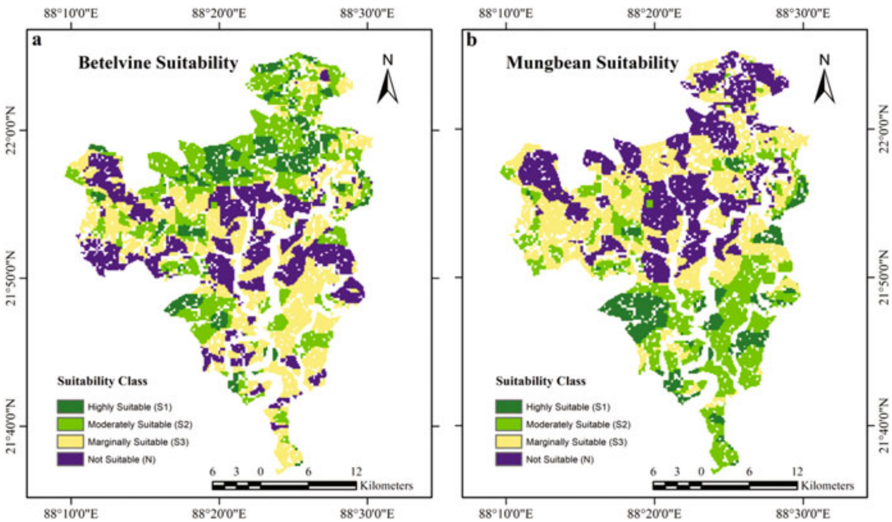

Fig. 5.8 Spatial variation in land suitability classes for (**a**) betelvine and (**b**) mung bean cultivation

Table 5.6 Spatial variation in land suitability classes for paddy cultivation

Class	Patharpratima		Kakdwip		Mathurapur II		Total experimental site	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
S1	7759.82	23.39	3238.68	17.51	2034.43	13.12	13,032.93	19.40
S2	11,232.83	33.86	5279.89	28.54	6106.79	39.39	22,619.52	33.67
S3	10,702.31	32.26	5617.35	30.36	3995.43	25.77	20,315.09	30.24
N	3475.71	10.48	4365.46	23.60	3365.26	21.71	11,206.43	16.68
Total	33,170.66	100.00	18,501.38	100.00	15,501.92	100.00	67,173.96	100.00

rainfall range above 1400 mm, texture class (fine (clay, clay loam, silty clay)), pH level of soil between 5.5 and 7.5, electrical conductivity level between 0.75 and 1.50, and organic carbon >0.75%. Most of the suitable areas are concentrated on the Kakdwip block (23.60%) and are characterized by low organic content (<0.50%), intense salt stress, acidic soil (pH 4.5–5.5), and several climatic adversities such as cyclones.

Table 5.7 and Fig. 5.7b results show that the agricultural area of 22,555.17 ha (33.35%) is highly suitable for potato cultivation while 8383.47 ha (12.40%) is not suitable for potato cultivation. If we look at the block-wise variation for potato crop suitability, Kakdwip has the largest area in the most suitable category (50.35%), followed by Patharpratima (27.25) and Mathurapur II (26.06%). Therefore, the findings showed that the highly suitable (S1) region was characterized by temperatures between 16 and 24 °C, rainfall range above 1000 mm, textural class (loam), soil pH level between 5.5 and 6.5, electrical conductivity <0.25 dS/m, and organic carbon of more than 0.75%.

Table 5.7 Spatial variation in land suitability classes for potato cultivation

Class	Patharpratima		Kakdwip		Mathurapur II		Total experimental site	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
S1	9102.82	27.25	9396.09	50.35	4056.25	26.06	22,555.17	33.35
S2	5600.61	16.76	4798.69	25.71	4840.75	31.10	15,240.04	22.53
S3	13,206.46	39.53	3808.83	20.41	4440.33	28.53	21,455.63	31.72
N	5499.96	16.46	658.22	3.53	2225.30	14.30	8383.47	12.40
Total	33,409.85	100.00	18,661.83	100.00	15,562.63	100.00	67,634.32	100.00

Table 5.8 Spatial variation in land suitability classes for betelvine cultivation

Class	Patharpratima		Kakdwip		Mathurapur II		Total experimental site	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
S1	9525.90	28.56	6180.24	33.26	1156.55	7.39	16,862.68	24.95
S2	13,009.64	39.01	6612.21	35.59	3757.50	24.01	23,379.35	34.60
S3	7246.17	21.73	4807.19	25.87	7606.88	48.61	19,660.25	29.09
N	3568.72	10.70	979.54	5.27	3128.55	19.99	7676.81	11.36
Total	33,350.43	100.00	18,579.17	100.00	15,649.49	100.00	67,579.09	100.00

Betelvine and Mung Bean Crop Suitability Crop betelvine is a perennial climber who is cultivated for the leaf. It is an important commercial crop of India. In India, betelvine (paan) is expanded in about 20 states. Karnataka, Orissa, Tamil Nadu, West Bengal, and Bihar grow the most betelvine in the country. However, after analysis, the results showed that 16,862.68 ha (24.95%) for betelvine cultivation was highly suitable and 7676.81 ha (11.36%) was not suitable in the selected study area. Block-wise spatial variation in land suitability for betelvine crop cultivation is shown in Table 5.8 and Fig. 5.8a. Kakdwip (33.26%), Patharpratima (28.56%), and Mathurapur II (7.39%) were found to be the leading areas under the highly suitable category. On the other hand, a large number of areas suitable for betelvine cultivation have not been distributed in the Mathurapur II block (19.99%). The land suitable for cultivation of this crop is fertile which is upland having well drained with loamy to clay loam soil. Soil with good water holding capacity and which is slightly acidic or neutral is considered ideal for its cultivation.

Mung bean [*Vigna radiata* (L.) Wilczek] is the most important crop of the *Vigna* group. In India, although it is widely cultivated in various seasons, it is the largest part of kharif cultivation. For mung bean cultivation, the most important factors are 400–600 mm rainfall, loam to sandy loam soil texture, large amount of organic carbon (>0.75%), soil pH of 6.2–7.2, and very low flood susceptibility. For this factor, the results showed that the agricultural area of 19,613.80 ha (28.96%) was highly suitable and 7096.09 ha (10.48%) was not suitable in the sample study area. Block-wise spatial variation in land suitability for cultivation of mung bean crop is shown in Table 5.9 and Fig. 5.8b which reveals that the largest area is Mathurapur II

Table 5.9 Spatial variation in land suitability classes for mung bean cultivation

	Patharpratima		Kakdwip		Mathurapur II		Total experimental site	
Class	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
S1	6824.60	20.47	5791.68	30.98	6997.53	44.63	19,613.80	28.96
S2	8103.01	24.30	9261.03	49.54	6140.31	39.16	23,504.35	34.71
S3	12,305.66	36.90	3425.16	18.32	1771.55	11.30	17,502.38	25.85
N	6112.48	18.33	214.91	1.15	768.69	4.90	7096.09	10.48
Total	33,345.75	100.00	18,692.78	100.00	15,678.08	100.00	67,716.62	100.00

(44.63%) followed by Kakdwip (30.98%) and Patharpratima (20.47%). If we focus on the not suitable area for mung bean cultivation, the largest number of share is demonstrated by Patharpratima block (18.33%), and this happened due to various physical constraints which cannot be corrected. Land of this class was found to be very at risk of high flood and severe soil erosion, and its soil pH was either acidic or too alkaline, and distribution of organic carbon was very low.

Thus, the results showed that most of the agricultural areas in the experimental sites are moderately suitable for crop cultivation. From the data point of view, about 58.36% of the entire testing sites have been covered in high and medium suitable areas of crop suitability, which are considered admirable for cultivation of the aforesaid crop. Therefore, economic levels of agricultural production can only be efficient by cultivating above rated crops in high (S1) and medium (S2) suitable areas and practicing diversification of suitable (S3) areas for other crops.

5.8 Conclusions and Recommendations

The land suitability for major crops (paddy, potato, betelvine, and mung bean) has been generated in selected three blocks (Patharpratima, Kakdwip, and Mathurapur II) of South 24 Parganas district, West Bengal, using FAO framework, RS-GIS, and MCDA approach. This was achieved by evaluating the physicochemical properties of soil and climatic factors as major determinants of agricultural crops which are identified by various references of literature review and opinions of crop specialists. The study takes into account LULC distribution in order to compute the amount of agricultural land. The land suitability appraisal for agricultural crops has been conducted to assist the judgment building as well as agricultural development planning. The commonly used analytic hierarchy process (AHP) method in multi-criteria decision-making exercises was found to be a useful method for determining weight. It can deal with inconsistent decisions and provides a measure of inconsistency of respondents' decisions. GIS is found as a technology that provides greater flexibility and accuracy for handling digital spatial data. The combination of the AHP method with GIS in our experiment proves that it is a powerful combination to apply for land use suitability analysis.

Thus, the present study of land suitability assessment for agricultural crops is new and originally implemented in this experimental site. Thus, the present study is quite helpful from agricultural point of view, especially the farmers who are interested in the aforementioned crop farming. Therefore, land appraisal, LULC mapping, and climatic evaluation would help the farmers to recognize their lands for potential use in this region. But the local farmers are not educated enough. To solve this issue, it is recommended that the local government introduce it in every farm to increase the yield per acre. In addition, the changing climate can have a significant impact on agricultural productivity in India as well as the present study area. In view of this, future studies must incorporate the impact of climate change on major agricultural crops. Additionally, this result may be useful for diverse studies of other investigators. In the future we propose to take more factors such as socioeconomic conditions, soil fertility, irrigation facilities, risk of erosion, and distance from the road which affect the sustainable use of land.

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Part II
Changes of Cropping Pattern and Food Security

Chapter 6
Levels of Agriculture Development and Estimated Growth and Pattern of Area, Production and Yield of Major Crops in Selected Region of Uttar Pradesh

Rukhsana

Abstract Plantation crops are high-value commercial crops of high economic importance and play an important role in the Indian economy. It is a source of livelihood for millions of small and marginal farmers and provides employment for millions of plantation workers. Uttar Pradesh (UP) cultivates a huge variety of crops developed by the geographical location and its wide agricultural climate change in the fertile Gangetic Plains. It is one of the major food grains and sugarcane-producing states of India. In 2013–2014, food grains accounted for about 78% of the gross cropped area (GCA) in Uttar Pradesh. Wheat is the most important crop at 36.9% of the GCA. The average landholding size of agriculture in Uttar Pradesh is 0.76 hectares, which is less than the national average of 1.15 hectares. The western part of Uttar Pradesh State has been selected for the detailed study which has experienced rapid economic growth similar to Haryana and Punjab due to the successes of the Green Revolution. The purpose of this chapter is to study the changing patterns in agriculture, area, production and productivity of major crops in western Uttar Pradesh for the years 1970–1973, 1980–1983, 1990–1993 and 2000–2003 on a 3-year moving average of 30 years. The northern portion of the study area recorded for highest cash crops but low in food grain crop and has enjoyed high level of agricultural development. The area under food grains is replaced by cash crops like sugarcane and potato crops. The farmers in the sample study area mostly prefer to grow cash crops because of the benefits, but it is particularly beneficial for large farmers as compared to small and marginal farmers due to the lack of purchasing power.

Keywords Components of agriculture · Cropping pattern · Area · Production and yield

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6.1 Introduction

After five decades of independence and with a population of one billion, India is still the largest democratic country in the world; maintaining this independence is necessary to ensure food security, economic empowerment and environmental security in the country. Such food security depends not only on how much food is available but also on where people have to get food—whether by purchasing it or producing it themselves. Access depends on economic variables such as food price and income as well as the quality of agricultural production, technology and natural resources. Since independence, there has been a threefold increase in population, while food production has increased fourfold (Sarkar 2001). India has made impressive progress in the agricultural sector during the last three decades. Much of the credit for this success must go to the many lakh small farmer families. Public investment in policy support, production strategies, infrastructure and research has greatly helped to increase food production and its availability. During the last 30 years, the production of Indian food grains has increased from 102 million tonnes in 1973 to 203 million tonnes in 2000. In fact the increase in production resulted in an increase in the production rather than the expansion of the cultivated area. India has made impressive progress in the agricultural sector during the last three decades. Much of the credit for this success must go to the many lakh small farmer families. Public investment in policy support, production strategies, infrastructure, and research has greatly helped to increase food production and its availability. During the last 30 years, the production of Indian food grains has increased from 102 million tonnes in 1973 to 203 million tonnes in 2000. In fact the increase in production resulted in an increase in production rather than the expansion of the cultivated area. The growth rate of agricultural production is generally measured by the performance of food and non-food production. The agricultural product of food production from these two is more important for two reasons: first, it provides the basis for subsistence by supplying basic foods, and second, it is the only group of agricultural produce where the Green Revolution was first introduced more successfully. At the time of independence, agriculture occupied the most prominent position in the Indian economy by providing livelihood to about 70% of the population and contributing about 48.6% to the gross domestic product (Sharma 2005).

Since the beginning of the Green Revolution, the scene about Indian agriculture has changed completely, from food shortages to self-sufficiency. This has become possible due to technological changes as well as government initiatives in the form of various programmes. The new method of farming brought about a drastic change in productivity and production. More and more arable land is brought under cultivation with advanced irrigation facilities (with the help of assured means of irrigation) with cheaply available chemical fertilizers and supply of seeds of high-yielding varieties (HYV) in the market. Farm mechanization has also shortened the agricultural ploughing, sowing and harvesting processes. The implementation of land reform has added a new dimension to Indian agriculture. Hence the successful implementation of the Green Revolution and land reform not only increases productivity but also increases the area of farming which paves the way for higher development of the agricultural sector. With the passage of time as a fruit of the Green Revolution and land reform, Indian agriculture moved from food shortages to self-sufficiency and from self-sufficiency to surplus agricultural produce. The period 1980 has seen a higher increase in the population of food grains than the increase in demand, which increases the supply of food grains in the economy more than the demand (Yadav 2005).

Production of food grains in India has increased from 46 million tonnes in 1950–1951 to 137 million tonnes in 1981–1982. India has made impressive progress on the agricultural front during the last three decades, and the credit for this success goes to the millions of small farming families compared to the farm and economy. Policy support, production strategies, public investment in infrastructure research and expansion for crop, livestock and fisheries have greatly helped in increasing food production and its availability during the last 30 years. A study shows that food production has almost doubled from 102 million tonnes in 1973 to about 203 million tonnes in 2000. Agricultural productivity and rapid industrial development contributed to a significant reduction in poverty levels in India from 55% in 1998 to 26% in 1998 (Singh 2003).

Veni and Alivelu (2005) examined the structure of food production in India during 1950–1951 to 2002–2003, which shows that the food grains including rice, wheat and coarse grain growth rate increased by 48.93% during 1950–1951 to 2002. In cereals, rice production was reported to be larger than wheat and coarse grains. This paper suggests that the production of pulses has indicated an unsatisfactory picture with frequent fluctuations. In 28 states, Andhra Pradesh dominated rice production. Uttar Pradesh topped the production of wheat and pulses. Mohammad (1989) analysed food production and food problem in India. He attempted a state-level analysis for production in the region, yield of food crops, supply of food grains, demand and availability of food grains in the country and surplus and deficit conditions and suggested various strategies to achieve food security.

Radhakrishna (1996) examined trends in food production and food consumption in India. India has achieved moderate success in combating transient food insecurity caused by crop failure due to drought or flood. Singh (1998) has suggested that despite spectacular progress, Indian agriculture is largely in deficit and as a result rural and agricultural poverty has increased. Poverty is the first source of limitation on the conception of food items by large sections of the population. Costly foods like animal products will always meet the needs of the wealthiest market; they have little chance of reaching the poor in sufficient quantities. Alaimo et al. (1998) estimated the prevalence of food inadequacy in the United States and found that from 1988 to 1994, the overall prevalence of food insufficiency was 4.1% and was primarily in a state of poverty. In a low-income group of people, food inadequacy was positively associated with Mexican, American, who were younger than 60, the head of a family who had not completed high school, participating in the food stamp program were not insuring health. Hanafi et al. (1999) in their study also examined the decreasing trend of food availability in Uttar Pradesh. He observed that the state was self-sufficient in food production, but there were a large number of districts lacking in food availability.

Uttar Pradesh is the most populous and fifth largest state in the Union of India. Uttar Pradesh covers a large part of the densely populated Gangetic Plain. The western region of the state is more advanced in terms of agriculture. Majority of the population relies on farming as the main occupation. Wheat, rice, sugarcane, oilseeds and potatoes are its main products. Sugarcane is an important cash crop in almost the entire state. Food production has increased in western Uttar Pradesh with the onset of Green Revolution, but the population has increased more than production. During the achievements of the Green Revolution, pulses have been neglected compared to other crops. Production of food grains has increased from 581.66 lakh quintals in 1972 to 1589.7 lakh quintals, with a growth rate of 173%. The growth rate of population was found to be higher than food production during 1971–2001, which increased from 31.34 million in 1972 to 61.53 million in 2001. In 1972, the availability of food grains increased from 669 g/head to 788 g/head per day in 2002. The calorie availability of food grains increased from 2359 calories/day in 1972 to 2710 calories/day in 2002.

The major objectives of the present study are as follows: first, to analyse the regional trends and patterns of area, production and yield of major crops in western UP; second, to assess the spatio-temporal variations of levels of agricultural determinants and to find out the nature and magnitude of disparity in agriculture in the study area; and third, to examine the interrelationship between the variables of agriculture development and productivity of selected crops and to make suggestions for furthering to increase area, production and yield of major crop towards the sustainability of agriculture in the region.

6.2 Study Area

Western Uttar Pradesh has been selected for a detailed study as the area is rapidly changing from agricultural to industrial activities and commercialization of crops replacing food grains. Due to the great impact of the Green Revolution, western Uttar Pradesh is the most developed and prosperous in agriculture, although regional variation is found in the area, production and productivity of major crops. The technology used by farmers is labour-intensive, and production depends mainly on the amount of labour that the farmer can put into it. The lack of knowledge about farmers' water management, soil fertility and land practices is prevalent in areas of western Uttar Pradesh that are facing agricultural development problems. Western Uttar Pradesh lies in the Upper Gangetic Plains, which is endowed with fertile soil and level topography with suitable climatic conditions. It lies between 26°20′ and 30°20′ north latitudes and 77°45′ to 80°22′ east longitudes. It covers an area of about 80,076 sq km and has a population of about 61.06 million persons (Census of India 2001). According to 1971 census, western UP formed 18 districts. After 1971, one district was bifurcated, i.e. Ghaziabad from Meerut in 1981. After 1981, one district, i.e. Firozabad, was bifurcated from Mainpuri in 1991. According to 2001 census, five districts were bifurcated which include Baghpat from Meerut, Gautam Buddha

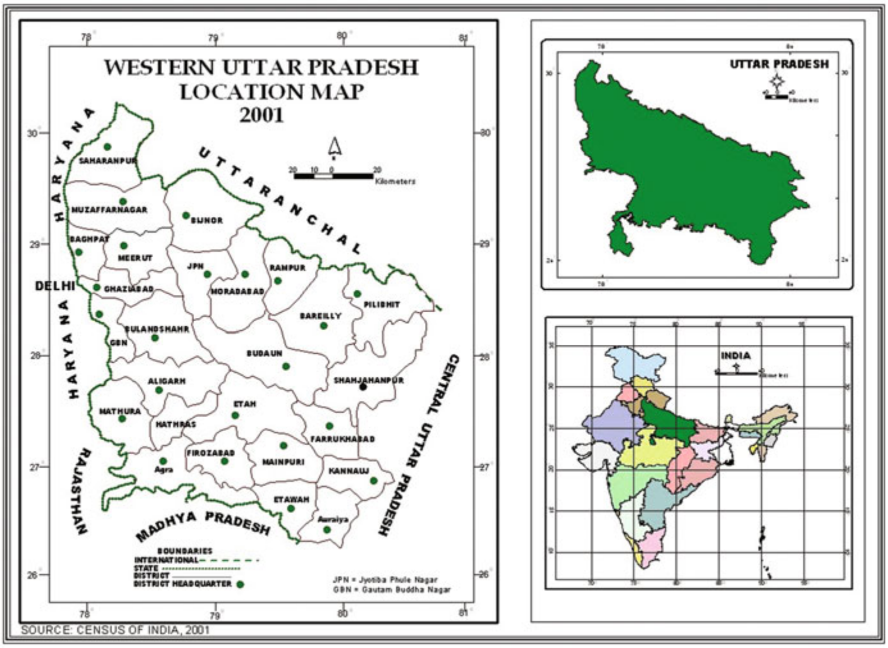

Fig. 6.1 Location map of the study area. (Source: Census of India 2001)

Nagar from Bulandshahr, Hathras from Aligarh, Auraiya from Etawah and Kannauj from Farrukhabad. The study area includes 26 districts, namely, Saharanpur, Muzaffarnagar, Meerut, Baghpat, Bulandshahr, Gautam Buddha Nagar, Ghaziabad, Jyotiba Phule Nagar, Aligarh, Hathras, Mathura, Agra, Firozabad, Mainpuri, Etah, Bareilly, Budaun, Shahjahanpur, Pilibhit, Bijnor, Moradabad, Rampur, Kannauj, Farrukhabad, Etawah and Auraiya (Fig. 6.1).

6.2.1 Data Base and Research Methodology

The present study is based on the secondary sources of related data conducted at the district level where district has been taken as a unit of analysis.

The data has been collected from various published and unpublished records of the government and non-government organizations. Agriculture data have been collected for the years 1970–1973, 1980–1983, 1990–1993 and 2000–2003 on a 3-year moving average from the Ministry of Agriculture, Department of Statistics and Economics, Lucknow, Government of Uttar Pradesh. Data of literature have been collected from various published books, journals and articles.

In order to reach on standardization, the raw data for each component level of agriculture development have been computed into standard scores. It is commonly known as *Z*-score or standard score. In the first step, district-wise *Z*-score for each indicator is calculated (Smith 1973). The values so obtained are added district-wise and standardized scores taken out of this composite *Z*-score which may be known as composite *Z*-score (Cs) for each district. Again, these results have been transformed back into *Z*-score, so that 'zero' indicates the average performance and unity (either + or −) which represents one standard deviation indicates high and low values, respectively. Thus, the levels of agricultural development have been examined with the help of composite *Z*-score technique, which is expressed as follows:

$$Z = \frac{X - \overline{X}}{\mathrm{SD}}$$

where:

Z = Standard score
X = Original values of the score
$\overline{X}$ = Mean of variables
SD = Standard deviation of variables

The obtained *Z*-score of each indicator is added district-wise known as composite *Z*-score(s) for each spatial unit of the study area:

$$\mathrm{Cs} = \sum Z_{ij}$$

Cs denotes composite *Z*-scores, while Z_{ij} indicates the sum of *Z*-scores of indicators *j* in district *i*. Subsequently, choropleth maps have been prepared through GIS software to bring out the real contrast more effectively. A careful selection of class intervals to decide the categories drawn on the maps is based on the mean and standard deviation.

6.3 Results and Discussion

Levels of Agricultural Development In this section, the level of agricultural development comprises of eight components which are as follows:

1. Net sown area to the total cultivated area
2. Total irrigated to the total cultivated area
3. Percentage of availability of pumping sets and tube wells
4. Percentage of canal irrigation to the net irrigated area
5. Percentage of tube well irrigation to the net irrigated area
6. Cropping intensity

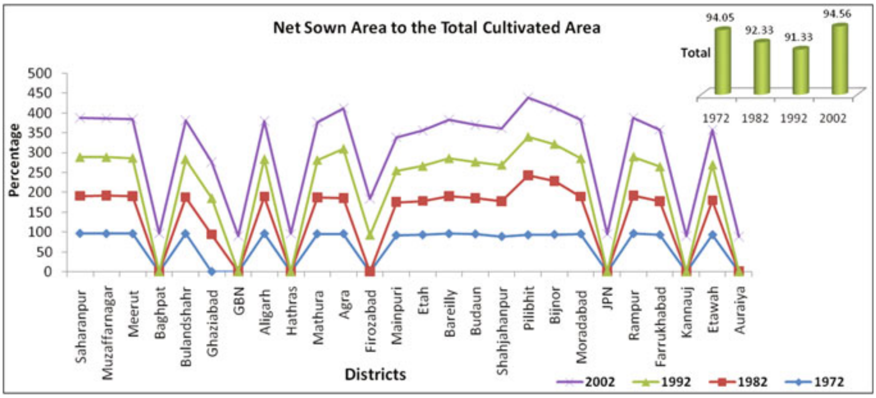

Fig. 6.2 District-wise distribution of net sown area and total of study area. (Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

7. Percentage of landholding by size groups below 1 hectare
8. Fertilizer consumption in kilogram per hectare of cultivated area

Figure 6.2 shows the spatial distribution of net sown area, a slight increase from 94.05% in 1972 to 94.56% in 2002. It was highest in Agra District at 95.22% in 1972 and 100.29% in 2002, while the lowest recorded in Mainpuri reduced from 91.46 to 84.06 during the same period. In 1992, highest increase in net sown area is found in three districts of Agra, Pilibhit and Rampur after 1982. These districts have been reported for highest concentration in cash crops production. Irrigation plays an important role in transforming the precarious agriculture of semiarid regions into productive agriculture. The success of HYV programmes depends mainly on the availability of adequate irrigation facilities as higher HYVs require higher chemical fertilizers and more water supply to the plants. The spatial pattern of total irrigated area increased from 91.87% in 1972 to 126.92% in 2002. During 1982–1992, it has increased from 85.85% to 91.12%. District-wise analysis shows that Bulandshahr has seen the most irrigated area which increased from 96.82% to 166.50% during 1972–2002, while the least irrigated area has been counted in Agra district, which has increased from 44.26% in 1972 to 87.22% in 2002 (Fig. 6.3).

Application of fertilizers is one of the most effective ways to increase soil fertility. The success of the new strategy in agricultural development depends on high-yielding varieties of seeds, fertilizers, irrigation, pesticides, agricultural implements and innovations. The consolidation of fragmented holdings as part of the land reform programme, agriculture and rural electrification are other components that are crucial to achieve optimal results from investment and the efforts put into farming. Advanced varieties of seeds are highly responsible for fertilizer input. They will not achieve full capacity without proper water and fertilizer, and their production

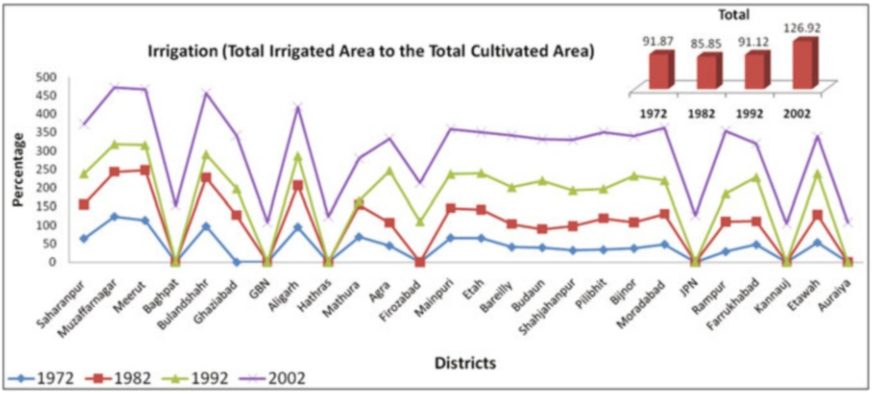

Fig. 6.3 District-wise distribution of total irrigated area and total study area. (Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

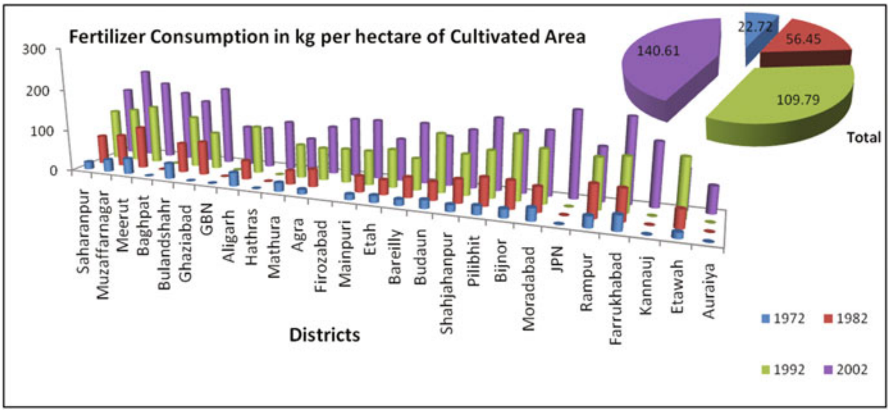

Fig. 6.4 District-wise distribution of fertilizer consumption and total of study area. (Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

will be highly variable or drastically degraded without the use of pesticides and herbicides (Chopra 1985).

Figure 6.4 shows the average spatial pattern of fertilizer consumption in kilogram per hectare. It has been increased from 22.72 kg/hectare in 1972 to 140.61 kg/hectare in 2002. Its consumption varies from district to district; Muzaffarnagar is the highest consumer of fertilizer in 2002, while the lowest consumption of fertilizer was in Auraiya, i.e. 62.20 kg/hectare, in 2002. All districts in the study area have recorded an increase in fertilizer use.

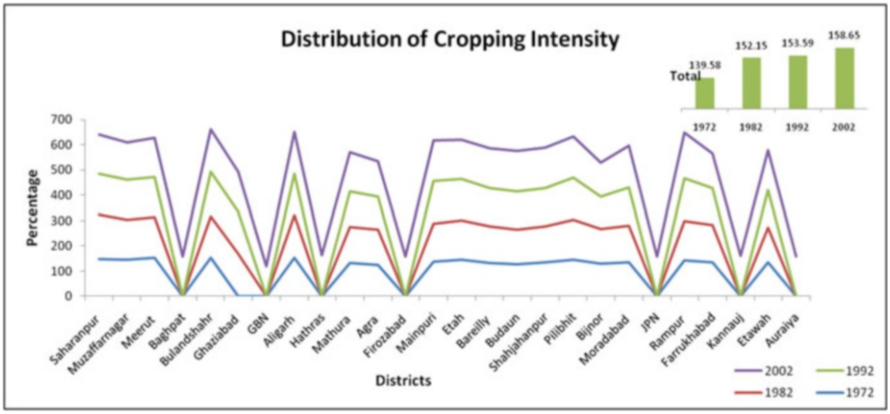

Fig. 6.5 District-wise distribution of cropping intensity and total of study area. (Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

The intensity of cropping refers to the ratio between gross cropped area and net cultivated area which is usually expressed in terms of percentage. A farmers can be produce, how many crops in a year or in other words how the farmer can harvest or double the intensity of the crop depends on many factors like availability of efficient irrigation facility, the use of manure and the nature of the crops that he decides to grow. As regards irrigation water and fertilizers, it can be argued that improving their use reduces crop intensity (Mishra 1968). Figure 6.5 shows the spatial pattern of crop intensity which increased from 129.58% in 1972 to 158.65% in 2002 in western Uttar Pradesh. Spatial analysis shows that maximum intensity of crop has been recorded in Rampur, which has increased from 142.8% in 1972 to 182.68% in 2002. The lowest intensity of the crop has been reported in Bijnor, although it has increased marginally from 129.8% to 124.86% during the study period (1972–2002).

It is generally accepted that fragmentation of landholding is a major cause of low productivity in agriculture in India. The size of landholdings is one of the important indicators of farmers, especially socio-economic status in an agricultural country like India where land is scarce and highly valued by the people (Roy and Mohammad 1968). Figure 6.6 shows the spatial pattern of landholdings below 1 hectare. It has increased from 62.55% in 1972 to 68.8% in 2002. The estimate of landholdings in 1982 was 62.6%, which increased to 66% in 1992. District-wise analysis shows that the highest land is 79.6% in Farrukhabad District in 2002, although it was 76.14% in 1972. As a result, the production of cash crops was recorded more in this district. But the lowest holdings were recorded in Agra (59%), which increased from 52.19% during the same period.

Figures 6.7 and 6.8 reveal the spatial pattern of irrigation through canals and tube wells. It exhibits that the canal irrigation has been reported a decline from 18.07% to 15.15% during 1972–2002 in the study area. On the other hand, area under tube well irrigation to the net irrigated area significantly increased from 18.11% in 1972 to

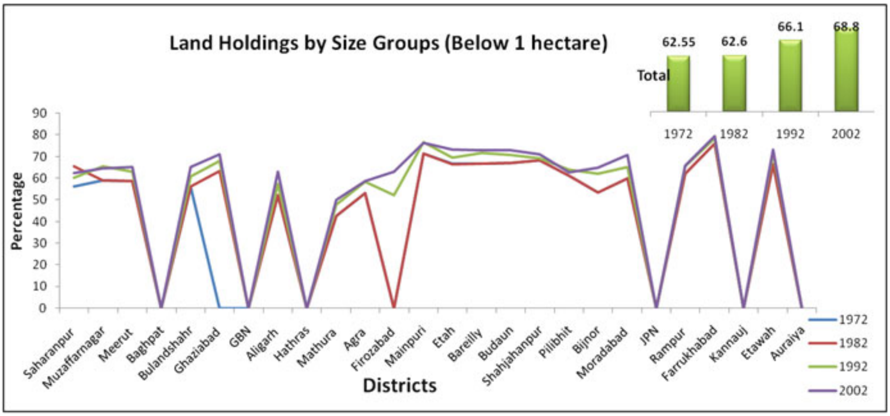

Fig. 6.6 District-wise distribution of landholding and total of study area. (Source: Calculation is based on data obtained from Economics and Statistics, State Planning Institute, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

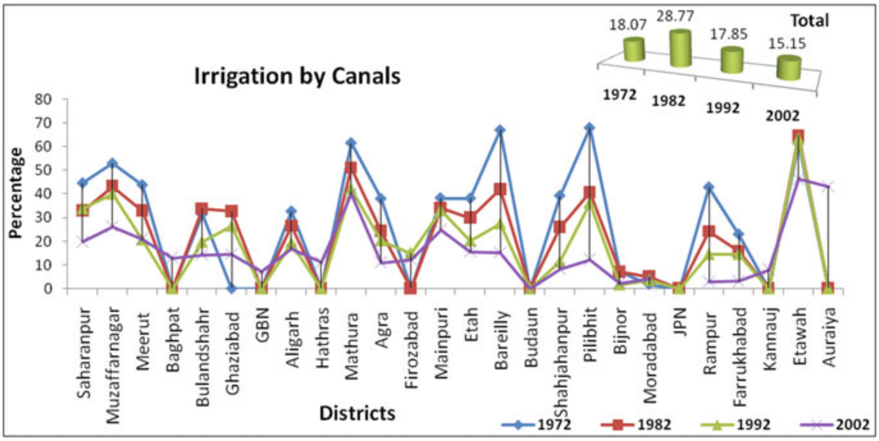

Fig. 6.7 District-wise distribution of irrigation by canal and total of study area. (Source: Calculation is based on data obtained from Economics and Statistics, State Planning Institute, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

85.1% in 2002. The district-wise analysis shows that the highest percentage of canal irrigation has been reported in Etawah though it declined from 61.44% in 1972 to 44.42% in 2002. Farrukhabad has observed a significant progress in tube well irrigation, which increased from 95.57% in 1972 to 46.66% in 2002. The lowest with 95.57% area under tube well irrigation has been registered in Etawah, whereas area under canal irrigation has been reported lowest in Moradabad though accounted an increase from 1.80% in 1972 to 4.45% in 2002.

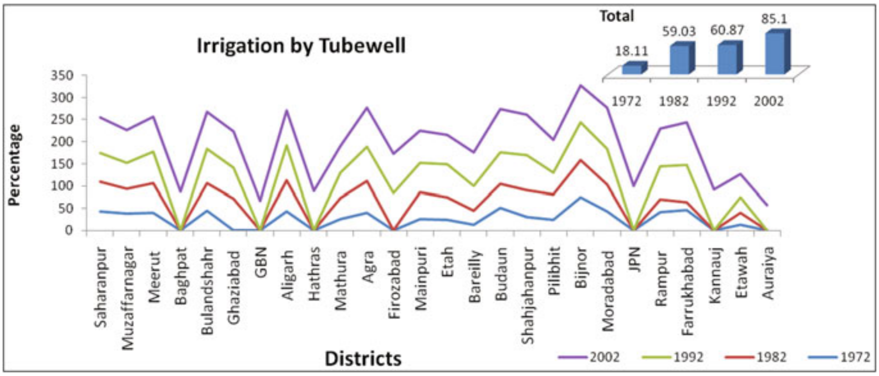

Fig. 6.8 District-wise distribution of irrigation by tube well and total of study area. (Source: Calculation is based on data obtained from Economics and Statistics, State Planning Institute, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

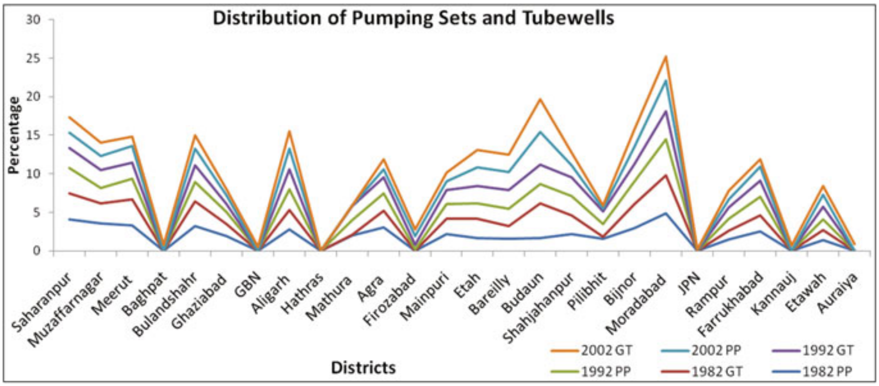

Fig. 6.9 District-wise distribution of pumping sets and tube well and total study area. (Source: Calculation is based on data obtained from Economics and Statistics, State Planning Institute, Lucknow, U.P. Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar. Districts were bifurcated after 1991 UP to which data are not available)

Pump sets assume immense significance in the development of agriculture in India. It is used for driving tube wells where electricity is not available or there is a frequent problem of load shedding. Figure 6.9 shows the distribution of pumping sets and tube wells which exhibits that the pumping sets have been reported a decline from 1.86% to 1.42% during 1992–2002 in the study area. The percentage of government tube wells declined from 1.72% in 1982 to 1.35% in 2002. The district-wise analysis shows that the highest percentage of pumping sets and government tube wells has been reported in Budaun (4.2% and 4.3%, respectively) in 2002.

The levels of agricultural development have been examined with the help of composite *Z*-score technique (eight indicators). In order to understand the level of agricultural development in details in sample study area, each indicator is analysed in spatial distribution. Western Uttar Pradesh has been categorized into five regions: very high (more than 1.5), high (0.5–1.5), medium (−0.5 to 0.5), low (−1.5 to −0.5) and very low in terms of composite *Z*-score (<−1.5) based on slandered interval (Fig. 6.10). The standardized composite *Z*-scores have been used to reveal the

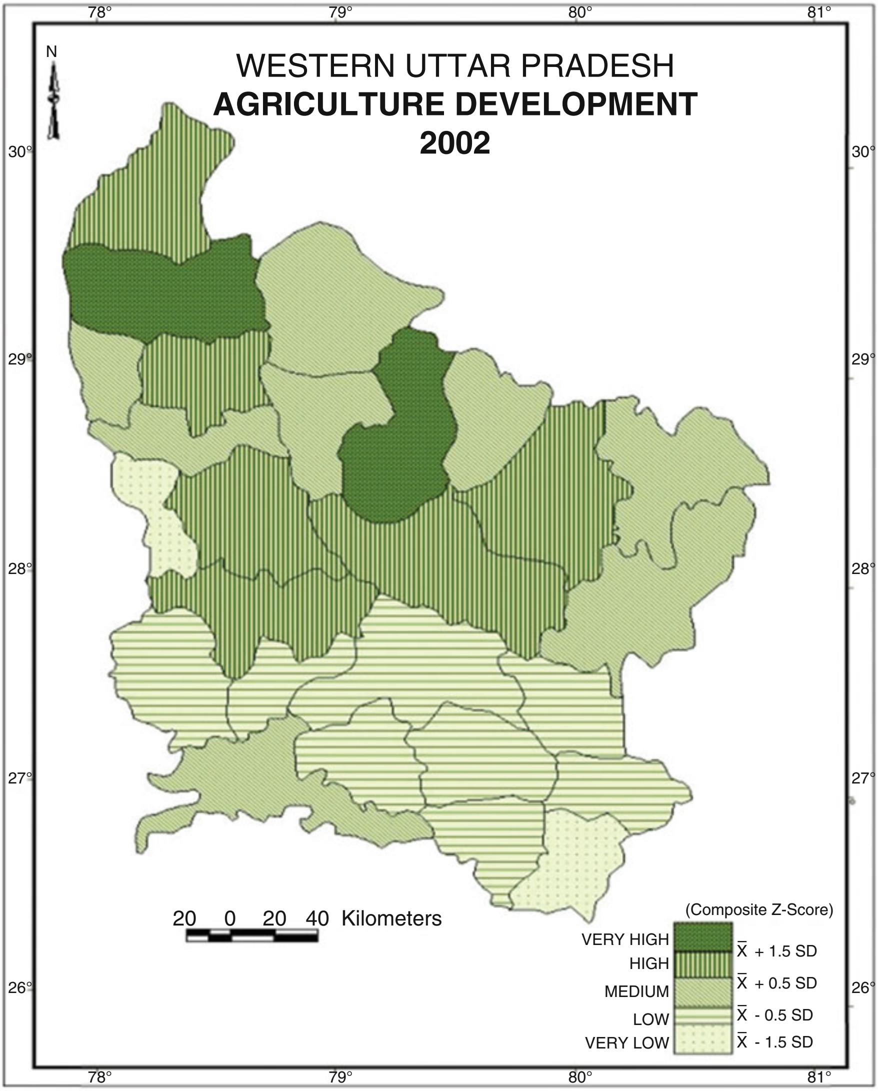

Fig. 6.10 District-wise distribution of the level of agricultural development. (Source: based on compiled data in Table 6.1)

Table 6.1 District-wise distribution of levels of agricultural development (in *Z*-scores) with indicators (2002–2003)

Districts	NSA	IRRI	FC	CI	PP	GT	Canal	TB	Composite standardized *Z*-scores
Saharanpur	1.14	0.35	0.6	0.01	0.52	0.7	0.38	−0.02	1.11
Muzaffarnagar	0.91	1.2	1.93	−0.49	0.34	0.38	0.9	−0.52	1.55
Meerut	0.83	1.1	1.24	−0.11	0.69	−0.16	0.48	−0.12	1.23
Baghpat	0.7	1.13	0.72	0.03	−1.24	−0.59	−0.18	0.54	0.32
Bulandshahr	0.83	1.73	0.27	1.09	0.69	0.38	−0.08	0.25	1.23
Ghaziabad	−0.74	0.77	1.18	0.14	−0.27	−0.59	−0.05	0.14	0.13
GBN	−1	−0.87	−1.17	−3.14	−1.24	−0.91	−0.65	−1.11	−2.11
Aligarh	0.48	0.28	−1.13	0.94	1.13	0.91	0.13	−0.11	0.51
Hathras	0.46	−0.18	−0.62	0.53	−1.24	−1.45	−0.33	0.66	−0.82
Mathura	0.44	−0.53	−1.56	0.06	−1.15	−1.45	2.03	−1.67	−1.18
Agra	1.71	−1.74	−0.67	−1.27	−0.27	−0.05	−0.34	0.62	−0.23
Firozabad	−0.67	−1.06	−0.05	0.06	−0.27	−0.48	−0.23	0.61	−0.65
Mainpuri	−2.4	−0.18	−0.01	0.46	−0.27	−0.27	0.79	−0.64	−0.91
Etah	−1.11	−0.72	−1.04	0.05	0.87	1.02	0.05	−1.19	−0.65
Bareilly	0.68	0.61	0.07	0.17	0.78	1.02	0	−0.46	0.82
Budaun	−0.28	−0.64	−0.59	0.37	2.27	2.85	−1.24	1.41	1.14
Shahjahanpur	−0.45	0.42	−0.07	0.4	0.17	0.27	−0.55	0.88	0.2
Pilibhit	1.09	1.19	0.76	0.61	−0.89	−1.02	−0.23	−0.52	0.11
Bijnor	−0.76	−0.85	0.16	−1.86	0.69	1.02	−1.05	0.24	−0.17
Moradabad	0.71	0.68	0.29	0.84	2.27	1.88	−0.88	1.05	1.82
JPN	0.38	−0.06	1.59	0.02	−1.15	−1.34	−1.24	1.58	−0.08
Rampur	1.1	1.9	−0.38	2.13	−0.27	−0.27	−1	0.35	0.43
Farrukhabad	−0.2	−1.53	1.47	−1.48	0.34	−0.38	−0.98	1.27	−0.01
Kannauj	−0.93	−1	0.19	0.18	−1.24	−0.7	−0.58	0.95	−1.01
Etawah	−1.55	−1.14	−1.19	0.21	0.17	−0.27	2.55	−2.26	−1.12
Auraiya	−1.35	−0.85	−2.01	0.07	−1.24	−0.48	2.29	−1.92	−1.69

Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics and Economics and Statistics, State Planning Institute, Lucknow, U.P.
Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar
NSA = % of Net sown area, IRRI = % of Irrigated area, FC = Fertilizer consumption in kg/hectare, CI = % of Cropping intensity

relative variation of agricultural development among districts of western Uttar Pradesh. The analysis reveals that the lowest composite *Z*-score of −2.11 is achieved by Gautam Buddha Nagar, while the highest as 1.82 is attained by the District of Moradabad (Table 6.1).

Figure 6.10 shows that a notable zone of very high concentration in agricultural development forms two districts, i.e. Muzaffarnagar and Moradabad. High concentration of agricultural development comprises of six districts: Bareilly, Saharanpur, Meerut, Bulandshahr, Budaun and Aligarh. It is clear from this figure that development of agriculture is found high in northern and central portion of the study area. But these areas are counted for low food availability due to high density of population and more industrialization coupled with cash crops. Eight districts of the study area form a contiguous region of medium grade of agricultural development with major concentration in the eastern pocket of the study area. Low grade of agricultural development constitutes the southern part which includes eight districts, namely, Etah, Hathras, Mainpuri, Firozabad, Mathura, Farrukhabad, Kannauj and Etawah. Very low concentration in agricultural development constitutes two districts, i.e. Gautam Buddha Nagar and Auraiya.

6.4 Cropping Pattern and Trends in Area, Production and Yield of Major Crops in Western Uttar Pradesh

Cropping pattern means area under different crops at a time, whereas a change in cropping pattern means a change in the proportion of area under different crops at two different points of time. The cropping pattern of any region is usually controlled by physical, socio-economic and technical factors. The biggest changes have occurred in cropping patterns, which have moved to total acres with qualitative and quantitative changes across different crop seasons, especially from the standpoint of individual crops.

This is due to techno-factors enumerated. If agricultural production is considered a stable one, then mere import of food will not be enough to feed them all. Now the question arises whether only increasing production will be sufficient or not. If the country's production itself is not distributed and is basically stable, people cannot access those food items. As a result, regional imbalances and inequalities oversee the country's development. The changing climatic pattern (Chattopadhyay 2011), improving technology, condition of soil, preservation techniques, etc. impact on the agricultural development (Kalpana Sastry et al. 2011; Thrupp 2000; Tscharntke et al. 2012) of the country. Now farmers have more crop options through diversity, higher incomes and dietary diversity. But there is a series of events such as arable land scarcity, water scarcity, coastal land harvesting, choice of altered crop, etc. It is believed that people have to starve and reduce them. The infrastructural incentives provided to the farmers are well utilized by the big farmers as compared to the small ones. Rising (food) quota has to be deducted from the rising cost of production of high selling prices paid by all and poor people. In addition to climate determination, rapid urbanization and changing food habits create a market for cash crops. Farmers transferred to it to make extra money; thus, food production falls (Saxena 2018).

6.4.1 District-Wise Distribution of Area, Production and Yield of Food Grains

Data on production and their growth in the area of food grains during the periods 1970–1972, 1980–1982, 1990–1992 and 2000–2002 represent the average years 1972, 1982, 1992 and 2002. Table 6.2a, b shows the district-wise distribution pattern and growth of area, production and yield of food grains. In the study area, the area under food grains decreased from 6024.1 to 6005.82 thousand hectares during 1970–2002, with percentage growth of −0.47%. During the decade of 1982–1992, the area under food grains has reduced from 6272.91 to 6054.22 thousand hectares with a growth rate of −5.00% in the study area. District-wise analysis exhibits that the highest area under food grains was increased from 297.42 thousand hectares in Shahjahanpur District to 459.88 thousand hectares during 1970–2002 due to the large size of land and low density of population; this district has the highest area of food grains. The maximum decline in area under food grains has been recorded at Rampur District, which has come down from 218.71 thousand hectares in 1972 to 27.68 thousand hectares in 2002, with a growth rate of −87.24%.

On the other hand, production of food grains increased from 581.66 lakh quintals in 1972 to 1589.74 lakh quintals in 2002, with a growth rate of 172% in western Uttar Pradesh. During 1972–1982, it was found to have increased to 69% but decreased to 26% during 1982–1992. During this period, the impact of new agricultural technology was observed, for example, fertilizer consumption increased from 22 kg/hectare in 1972 to 56 kg/hectare in 1982, followed by 109 kg/hectare in 1992. Food production increased to 172.21% during 1970–2002, while the yield was 174.60% during 1970–2002. The average rate of development hides from the fact that there has been a large fluctuation in food production in the region from year to year. Production has increased due to increased productivity in the study area. Yields of food grains have been reported to have positively increased during all study periods. District-wise analysis shows that the highest growth rate of food grain production is reported to have increased from 789 to 1957 kg/hectare in Shahjahanpur during 1972–2002, an increase of 247%. During 1972, Muzaffarnagar recorded the maximum decline in food grain production from 1998 to 1202, which was 66% during the same period (1970–2002).

Figure 6.11a–c sheds light on the spatial distribution in the growth of food grain area, production and yield during 1970–2002, which are categorized into five groups: very high, high, medium, low and very low. It shows that the highest concentration of food grain area and production was found to be high in eastern part of western Uttar Pradesh including Pilibhit, Bareilly, Shahjahanpur and Budaun districts. In addition, very high concentration of yield in food grains is observed in the eastern part of the region, including only one district, i.e. Shahjahanpur. Very low concentration of yield constitutes only one district, i.e. Muzaffarnagar, which is located in northern portion of the study area. The yield increased due to the increase in the application of modern inputs like fertilizers, availability of infrastructure specially irrigation, markets and road network to the farmers. Overall analyses

Table 6.2 (a) Distribution of area, production and yield of food grains in western UP. (b) Percentage growth of area, production and yield of food grains

(a)

Districts	**1970–1973**			**1980–1983**			**1990–1993**			**2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	340.4	35.341	1038	328.62	52.88	1609	222.97	51.89	2327	198.27	51.13	2579
Muzaffarnagar	248.84	29.92	1202	239.61	46.63	1946	198.78	53.3	2681	269.18	53.77	1998
Meerut	387.77	46.06	1188	155.96	47.74	3061	194	56.19	2896	106.8	34.88	3266
Baghpat	–	–	–	–	–	–	–	–	–	65.41	21.75	3325
Bulandshahr	430.71	52.59	1221	257.01	49.24	1916	448.21	107.78	2405	330.75	99.64	3013
Ghaziabad	–	–	–	344.92	65.63	1903	159.98	40.8	2550	101.18	31.07	3071
GBN	–	–	–	–	–	–	–	–	–	115.62	33.76	2920
Aligarh	481.62	55.39	1150	532.37	82.73	1554	484.12	99.11	2047	383.42	105.56	2753
Hathras	–	–	–	–	–	–	–	–	–	163.39	31.32	1917
Mathura	327.98	32.48	990	329.45	50.64	1537	258.97	60.99	2355	287.73	83.8	2912
Agra	360.54	28.97	804	343.28	49.17	1432	201.66	41.46	2056	224.47	61.19	2726
Firozabad	–	–	–	–	–	–	191.87	39.88	2078	195.99	49.05	2503
Mainpuri	315.89	29.35	929	356.54	47.3	1327	241.69	51.33	2124	251.71	65.24	2592
Etah	355.79	33.07	929	407.23	53.19	1306	420.32	77.58	1846	387.93	95.13	2452
Bareilly	316.95	25.011	789	365.92	48.76	1333	357.71	66.59	1862	427.14	83.6	1957
Budaun	381.46	31.87	835	439.02	55.89	1273	499.53	86.9	1740	500.79	120.51	2406
Shahjahanpur	297.43	23.56	792	407.72	56	1373	436.34	94.38	2163	459.88	126.76	2756
Pilibhit	213.22	18.49	867	273.75	45.79	1673	288.51	70.74	2452	294.23	86.49	2940
Bijnor	255.04	22.98	901	233.86	32.78	1402	191.59	45.87	2394	172.14	48.48	2816
Moradabad	474.39	36.59	771	474.34	71.38	1505	474.23	103.87	2190	358.98	94.31	2627
JPN	–	–	–	–	–	–	–	–	–	131.92	36	2729
Rampur	218.71	19.75	903	227.94	40.17	1762	236.71	55.22	2333	27.68	70.75	2800
Farrukhabad	312.29	27.62	884	314.9	37.28	1184	301.49	62.07	2059	128.69	36.97	2873

Kannauj	–	–	–	–	–	–	–	–	–	109.7	39.57	3607
Etawah	315.13	32.62	1035	340.47	51.07	1500	245.55	76.04	3097	179.79	44.89	2497
Auraiya	–	–	–	–	–	–	–	–	–	133.04	47.12	3542
Total	**6034.16**	**581.66**	**964**	**6372.91**	**984.27**	**1544**	**6054.23**	**1341.99**	**2217**	**6005.83**	**1589.74**	**2647**

(b)

Districts	**1970–1973 to 1980–1983**			**1980–1983 to 1990–1993**			**1990–1993 to 2000–2003**			**1970–1973 to 2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	−3.46	49.63	54.99	−32.15	−1.87	44.62	−11.08	−1.46	10.81	−41.75	44.68	148.39
Muzaffarnagar	−3.71	55.85	61.85	−17.04	14.30	37.78	35.42	0.88	−25.50	8.17	79.71	66.13
Meerut	−59.78	3.65	157.70	24.39	17.70	−5.38	−44.95	−37.92	12.76	−72.46	−24.27	174.95
Baghpat	–	–	–	–	–	–	–	–	–	–	–	–
Bulandshahr	−40.33	−6.37	56.91	74.39	118.89	25.51	−26.21	−7.55	25.28	−23.21	89.47	146.73
Ghaziabad	–	–	–	−53.62	−37.83	34.03	−36.75	−23.85	20.41	–	–	–
GBN	–	–	–	–	–	–	–	–	–	–	–	–
Aligarh	10.54	49.36	35.12	−9.06	19.80	31.74	−20.80	6.51	34.48	−20.39	90.58	139.39
Hathras	–	–	–	–	–	–	–	–	–	–	–	–
Mathura	0.45	55.91	55.22	−21.39	20.44	53.22	11.11	37.40	23.67	−12.27	158.00	194.10
Agra	−4.79	69.73	78.26	−41.25	−15.68	43.54	11.31	47.59	32.59	−37.74	111.22	239.26
Firozabad	–	–	–	–	–	–	2.15	22.99	20.41	–	–	–
Mainpuri	12.87	61.16	42.78	−32.21	8.52	60.09	4.15	27.10	22.04	−20.32	122.28	178.96
Etah	14.46	60.84	40.52	3.21	45.85	41.31	−7.71	22.62	32.86	9.03	187.66	163.83
Bareilly	15.45	94.95	68.86	−2.24	36.57	39.70	19.41	25.54	5.14	34.77	234.25	148.03
Budaun	15.09	75.37	52.38	13.78	55.48	36.65	0.25	38.68	38.33	31.28	278.13	188.03
Shahjahanpur	37.08	137.69	73.39	7.02	68.54	57.48	5.39	34.31	27.43	54.62	438.03	247.97
Pilibhit	28.39	147.65	92.89	5.39	54.49	46.58	1.98	22.26	19.89	37.99	367.77	238.98
Bijnor	−8.30	42.65	55.56	−18.07	39.93	70.81	−10.15	5.69	17.63	−32.50	110.97	212.56
Moradabad	−0.01	95.08	95.10	−0.02	45.52	45.55	−24.30	−9.20	19.95	−24.33	157.75	240.61

(continued)

Table 6.2 (continued)

JPN	–	–	–	–	–	–	–	–	–	–	–	–
Rampur	4.22	103.39	95.16	3.85	37.47	32.37	−88.31	−85.97	20.02	−87.34	246.76	210.05
Farrukhabad	0.84	34.97	33.86	−4.26	66.50	73.90	−57.32	−40.44	39.54	−58.79	33.85	224.82
Kannauj	–	–	–	–	–	–	–	–	–	–	–	–
Etawah	8.04	56.56	44.91	−27.88	48.89	106.45	−26.78	−40.97	−19.37	−42.95	37.61	141.21
Auraiya	–	–	–	–	–	–	–	–	–	–	–	–
Total	**5.61**	**69.22**	**60.22**	**−5.00**	**36.34**	**43.52**	**−0.80**	**18.46**	**19.42**	**−0.47**	**173.31**	**174.60**

Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P.
Three-year moving average of data is taken
A area (in ‘000 hectares), *P* production (in lakh quintals), *Y* yield (in kg/hectare)
Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar
Districts were bifurcated after 1991 UP to which data are not available

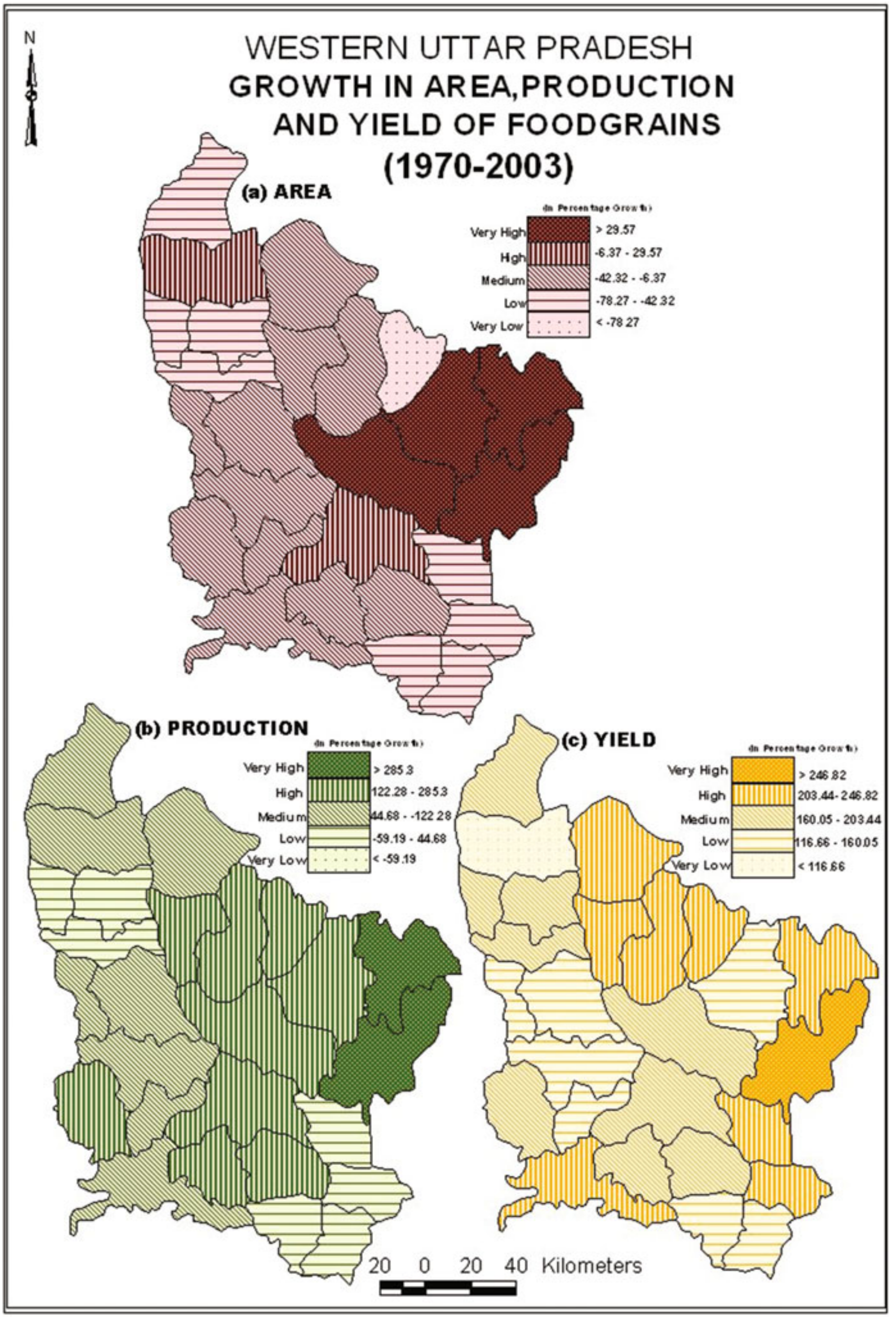

Fig. 6.11 (**a–c**) District-wise distribution of growth of area, production and yield of food grains. (Source: complied with the data available in Table 6.2b)

show that very high and high concentration of area, production and yield is found in eastern pocket of the study area. In western portion, only Mathura District is found to have highest production of food grains. The northern and western portions are low in food grain production because these areas are high specialty crops.

6.4.2 District-Wise Distribution of Area, Production and Yield of Pulses

Pulses are the most important part of a balanced diet. It is an important source of dietary protein for most of the population in India. They are also rich sources of energy, minerals and some vitamins. Apart from these nutritional values, they are also restoring the atmospheric properties of the soil by their deep and well-spread root system properties. Western UP pulses are the most neglected crop due to very low productivity as compared to wheat and rice and other major crops like cash crops in the study area.

The area under pulses accounted for about 5% of the food grains in the study area in 2002. Table 6.3a, b rate in the area of pulses is counted in Aligarh District to 10% which increased from 25 thousand hectares in 1972 to 27.5 thousand hectares in 2002. The area of pulses has seen a significant decline in Meerut District which has come down from 21.8 thousand hectares in 1972 to 2.7 thousand hectares in 2002. The area of pulses has been replaced by other crops such as wheat and rice. The production of pulses was only 1% among the food grains in 2002, which decreased a lot from 1970 (9%) in the study area. Table 6.3 and Fig. 6.12b represent that the production of pulses decreased from 54 to 26.29 lakh quintals during 1970–2002, with growth rate of −51%. District-wise analysis shows that the production of pulses in Aligarh (−22%) declined slightly, from 2.74 lakh quintals in 1972 to 2.1 lakh quintals in 2002, while in Muzaffarnagar, it declined by −57% from 0.88 to 0.27 lakh quintals. The above discussion shows that there is a clear shift in the area from pulses and coarse grains to fine grains. The region is the seat of the ‘Green Revolution’, which was essentially the wheat revolution. After the introduction of high-yielding varieties of seeds, fertilizers and technology with a generous supply of irrigation water, farmers in the region took up almost exclusively for wheat production. The region also specializes in the cultivation of wheat as farmers consider it economically more profitable. It was due to the introduction of an early maturing variety which is grown in rotation with wheat. Rice is also one of the preferred crops due to favourable conditions and irrigation facilities.

Table 6.3 (a) Distribution of area, production and yield of pulses in western UP. (b) Percentage growth of area, production and yield of pulses

(a)

Districts	**1970–1973**			**1980–1983**			**1990–1993**			**2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	23.7	1.46	616	17.83	0.75	421	12.84	0.81	631	8.13	0.47	578
Muzaffarnagar	12.39	0.88	710	10.05	0.51	507	12.53	0.85	678	6.45	0.37	574
Meerut	21.8	2.07	950	10.46	0.79	755	10.75	1.05	977	3.7	0.27	730
Baghpat	–	–	–	–	–	–	–	–	–	1.76	0.12	682
Bulandshahr	22.6	3.11	1376	27.67	2.1	759	32.46	3.1	955	18.03	1.01	560
Ghaziabad	–	–	–	11.95	1.08	904	8.57	0.99	1155	3.05	0.24	787
GBN	–	–	–	–	–	–	–	–	–	3.98	0.33	829
Aligarh	25	2.74	1096	90.32	7.23	800	66.96	6.09	909	27.52	2.1	763
Hathras	–	–	–	–	–	–	–	–	–	11.88	0.85	715
Mathura	34.34	4.4	1281	34.32	2.73	795	14.95	1.18	789	8.75	0.43	491
Agra	79.02	6.77	857	56.74	6.3	1110	19.17	2.35	1226	14	1.88	1343
Firozabad	–	–	–	–	–	–	16.89	1.85	1095	9.15	0.74	809
Mainpuri	25.55	2.8	1096	30.38	2.9	955	19.1	2.08	1089	14.39	0.89	618
Etah	28.1	3.36	1196	71.44	8.48	1187	58.48	6.92	1183	24.32	1.64	674
Bareilly	35.61	2.56	719	40.97	3.32	810	33.12	2.14	646	27.45	1.48	539
Budaun	40.05	4.38	1094	58.09	5.01	862	39.33	2.93	745	29.27	2.83	967
Shahjahanpur	39.58	3.14	793	59.21	4.16	703	44.16	3.04	688	15.41	1.46	947
Pilibhit	17.66	1.33	753	23.2	1.25	539	12	0.62	517	6.35	0.48	756
Bijnor	22.05	1.33	603	17.68	1	566	12.4	0.76	613	12.61	0.47	373
Moradabad	25.74	2.2	855	19.74	1.45	735	13.47	0.9	668	9.58	1.28	1336
JPN	–	–	–	–	–	–	–	–	–	3.62	0.26	718
Rampur	19.61	1.5	765	14.99	1.22	814	8.6	0.57	663	6.69	0.66	987
Farrukhabad	32.08	3.1	966	34.67	3.31	955	33.83	2.94	869	9.2	0.89	967

(continued)

Table 6.3 (continued)

Kannauj	–	–	–	–	–	–	–	–	–	13.44	1.19	885
Etawah	40.66	6.87	1690	57.29	6.8	1187	55.155	6.87	1246	17.404	1.97	1132
Auraiya	–	–	–	687	60.39	–	–	48.04		23.404	2.08	889
Total	**545.54**	**54.00**	**990**	**687.00**	**60.39**	**879**	**524.77**	**48.04**	**915**	**329.54**	**26.39**	**801**
(b)												
Districts	**1970–1973 to 1980–1983**			**1980–1983 to 1990–1993**			**1990–1993 to 2000–2003**			**1970–1973 to 2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	−24.77	−48.63	−31.72	−27.99	8.00	49.97	−36.68	−41.98	−8.36	−65.70	−67.81	−6.16
Muzaffarnagar	−18.89	−42.05	−28.55	24.68	66.67	33.68	−48.52	−56.47	−15.44	−47.94	−57.95	−19.23
Meerut	−52.02	−61.84	−20.46	2.77	32.91	29.33	−65.58	−74.29	−25.29	−83.03	−86.96	−23.15
Baghpat	–	–	–	–	–	–	–	–	–	–	–	–
Bulandshahr	22.43	−32.48	−44.85	17.31	47.62	25.84	−44.45	−67.42	−41.34	−20.22	−67.52	−59.29
Ghaziabad	–	–	–	−28.28	−8.33	27.82	−64.41	−75.76	−31.88	–	–	–
GBN	–	–	–	–	–	–	–	–	–	–	–	–
Aligarh	261.28	163.87	−26.96	−25.86	−15.77	13.62	−58.90	−65.52	−16.10	10.08	−23.36	−30.38
Hathras	–	–	–	–	–	–	–	–	–	–	–	–
Mathura	−0.06	−37.95	−37.92	−56.44	−56.78	−0.77	−41.47	−63.56	−37.74	−74.52	−90.23	−61.65
Agra	−28.20	−6.94	29.60	−66.21	−62.70	10.41	−26.97	−20.00	9.54	−82.28	−72.23	56.74
Firozabad	–	–	–	–	–	–	−45.83	−60.00	−26.16	–	–	–
Mainpuri	18.90	3.57	−12.89	−37.13	−28.28	14.08	−24.66	−57.21	−43.21	−43.68	−68.21	−43.56
Etah	154.23	152.38	−0.73	−18.14	−18.40	−0.31	−58.41	−76.30	−43.01	−13.45	−51.19	−43.60
Bareilly	15.05	29.69	12.72	−19.16	−35.54	−20.26	−17.12	−30.84	−16.56	−22.91	−42.19	−25.00
Budaun	45.04	14.38	−21.14	−32.29	−41.52	−13.62	−25.58	−3.41	29.78	−26.92	−35.39	−11.59
Shahjahanpur	49.60	32.48	−11.44	−25.42	−26.92	−2.02	−65.10	−51.97	37.63	−61.07	−53.50	19.43
Pilibhit	31.37	−6.02	−28.46	−48.28	−50.40	−4.11	−47.08	−22.58	46.30	−64.04	−63.91	0.37
Bijnor	−19.82	−24.81	−6.23	−29.86	−24.00	8.36	1.69	−38.16	−39.19	−42.81	−64.66	−38.21
Moradabad	−23.31	−34.09	−14.06	−31.76	−37.93	−9.04	−28.88	42.22	99.97	−62.78	−41.82	56.33

JPN	–	–	–	–	–	–	–	–	–	–	–	–
Rampur	−23.56	−18.67	6.40	−42.63	−53.28	−18.56	−22.21	15.79	48.85	−65.88	−56.00	28.97
Farrukhabad	8.07	6.77	−1.20	−2.42	−11.18	−8.97	−72.81	−69.73	11.32	−71.32	−71.29	0.11
Kannauj	–	–	–	–	–	–	–	–	–	–	–	–
Etawah	40.90	−1.02	−29.75	−3.73	1.03	4.94	−68.45	−71.32	−9.12	−57.20	−71.32	−33.01
Auraiya	–	–	–	–	–	–	–	–	–	–	–	–
Total	**25.93**	**11.83**	**−11.19**	**−23.61**	**−20.45**	**4.14**	**−37.20**	**−45.07**	**−12.52**	**−39.59**	**−51.13**	**−19.10**

Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P.
Three-year moving average of data is taken
A area (in '000 hectares), *P* production (in lakh quintals), *Y* yield (in kg/hectare)
Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar
Districts were bifurcated after 1991 UP to which data are not available

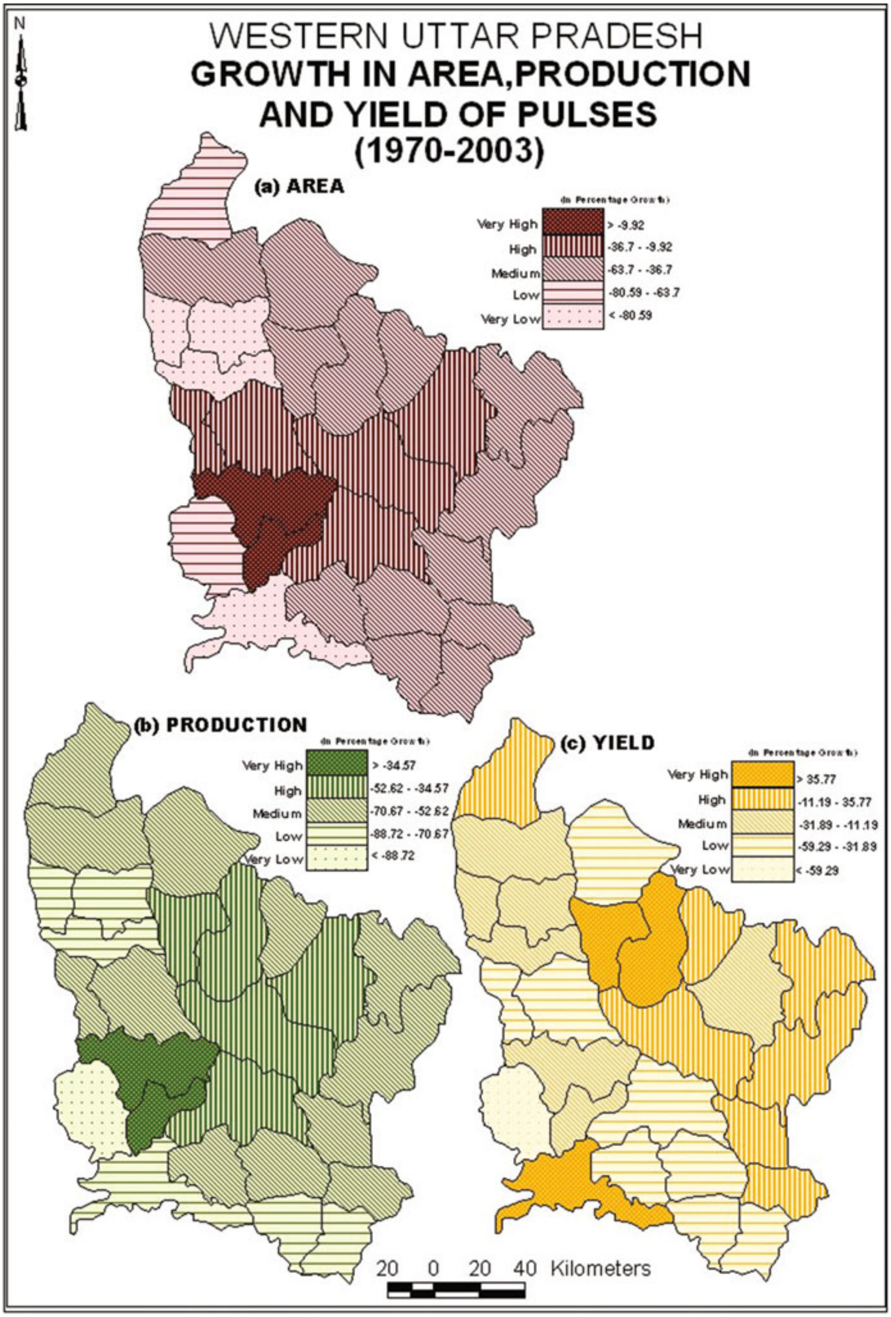

Fig. 6.12 (**a–c**) District-wise distribution of growth of area, production and yield of pulses. (Source: complied with the data available in Table 6.3b)

6.4.3 District-Wise Distribution of Area, Production and Yield of Cereal

Cereal crop has a prominent and highly important position. Table 6.4 shows that the area under cereals increased from 5282.78 thousand hectares in 1972 to 6529.5 thousand hectares in 2002, with a growth rate of 21% in the study area. Cereal production increased from 564.49 lakh quintals in 1972 to 1422 lakh quintals in 2002, with a growth rate of 152% in the study are. As per district analysis, the maximum growth rate in production was recorded in Pilibhit (401%), which increased from 17.16 lakh quintals in 1972 to 86.04 lakh quintals in 2002. The yield of crops varies due to differences in climate, type of soil and inputs like fertilizers used, irrigation quality of seeds and pesticides used (Shaf 2006). Rampur District was reported to have the highest growth rate of yield which increased from 916 kg/hectare in 1972 to 2800 kg/hectare in 2002, with a growth rate of 205%. The worse situation in the production and yield of grains has been found in Mainpuri District. The yield in Mainpuri decreased from 914 kg/hectare in 1972 to 258 kg/hectare in 2002, while in Mainpuri the −71%.

Figure 6.13a–c displays spatial variation in area, production and yields of cereals in overall western Uttar Pradesh. It explains that the very highest percentage growth of area and production of cereals during 1970–2003 was found in eastern pocket of western Uttar Pradesh. On the other hand, only Rampur District comes under very high concentration of yield. Three districts, namely, Firozabad, Shahjahanpur and Mainpuri, fall under very low yield of cereal lying in the southern pocket of the study area. Overall analyses show that very high and high concentration of area, production and yield of cereals is exhibiting similar patterns that have been also observed in the case of food grains.

6.4.4 District-Wise Distribution of Area, Production and Yield of Cash Crops

Sugarcane is the most important commercial crop grown in western UP. This crop has gone up during all study period in western UP. Table 6.5a, b illustrates that the sugarcane tends to rise on a large scale in area, production and yield in most districts of the study region during all study periods. The area under sugarcane has gone up from 628.27 to 1060.97 thousand hectares during 1970–2002, recording an increase of 66%. Production under this crop has also gone up from 2264.85 to 6822.94 lakh quintals with a growth rate of 109%. Yield has also rose from 51,152 to 64,412 kg/hectare with a growth rate of 26% in the study area. District-wise analysis shows that highest increase in area under sugarcane is found in Meerut with a growth rate of 778% that significantly rose from 12.99 to 122.9 thousand hectares during 1970–2002. Similarly, production has augmented in Bijnor that significantly increased from 121.42 to 829.09 lakh quintals with a growth rate of 582%.

Table 6.4 (a) Distribution of area, production and yield of cereals in western UP. (b) Percentage growth of area, production and yield of cereals

(a)

Districts	1970–1973			1980–1983			1990–1993			2000–2003		
	A	*P*	*Y*	*A*	*P*	*Y*	*A*	*P*	*Y*	*A*	*P*	*Y*
Saharanpur	316.7	33.87	1069	310.79	52.12	1677	210.12	51.07	2431	190.14	50.65	2664
Muzaffarnagar	236.45	39.03	1651	219.56	33.21	1513	186.25	52.45	2816	162.73	46.72	2871
Meerut	365.96	43.98	1202	218.04	46.95	2153	183.25	55.17	3011	103.1	34.6	3356
Baghpat	–	–	–	–	–	–	–	–	–	63.64	2.16	339
Bulandshahr	408.1	48.48	1188	322.31	63.92	1983	395.74	39.81	1006	312.71	98.24	3142
Ghaziabad	–	–	–	250.03	47.77	1911	141.16	30.67	2173	98.27	30.82	3136
GBN	–	–	–	–	–	–	–	–	–	111.83	33.42	2988
Aligarh	456.618	52.64	1153	443.72	75.5	1702	417.16	93.2	2234	383.76	103.45	2696
Hathras	–	–	–	–	–	–	–	–	–	165.13	43.57	2639
Mathura	292.63	43.98	1503	291.96	47.91	1641	244.1	58.81	2409	301	83.37	2770
Agra	281.51	22.2	789	286.54	43.03	1502	182.49	38.78	2125	249.17	59.3	2380
Firozabad	–	–	–	–	–	–	174.97	38.02	2173	21.07	48.3	22,924
Mainpuri	290.33	26.53	914	326.16	44.39	1361	222.65	49.25	2212	249.49	6.43	258
Etah	327.69	29.71	907	335.78	46.59	1388	258.4	70.97	2747	394.71	93.48	2368
Bareilly	281.34	22.44	798	324.95	45.44	1398	327.91	64.44	1965	353.73	82.11	2321
Budaun	341.4	27.48	805	380.96	50.87	1335	460.19	83.97	1825	518.11	91.76	1771
Shahjahanpur	257.84	20.41	792	315.14	51.83	1645	392.18	91.34	2329	389.8	12.52	321
Pilibhit	195.56	17.16	877	250.55	44.54	1778	276.5	70.12	2536	390.35	86.04	2204
Bijnor	232.98	21.65	929	216.21	21.95	1015	179.18	44.44	2480	171.48	48.01	2800
Moradabad	343.9	44.86	1304	454.6	66.6	1465	460.76	102.97	2235	358.96	93.02	2591
JPN	–	–	–	–	–	–	–	–	–	274.64	35.74	1301
Rampur	199.09	18.24	916	212.94	38.94	1829	228.1	54.65	2396	274.64	76.89	2800
Farrukhabad	280.21	25.51	910	280.23	33.96	1212	269.32	58.99	2190	217.23	36.08	1661

Kannauj	–	–	–	–	–	–	–	–	–	230.32	38.37	1666
Etawah	274.47	26.32	959	283.31	44.26	1562	311.75	69.17	2219	265.47	42.92	1617
Auraiya	–	–	–	–	–	–	–	–	–	278.02	45.03	1620
Total	**5382.78**	**564.49**	**1049**	**5723.78**	**899.78**	**1572**	**5522.18**	**1218.29**	**2206**	**6529.5**	**1423**	**2179**

(b)

Districts	**1970–1973 to 1980–1983**			**1980–1983 to 1990–1993**			**1990–1993 to 2000–2003**			**1970–1973 to 2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	−1.87	53.88	56.81	−32.39	−2.01	44.93	−9.51	−0.82	9.60	−39.96	49.54	149.08
Muzaffarnagar	−7.14	−14.91	−8.37	−15.17	57.93	86.18	−12.63	−10.92	1.95	−31.18	19.70	73.93
Meerut	−40.42	6.75	79.18	−15.96	17.51	39.82	−43.74	−37.28	11.47	−71.83	−21.33	179.25
Baghpat	–	–	–	–	–	–	–	–	–	–	–	–
Bulandshahr	−38.73	−1.46	60.83	−43.54	−35.80	13.72	121.53	220.31	44.59	−23.37	102.64	164.45
Ghaziabad	–	–	–	22.78	−37.72	−49.28	−75.17	−22.58	211.77	–	–	–
GBN	–	–	–	–	–	–	–	–	–	–	–	–
Aligarh	−2.82	43.43	47.60	−5.99	23.44	31.30	−8.01	11.00	20.66	−15.96	96.52	133.83
Hathras	–	–	–	–	–	–	–	–	–	–	–	–
Mathura	−0.23	8.94	9.19	−16.39	22.75	46.82	23.31	41.76	14.96	2.86	89.56	84.29
Agra	1.79	93.83	90.43	−36.31	−9.88	41.51	36.54	52.91	11.99	−11.49	167.12	201.79
Firozabad	–	–	–	–	–	–	−87.96	27.04	954.96	–	–	–
Mainpuri	12.34	67.32	48.94	−31.74	10.95	62.53	12.05	−86.94	−88.35	−14.07	−75.76	−71.80
Etah	2.47	56.82	53.04	−23.04	52.33	97.94	52.75	31.72	−13.77	20.45	214.64	161.22
Bareilly	15.50	102.50	75.32	0.91	41.81	40.53	7.87	27.42	18.12	25.73	265.91	191.03
Budaun	11.59	85.12	65.89	20.80	65.07	36.65	12.59	9.28	−2.94	51.76	233.92	120.03
Shahjahanpur	22.22	153.94	107.77	24.45	76.23	41.61	−0.61	−86.29	−86.21	51.18	−38.66	−59.42
Pilibhit	28.12	159.56	102.59	10.36	57.43	42.66	41.18	22.70	−13.08	99.61	401.40	151.19
Bijnor	−7.20	1.39	9.25	−17.13	102.46	144.30	−4.30	8.03	12.88	−26.40	121.76	201.29
Moradabad	32.19	48.46	12.31	1.36	54.61	52.54	−22.09	−9.66	15.96	4.38	107.36	98.66

(continued)

Table 6.4 (continued)

JPN	–	–	–	–	–	–	–	–	–	–	–	–
Rampur	6.96	113.49	99.60	7.12	40.34	31.02	20.40	40.70	16.85	37.95	321.55	205.58
Farrukhabad	0.01	33.12	33.11	−3.89	73.70	80.74	−19.34	−38.84	−24.17	−22.48	41.43	82.44
Kannauj	–	–	–	–	–	–	–	–	–	–	–	–
Etawah	3.22	68.16	62.91	10.04	56.28	42.02	−14.85	−37.95	−27.13	−3.28	63.07	68.60
Auraiya	–	–	–	–	–	–	–	–	–	–	–	–
Total	**6.34**	**59.40**	**49.90**	**−3.52**	**35.40**	**40.34**	**18.24**	**16.80**	**−1.22**	**21.30**	**152.09**	**107.81**

Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P.
Three-year moving average of data is taken
A area (in ‘000 hectares), *P* production (in lakh quintals), *Y* yield (in kg/hectare)
Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar
Districts were bifurcated after 1991 UP to which data are not available

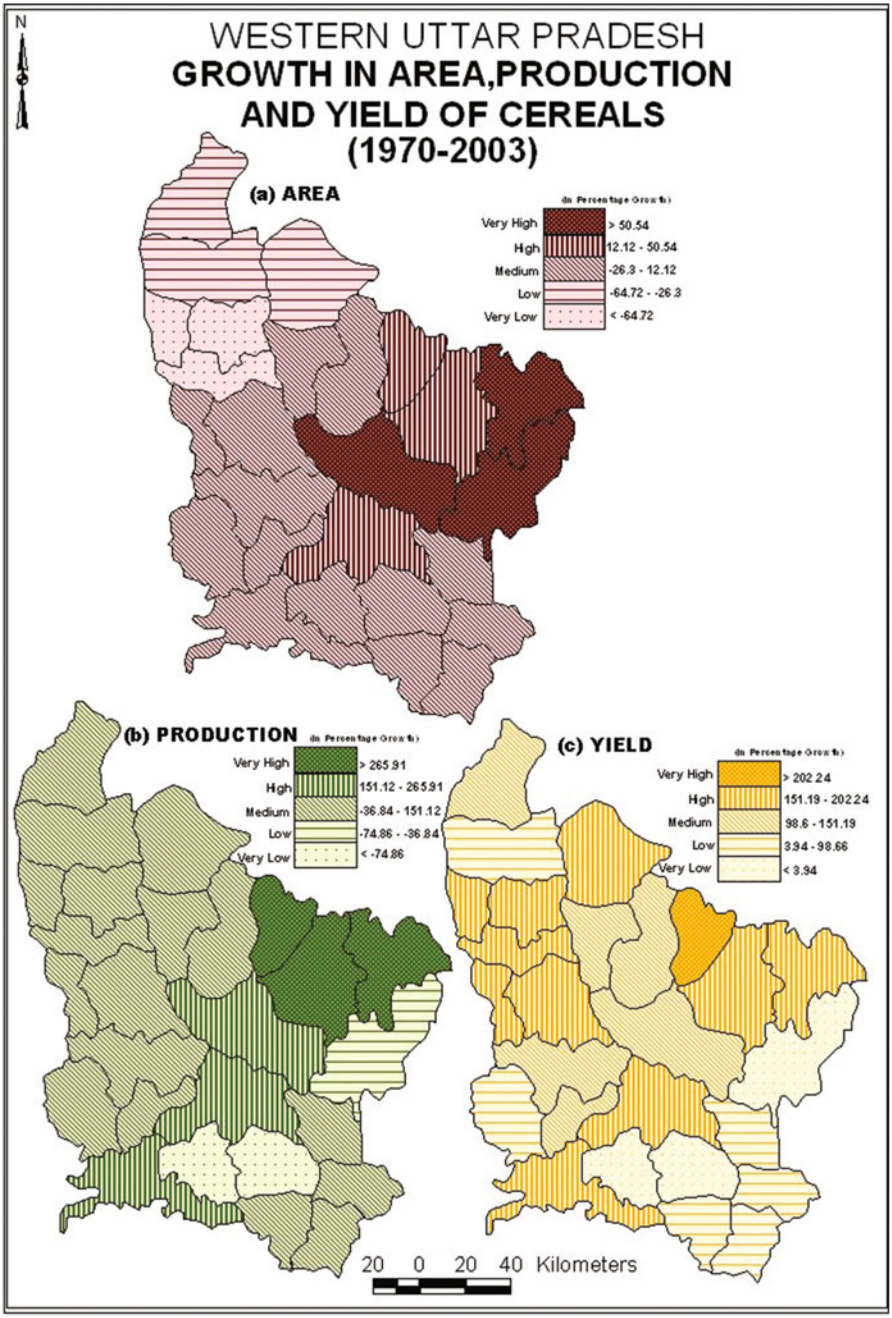

Fig. 6.13 (**a**–**c**) District-wise distribution of growth of area, production and yield of cereals. (Source: complied with the data available in Table 6.4b)

Table 6.5 (a) Distribution of area, production and yield of sugarcane in western UP. (b) Percentage growth of area, production and yield of sugarcane

(a)

Districts	1970–1973			1980–1983			1990–1993			2000–2003		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	89.5	332.92	37,198	129.26	652.06	50,446	114.98	732.29	63,688	127.35	731.51	57,441
Muzaffarnagar	126.04	614.54	48,758	173.72	927.77	53,406	194.46	1273.33	65,480	21.84	1392.72	637,692
Meerut	13.99	671.66	480,100	156.3	789.49	50,511	167.21	1026.48	61,389	122.9	762.11	62,011
Baghpat	–	–	–	–	–	–	–	–	–	65.61	402.06	61,280
Bulandshahr	46.89	163.72	34,916	45.4	204.74	45,097	45.74	274.57	60,028	47.67	271.79	57,015
Ghaziabad	–	–	–	52.6	265.41	50,458	53.03	328.62	61,969	61.06	268.82	44,026
GBN	–	–	–	–	–	–	–	–	–	4.05	23.88	58,963
Aligarh	17.71	48.32	27,284	15.45	65.31	42,272	13.43	80.75	60,127	9.54	56.39	59,109
Hathras	–	–	–	–	–	–	–	–	–	0.47	2.48	52,766
Mathura	17.04	58.37	34,255	17.09	58.66	34,324	12.1	63.44	52,430	10.06	49.84	49,543
Agra	3.95	17.18	43,494	2	7.85	39,250	0.78	5.15	66,026	0.503	2.33	46,322
Firozabad	–	–	–	–	–	–	0.23	0.97	42,174	0.17	0.83	48,824
Mainpuri	3.35	14.81	44,209	1.89	7.43	39,312	0.94	2.69	28,617	0.43	2.26	52,558
Etah	10.18	35.64	35,010	7.82	33.03	42,238	9.08	53.42	58,833	10.22	50.78	49,687
Bareilly	39.72	159.88	40,252	43.77	185.28	42,330	65.89	383.35	58,180	77.16	427.02	55,342
Budaun	81.58	374.91	45,956	19.91	85.25	42,818	21.43	961.35	448,600	22.18	132.39	59,689
Shahjahanpur	22.69	82.11	36,188	30.07	141.32	46,997	47.25	253.33	53,615	51.17	245.1	47,899
Pilibhit	64.89	295.82	45,588	34	148.12	43,565	42.96	248.04	57,737	48.36	272.98	56,447
Bijnor	31.86	121.43	38,114	91.25	641.29	70,278	179.33	1088.5	60,698	213.2	829.09	38,888
Moradabad	34.83	141.51	40,629	126.03	630.67	50,041	132.94	754.8	56,777	66.45	361.37	54,382
JPN	–	–	–	–	–	–	–	–	–	68.84	403.67	58,639
Rampur	20.06	85.5	42,622	26.11	116.29	44,538	32.2	191.89	59,593	21.71	128.3	59,097
Farrukhabad	8.12	27.04	33,300	9.08	36.37	40,055	8.07	44.75	55,452	7.29	14.06	19,287

Kannauj	–	–	–	–	–	–	–	–	–	0.45	2.28	50,667
Etawah	5.87	19.49	33,203	24.98	21.71	8691	4.04	14.6	36,139	1.05	3.93	37,429
Auraiya	–	–	–	–	–	–	–	–	–	1.24	5.95	47,984
Total	**638.27**	**3264.85**	**51,152**	**1006.73**	**5018.05**	**49,845**	**1146.09**	**7782.32**	**67,903**	**1060.973**	**6833.94**	**64,412**

(b)

Districts	**1970–1973 to 1980–1983**			**1980–1983 to 1990–1993**			**1990–1993 to 2000–2003**			**1970–1973 to 2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	44.42	95.86	35.61	−11.05	12.30	26.25	10.76	−0.11	−9.81	42.29	119.73	54.42
Muzaffarnagar	37.83	50.97	9.53	11.94	37.25	22.61	−88.77	8.59	866.88	−82.67	126.63	1207.88
Meerut	1017.23	17.54	−89.48	6.98	30.02	21.53	−26.50	−25.76	1.01	778.48	13.47	−87.08
Baghpat	–	–	–	–	–	–	–	–	–	–	–	–
Bulandshahr	−3.18	25.05	29.16	0.75	34.11	33.11	4.22	−1.01	−5.02	1.66	66.01	63.29
Ghaziabad	–	–	–	0.82	23.82	22.81	15.14	−18.20	−28.96	–	–	–
GBN	–	–	–	–	–	–	–	–	–	–	–	–
Aligarh	−12.76	35.16	54.93	−13.07	23.64	42.24	−28.97	−30.17	−1.69	−46.13	16.70	116.64
Hathras	–	–	–	–	–	–	–	–	–	–	–	–
Mathura	0.29	0.50	0.20	−29.20	8.15	52.75	−16.86	−21.44	−5.51	−40.96	−14.61	44.63
Agra	−49.37	−54.31	−9.76	−61.00	−34.39	68.22	−35.51	−54.76	−29.84	−87.27	−86.44	6.50
Firozabad	–	–	–	–	–	–	−26.09	−14.43	15.77	–	–	–
Mainpuri	−43.58	−49.83	−11.08	−50.26	−63.80	−27.21	−54.26	−15.99	83.66	−87.16	−84.74	18.89
Etah	−23.18	−7.32	20.65	16.11	61.73	39.29	12.56	−4.94	−15.55	0.39	42.48	41.92
Bareilly	10.20	15.89	5.16	50.54	106.90	37.44	17.10	11.39	−4.88	94.26	167.09	37.49
Budaun	−75.59	−77.26	−6.83	7.63	1027.68	947.70	3.50	−86.23	−86.69	−72.81	−64.69	29.88
Shahjahanpur	32.53	72.11	29.87	57.13	79.26	14.08	8.30	−3.25	−10.66	125.52	198.50	32.36
Pilibhit	−47.60	−49.93	−4.44	26.35	67.46	32.53	12.57	10.05	−2.23	−25.47	−7.72	23.82
Bijnor	186.41	428.11	84.39	96.53	69.74	−13.63	18.89	−23.83	−35.93	569.18	582.77	2.03
Moradabad	261.84	345.67	23.17	5.48	19.68	13.46	−50.02	−52.12	−4.22	90.78	155.37	33.85

(continued)

Table 6.5 (continued)

JPN	–	–	–	–	–	–	–	–	–	–	–	–
Rampur	30.16	36.01	4.50	23.32	65.01	33.80	−32.58	−33.14	−0.83	8.23	50.06	38.65
Farrukhabad	11.82	34.50	20.28	−11.12	23.04	38.44	−9.67	−68.58	−65.22	−10.22	−48.00	−42.08
Kannauj	–	–	–	–	–	–	–	–	–	–	–	–
Etawah	325.55	11.39	−73.82	−83.83	−32.75	315.82	−74.01	−73.08	3.57	−82.11	−79.84	12.73
Auraiya	–	–	–	–	–	–	–	–	–	–	–	–
Total	**57.73**	**53.70**	**−2.55**	**13.84**	**55.09**	**36.23**	**−7.43**	**−12.19**	**−5.14**	**66.23**	**109.32**	**25.92**

Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P.
Three-year moving average of data is taken
A area (in '000 hectares), *P* production (in lakh quintals), *Y* yield (in kg/hectare)
Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar
Districts were bifurcated after 1991 UP to which data are not available

Production has improved due to increase in area and yield in all districts of the study area. Lowest production in sugarcane is reported in Agra a with growth rate of −86% which declined from 17.18 to 2.22 lakh quintals during the last study period.

Potato is one of the most popular vegetables in the country and is widely cultivated; it is a commercial product. It can be kept for a few months without too much deterioration or can handle long distances without serious damage. Table 6.6a, b illustrates that potatoes tend to rise on a large scale in area, production and yield in all districts of the study region during all study periods. The area under potatoes has gone up from 72.99 to 210.07 thousand hectares during 1970–2002 with an increase of 188%. Production under this crop has also gone up from 62.84 to 560.29 lakh quintals with a growth rate of 792%. Similarly, yield has rose from 8609 to 26,672 kg/hectare with a growth rate of 210%. District-wise analysis shows that the highest increase in area under potatoes is found in Budaun with a growth rate of 1985% that significantly rose from 0.89 to 18.56 thousand hectares during 1970–2002. Similarly, production has augmented in Budaun that significantly increased from 0.89 to 21.82 lakh quintals with a growth rate of 2499%. Production has improved due to increase in area and yield in all districts of the study area. Lowest production in potatoes is reported in Pilibhit with −62% which declined from 2.27 to 1.22 lakh quintals during the last study period. Thus, the discussion suggests that food production is found more in those areas which are less in the production of cash crops, while, on the other hand, production of cash crops is found more in those areas where the production of food grains is less. This means that more area under food grains is replaced by cash crops like sugarcane. Farmers in the western part of the study area mostly prefer to grow cash crops because of the benefits, but this is especially beneficial for large farmers.

6.5 Summary

Sustainable development of any country is dependent on food; agricultural research proved it. Over the last several years, irrigation has played an important role in transforming unstable agriculture of semi-agricultural areas into productive agriculture. The success of high-yielding programmes depends mainly on the availability of sufficient irrigation facilities because different high-yielding seeds necessitate higher doses of chemical fertilizers and more water supplies to the plants. It is clear that food security based on food production is one of the major aspects of agricultural development. In the study area, it is found that growth rate of area under food grains has been reported to have declined during 1970–2003 in western Uttar Pradesh, while the production and yield have observed to have increased during 1970–2003. But pulses have lost more area, production and yield due to its replacement by wheat, rice and cash crops. A picture of cash crop shows that more area of food grains has been replaced by cash crop; for example, Meerut District is counted highest in sugarcane production, while it is lowest in food grain production. Thus, it has been observed that the Green Revolution led to the development of western UP

Table 6.6 (a) Distribution of area, production and yield of potatoes in western UP. (b) Percentage growth of area, production and yield of potatoes

(a)

Districts	**1970–1973**			**1980–1983**			**1990–1993**			**2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	0.69	0.46	667	1.38	2.6	1890	1.01	2.33	2308	7.57	1.64	217
Muzaffarnagar	1.11	0.83	748	1.94	3.62	1870	2.93	6.78	2308	2.58	5.63	2179
Meerut	5.93	2.6	438	5.22	9.37	1792	7.71	17.56	2276	7.06	16.21	2295
Baghpat	–	–	–	–	–	–	–	–	–	0.36	0.83	2286
Bulandshahr	4.22	5.12	1214	7.42	13.5	1820	6.8	14.69	2157	6.71	14.48	2156
Ghaziabad	–	–	–	4.96	9.93	2002	5.8	14.59	2516	4.62	11.32	2447
GBN	–	–	–	–	–	–	–	–	–	0.31	0.71	2268
Aligarh	2.77	0.34	125	4.99	7.68	1540	5.3	10.45	1972	6.57	16.8	2554
Hathras	–	–	–	–	–	–	–	–	–	14.38	44.58	3098
Mathura	3.91	2.02	2203	2.52	4.23	1672	4.43	9.39	2118	6.68	17.98	2690
Agra	1.75	1.2	685	4.31	7.17	1661	6.45	14.25	2209	22.69	68.12	3001
Firozabad	–	–	–	–	–	–	9.8	20.75	2116	21.97	53.62	2440
Mainpuri	6.26	3.14	502	13.53	25.88	1912	10.12	21.21	2095	10.69	25.27	2364
Etah	4.01	3.78	942	7.31	9.74	1331	7.83	11.51	1468	7.57	15.53	2050
Bareilly	2.05	1.93	943	4	5.73	1432	3.98	5	1257	5.2	10.05	1930
Budaun	0.89	0.84	942	8.65	11.32	1309	16.12	2.66	165	18.56	21.83	1175
Shahjahanpur	2.93	3.71	1263	5.07	6.27	1236	5.9	8.54	1447	5.31	10.59	1992
Pilibhit	3.49	3.27	939	1.42	1.88	1317	0.57	1.32	2300	0.59	1.22	2072
Bijnor	3.08	2.9	942	1.49	2.63	175	0.91	0.93	1021	0.96	1.92	1988
Moradabad	0.81	1.34	1647	5.63	9.83	1744	11.04	18.31	1659	8.8	22.82	2593
JPN	–	–	–	–	–	–	–	–	–	4.1	8.43	2055
Rampur	1.42	3.27	2303	2.67	4.88	1825	2.84	4.28	1508	2.07	4.93	2382
Farrukhabad	23.14	21.82	942	38.31	72.11	1882	35.36	95.81	2671	31.68	81.64	2576

Kannauj	–	–	–	–	–	–	–	–	–	2.46	80.76	3279
Etawah	4.53	4.27	942	8.54	15	1755	10.28	16.48	162	4.99	16.04	3211
Auraiya	–	–	–	–	–	–	–	–	–	5.59	7.34	1312
Total	**72.99**	**62.84**	**8609**	**129.36**	**223.37**	**17,267**	**155.18**	**296.84**	**19,129**	**210.07**	**560.29**	**26,672**

(b)

Districts	**1970–1973 to 1980–1983**			**1980–1983 to 1990–1993**			**1990–1993 to 2000–2003**			**1970–1973 to 2000–2003**		
	A	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***	***A***	***P***	***Y***
Saharanpur	100.00	465.22	183.36	−26.81	−10.38	22.12	649.50	−29.61	−90.60	997.10	256.52	−67.47
Muzaffarnagar	74.77	336.14	150.00	51.03	87.29	23.42	−11.95	−16.96	−5.59	132.43	578.31	191.31
Meerut	−11.97	260.38	309.13	47.70	87.41	27.01	−8.43	−7.69	0.83	19.06	523.46	423.97
Baghpat	–	–	–	–	–	–	–	–	–	–	–	–
Bulandshahr	75.83	163.67	49.92	−8.36	8.81	18.52	−1.32	−1.43	−0.05	59.00	182.81	77.59
Ghaziabad	–	–	–	16.94	46.93	25.67	−20.34	−22.41	−2.74	–	–	–
GBN	–	–	–	–	–	–	–	–	–	–	–	–
Aligarh	80.14	2158.82	1132.00	6.21	36.07	28.05	23.96	60.77	29.51	137.18	4841.18	1943.20
Hathras	–	–	–	–	–	–	–	–	–	–	–	–
Mathura	−35.55	109.41	−24.10	75.79	121.99	26.67	50.79	91.48	27.01	70.84	790.10	22.11
Agra	146.29	497.50	142.48	49.65	98.74	32.99	251.78	378.04	35.85	1196.57	5576.67	338.10
Firozabad	–	–	–	–	–	–	124.18	158.41	15.31	–	–	–
Mainpuri	116.13	724.20	280.88	−25.20	−18.04	9.57	5.63	19.14	12.84	70.77	704.78	370.92
Etah	82.29	157.67	41.30	7.11	18.17	10.29	−3.32	34.93	39.65	88.78	310.85	117.62
Bareilly	95.12	196.89	51.86	−0.50	−12.74	−12.22	30.65	101.00	53.54	153.66	420.73	104.67
Budaun	871.91	1247.62	38.96	86.36	−76.50	−87.39	15.14	720.68	612.12	1985.39	2498.81	24.73
Shahjahanpur	73.04	69.00	−2.14	16.37	36.20	17.07	−10.00	24.00	37.66	81.23	185.44	57.72
Pilibhit	−59.31	−42.51	40.26	−59.86	−29.79	74.64	3.51	−7.58	−9.91	−83.09	−62.69	120.66
Bijnor	−51.62	−9.31	−81.42	−38.93	−64.64	483.43	5.49	106.45	94.71	−68.83	−33.79	111.04
Moradabad	595.06	633.58	5.89	96.09	86.27	−4.87	−20.29	24.63	56.30	986.42	1602.99	57.44

(continued)

Table 6.6 (continued)

JPN	–	–	–	–	–	–	–	–	–	–	–	–
Rampur	88.03	49.24	−20.76	6.37	−12.30	−17.37	−27.11	15.19	57.96	45.77	50.76	3.43
Farrukhabad	65.56	230.48	99.79	−7.70	32.87	41.92	−10.41	−14.79	−3.56	36.91	274.15	173.46
Kannauj	–	–	–	–	–	–	–	–	–	–	–	–
Etawah	88.52	251.29	86.31	20.37	9.87	−90.77	−51.46	−2.67	1882.10	10.15	275.64	240.87
Auraiya	–	–	–	–	–	–	–	–	–	–	–	–
Total	**77.23**	**255.46**	**100.56**	**19.96**	**32.89**	**10.78**	**35.37**	**88.75**	**39.43**	**187.81**	**791.61**	**209.80**

Source: Calculation is based on data collected from Directorate, Ministry of Agriculture, Department of Statistics and Economics, Lucknow, U.P.
Three-year moving average of data is taken
A area (in ‘000 hectares), *P* production (in lakh quintals), *Y* yield (in kg/hectare)
Note: *GBN* Gautam Buddha Nagar, *JPN* Jyotiba Phule Nagar
Districts were bifurcated after 1991 UP to which data are not available

and production of leftover pulses of untouched wheat and rice has been greatly encouraged. It is also found that farmers prefer to cultivate wheat and rice in fertile land with the yield-raising inputs while the pulses on poor marginal land of low soil fertility under rain-fed conditions without inputs like pesticide, fertilizers, etc. The northern portion of the study area was recorded for its highest cash crops but low in food grain crop and has enjoyed high level of agricultural development. The area under food grains is replaced by cash crops like sugarcane and potato crops. The farmers in the sample study area mostly prefer to grow cash crops because of its benefits, but it is particularly beneficial for large farmers as compared to small and marginal farmers due to the lack of purchasing power. If the farmers could be provided with fertilizer and other inputs of cheaper rates, the regional disparities among food crops can be minimized up to the certain extent and for more benefit to lift the income of poor and small farmers.

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Chapter 7
Household Analysis of Crop Diversification and Socioeconomic Classifications of Agriculture Practitioner

Rukhsana and Asraful Alam

Abstract Crop diversification is a significant tool for the acceleration of agricultural development in developing countries by supporting income, employment generation, food and nutritional security, poverty alleviation, and ecological management. The farming system in West Bengal is being shifted by integration between a set of cash crops and main food cropping process. This transformation into diversified farming systems, where smallholders have a production base in rice, can affect output complementarity, technical efficiency, and performance of farms. This study aims to examine the status of crop diversification and effects on smallholders based on both primary and secondary data. The results of the study show that agricultural sector of West Bengal is gradually diversifying toward high-value commodities.

Keywords Agriculture · Household · Demography · Education · Economy · Crop diversification

7.1 Introduction

Despite substantial improvements in food security over the last few decades, undernutrition remains a global burden. Approximately 800 million people are chronically hungry, most of them living in developing countries (Food and Agriculture Organization of the United Nations 2015). Global agricultural systems are currently undergoing rapid changes. The acknowledged responsibility of agriculture for environmental degradation, the changes in the demand for food and nonfood products, the globalization of trade leading to fluctuations in the prices of farm products,

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and the changing role of agriculture in territories are major driving forces which require a shift toward new production systems (Meynard et al. 2012). Conservation agricultural systems represent a break with conventional practices. Today, farmers throughout the world face a wide range of situations and significant variability in the efficiency of CA systems (Erenstein 2012). The movement of low-value agriculture to high-value agriculture includes crop diversification pilots that increase agricultural production. Crop diversification has become an important option in developing countries to achieve the objectives of production growth, employment generation, and sustainability of natural resources (Petit and Barghouti 1992). Crop diversification is necessary for an agro-based economy. Over the years, practices known to farmers have forced them to diversify agricultural activities to meet their families' cash needs and water tables, reducing floods and droughts, climate change, and net sown to reduce risks such as reducing the area (Sinha and Ahmad Nasim 2016). Crop diversification is getting a lot of attention due to the availability of resources, market infrastructure, public participation, research, development, price, policies, and globalization of agriculture (Singh et al. 2013). Crop diversification has a variety of benefits, including income growth, poverty reduction, food and nutritional security, employment generation, proper use of land and water resources, sustainable agricultural practices, and environmental development; also in many situations, diversification is needed to restore degraded natural resource base or improve natural resources. It is generally said that cropping systems have diversified or that new cropping systems have been introduced to maintain or increase the value of natural resources. It has also been observed that due to the pattern of diversification, diversification tends to stabilize agricultural income at higher levels, such as accommodating more and more rewarding crops (Saleth and Maria 1995). Crop diversification is an important scientific method and relates the spatial variation of crops to each other, which directly defines the number of crops growing. It focuses on a movement of low-value to high-value agriculture and is an important way of increasing agricultural production (Dutta 2012). Crop diversification is fundamentally regulated by both physical and socioeconomic conditions of the region where there will be a higher level of agricultural technology and a lower degree of diversification (Raju 2012). Farmers are more vulnerable to the overall effects of climate change since they have limited resources to invest in expensive coping strategies (Lin 2011). Farmers' access to production factors (land, capital, labor, inputs, mechanization, and knowledge) varies greatly not only between countries but also between regions and even between different types of farms in one country. For these reasons, cropping systems need to be tailored to local conditions; a range of different agricultural systems needs to be co-designed with the farmers at field, farm, and landscape scales; and supporting measures need to be developed to accompany agricultural extension activities (Husson et al. 2015). Diversity of livelihoods and farmers' strategies is one of the backbones of sustainability, as it is through diverse farm livelihoods that greater resilience against stresses and shocks may be ensured (Block and Webb 2001; Ellis 2000; Tesfaye et al. 2004). At regional level, sustainability targets call for a holistic perspective taking into account the whole range of farmers' responses.

The following objectives have been taken into consideration for the study: first to explore regional disparities and status of crop diversification at the district level in West Bengal, second to check the status of crop diversification to small farmers at household level, and third to make suggestions and options for furthering the diversification toward the sustainability of agriculture in the region.

7.2 Study Area

The state is situated between 21°31′ and 27°13′14″ North Latitudes and 85°45′20″ and 89°53′ East Longitudes. The total geographical area of the State of West Bengal is 88,752 sq km, which constitutes about 2.7% of the total land area of the country. West Bengal is organized into 19 districts, 66 subdivision, and 341 development blocks (Census 2011). It is a state in the eastern zone of India which has a wide range of physical variety and shares international borders with Bangladesh and Nepal. In West Bengal, diversification in cropping pattern is a very recent phenomenon other than the case of plantation crop tea, from the pre-independence period. It is basically a rice-producing state which has achieved a very high level of productivity in paddy cultivation during the 1980s and 1990s and is now the largest producer of rice in the country. However, diversification toward high-value crops is being considered as a way to increase the contribution of non-rice crops to output ratio to attain higher agricultural growth rates in the future. Besides enhancing growth, it is felt that diversification will also be able to contribute toward a higher nutrition level, poverty alleviation, employment generation, and sustainable natural resource management.

7.3 Materials and Methods

The present study is based on both primary and secondary data which have been collected from various issues of Statistical Abstract and Economic Review of West Bengal, published by the Bureau of Applied Economics and Statistics, Government of West Bengal. For the study of the extent of diversification, there are various methods which are available in the literature. There are number of statistical methods which measured the magnitude of diversification including index of maximum proportions, Simpson index, entropy index, modified entropy index, composite entropy index, ogive index, Herfindahl-Hirschman index, etc. Benin et al. (2004) and Chand (1996) have used these indices in their studies. Each of these tools has its own advantages and limitations in terms of data requirement, level of sophistication, and ease of computation and interpretation. Additionally, the results obtained through these methods are more or less similar.

Crop diversification index (CDI) in determining crop diversification for the particular crops of interest has been computed. The CDI has been obtained by subtracting the Herfindahl index (HI) from one. The CDI is an index of concentration and has a direct relationship with diversification such that a zero value indicates specialization and a value greater than zero signifies crop diversification. Thus, it becomes easy to identify those farmers that are practicing crop diversification.

To delineate the crop diversification region in the study area, Herfindahl index formula has been applied. Herfindahl index given below is computed by taking the sum of squares of acreage proportion of each crop in the total cropped area. Mathematically, the index is given as below:

$$\text{Herfindalh Index(HI)} = \sum_{i-1}^{N} P_i^2$$

where N is the total number of crops and P_i represents the area proportion of the ith crop in total cropped area. With the increase in diversification, the Herfindahl index would decrease. This index takes a value 1 when there is complete concentration and approaches 0 when diversification is perfect. Thus, the Herfindahl index is bounded by 0 and 1.

7.3.1 Process of Selection of Sample Study Area

Primary information has been collected through intensive field survey. For field investigation, 15 sample blocks, 68 villages, and 1472 households of West Bengal have been selected from 3 districts based on stratified and purposive sampling. Firstly, West Bengal has been divided into five regions, very high, high, medium, low, and very low in crop diversification regions (Fig. 7.1) on the basis of secondary data in order to find out the volume interdisparities in agricultural practices. Secondly, from each of crop diversification region, three districts have been chosen (Fig. 7.2), and one district has been chosen from each category of crop diversification region (5% of the total districts). Thirdly, selected districts again have been categorized into three regions of crop diversification (very high, high, medium, low, and very low). Fourthly, a *total of 1472 households based on 15% sampling figured out* has been randomly selected from the total household of each selected village (*total sample 68 villages, 3% sampling of the total number of villages of selected block*). Survey has been done with the help of well-prepared questionnaire.

7.4 Results and Discussion

West Bengal is mainly divided into five categories (very high, high, medium, low, and very low) based on the Herfindahl index of crop diversification. Table 7.1 depicts that the present scenario of crop diversification in West Bengal during 2012–2013 significantly moves as compared to the previous records of agricultural sector. Figure 7.1 describes the annual crop diversification index by regions in West

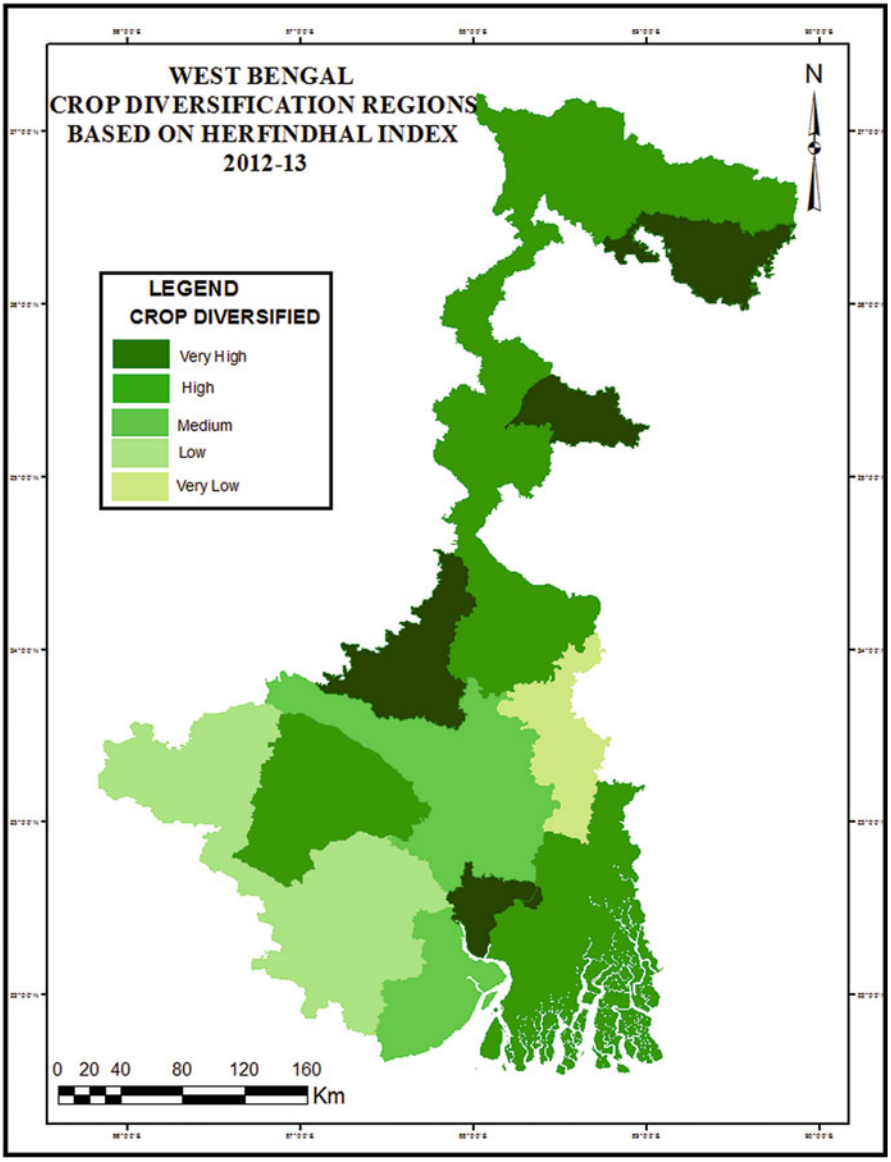


Fig. 7.1 Crop diversification in West Bengal regions based on Herfindahl index

Bengal. The sample mean of the Herfindahl index is 0.057 which counted as the highest Herfindahl index. Conversely crop diversification mainly occurs in northern regions of West Bengal. Figure 7.1 and Table 7.1 portrayed that District Howrah is the very highest diversified district followed by Dakshin Dinajpur (0.01), Birbhum (0.01), and Cooch Behar (0.01) while highest diversification reported in eight

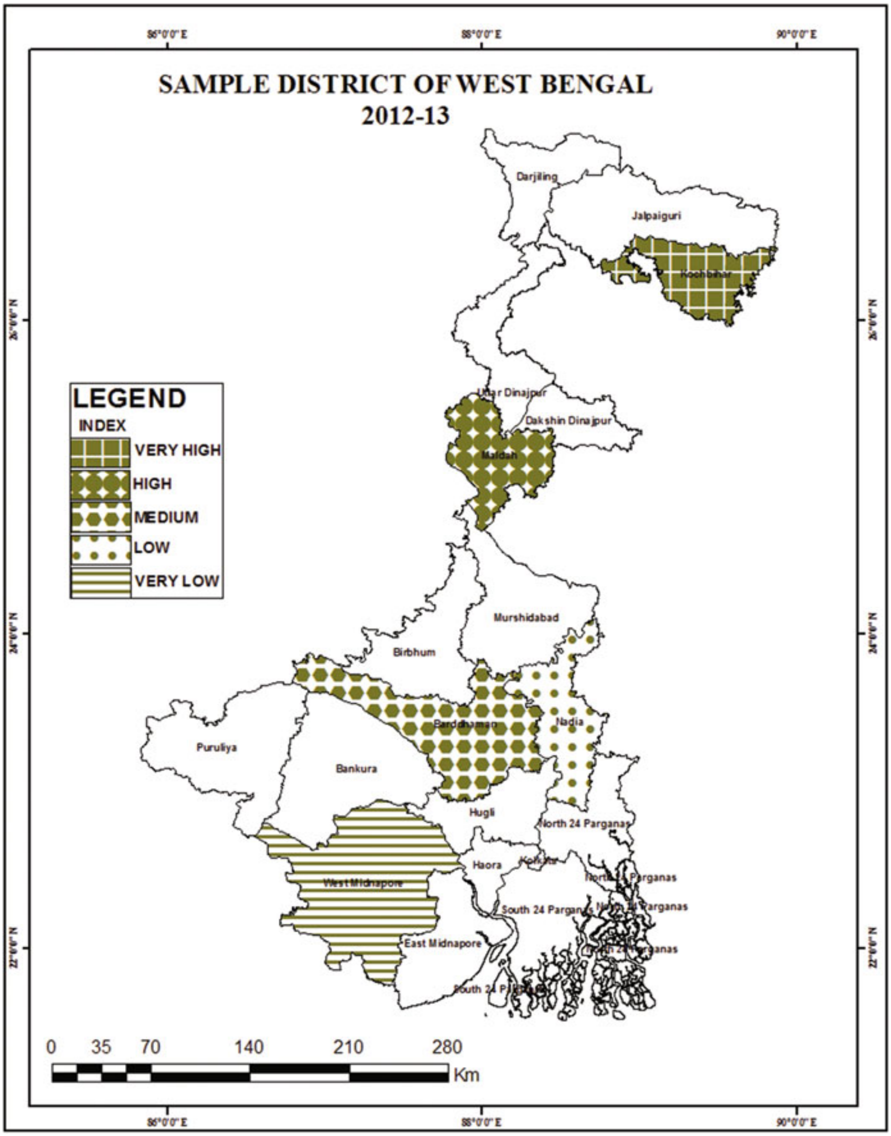


Fig. 7.2 Sample district in West Bengal regions based on Herfindahl index

districts, namely, South 24 Parganas (0.03), North 24 Parganas (0.02), Bankura (0.02), Jalpaiguri (0.03), Uttar Dinajpur (0.02), Malda (0.03), Murshidabad (0.03), and Darjeeling (0.04) in terms of agricultural practices during 2012–2013. Therefore, it observed that districts like Birbhum along with Uttar Dinajpur have made tremendous improvement in terms of crop diversification during the said period in the State of West Bengal. The moderate diversification has been noticed in the

Table 7.1 District-wise disparity of crop diversification in West Bengal

S. no.	Name of the district	2012–2013
1	Burdwan	0.06
2	Cooch Behar	0.01
3	South 24 Parganas	0.03
4	North 24 Parganas	0.02
5	Bankura	0.02
6	Dakshin Dinajpur	0.01
7	Darjeeling	0.04
8	Howrah	0.00
9	Malda	0.03
10	Hooghly	0.08
11	Jalpaiguri	0.03
12	Murshidabad	0.03
13	Nadia	0.25
14	Paschim Medinipur	0.17
15	Purba Medinipur	0.08
16	Uttar Dinajpur	0.02
17	Purulia	0.13
18	Birbhum	0.01
Total average		0.057

Source: Compiled by the author after taking from Statistical Handbook West Bengal (2011), Bureau of Applied Economics and Statistics Department, Kolkata, West Bengal

districts of Hooghly (0.08), Burdwan (0.08), and Purba Medinipur (0.08). These districts have made significant improvement in agricultural field in general and crop diversification in particular during 2012–2013 due to improvement of irrigation facilities and changes in institutional holding size and accessibility to market.

From three categories of West Bengal crop diversification region, three sample districts have been selected which include *Cooch Behar District* from very high diversification region, *Bardhaman District* from medium category of diversification, and *Paschim Medinipur District* from low diversification region. Five from each sample district with a total of 15 sample blocks have been chosen for field investigation (Fig. 7.2).

Table 7.2 describes that out of the total sample *population* (6608) of the total sample household (1472), the percentage of male (52.66%) is found to be more than the female (47.34%) population. On the other hand, the highest percentage of female population have been registered in Tufanganj I block (50.82%) followed by Mathabhanga II (52.03%), Katwa II (50.57%), and Sabang (51.24%), while the remaining sample block was reported highest in male than female population. The role of education in improving the choice and quality of lives enhances social and economic growth. The same table reveals that out of the total sample population, more than 71.78% of the population are literates, where the highest literacy rate is found in the blocks of Sabang (92.72%) while lowest found in Ketugram II (47.22%).

Table 7.2 Distribution of sample villages, sample household, population, and sex ratio in selected blocks

S. no.	Sample districts	Name of the sample blocks	Total no. of sample villages	Total sample household/respondent	Total sample population	Sex structure		Literate population	Illiterate population
						Male	Female		
1	Cooch Behar District	Tufanganj I	2	28	122	49.18	50.82	65.57	34.43
2		Mathabhanga II	2	89	394	47.97	52.03	75.13	24.87
3		Tufanganj II	2	116	505	50.1	49.9	69.7	30.3
4		Mekhliganj	5	260	1147	52.66	47.34	67.61	31.39
5		Sitalkuchi	2	37	160	57.75	41.25	77.5	22.5
6	Bardhaman District	Jamuria	1	25	96	47.96	51.04	62.5	37.5
7		Katwa II	2	40	176	49.43	50.57	67.18	31.82
8		Katwa I	2	263	1199	51.54	47.46	69.97	30.03
9		Ketugram II	2	24	144	76.39	23.61	47.22	52.78
10		Jamalpur	4	146	677	51.11	47.89	67.98	31.02
11	Paschim Medinipur District	Keshpur	18	146	638	50.31	49.69	70.53	29.47
12		Garbeta II	9	70	323	52.8	47.2	90.4	9.6
13		Mohanpur	3	53	222	47.65	51.35	77.48	22.52
14		Sabang	7	128	604	50.83	49.17	92.72	7.28
15		Sankrail	7	47	201	51.24	47.76	72.14	27.86
Total			68	1472	6608	52.66	47.34	71.78	27.22

Source: Primary survey (2017–2018)

Table 7.3 Distribution of income structure (in percentage) in the selected block according to respondents from sample villages

Name of blocks	Income structure (%)			Monthly average per capita income
	Below 4000	4000–8000	Above 8000	
Tufanganj I	39.29	35.71	25	1934
Mathabhanga II	41.57	32.58	25.84	1898
Tufanganj II	41.38	37.07	21.55	1853
Mekhliganj	42.31	37.08	19.62	1786
Sitalkuchi	59.46	29.73	10.81	1500
Jamuria	50	45.83	4.17	1583
Katwa II	23.08	47.72	27.21	2068
Katwa I	36.5	47.15	16.35	1721
Ketugram II	42.31	50	7.69	1250
Jamalpur	37.58	50.34	12.08	1643
Keshpur	36.49	37.51	25	1981
Garbeta II	44.95	44.95	10.09	4731
Mohanpur	37.6	37.5	23.9	10,252
Sabang	57.61	31.17	11.22	4377
Sankrail	27.23	47.21	24.55	19,781
Total average	41.22	41.04	17.74	3891

Source: Primary survey (2017–2018)

Economic Classification of Sample Population Table 7.3 shows the block-wise distribution of monthly income structure in the selected study area. Some of the villages, namely, Sitalkuchi (59.46%), Sabang (57.61%), Garhbeta II (44.59%), and Ketugram II (42.31%), have been suffering due to poor economic condition; almost 50% household of these blocks are coming under the income group of <4000. Only 17.74% family has their monthly family income above 8000. The total monthly average of per capita income is 3891 rupees that is very crucial to fulfill their basic needs of the total sample population. Some serious steps should be taken to create equality in income structure and better economic condition among household. These are to create employment avenues for smallholders outside agriculture and increase agricultural productivity; small as well as marginal farmer's supplementary sources of income, i.e., poultry, dairying, etc., can directly increase their income level.

7.4.1 Crop Diversification at Household Level

Though, agricultural sector made immense progress in terms of the total output of different crop productions, but Indian agricultural sectors still bear some traditional problems associated with it like dominance of small and marginal farmers, fragmented and smallholdings, rural poverty, lack of modern means and technology,

Table 7.4 Distribution of crop diversification based on Herfindahl index in the selected block

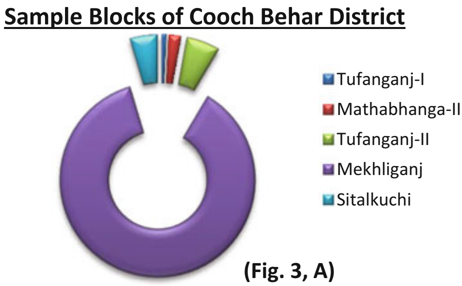
Name of the block	Crop diversification based on Herfindahl index	
Tufanganj I	0.005	Figure 7.3a
Mathabhanga II	0.0137	
Tufanganj II	0.03654	
Mekhliganj	0.56434	
Sitalkuchi	0.02983	
Jamuria	0.00918	Figure 7.3b
Katwa II	0.00299	
Katwa I	0.02929	
Ketugram II	0.01614	
Jamalpur	0.00997	
Keshpur	0.06701	Figure 7.3c
Garbeta II	0.00924	
Mohanpur	0.02436	
Sabang	0.03965	
Sankrail	0.27466	

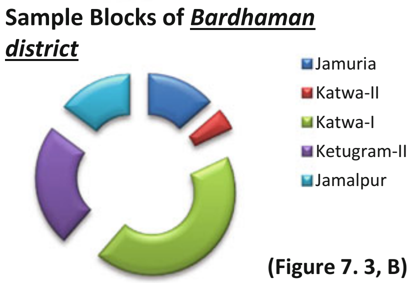
Sources: calculation based on collected data from field survey at household rank during 2017–2018

heavy dependency on monsoon, etc. In addition, to understand the diversification at village level, information of district-level agricultural practices have been analyzed. Further, to consolidate the block level, Herfindahl index has been utilized to understand the disparity of agricultural diversification in different sample blocks at household level.

Table 7.4 shows the crop diversification by Herfindahl index of sample block. From the Herfindahl index, it has been mentioned that the highest diversification was found in blocks Katwa II (0.002), Tufanganj (0.005), Jamuria (0.009), Jamalpur (0.009), and Garbeta (0.009). The sample blocks are geographically located in river-based area in that this area is getting sedimentary fertile soil during flood condition frequently. As a result, various types of crops have been grown in this area compared to other districts. All figures in Fig. 7.3 portray the analysis of crop diversification in sample block of selected districts at household point. Based on household survey conducted in 5 blocks of selected 5 districts with 1472 households, it shows a great variation in sample blocks with more diversified agriculture in Tufanganj I, Ratua II, Garbeta II, Jamalpur, Jamuria, and Katwa II, and the remaining blocks have been reported to be less diversified in terms of agriculture. Figure 7.3a shows that only one block, i.e., Mekhliganj, has very lowest crop diversification due to the cultivation of only one crop, namely, tea, while highest diversification was found in Tufanganj I; these blocks are located in Cooch Behar District selected from very high diversified regions of the state. The findings of the study show that the level of crop diversification varies across the regions and different income groups. On an average, the households in the sample study area grow more than doubled crops, with the highest number of crops being grown by the cultivator group, the households in sample study area growing at most two crops, with as high as 17.08% of sample households

Sitalkuchi	0.02983
Jamuria	0.00918
Katwa-II	0.00299
Katwa-I	0.02929
Ketugram-II	0.01614
Jamalpur	0.00997
Keshpur	0.06701
Garbeta II	0.00924
Mohonpur	0.02436
Sabang	0.03965
Sankarail	0.27466





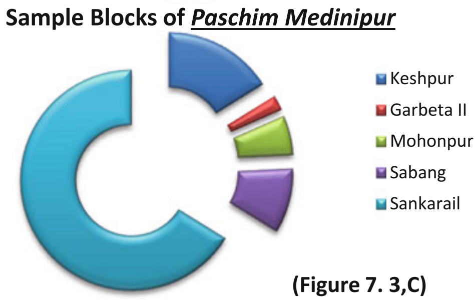


Fig. 7.3 (**a–c**) Distribution of crop diversification based on Herfindahl index in the selected block. (*Sources*: calculation based on collected data from field survey at household rank during 2017–2018)

growing only one crop per annum. There is a low level of crop diversification in Mekhliganj, Sankarali, Sabang, Mohanpur, and Keshpur blocks; these sample blocks lie in selected districts from lowest diversification region of the state except Mekhliganj, which has a lack of awareness about diversification, weak socioeconomic in nature, nonavailability of quality seeds, and presence of pests and diseases (Fig. 7.3a–c). It has been seen from survey result that productive assets such as land and livestock, labor availability, and access to credit differ across smallholder groups. Therefore, though all the smallholder groups face these limitations because of poor asset base, the severity of the constraints is more for the landless laborer groups and least for the resource-rich salaried class. High volatility in prices, absence of market, and lack of access to technical know-how are the main cultivator group. A large proportion of small and marginal farmers gain income through production on small pieces of land. Economy which is the main function leads to increase the crop diversification or any development in the region; these poor economic blocks proved the same such as Sitalkuchi, Sabang, Garbeta II, and Ketugram II which have been suffering due to poor economic condition. These blocks reported low crop diversification also which lies in selected very lowest diversified District Paschim Medinipur (Fig. 7.3c) except Ketugram II which lie in Bardhaman District.

7.4.2 Summary

Crop diversification is influenced by a number of factors both in the supply side, which includes infrastructure development, technology adoption, relative income, and resource endowments, and the demand side, containing the size of population and per capita income as well as climatic variable (rainfall). Economy which is the main function leads to increase the crop diversification or any development in the region; these poor economic blocks proved the same such Sitalkuchi, Sabang, Garbeta II, and Ketugram II which have been suffering due to poor economic condition. These blocks reported low crop diversification also which lies in selected very lowest diversified district except Ketugram II which lie in Bardhaman District. Per capita income of the study area is very low to afford better livelihood which results in low level of capital formation. Most of sample block in western, northern, and southern portion of West Bengal faced natural disaster year to year which prevents the rural households to move from for better development in field of agriculture and diversification (90% of the population favored to face natural disaster in their respective area). The poor households in the rural area need credit facilities to develop their better life and mounting to agricultural technology. Without access to institutional credit, they are not able to undertake any income-generating activity which requires some initial investment due to increasing price of technology used for crop diversification or in agricultural practice. As a consequence, they are forced to engage themselves in less remunerative nonfarm work and wage work. Many households or small farmers are unable to get loans for lack of collateral requirements of the financial institutions. Most of the marginal and small farmers borrow money from a money lender or large farmers at a high rate of interest. Irrigation plays a vital role in crop diversification run by electricity for more water so keeping this importance; it has been recorded that West Bengal is the most generated electricity state in India due to sufficient rainfall, but still few sample blocks face poor electricity and water supply for better agricultural development specially diversification. Because of poor infrastructure, few sample blocks which are recorded for their low crop diversification are facing the same problem. Education has also a great role for transforming traditional agriculture to modern agriculture, for augmenting crop diversification from low-value to high-value crop, for generating employment, and for making the region economically sound. Only 71% of the population is literate in the sample study area. Thus, the above-said weakness is very necessary to enhance the low diversified region. Targeting of education and skill development trainings toward poor households in the rural areas is likely to have a relatively large impact on their ability to diversify livelihood options. There should be made to make remunerative developed farm sector opportunities accessible to the rural households, particularly in the backward regions of West Bengal. This includes the development of rural infrastructure in terms of road, market, electrification, awareness, training, education, new agricultural technology, telecommunication, storage facilities, etc. and also institutional innovations to reduce entry costs and barriers to poor smallholder.

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Chapter 8
Assessment of Food Security Using Geospatial Techniques in Rural India: A Study from Koch Bihar, West Bengal

Asraful Alam, Rukhsana, and L. N. Satpati

Abstract Food security is a global issue, which comes before in the time of the 1970s. The term food security became well-known after the World Food Conference held in Rome in 1974. Food security is simply defined as the absence of hunger or the ability to provide a sufficient amount of food at the global, national, community, or household level (Anderson et al., J Nutr, 2009:120, 2009). Evaluation criteria objectives and attributes need to be identified concerning the particular situation under consideration in order to obtain the importance of each criterion for the model of aggregation and employed the analytic hierarchy process (AHP) to take out standard weights. Food security based on food production is one of the major aspects of agricultural development. Agricultural production in general and food self-sufficiency in particular are the basic objectives of agricultural planning. This research began with the assumption that geographic information system (GIS) spatial analysis provides a powerful methodology for food security assessment (FSA). The results demonstrated that GIS indeed provides essential techniques that can be used to better understand the changing relationships between food availability, the accessibility of landmass, and the effects of climate change on agricultural production. In this research work, the methods have been applied to assess the risk and likelihood of food insecurity based on an assessment of food security status. The FSA model was based on geospatial analysis of factors ranging from topography, land use, climate, and agricultural activities. The study resulted in the ability to illustrate regions at risk within the Koch Bihar District. A total of seven major indicators and 25 sub-indicators have been applied to find out the status of the food security in the study area. The results of the secondary data indicate a significant promise for extending the GIS spatial analysis. Based on the achieved results, future

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work will benefit from fuzzy logic for the integration of AHP when applying sensitivity and uncertainty analyses, and the primary data represent the ground truth of the food security status in the Koch Bihar.

Keywords Agricultural production · Analytic hierarchy process (AHP) · Food security · Fuzzy logic

8.1 Introduction

Food security is a global issue, which comes ahead in the time of 1970s. The term food security became well-known after the World Food Conference held in Rome in 1974. Food security is simply defined as the absence of hunger or the ability to provide a sufficient amount of food at the global, national, community, or household level (Anderson et al. 2009). It also defined as "no child, woman or man should go to bed hungry and no human being's physical and mental capabilities should be stunted by malnutrition" (Acharya 1983; Mohammad 2003). Food security (access to safe, nutritious, affordable food) is fundamentally linked to feelings of stress or distress, and it is strongly linked with socioeconomic factors (Carter et al. 2011). Efficiency-oriented, demand-restraint, and food system transformation are three broad terms for food security issue. Food security means perennial availability of the sufficient quantity and quality of food to every person of an area (Garnett 2014). Food security has two dimensions: the physical availability of food and the capacity of people to pay for the food they need. On the other hand, it is also defined as access by all people, at all times, to enough food for an active, healthy life, which includes at an optimum level (a) the availability of safe and nutritionally adequate foods and (b) the assured ability to acquire acceptable food in socially acceptable ways, e.g., without resorting to emergency food supplies, scavenging, stealing, and other coping strategies. The nonstop growth of the world population creates a situation which is increased of wealth, and with higher purchasing power comes higher consumption and a greater demand for processed food, meat, dairy, and fish, all of which add pressure to the food supply system (Simbarashe, G. et al. 2010).

The foundation of food security is built on four pillars. These are (1) food availability, (2) food accessibility, (3) food utilization, and (4) food stability. Food availability is defined as the sufficient quantities of food of appropriate quality, supplied through household production, other domestic output, and commercial input imports, including food assistance to all individuals within a country or a spatial unit. Food access is ensured when all households and individuals have enough resources to obtain food in sufficient quantity, quality, and diversity for a nutritious diet. This depends mainly on the number of household resources and the income available to the household, on the distribution of income within the household, and on the price of foods. Besides, accessibility is also a question of the physical, social, and policy environment. Food utilization refers to the appropriate biological use of food, giving enough energy and essential nutrients, drinkable water, and satisfactory sanitation. It mainly depends on the managing knowledge of food, proper utilization of food, food processing technique, basic principle of nutrition, proper childcare, and health management. Adequate food at all level for all times is an essential dimension for food and nutrition security, which cannot be hampered by any kind of consequence of sudden shocks; it may be economic, political, or social causes. The concepts of stability depend on both the availability and access dimensions of food and nutrition security (FAO 2006). Experiences from India and other countries have shown that even when the national-level food security is achieved, individuals and groups in the country can still go hungry because they do not have the means to access food. Nutritional security is defined as the condition when every person has a diet, nutritionally adequate in quantity as well as in quality and the food consumed is biologically utilized for a healthy living. Per capita availability of food grains declined in the 1980s and 1990s due to the concentration on the cash crop production (Rao, C. H. 1998), and on the other hand, there was a decline in the seasonal and regional variations in the prices of food grains (Bhalla 1994). The objective of this research is to explain the food status of food and nutrition security as well as the status of food security in the study area using remote sensing and GIS techniques.

8.2 Study Area

District Koch Bihar, which has been selected for the study, lies between 25°57′40″ and 26°32′20″ north latitude and between 88°47′40″ and 89°54′35″ east longitude. Physiographically the district belongs to the *Barind* Tract of the Lower Gangetic Plain which lies between the peninsular plateau in the south and the Himalayas in the north where the *Terai* (marshy) kind of vegetation prevails on the northern side. Maximum percentage of land area of Koch Bihar is cultivable land. Koch Bihar District is the only district where highest concentration of scheduled caste (SC) is recorded, not only in West Bengal but also in India. Scheduled caste peoples are engaged in agricultural activities, but the regional as well as total food security is low than other districts of West Bengal. Agriculturally, Koch Bihar is a backward district as its total as well as its block-wise output is low. Basically, 90% of the district area pertains to the rural background where improper irrigational facilities, basic agricultural equipment, and lack of agricultural knowledge all hamper agricultural activities of the farmers in the study area. So overall picture depicts that Koch Bihar District is a backward district in West Bengal. The people of this district face several problems in food, education, employment, infrastructure facility, etc. Koch Bihar District has 12 blocks, namely, Haldibari, Mekhliganj, Mathabhanga I, Mathabhang II, Sitalkuchi, Koch Behar I, Koch Behar II, Tufanganj I, Tufanganj II, Dinhata I, Dinhata II, and Sitai.

8.3 Data Sources and Methodology

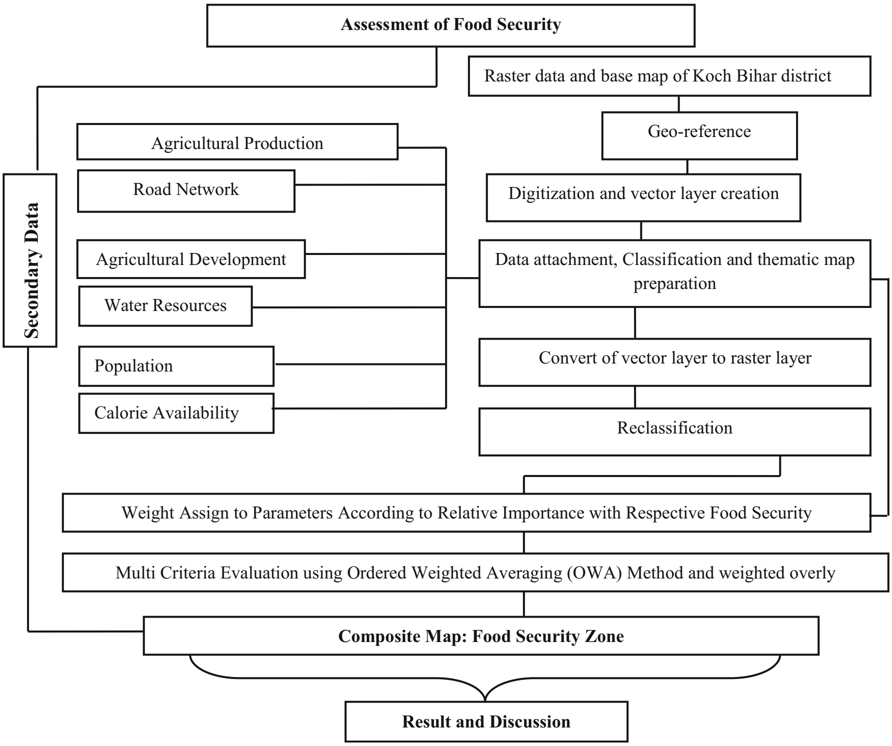
8.3.1 Selection of Evaluation Criteria

Evaluation criteria objectives and attributes need to be identified concerning the particular situation under consideration. A set of criteria selected should adequately represent the decision-making environment and contribute toward the final goal of the target objectives (Feizizadeh and Blaschke 2014). There are no universal guidelines but have different methods and parameters to find out the food security assessment (FSA). Also, each geographical area has its specific condition which needs to be taken into account. In this study, topography and agricultural and economical properties of the rural areas, climate, vegetation, and anthropogenic factors were selected based on the expert knowledge, based on field studies related to food security. In this research work, 21 factors have been selected as effective criteria for food security assessment in Koch Bihar. The first step in our study was to establish a spatial database for the spatially explicit analysis of the FSA. Data processing is important and data processing was performed to create each decisive factor as the cavernous GIS layer. For this to happen, agricultural crop areas were derived from the agricultural database of the Koch Bihar District. This database was also used as the basis of our food availability, accessibility, utilization, and stability indices. In the preparation phase, all necessary geometric thematic editing was done on the original datasets, and topology was created. In the next step, all vector layers were converted into a raster format with 30-m resolution, and the spatial datasets were processed in ArcGIS. In that purpose, all criteria have been standardized. This technique is an extension of the classic binary logic, which enables the definition of sets without sharp boundaries and allows elements to be partially assigned to a particular set. A fuzzy set is essentially a set whose members have degrees of membership ranging between 0 and 1, as opposed to a classic binary set in which each element should have an association degree of either 0 or 1 (Malczewski 2004; Feizizadeh et al. 2013). Weightage is given in the percentage scale according to their importance of food security assessment in the rural area (Table 8.1). Layers thus obtained were then multiplied by the respective weightage.

Table 8.1 Evaluation criteria of food security assessment and analytic hierarchy process weights

Sl. no.	Parameters of erosion	Subdivisions of parameters	Parameter weightages	Share of total percentage of parameter weightages
1	Agricultural production	Cereals	8	25
		Cash crops	7	
		Pulses	2	
2	Calorie availability	Cereals	7	21
		Pulses	3	
3	Agricultural development	Cropping intensity	6	18
		Cropped land	7	
		Cropping yield (kg/ha)	5	
		Total irrigated area in ha	4	
		Population served per bank office (Commercial & Gramin, 000)	3	
4	Working participations	Main working population person	6	14
		Main cultivator population person	4	
		Main agricultural laborer population person	3	
		Main household industry population person	2	
		Main other worker population person	1	
		Marginal worker population person	1	
5	Population density	Low	3	11
		Moderate	5	
		High	4	
6	Groundwater availability	High	3	7
		Moderate	2	
		Low	1	6
7	Road network/road density	High	6	4
		Moderate	4	
		Low	3	
Total			100	100

8.3.2 Methodology and Flow Chart



In this particular FSA for the rural area, the criteria used to relate to topography, climate, agricultural factors, vegetation, and anthropogenic factors, all of which were represented by separate data layers with memberships of different potential classes, were subsequently standardized using the maximum eigenvectors approach on a 0–1 scale. Determination of the degree of erosion hazard for each factor individually is an important assessment process. To assign a food security assessment score for each factor, the rank sum method (Janssen and Van Herwijnen 1994) was used due to its relevance from the perspective of the decision-makers. Where w_j is the normalized weight for the jth criterion, n is the number of criteria under consideration ($j = 1, 2...n$), and r_j is the rank position of the criterion in any AHP calculation. Each criterion is weighted ($n - r_j + 1$) and then normalized by the sum of weights, that is, $\sum(n - r_j + 1)$ (Surjit Singh Saini and S.P. Kaushik 2012).

8.3.3 Assisting Criteria Weights

In order to obtain the importance of each criterion for the model of aggregation and employed the analytic hierarchy process (AHP) to take out standard weights, the AHP method is naturally used for rating and normalizing ordinal values (Malczewski 2004). The AHP method is basically a famous multi-criteria technique, which has been incorporated into GIS-based multi-criteria analysis (Marinoni 2004). The AHP method has been applied to reduce the complexity of a decision problem to a sequence of couple-wise assessment, which is produced in a ratio matrix, and the result represents a clear rationale for ordering the decision alternatives from the most to the least desirable. The development of the AHP pair-wise comparison is based on the rating of relative preferences for two criteria at a time. Each comparison is a two-part question, determining which criterion is more important and to what extent, using a scale with values from the set: {1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/2, 1, 2, 3, 4, 5, 6, 7, 8, 9}. The values range from 1/9 for the least important (than) to 1 for equal importance and to 9 for the most important (than), covering all the values in the set (Feizizadeh et al. 2013). In this study, we utilized the AHP's ability to incorporate different types of input data, and the pair-wise comparison method for comparing two parameters at the same time, and both the assessment of the parameters comparative to each other and the willpower of the result alternatives, basically its depends on the effect values of the sub-criteria of the indicators; (weight), which one based on the comparison of FSA factors. Respective to the implementation of the pair-wise comparison matrix, experts' opinions were asked to calculate the relative importance of the factors and criteria involved. Consequently, the weight values were determined accurately for the datasets used. In the next step, the consistency ratio (CR) (Saaty 1977) was calculated. One of the strengths of the AHP method is that it allows for inconsistent relationships while at the same time providing a CR as an indicator of the degree of consistency or inconsistency. Therefore, we implemented the AHP method with the option to let the user define an acceptable CR threshold value in this study. If the CR > 0.10, it is important to be careful in accepting the resulting weights without changing the inputs of the pair-wise comparison matrix and also to ensure that the matrix really reflects the user's beliefs and does not contain errors. In our study, the resulting CR for the pair-wise comparison matrix for nine dataset layers was 0.033, indicating that the comparisons of characteristics were perfectly consistent and that the relative weights were appropriate to FSA model.

8.4 Result and Discussion

Figure 8.1 presents the parameters with nine sub-indicators of food security in weightage value based on analytic hierarchy process weights which have been developed into a raster map to show the spatial variation of the said parameters

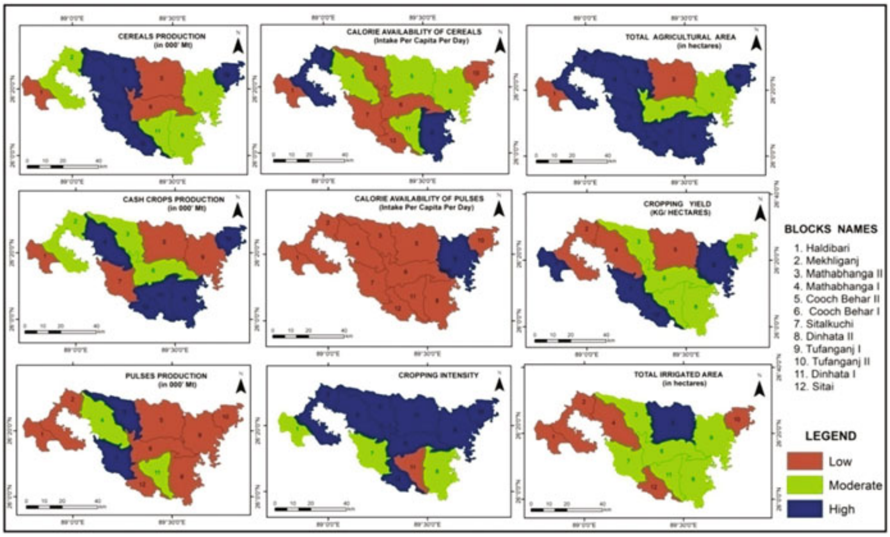


Fig. 8.1 Parameters of food security in weightage value based on analytic hierarchy process in rural areas of Koch Bihar District, I (1–9 sub-indicators)

separately. Agriculture plays a vital role in India's economic development by sharing its 18.3% to India's gross domestic product (GDP) in 2016–2017, and over 55% of the population is engaged in the agricultural sector. Given the significance of the agricultural sector, India becomes a leading producer of rice and wheat over the years. India is the second biggest producer of wheat in the world with ~30 million ha of cultivation land (DAC and FW 2018). Cereal crops and pulse crops are known as food grains. With the production of 16,501.24 thousand tons, West Bengal occupied the top position in the food grain production in India and has a positive sign and in recent years has a number of proofs of the stagnancy in growth rate of food grain production (Ghosh and Kuri 2007). It is a fact that food grain dominates the cropping pattern in West Bengal (Ghosh and Kuri 2005). Figure 8.1 (a) shows the highest weightage value of cereal crop production has been reported in Haldibari, Mathabhanga I, Sitalkuchi, Sitai, and Tufanganj II, due to the highest agricultural area (Fig. 8.1, c), while these blocks are found to have low and moderate caloric availability of cereals (Fig. 8.1, b). Cereals occupy a major and highly significant position on account of the less percentage share of pulse crops (Fig. 8.1, g). It has been noticed that area under total cereals in Koch Behar District has been declining slowly due to commercialization of cash crops (Fig. 8.1, d) for greater earning of large farmers, which shows that the highest weightage value of cash crop production dominated in southern and western portion of Koch Behar District including only one district in eastern portion, i.e., Tufanganj I. To develop the planning and sustainable development in the agricultural sector, the information on crop acreage and yield is very necessary. Reliable and timely detailed information on crop acreage provides important information to the policymakers and planners for deciding concerning procurement, storage, public distribution, export-import, and finally food security of the nation. The main factor of food stability, i.e., cropping yield, is counted low in overall blocks of Koch Behar District, except four blocks including Haldibari, Tufanganj I, Sitalkuchi, and Sitai, which are found to be under the highest cropping yield (Fig. 8.1, f). In the era of water scarcity at the global level, it is clear from Fig. 8.1 (i) that the highest weightage of the area under irrigation is found only in one block (Koch Behar II) and all are under moderate- and low-grade situation which is a dangerous alarm for food security.

Food security based on food production is one of the major aspects of agricultural development. Agricultural production in general and food self-sufficiency in particular are the basic objectives of agricultural planning. The achievement of food security employs that the level of domestic production is at least adequate to meet the basic food requirement of the existing population (Mohammed 2004). The growth rate of agriculture declined from 3.25% (1981–1985) to 1.5% (1996–2003) due to low yields which affected the standard of living of the rural population in India (Dhillon et al. 2010). Crop productivity is low in India in comparison with other countries in Asia (Joshi 2008). Irrigated area is increased from 34 m ha in 1975 to 60 m ha in 2007, which is a major factor in enhancing food production (Lal 2008). The rapid depletion of ground and sub-groundwater associated with the use of electric pumps for irrigation is common. Production differs as per cultivation, texture, and farm inputs and fertility of soil methods. During the Green Revolution era, there was a sudden increased in the use of chemical fertilizer, and crops responded positively in productivity. Besides, 20–70 mt of crop residues and 36–108 mt of animal dung are used as household fuel rather than as soil alteration (Venkataraman et al. 2005).

Figure 8.1 presents the parameters with 10–18 sub-indicators of food security in weightage value based on analytic hierarchy process weights which have been developed into a raster map to show the spatial variation of the said parameters separately. The rate of growth of population was insignificant in 1921, while there was an actual turn down in the population during 1911–1921. The annual average rate of growth in population during 1921–1951 was about 1.2% which increased during the 30-year period from 1951 to 1981, with 2.2% per annum (Premi and Tyagi 1982). As per census of 1991, the growth rate of the population was 2.1% per annum during 1981–1991. During the last 90 years, India's population was increased three and a half times. In that time, the size of the population of India was very much affected by famines and epidemics which took heavy toll of lives (like famine year 1876–1877 and 1877–1878, 1896–1897 and 1900–1901 and influenza in 1918–1919) before 1921. That's why the growth rate of population was very slow (Myrdal 1968). The Bengal famine of 1943–1944, though took many lives (2.5–3 million in the course of just 3 months), did not appreciably affect the growth rate of the subcontinent (Myrdal 1968). During the famine, there were many losses, and many people died by the experience during a severe drought in 1988. In this way, there were losses in various places, but since the Green Revolution, production in India has increased. Before Green Revolution, the Indian agriculture was not in good condition, and the food situation was far from satisfactory. Figure 8.2

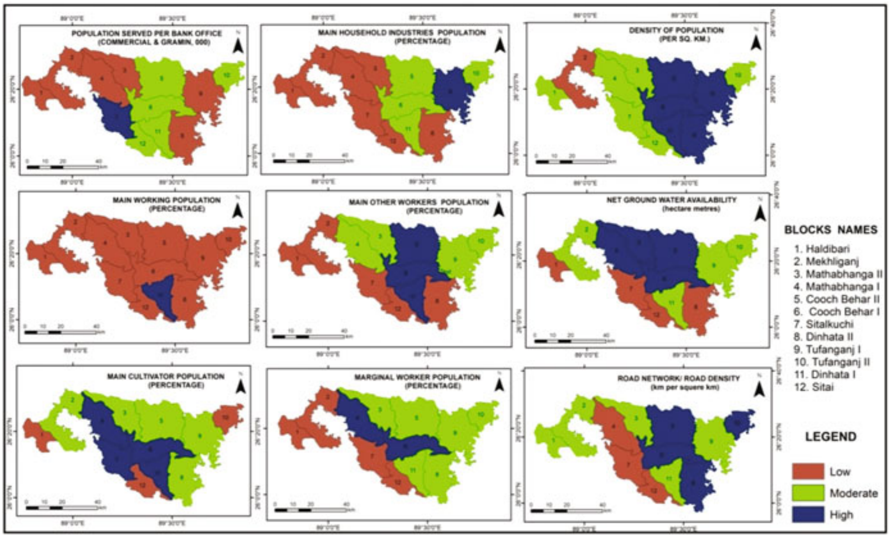


Fig. 8.2 Parameters of food security in weightage value based on analytic hierarchy process in rural areas of Koch Bihar District,I (10–18 sub-indicators)

a describes that the population per bank in Koch Behar District was found to be higher only in one block, namely, Sitalkuchi, while moderately and low distributed over all district. Similarly, the main household industry population dominated only in one block, i.e., Tufanganj I (Fig. 8.2). The density of the population has been reported higher in the eastern portion of the study area (Fig. 8.2, c) which shows that this pocket of the study area encroaches agricultural land (Fig. 8.2, c). The significant parameters lead to food security, i.e., work participation shows that the main working population is very low in the study area; only one block, i.e., Dinhata I, has the highest record for this population (Fig. 8.2, d). The main cultivators' populations are high in the northwestern and southwestern portion of the selected study area (Fig. 8.2, d). On the other hand, the concentration of main other workers (Fig. 8.2, e) and marginal workers (Fig. 8.2, h) recorded three (Mathabhanga I, Koch Behar II, and Dinhata I) and two blocks only (Mathabhanga I and Koch Behar I), respectively, in the study area. The most significant indicators of food security, i.e., water availability, are presented in Fig. 8.2 (f), which describes that the net groundwater availability is highly concentrated only in four blocks of the study area while moderately and low distributed in overall area of Koch Behar District. Infrastructure facility and network are the main functions of food security; Fig. 8.2 (i) presents the road network or density of road which shows that still its conditions or the network of road facility in the study area is very much poor (Fig. 8.3).

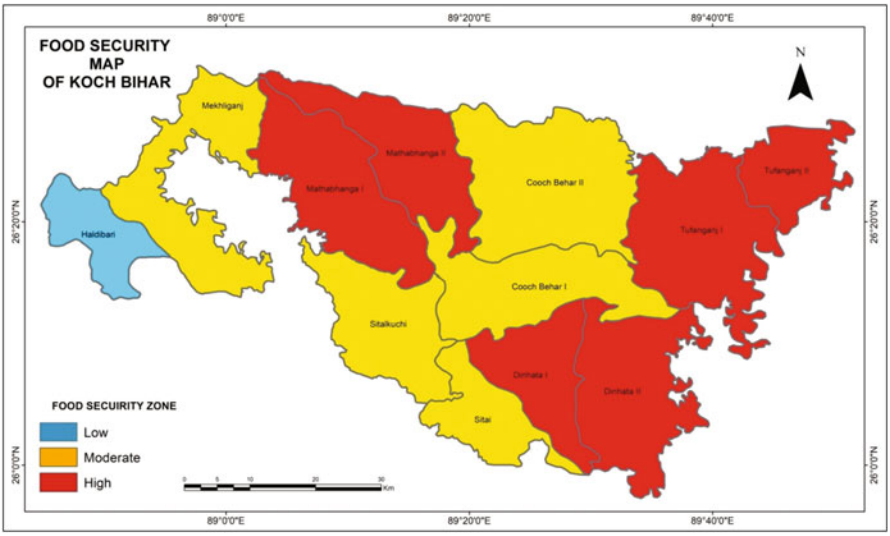


Fig. 8.3 Food security map in rural areas of Koch Bihar District, West Bengal

8.5 Conclusion

GIS spatial analysis is a powerful methodology for FSA to get a well-structured and scientific outcome. The results demonstrated that GIS indeed provides essential techniques that can be used to better understand the changing relationships between food availability and accessibility and the effects of physio-climatic factors on agricultural production. In this research work, we have tried to describe a method which assesses the risk and likelihood of food insecurity based on an assessment of food insecurity and vulnerability. The FSA model was based on geospatial analysis of factors ranging from topography, land use, climate, and agricultural activities. The study resulted in the ability to illustrate regions at risk within the Koch Bihar District. The results of secondary data indicate a significant promise for extending the GIS spatial analysis. Stable food security is possible by sustainable food management which is important for the future generations. As per field investigation and secondary data, it also proved that among all crops of the study area, rice is the major crop that occupied largely the agricultural area and gives the highest production due to its favorable climatic condition in overall study area. It has been found out that the maximum of the agricultural labors faces food security problems due to the lack of cultivable land and minimum purchasing power. After harvesting their produced crops, the cultivators save some crops for their own needs and sell the remaining crops in the market. It has been found out or concluded from the above analysis that after harvesting the crops, the farmers consumed some of their produce at their houses, while the remaining are sold in the market immediately because of the burden of the loan the cant preserved the same. It is also seen that agricultural labor or landless people are facing malnutrition due to the shortage of accessibility or purchasing power and food availability. It is also observed that the landless people or poor section people who spend all their money in their daily food consumption face the problem of accessibility of medicine, education, electricity, or basic needs because of low purchasing power. After going through the overall study of household food security in the study area, the majority of the households prepare food items daily twice a day, and they take food daily three times. Some of the sample households take food daily two times. All food items are prepared by the household itself. Generally, nonvegetarian items are consumed more during the evening meal (dinner) than the daytime (lunch). On the other hand, with lack of production and lack of agricultural land, some of the households face perennial food insecurity problems. So to achieve the desired levels of productivity, immediate steps should be taken to improve infrastructure – such as public distribution system; power resources; rural and urban linkage; road network and marketing system; quality seed supply; dissemination of proper knowledge about fertilizers, land policy, modern technology, and machineries; and creation of a farmer-friendly environment and effective credit facility in keeping with adequate credit absorptive capacity of the farmers in the study area.

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Chapter 9
Problems and Prospects of Food Security in India

Asraful Alam, Rukhsana, and Sabir Hossain Molla

Abstract Agriculture plays a pivotal role in the Indian economy. Nevertheless, its contribution to gross domestic product (GDP) is now close to one-sixth, and it employs 55% of Indian workers. Therefore, agriculture not only contributes to comprehensive growth of the economy but also reduces poverty by providing livelihoods and food security. The concept of food security is multifaceted. Food security exists when all people at all times have physical and economic access to sufficient and nutritious food that meets their dietary needs and food preference for an active and healthy life. Attaining food security is crucial for India where more than a third of its population is estimated to be absolutely poor and as many as one-half of its children have suffered from malnourishment over the past three decades. The World Bank report says that India has uppermost number of people living below poverty line. The Asian Development Bank in its Basic Statistics says that the share of population below the national poverty line is 21.9% in 2018. The Government of India estimates say that poverty declined from 37% in 2004–2005 to 22% in 2011–2012, thus discussing and calling for continued research to address food safety issues. The present paper focused on the comprehension of concepts, dimensions, and measurements related to food security and looked into issues and challenges in achieving food security; several initiatives have been taken to tackle the challenge of food security in terms of availability, accessibility, and affordability to achieve food and nutritional security in India for overall growth of an individual and sound and sustainable development of the Indian economy. This paper also examines about the future prospects of food security in India. The study additionally concludes by suggesting measures to ensure national food security.

Keyword Food security · Challenges · Policies · Prospects · National policy

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9.1 Introduction

Food is one of the basic needs of life. To lead a life with full potential, food is inseparable for everyone. A country like India with overpopulation creates demand for food enormously. Also the conventional agriculture reaches its limit. Thus, a crisis is surely generated by the misfit demand-supply nexus. This crisis is not uncommon but was experienced before. As a consequence, a large mass of people are compelled to remain hungry (Shaw 2007). If the agricultural production is considered as a constant, only import of food would not be sufficient to feed them all. Now the question arises: Would raising the production be enough or not? If the production of the country itself is not distributed and remain stagnant to the origin, people cannot access those foodstuffs. As a result, regional imbalances and inequality overshadow the development of the country. On the other hand, the changing climatic pattern (Chattopadhyay 2011), condition of soil, improving technology, conservation techniques, etc. influence the agricultural pattern (Kalpana Sastry et al. 2011; Thrupp 2000; Tscharntke et al. 2012) of the country. Now farmers have more crop choices through diversity, more income, and diversity of diet. But how is there a series of events like reduction of arable land, water scarcity, inundation of coastal land, converted crop choice, etc. taking place; it is assumed that people will have to starve and be undernourished. The high prices of the commodities are like fuel in the fire. The infrastructural incentives provided to the farmers are well used by the large farmers than the smaller ones. The increasing costs of production incur high selling price paid by all, and poor people have to cut off some amount from the quota of ration (food). Besides climatic determinism, rapid urbanization and changing food habit create a market for cash crops. To make extra money, farmers shifted to it, and again food production drops (Saxena 2018). Where the citizens are considered as capital and wealth for a nation, the deprived hungry people will indicate the underdevelopment and struggle of the country. Since 1990, India faces different types of nutritional problems such as inadequate and excess calorie intake, pervasive micronutrient deficiencies leading to underweight, obesity, malnutrition, and diseases which are needed to be solved with care (Narayanan 2015; Smith et al. 2000).

In this context, the security of food is very relevant. Security gives certainty to something in consideration. By food security, it is meant that food is for all, and by fair price, people can buy food anytime anywhere in a country. By providing equity, food security gives everyone the right to have safe and nutritious food to lead a healthier life ahead. The concept of food security has evolved through many modifications and has many definitions of it (Kumar and Ayyappan 2014). There are many challenges approaching the concept based on availability, accessibility, utilization, and stability of food. People's perception also creates instability sometimes (Barrett 2002; Maxwell 1996; Smith et al. 2000). There are many ways to encounter the situation. These are discussed in this article.

9.2 Background and Concept of Food Security

Food security is a dynamic concept that has gone through many modifications. The concept can be traced back to the evolution of a concept of "secure, adequate and suitable supply of food for everyone" in Hot Springs Conference, 1943. It was the period of food surplus. Different countries with that surplus agreed to help nations in need. With the passing time, there was a realization taking place that helping the demanding nations may inhibit their growth and development. To develop a country from within, it should be self-sufficient to produce food for its citizens. That concern called forth a transition toward a new concept of food and development and established World Food Programme (WFP) in 1963. With the emergence of global food crisis in the 1970s, the transition took a new turn (Napoli et al. 2011). When there was a big issue of nonavailability of foodstuff, i.e., famine, worldwide, food security or good health provided by proper food was understood from deep inside. In 1974, World Food Conference in Rome defined food security as "Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (FAO 2006). From this definition, it is clear that the perspective of food security was on the bountiful supply of food in a stable price to every corner of the human habitat.

The Green Revolution all over the world took place since the 1960s, which brought significant increase in the production of some crops, but also brought regional inequality in terms of production and income generation. Increasing poverty and unequal distribution appealed for equal access to food (Evenson and Gollin 2003; Randhawa 1986). The poor people showed strange behavior, for example, poverty imposed people to remain in hunger to save food for the future (Maxwell 1996). The situation was further strengthened when Amartya Sen put weight on the entitlement of food against starvation due to poverty and unequal access to food in his book *Poverty and Famines* (1981) (Napoli et al. 2011). As an effect, in 1983, the concept was revised to the accessibility of food by all. The new definition put forward by FAO was "Ensuring that all people at all times have both physical and economic access to the basic food that they need" (FAO 2006).

As every person is unique and equally important, so the concept of food security contained individuals in micro level together with the nation and world in macro level to get the broader aspect of food consumption behavior (Barrett 2002). Introduction of time factor in 1986 by the World Bank Report on Poverty and Hunger divided the constraints of food security into two—chronic and transitory insecurity. Insecurity is just the opposite situation of security, when people are unable to access the right nutritious food on their side and also the production of food is hampered on the other side. A study identified three types of household based on food security, including household who can afford security with continuity, resilient household who can recover from food shortage and nutritional shock, and fragile household who are vulnerable to any shock. Any kind of insecurity whether chronic or transitory or seasonal was under observation and tackled so that food can be accessed by all at any time. Only availability and access to food are not enough;

balanced nutritious food is necessary for human well-being. There was objectivity in measuring food security, but here came a question of adequacy in terms of quality. The type and quality of food that people need depend on various factors like self-determination, legacy and dignity, cultural acceptance, etc. Lower and higher nutrition than optimum brings nutritional risk. But finding the optimum nutritional level is difficult in some cases because it is a matter of age, sex, environment, activity, own behavior, etc., and this concern added another component to the definition of food security (Maxwell 1996). The most acceptable definition till date came forth in 1996 by the World Food Summit, i.e., "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Barrett 2002; FAO 2006, 2008; Napoli et al. 2011). From the several definitions of food security, it is evident that the issue has come through different casualties and confrontations in different times and modifies characteristic in harmony to the changing situations across the world.

9.2.1 Dimensions of Food Security

Food security comprises of four dimensions or pillars, three physical dimensions, and one temporal dimension. These are availability, accessibility, utilization, and stability. All are equally important to make a country free from miserable conditions. Availability of food depends on the production system and import of food products. But there is no guarantee that availability of food gives access to all human. Through proper utilization of food, human well-being can be assured. But without stability, nothing will be risk-free and can prohibit the other dimensions to work effectively:

- Availability: It is the supply side of food security, which determines the presence of food with the expected quality within a country. Food produced, aids, and imports are included in this context.
- Accessibility: Where the availability works on the macro level, accessibility focuses on the micro level, i.e., household level. It is the ability of a household to get quality food on a regular basis. It is comprised of three elements, which are physical, economic, and sociocultural elements. When the foodstuffs are physically inaccessible, like in remote areas or in some hostile areas, there will be a gap to distribute the produced items. People also have money enough to buy food with consistency. Hunger and malnutrition are the results of unaffordable poor condition of people, especially in developing countries. Not only that market system run by supply-demand relationship also determines the access to food. The sociocultural elements like religious rituals, social norms, etc. may prevent a group of people to go for a food choice.
- Utilization: How the energy and nutrient of food are utilized is discussed here. It is the nonfood element of food security. Nutrient-rich food intake by individual and household is dependent on food choice, how food is prepared, health care,

dietary plan, intra-household food distribution, sanitation, potable water, etc. To avert diseases and to procure goodness from safe food, this element is a fundamental pillar.

- Stability: It is that element which ensures food production and access by the people all the time. Causes such as environmental degradation, climate change, soil degradation and low fertility, rising population increase, extended period of poverty, lack of resources, etc. result in chronic or persistent instability. Some seasonal causes like fluctuating market price, limited opportunities in labor market, weather extremities, reduced mobility, productions, trade disruptions, etc. are also liable for transitory instability. To withstand the food insecurity, it is necessary to maintain stability (FAO 2006, 2008; FAO and WFP 2016; Napoli et al. 2011).

9.2.2 Indicators

The initial indicators suggested by experts united in the Committee on World Food Security (CFS) Round Table on hunger measurement in 2011 are in use with the aim of further addition of new indicators. The indicators were decided based on the availability of data with a long and cross-profile view. FAO also built worldwide food security information system. The indicators are based on the dimensions or pillars of food security and are listed here.

9.2.2.1 Based on Availability

1. Average dietary energy supply adequacy
2. Average value of food production
3. Share of dietary energy supply derived from cereals, roots, and tubers
4. Average protein supply
5. Average supply of protein of animal origin

9.2.2.2 Based on Accessibility

1. Rail lines density
2. Gross domestic product per capita (in purchasing power equivalent)
3. Prevalence of undernourishment
4. Prevalence of severe food insecurity in the total population
5. Prevalence of moderate or severe food insecurity in the total population

9.2.2.3 Based on Utilization

1. Percentage of population using at least basic drinking water services
2. Percentage of population using at least basic sanitation services

3. Percentage of population using safely managed drinking water services
4. Percentage of population using safely managed sanitation services
5. Percentage of children under 5 years of age affected by wasting
6. Percentage of children under 5 years of age who are stunted
7. Percentage of children under 5 years of age who are overweight
8. Prevalence of obesity in the adult population (18 years and older)
9. Prevalence of anemia among women of reproductive age (15–49 years)
10. Prevalence of exclusive breastfeeding among infants 0–5 months of age
11. Prevalence of low birth weight

9.2.2.4 Based on Stability

1. Cereal import dependency ratio
2. Percentage of arable land equipped for irrigation
3. Value of food imports over total merchandise exports
4. Political stability and absence of violence/terrorism
5. Per capita food production variability
6. Per capita food supply variability (FAO, n.d.)

9.3 Conditions of Food Security in India

India is a country with a population of 1.35 billion, and it still has the largest number of poor and malnourished people in the world; thus, ensuring food security for the masses is one of the major concerns of the government policy. It may be worth noting that an average Indian household still spends about 45% of its total expenditure on food (NSSO 2013). The decade of the 2000s saw the overall GDP increase by an average annual growth rate of more than 7%. With the population growing at less than 1.5% per annum, as such, per capita income has increased by more than 9.5% per annum. Thus, the pressure on food demand intensifies, and the pressure is only going to widen in the foreseeable times. If India can increase domestic food production faster than its domestic demand, it may have enough food supply to the population at least from domestic sources. Otherwise, India will have to rely on increasing food imports.

The food policy and agricultural development strategy adopted by India to improve the food security situation paid rich dividends, and the ensuing improvements in food security can be assessed from several angles. The most significant change was the increase in the domestic output of food grains, particularly cereals (Table 9.1). The production of cereals increased from 72.1 million tons during the triennium ending (TE) 1964/1965 to 130.2 million tons during TE 1984/1985 and further to 186.4 million tons during TE 2003/200s4 (Acharya 2007).

Staple food (cereals) production has consecutively increased in line with population growth. Per capita net output of cereals, which had increased from 19.4 kg in 1951 to 130.9 kg in 1964, increased further to 166.1 kg in 1984 and has hovered

Table 9.1 Production of food grains in India (million tons)

Period	Cereals				Pulses	Total food grains
	Rice	Wheat	Coarse	Total		
TE 1951/2	21.80	6.30	16.10	44.20	8.30	52.50
TE 1964/5	36.50	11.00	24.60	72.10	11.30	83.40
TE 1974/5	41.00	23.50	26.00	90.50	9.00	100.50
TE 1984/5	59.20	44.10	30.90	130.20	12.20	142.40
TE 1994/5	78.10	60.80	32.60	171.50	13.40	184.90
TE 2003/4	84.30	70.00	32.10	186.10	13.20	199.30

Sources: Acharya (2012); GoI (2005)
TE triennium ending

Table 9.2 Compound growth rates of production of cereals in India

Period	Rice	Wheat	Coarse cereals	All cereals
1949/1950–1964/1965	3.50	3.98	2.25	3.21
1967/1968–1980/1981	2.22	9.65	0.67	2.61
1980/1981–1989/1990	3.62	3.57	0.40	3.03
1990/1991–1999/2000	1.90	3.81	1.48	2.10
1967/1968–2001/2002	2.78	4.34	0.54	2.77

Sources: GoI (1999; 2000; 2003)

more or less than the level for the last 20 years. The long-period growth rate of all cereals, which was 2.61% per annum during the period 1967/1968 to 1980/1981 and 2.77% per annum over 1967/1968 to 2001/2002, has conquered the Indian rate of population growth (Table 9.2).

The increase in achievement in cereal production has reduced the dependence on the imports to meet the staple food needs of the population. During the mid-1960s, net imports as a percentage of net domestic output had increased to the highest level ever. For example, in 1966, the net import of cereals at 9.3 million tons represented 19% of the net production. In addition to the increase in domestic cereal production, the inter-year instability in production was reduced considerably. This happened for two reasons: First, the irrigated area under cereals expanded considerably, reducing the dependency on uncertain rainfall of the total cereal area; irrigated areas increased from 23.1% in 1964/1965 to 50.1% by 2000/2001. Second, the share of more stable grains (wheat) increased, while unstable grains (coarse cereals) decreased. Wheat had accounted for 19.2% of the total cereals in TE 1964/1965, increasing to 37.6% in TE 2003/2004. On the other hand, the share of coarse cereals declined from 34.1 to 17.2% during this period (Acharya 2007).

Another essential highlight of India's progressions in macroscale food security is that 97.4% of the incremental output of cereals between TE 1964/1965 and TE 2003/2004 were due to improvements within the per hectare productivity; area propagation has been achieved for only 2.6%. During this period, the area covered by cereals increased from 93.7 million ha to 97.3 million ha, and the average yield per hectare

Table 9.3 Per capita production of food commodities in India (kg/annum)

Year (TE)	1983–1984	1993–1994	2004–2005	2011–2012
Food grains	198	206	184	202
Cereals	181	191	172	188
Pulses	17	15	12	14
Vegetables	56	68	86	122
Fruits	31	33	45	62
Milks	52	67	84	102
Eggs	17	27	39	53
Fish	35	9.1	9.9	7.0

Source: Agricultural Statistics at a glance (various years)

grown from 770 kg during TE 1964/1965 to 1946 kg during TE 2003/2004 due to advancements in technology, irrigation, and diversion of low-yielding crops to high-value produce. In different parts of the nation, there has been significant enhancement within the physical access to food helped by several initiatives and measures. First, the rice production became more geographically dispersed and contributed 42% of the increase of 114.3 million tons in cereal production between TE 1964/1965 and TE 2003/2004. Second, the network of Public Distribution System was expanded to enable food grains to reach deficits in geographically difficult areas (hill or desert) and tribal inhabited areas.

Improved availability of staple food at declining real prices has contributed to improved nutritional security. Farmers have shifted from the low-yielding coarse cereals to noncereal food products since the middle of the 1980s (Acharya 2003). During the last two decades, the output of fruits and spices increased at a compound rate of 3.07–3.91% per annum, while the production of vegetables, edible oilseeds, milk, and fish recorded an increase of 4.33–4.56% per annum during this period (Acharya 2007). However, in spite of impressive agricultural growth, the per capita production of food grains hovered around 200 kg per annum between TE 1983–1984 and TE 2011–2012, and the availability of cereals varied from 181 kg per annum to 188 kg per annum during this period (Table 9.3). Production growth has been much higher in horticulture, fish, and livestock products than in food grains. Per capita production of vegetables, fruits, milk, and fish has doubled, and eggs have tripled during this period. The horticultural, fish, and livestock products are critical to improve nutrition security.

Today, the problem of food management system faced by the country is not the food grain shortage but consists of finding ways and means of managing the accumulated surplus (Virmani and Rajeev 2002). The Economic Survey of India (Ministry of Finance 2013) has called for an urgent attention to efficient food stock management, timely off-loading of stocks, and a stable and predictable trade policy. A recent analysis showed that on an average, the costs of maintaining buffer stocks of rice and wheat are higher than procurement costs in domestic or international markets (Dorosh 2008). So, the need to off-load them has become more of an immediate concern than poverty relief, and off-loading stocks has a fiscal cost.

Table 9.4 Present food scenario in India and the world

Food scenario	World	India
Food produced (million tons 2016)[a,b]	2577	252
Undernourished (millions 2015)[c]	795	194
Proportion of undernourished people (%)[c]	9.9	19.2
Global Hunger Index[d]	–	28.5
Total cereal exports (millions tons 2015)[e]	39,622	12.42
Total cereal imports (millions tons 2015)[e]	–	0.72

Sources of data:
[a]FAO Cereal Supply and Demand Brief
[b]Annual Report (2015–2016), Ministry of Agriculture
[c]The State of Food Insecurity in the World 2015
[d]Global Hunger Index 2016
[e]Agricultural Market Information System

Heavy input subsidies and technological change, coupled with farm price support policies, have led to heavy accumulation of food grain stocks with the government, and the internal carryover costs have increased, while at the same time the hard core poor continued to suffer from food insecurity (Rao 1994). A study by the International Food Policy Research Institute (IFPRI) finds that the government spent $3.40 to transfer $1.00 to the poor (Morley and Coady 2004). In spite of the present government schemes of distribution, the number of undernourished people in India remains to be 194 million, 19.2% of the total undernourished in the world with a GHI of 28.5 (Table 9.4).

In addition to the advancements made in macro-food security, there has been considerable improvement in food availability and a reduction of hunger at the household level. In the rural areas, which account for nearly three-quarters of the poor in India, the percentage of households reporting sufficient food availability every day throughout the year for all family members increased from 81.1% in 1983 to 96.2% in 2000. The percentage of households with at least one member not getting enough food daily during some months declined from 16.2% in 1983 to 2.6% in 2000, and the percentage of households with at least one member without sufficient daily food throughout the year came down from 2.4% in 1983 to 0.7% in 2000 (NSSO 2001).

9.4 Problems of Food Security

Attaining a situation of security in a developing country like India is not very easy. Food security has many aspects, not only to produce food for all but also to encompass a variety of factors like climate change, crop diversity, available land for agriculture, income of the nation as well as individuals/household, analysis of affected people by nutrition-related diseases, connectivity and accessibility to production epicenters, evaluation of Public Distribution System, presence of basic amenities like safe drinking water, sanitation, import of food, political instability, etc. Any of the factors is liable to create or to destruct the food security of the nation.

Food production is highly dependent on climate, and any change of it would influence the production and hence the security. In India, the profiles of annual mean temperature, maximum temperature rise, and minimum temperature rise since 1901–2019 were 0.61 °C/100 year, 1.0 °C/100 year, and 0.22 °C/100 year, respectively (IMD 2020). The temperature rise in warmer months may lead to increased evapotranspiration, occurrence of heat waves, water scarcity, agricultural drought, soil degradation together with shortened crop duration and grain filling, etc. The increasing temperature would melt the cryospheres resulting in the global sea level rise and lessening of the arable land area (Aggarwal 2008; Teixeira et al. 2013). However, increasing greenhouse gases mainly the Co_2 gas which reached to 147% in 2018 of preindustrial level (World Meteorological Organization 2019) helps in carbon fertilization and can boost the yield and productivity of crops. But excessive increase in temperature would suppress that effect (Kumar and Parikh 2001). The annual precipitation has departed nearly about −20% from the normal since 2000 (IMD 2020). The shortfall in precipitation may lead to drought. Also the prolonged dry spell and associated sudden downpour often degrade the soil and productivity greatly (Auffhammer et al. 2012; Dash et al. 2009). The change in climate pushes the farmers toward the uncertainty and crop failure risk, especially in the areas with water stress.

To withstand the losses incurred by climate change, the farmers tend to go for crop diversification. It was aimed to increase the income as well as agricultural production, but the scenario portrays a different picture which can be a serious issue in regard to the food security context. Where the country people used to have Kharif crops as their staple food in most places of humid reign, the production and area under Kharif decline with time and replaced by rabi crops as they are less sensitive to climate change (Barnwal and Kotani 2013; ICAR 2018; Mall et al. 2006). But to increase the income, farmers choose cash crops, plantation crops, fruits, and vegetables together with dairy products. This causes to lessen the production of food that people generally want to have as staples like cereals, pulses, etc. Though fruits and vegetables are nutrient-rich, those are costly as well as perishable goods to buy for poor, and cash crops leave nothing for poor households to feed themselves. Where there was 80% and 69% increase in fruit and vegetable production in 2011–2012 over 2001–2002, the output of cereals were merely 17% in the same time frame (Saxena 2018).

In addition to this, many productive land engaged for cereals are now engaged in production of medicinal and biofuel plants. This kind of reduction in arable land under food crops may foster the severity (Brahmanand et al. 2013). Population explosion creates more stress on agricultural output. In a country with fast-growing economy, rapid urbanization is common. But that costs the productive agricultural lands. The infrastructures made to cope any crisis sometimes dislocated large mass of population with their arable land. Such cases thrive the imbalances within the society (Hanjra and Qureshi 2010). Rural people who are seasonal workers and cannot able to add any marginal production have no considerable productivity. Such pseudo-unemployed persons are vulnerable in this context (Barrett 2002).

The less production of cereals and pulses in India widened the gap of demand-supply, and consequently the prices go upward. If the tendency remained the same, the poor people have to withdraw these elements from their choices and be under-nourished or remain hungry to save food for the future and for those who needed the most (Maxwell 1996). Women are more vulnerable in this context as gender bias still exists in the society (Burchi and De Muro 2016).

The prices of food coming from animal origin go out of reach of the ordinary people, but the demand of it increases day by day. These kinds of food like meat, dairy products, etc. are mainly supplied from areas which are semi-arid or arid in nature and have little arable land and water for agricultural practice. Ignoring the small-scale practices of this kind, most of the instances require high water supply to grow fodder plants and to feed the animals for better return. But there is a misfit situation of water availability. A study reflected that the demand for water will shoot up to 1027 BCM in 2025 from 750 BCM in 2000. The need for water through irrigation only will account for 730 BCM by 2029. This need compels farmers to exploit rather than overexploit the groundwater. Prolonged dry spells added further emphasis (Brahmanand et al. 2013; Hanjra and Qureshi 2010). Moreover, the well-to-do farmers dig bore wells with electric motors. These installations have more suction power than shallow wells. The affluent farmers pull out large quantity of water resulting in lowering of water table. Shallow wells cannot reach that level to provide water, so the poor farmers often experience water crisis and have to buy it from richer persons through loan with high interest (Kumar et al. 2012). Besides the water crisis for extensive use of groundwater, the irrigation causes soil salinization and renders low productivity (Hanjra and Qureshi 2010).

Since the Green Revolution phase, the government decided to provide subsidies to power, water, and fertilizer inputs to increase production. But the subsidies were largely enjoyed by the large farmers. As a result, regional and interclass inequality appeared, and hence small landholders and marginal farmers were pushed to deprivation and poverty. As the large farmers can afford capital-intensive agriculture and can produce huge amount of crop, the increased cost of production (including the storage and transport cost) brings high income. But the high selling price of food creates insecurity (Saxena 2018). Increased price of energy resources especially the fund resources raises the selling prices of food items. There is a problem of credit crisis in the market. Lower availability of credit for smallholders prohibits the use of fertilizers, pesticides, etc. so the yield dwindles often. The excessive demand and corresponding lower supply fuel the price hike and inflation (Hanjra and Qureshi 2010; Siamwalla and Valdés 1980).

The Green Revolution crops have limited capacity to increase the yield as the maximum potential of those is exploited already. These crops also need some particular physical setting to grow with full potential. Any problem can hinder that growth. People also are either unaware or unable to access the new varieties that can withstand this condition (Brahmanand et al. 2013).

Fragmentation of land is widespread in India, and it is believed that fragmented nature of landholding plays a major role in explaining low levels of agricultural productivity. Increasing population has led to reduction in availability of land over the decades. There has been an increase in putting agriculture land into nonagricultural uses to accommodate developmental activities leading to land fragmentation and low productivity. Therefore, there is a need for shift in land use and cropping pattern (Jain 2016).

In the regions of food-deficit countries, import of foodstuffs is practiced. A study revealed that the higher the dependence on import of food mainly for cereals, the higher the food consumption instability (Diakosavvas 1989). The free trade policy of the country leads to the destruction of indigenous industries. The free trade zones enjoy many relaxations in terms of tax and duties. This imbalance shuts down many industries leaving its workers jobless (Brahmanand et al. 2013). This further widened the gap between rich and poor classes within the country.

Without the basic amenities like clean potable water, hygienic sanitation, etc., food security cannot be attained because unclean water and unhygienic living conditions and sanitation provoke diseases among low immune poor people. This can lower down the prospects of food (Haddad et al. 1994; Pinstrup-Andersen 2009).

To make the food accessible for all, Public Distribution System (PDS) has been introduced in our country. Although the intervention of PDS helps in distributing the stuffs, the enrolment to it, forging of ration cards, ghost cards, leakages, corruptions, etc. put a question mark on its reliability and credibility (Kumar and Ayyappan 2014; Saxena 2018). Food insecurity can be addressed from another point of view, i.e., nutrition status of children. Lower than and higher than optimal nutrition can bring diseases, collectively known as malnutrition diseases. The indicators of these are wasting (low weight for height) which is a strong precursor of mortality, stunting (low height for age) which is liable to delayed development of a child, overweight (high weight for height), and underweight (low weight for age)—all are caused by malnutrition, especially for acute hunger and prolonged starvation (UNICEF n.d.; WHO n.d.). In India, the prevalence of nutritional imbalance is acute, and if the number of this kind of children is not reduced, that will ensure food insecurity for the future (Prosekov and Ivanova 2018).

9.5 Ways to Achieve the Security/Policy Initiative for It in India

Food policy in India has been centered on calorie consumption as the primary means of achieving food security. Prior to the 1970s, staple food availability and price stability were major concerns which led to an emphasis on self-sufficiency in food grain production. Large-scale productivity gains and self-sufficiency in food grain production through the Green Revolution (GR) subsequently led to a shift in focus toward ensuring food access at the household level (Radhakrishna 2005). To achieve food security at national level, a country must be able to produce or import the food it needs and be able to store it, distribute it, and ensure equitable access to it. At household level, households must have the means to produce or purchase the food that they need, and they must have the time and knowledge to ensure that the nutritional needs of all family members are met. In order to enhance the access to food, several policies on price and market regulation were introduced in 1969. Two new institutions were created: the Agricultural Prices Commission, a government agency to determine the level of support prices for various crops and several other administrative controls, and the FCI, with the responsibility for purchase, storage, movement, and distribution of food through the PDS, as well as acting as the main handling agent for imported grain and its distribution. The Targeted Public Distribution System (TPDS) and the Midday Meal Scheme (approximately 120 million children are signed up) are two large government food distribution schemes in India (Pal et al. 2019).

The Green Revolution strategy of staple grain self-reliance: In the early years after independence, India was a food-deficient country with frequent droughts and famines. Though India was primarily an agrarian economy at that time, agricultural productivity was low and food grains (rice, wheat, millets, maize, and barely) contributed to 75% of the total cropped area (Chakravarti 1973). In 1966–1967, high-yielding varieties of rice and wheat were introduced in India together with massive public investment in agricultural research and development. Improved GR seed varieties, along with investments in irrigation, promotion of fertilizers, and pesticides, led to massive gains in agricultural productivity (Janaiah et al. 2005; Pingali 2012). Annual per capita availability of food grains increased from around 140 kg in the 1950s to more than 160 kg in the 2000s. However, the GR crowded out the production of other nutrient-rich food crops such as coarse cereals and pulses from their traditional production environments (Kataki 2002; Pingali 2015). This was particularly true in the Indo-Gangetic plains which account for over 12 million ha of intensively cultivated land commonly referred to as the "food bowl of India." Punjab and Haryana, which constitute a bulk of the staple crop production zone, contribute around 84% and 54% of the total wheat and rice in the country (Singh and Sidhu 2014).

While there was a secular decline in the price, as well as seasonal variation in the price of staple grain crops, the relative price levels of other nutritious food, such as pulses, fruit, and vegetables, have not come down commensurately (Rahman 2012). The staple grain supply approach through GR did lead to an increase in calorie availability, but diversity in the food system suffered (Headey et al. 2012; Thow et al. 2016). Hence, while the GR was very successful in addressing calorie sufficiency, it failed to address micronutrient malnutrition, the problem of "hidden hunger," and dietary quality. Despite the relative high price differentials, the supply responsiveness has been low for non-staple crops and livestock products. Figure 9.1 shows the temporal decline in the per capita availability of rice and pulses. The persistence of GR era policies targeted toward staple grains hampers farmer incentives for the diversification of food production systems. Poorly developed markets

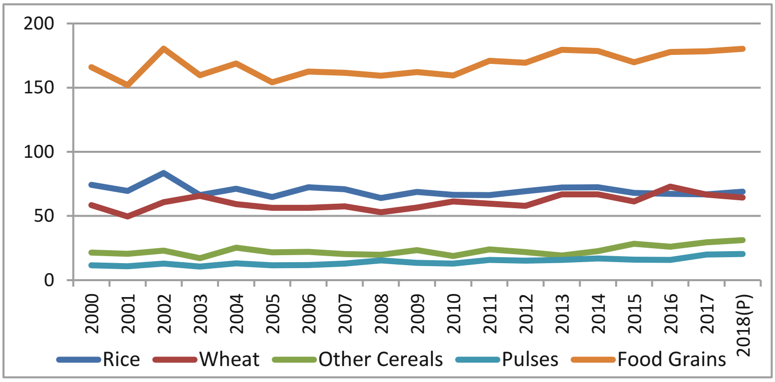

Fig. 9.1 Annual per capita availability of food grains (in kg)

for non-staples are also an important reason for the lower growth in their supply (Pingali 2015).

Addressing food access with the help of Public Distribution System (PDS): With achievement of self-sufficiency in staple food crops at the national level, policy orientation moved toward ensuring food access at the household level (Radhakrishna 2006).

Public Distribution System (PDS), the Integrated Child Development Services (ICDS) scheme, and the Midday Meal Scheme (MDMS) are the three main pillars of the food-based assistance programs in the country. According to an estimate by Narayanan and Gerber (2015), the central government's allocations to the ICDS, MDMS, PDS, and Mahatma Gandhi National Employment Guarantee Act (MGNREGA) constitute to about 1.7% of the gross domestic product (GDP). Under the PDS, rice, wheat, sugar, and kerosene are provided to the consumers through a chain of fair price shops (FPS) in the country. The PDS was considered a failure in terms of its coverage and escalating fiscal costs (Jha and Ramaswami 2010; Ramaswami 2002). TPDS was introduced in 1997 to benefit the poor and to keep the budgetary food subsidies under control to the desired extent following failure of the earlier PDS system (GoI 2005). Under the scheme, special cards were issued to families below poverty line (BPL), and food grains were distributed at a lower price for these families compared to those above the poverty line. The entire population was divided into three categories—BPL (below poverty line), APL (above poverty line), and AAY (Antyodaya Anna Yojana). The BPL families were given 35 kg of food grains per month at subsidized price. AAY were provided a monthly provision of 35 kg of food grains at specially subsidized rates of INR 2 per kg for wheat and INR 3 for rice (Dev and Sharma 2010).

The proportion of food grains accessed through the PDS in the total household consumption provides an indicator of the effectiveness of the PDS in ensuring food security in India. As seen in Table 9.5, at the national level, the consumption requirement met through the PDS by households has increased significantly during the period of 1993–1994 to 2009–2010. However, there are wide interstate

Table 9.5 The share of the PDS in rice and wheat consumption in different states, 1993–1994 to 2009–2010

	Rice		Wheat		Rice and wheat	
State	1993–1994	2009–2010	1993–1994	2009–2010	1993–1994	2009–2010
Andhra Pradesh	20.6	29.7	9.1	4.0	20.4	28.5
Assam	3.2	9.4	2.7	1.3	3.1	9.0
Bihar	0.2	4.7	0.3	4.8	0.3	4.7
Chhattisgarh	2.2	38.8	2.4	28.7	2.3	37.7
Gujarat	20.1	13.7	0.4	9.5	6.6	11.4
Haryana	4.3	0.5	0.0	12.4	0.4	11.4
Himachal Pradesh	32.5	43.3	0.3	44.3	12.3	43.9
Jammu and Kashmir	9.5	53.4	0.3	32.5	2.2	46.9
Jharkhand	0.3	12.7	1.9	19.4	0.7	13.5
Karnataka	14.5	34.5	1.4	26.1	12.5	32.9
Kerala	44.5	26.2	13.7	27.1	41.8	26.3
Madhya Pradesh	3.6	17.2	0.2	19.7	2.0	19.2
Maharashtra	13.4	22.4	0.3	21.4	7.2	21.8
Odisha	0.8	22.9	9.1	12.6	0.9	22.3
Punjab	2.3	0.1	0.1	12.7	0.3	11.5
Rajasthan	7.4	0.3	0.1	9.3	0.3	9.0
Tamil Nadu	17.9	47.6	2.8	51.8	17.1	47.9
Uttar Pradesh	3.2	16.1	0.0	6.8	0.9	9.0
Uttarakhand	49.9	19.6	0.2	13.2	20.6	16.0
West Bengal	1.7	9.3	2.0	28.3	1.7	8.3
All India	9.9	21.7	0.4	12.7	6.0	17.8

Source: Estimates of Anjani Kumar et al. 2012, using NSS data

variations reflecting the fact that the PDS has performed much better in meeting household requirements in some states as compared to others. The share of the PDS in the total consumption of both rice and wheat is seen to be much higher in Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Odisha, and Tamil Nadu. In these states, the PDS appears to be functioning well and providing access to households (Kumar et al. 2012).

The National Food Security Act 2013: In 2011, the government had passed the National Food Security Bill in the Parliament which had raised more questions than it had proposed to answer. The government's own Commission for Agricultural Costs and Prices (CACP) prepared a discussion paper (Gulati et al. 2012) which raised questions over several provisions of the Bill. One of the contentious issues was the Force Majeure clause (Clause 52) which said that "the Central Government, or the State Governments, shall not be liable for any claim by persons belonging to

Table 9.6 Provisions for nutritional security and entitlements in the act to special groups

Target group	Entitlement
Holders of Antyodaya cards	35 kg per household as before, wheat/rice/coarse grain and millets at Rs 2/3/1 per kg
75% of rural and 50% urban population minus those covered above	5 kg per unit of wheat/rice/coarse grain and millets at Rs 2/3/1 per kg
Pregnant woman/lactating mother	Meal, free of charge, during pregnancy, and 6 months after childbirth, maternity benefit of Rs 1000 per month for a period of 6 months
Children (6 months–6 years)	Age-appropriate meal, free of charge, through the local Anganwadi
Children suffering from malnutrition	Meals through the local Anganwadi, free of charge
Children (6–14 years)	One midday meal, free of charge, every working day, in all schools run by local bodies, government, and government-aided schools, up to class VIII

the priority households or general households or other groups entitled under this Act for loss/damage/compensation, arising out of failure of supply of foodgrains or meals when such failure of supply is due to conditions such as war, flood, drought, fire, cyclone, earthquake or any act of God" (GoI 2011). But the CACP report pointed out that it is precisely in these times and conditions that a failure of market forces, volatility in prices, and resultant distress occur. It is at times like this that the poor and vulnerable would depend on the government to ensure their food security (Gulati et al. 2012).

The other issue with the Bill was the eventual plan to move to cash transfer system. If the right to food security moves to the cash transfer system where those entitled to food subsidy will have to buy rice and wheat directly from the market, at the market price, and the subsidy will be directly paid into their bank accounts, then what will happen to the elaborate PDS put in place by the government? If half a million PDS outlets are closed, there is going to be a large-scale unemployment (Pal et al. 2019).

After a long period of deliberation and nationwide debate, the Indian Parliament passed by voice vote in September 2013 the National Food Security Act (NFSA) making the right to food a legal entitlement and proposing provisions to make staple food grains available at subsidized prices to some 67% of India's entire population (Chatterjee 2016). The main beneficiaries of the Act and their entitlements are summarized in Table 9.6.

Regarding the *Force Majeure* clause, the Act mentions that the Central Government, or the State Government, shall be liable for a claim by any person entitled under this Act, except in the case of war, flood, drought, fire, cyclone, or earthquake affecting the regular supply of food grains or meals to such person under this Act, provided that in such a case, the Central Government may declare whether or not any such situation affecting the regular supply of food grains or meals to such person has arisen or exists (GoI 2013).

9.6 Prospects of Food Security in India

Courtesy of Green Revolution, India became self-sufficient in food grains in the 1970s. Yet, with an increasing population, getting higher incomes and substantial disappointed demand among the poor, it is lucid that the country cannot do without continued high growth in agricultural production. Growing demand trends for both medium- and long-term human consumption and animal feeding require rigorous evaluation. Indian agriculture has taken big steps to provide food security to the people. Growing by achieving self-sufficiency in food grains at the national level, domestic production is one of the major achievements of the country in the postindependence period. From being a food-deficit country (food grain importer), even for two decades after independence, it has now achieved self-sufficiency in food grain production in macro level. After the mid-1970s, there was hardly any food grain import. Food grain production in the country increased from about 50 million tons in 1950–1951 to around 264.38 million tons in 2013–2014. The growth rate of food grains has been around 3.2% per annum between 1951 and 2013–2014. The production of oilseeds, cotton, sugarcane, fruits, vegetables, and milk has also increased appreciably (Sarkar and Thanai 2015). The experience of the last two decades has shown that the growth rate of production and yield has declined for the crops during the period 1996–2008 as compared to the period 1996–2006 (Table 9.7).

Indian agriculture has made great strides in providing food security for its people, and that has been possible through the significant positive growth rate in production. In the post-liberalization period (1995–1996 to 2009–2010), Gujarat, Haryana, Punjab, Andhra Pradesh, Odisha, and West Bengal observed significant positive growth rate in production, while Kerala observed significant negative growth rate during the same time. As compared to pre-liberalization period (1980–1981 to 1994–1995), all the major states observed significant and positive growth rates in

Table 9.7 Trend growth rates in production and yields of food grains and oilseeds

Crops	Production		Yields	
	1986–1987 to 1996–1997	1996–1997 to 2007–2008	1986–1987 to 1996–1997	1996–1997 to 2007–2008
Food grains	2.93	0.93	3.21	1.04
Cereals	3.06	0.97	3.36	1.19
Coarse cereals	1.19	1.53	3.66	2.25
Pulses	1.32	0.36	1.49	−0.02
Oilseeds	6.72	1.99	3.32	1.49
Rice	3.06	1.02	2.37	1.22
Wheat	4.09	0.65	2.93	0.34

Note: these are fitted trend growth rate
Source: CACP, Ministry of Agriculture (2009)

the production of food grains. As with the increasing trends in fertilizer consumption and spread of institutional loans, the share of tractor, power tillers, and use of electricity in agriculture for lifting water and other purposes have also increased after the 1990s. These are encouraging signs for Indian agriculture and are expected to set a positive tempo for agricultural productivity (Kavita 2017).

A major concern in the Indian livestock sector is low animal productivity. In India, the average milk yield per cow per day is only 0.92 and 9.42 kg for indigenous and crossbred cattle, respectively (Gandhi and Sharma 2005), whereas the world average is 6.3 kg per day. Furthermore, the actual milk yield of bovines is reported to be 26–51% below the attainable yield under field conditions (Birthal and Jha 2005). Since 2004, India's livestock production has increased by 23.5 points, but this progress has come from increase in numbers rather than increase in production efficiency. The population of cattle, buffalo, sheep, goat, and pig has increased 128.19, 242.71, 183.01, 297.75, and 252.95%, respectively, between 1951 and 2007.

Projected demands for crops: According to the NSS Consumer Expenditure Survey, GOI, the projected demands for rice were 84.2 million tons for 2011, 96.4 million tons for 2021, and 101.5 million tons for 2026. The corresponding supply projections are 99.7, 109.8, and 111.2 million tons, respectively, envisaging a surplus of 11.46, 9.38, and 9.73 million tons, respectively. Mittal's projections for wheat demand are 59.8, 66.1, and 68.1 million tons for the abovementioned years as compared to the supply projections of 80.2, 91.6, and 97.9 million tons indicating surpluses of 20.41, 29.53, and 29.84 million tons for 2011, 2021,and 2026, respectively. For total cereals, the projected surpluses are 27.59, 12.76, and 4.63 million tons (Sarkar and Thanai 2015).

Hanchate and Dyson (2004) projected demand and supply for total cereals for 2026 at 217.6 million tons and 269.8 million tons, respectively. Kumar (1998) projected the demand for cereals at 223.7 million tons and 269.7 million tons for 2010 and 2020, respectively, against the supply projections of 248.4 million tons and 309.0 million tons. Bhalla and Hazell (2001) computed demand for total cereals in 2020 as 374.7 million tons. These estimates are based on the IMPACT model and based on the assumptions of GDP growth of 7.5–7.7%. All studies, except that of Bhalla and Hazell, indicate that there would not be deficit for food grains particularly cereals (Radhakrishna 2002).

Projected demand for animal protein: The per capita meat consumption (kg/year) in the year 2009–2010 was only 9.1 kg (FAO 2006) and is projected to increase by 17.9 kg in 2030 (Keyzer et al. 2005). As proposed under the National Dairy Plan, the domestic demand for milk is expected to be 180 million tons in 2020; to meet this demand, milk production must increase at around 9.5% per annum. Egg demand is also expected to increase by 39.55 billion between 2012 and 2020 (Mohanty and Rajendran 2003). The growing demand for animal protein is difficult to meet with the current livestock farming system, as India is already short of food and livestock and has shrunk to pastures.

Climate change impact on food security: Climate change will have major impacts on more than 600 million poor people depending on livestock for their livelihoods in

Asia and sub-Saharan Africa (Thornton et al. 2002). Crop yields are projected to fall in the tropics and subtropics by 10 to 20% by 2050 due to combined effect of warming and drying (Jones and Thornton 2003). India is very much vulnerable to climate change due to its large crop sector, very warm springs (Mendelsohn 2014), and huge dependency ratio on agriculture; it is ranked 18 in Global Climate Risk Index 2014 (Kreft and Eckstein 2014). Around 68% of the country is prone to drought in varying degrees, of which 35% drought-prone receives rainfall between 750 and 1125 mm, while 33% chronically drought-prone receives less than 750 mm rainfall (GoI 2011). Small farmers and fisherfolk will suffer complex impacts of climate change, due to poor adaptive capacity and other climate-related vagaries, particularly in the Indo-Gangetic Plain (IPCC 2007). A rise in temperature of 2.5–4.9 °C will reduce rice yields by 15–45% and wheat yield by 25–55% (Parikh 2002); the largest reduction in yields between 2011 and 2040 will occur in the upper Indian Ganga Basin (Mishra et al. 2013). If temperatures rise by 2.0 °C with an 8% increase in precipitation, agricultural net revenue may fall by 12% or $4 billion/year in India (Sanghi and Mendelsohn 2008). Grazing and mixed rain-fed systems of livestock production will be the most damaged by climate change (Nardone et al. 2010) which supports India's 40% of the human and 60% of the livestock population.

Food security is a fundamental right. There is as much as necessary food in the whole world to feed every people, but a number of people have an impact of hunger, and malnutrition is still "disproportionately high," with not proportionate impacts on vulnerable and marginalized sections. Taken as a whole, it may be concluded that food security in India can be achieved by paying higher concern to issues such as climate change, integrated water management, agricultural pricing, insufficient storage capacity, disastrous delivery of public services, mismanagement of food products, and crop insurance. In spite of considerable effort being made to develop production, not much focus has been given to curb food supply chain losses. With over 1.2 billion people to feed, tackling the issue of food wastage is essential to India's efforts toward combating hunger and enhancing food security.

9.7 Measures to Ensure Food Security

In general, food security can be achieved by adopting the following measures:

- Increase yields, profitability, and environmental sustainability simultaneously.
- Reduce food loss and waste through more proficient distribution systems.
- Cooperative action in establishing food security infrastructures such as transport, road network, and agricultural infrastructure during the drought period.
- Encourage crop diversification to achieve food security, improved human nutrition, and increase in rural employment.
- Strategy for appetizer agricultural growth—Such type of attempt should be done in countries of high potential and agricultural resource countries so that

eco-friendly agriculture can be adopted without misusing the land resources. Early maturing crops should be adopted without misusing the land resources. Early maturing crops should be introduced to produce the items needed by the suffering population in a much faster manner as compared to the crops, which mature in long duration.

- Integrated nutrient management will maintain soil fertility and plant nutrient supply at an optimum level and will increase productivity.
- Endorsement of agri-horticultural forestry will enhance employment in agriculture, horticulture, livestock, fishing, and forestry and stimulate agricultural output that will increase non-farm employment.
- Promote education and literacy to empower the poor.
- Tackle impacts of climate change.
- Improved agricultural technology adoption will enhance farm produce.
- Livestock development will produce food, enhance crop production, and provide additional economic goods and services as well as cash income.
- Agribusiness activities will include agrichemicals, breeding, crop production distribution, farm machinery, processing, and seed supply, as well as marketing and retail sales.

9.8 Conclusion

In the present study, an effort has been made to exhibit various issues and challenges of the Indian food program. Simultaneously, potential competencies to address these issues and challenges and future prospects are also discussed. Right blending of various consistent policies will improve the state of the food program and ensure food security in the country. Lesser yield, small farmland size, and lack of irrigation are major problems related to the production of food grain in India. Land reforms, better irrigation, financial assistance through banking service, and adequate government support to handle uncertainties not only will help in augmenting food production but also will help in reducing the cost of cultivation.

The Indian State implements massive food, livelihood, and social security programs—some of the greatest in the world—which theoretically support vulnerable people from even before their birth to their survivors after death. On paper, expectant mothers are fed in ICDS centers, along with infants, children up to the age of six, and adolescent girls. Children in school receive school meals. As adults, women get maternity support, and bread earners are ensured 100 days of wage employment in public works; and if identified as poor, they can buy subsidized cereals from a massive system of half a million ration shops. The aged—and in many states widows and disabled people—are provided pensions. And if an earning adult dies prematurely, the survivor is eligible to a lump sum payment of 10,000 rupees.

It looks really good on paper, but the ground reality or physical existence is different. These programs are bedeviled by corruption, leakages, error in selection, delays, poor allotments, and little accountability. Furthermore, they tend to discriminate against and rule out those who most need them, by social barriers of gender, age, caste, ethnicity, faith, and disability and state hostility to urban poor migrants, street and slum residents, and unorganized workers.

The long-term trend of net food grain availability shows ups and downs from year to year. The availability ranges from 186.19 to 146.51 kg per person per year, the average being 167.14 kg per person with a standard deviation of 9. It declined consistently from its peak of 186.19 kg per person in 1991 to the bottom of 146.51 kg per person in 2013. The decline was nearly 40 kg per person in a year.

The key to achieving long-run food security involves targeting cereal productivity to rise extensively faster than the growth in population, so that sufficient land becomes obtainable for other agricultural uses. Measures also need to be taken to improve access to food and nutrition. Recent advances in science and novel technology/concepts need to be entirely explored to their optimum potential like genetic engineering, disease-resistant varieties, embryo transfer technology, artificial insemination, superior genetics and breeding practices, cloning, nutrigenomics, and immunomodulation, among others. Remote sensing and Geographic Information System (GIS) techniques also need to be thoroughly explored against various unforeseen consequences due to climate change. These altogether able to help increase and promote both agricultural and animal produces including crops, cereals, foods, milk, meat, and other products, and this will help us to accomplish the objective of feeding the population with superior food security for everyone.

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Chapter 10
Dietary Diversity Is Associated with Child Nutrition and Food Security Status: Empirical Evidence from Rural India

Asraful Alam, Rukhsana, and Nilanjana Ghosal

Abstract The importance of dietary diversity for health and nutrition has become increasingly popular in recent years as they are relatively simple to measure and are thought to reflect nutrient adequacy. Links between socioeconomic status and child nutrition have also been long established by dietary diversity. The present study focuses on child nutrition and food security from the family diet record at grassroots level in the rural India. The overall goal of the research was to determine whether there is an association between child dietary diversity and nutritional status in the selected households of the study area. The study is based on both primary and secondary data. Primary data has been collected from the direct field observation and proper interview process. As locals largely depend on agricultural productions for their living, investments in agriculture are being made to increase food security in the sample households so that no child goes to bed hungry and no physical and mental capabilities of the children should be stunted by malnutrition.

Keywords Dietary diversity · Child nutrition · Food security · Rural households

10.1 Introduction

Nutrition is defined as the adequate intake and utilization of enough energy and nutrients for maintenance of nutritional and health well-being (Ijarotimi 2013). All people require variety of foods to meet the needs for essential nutrients (Arimond and Ruel 2004). Consumption of sufficient nutrition is necessary from early

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childhood as it ensures normal growth, cognitive development, and healthy life (Ijarotimi, O. S., & Keshinro, O. O. 2013). Children and adolescent are considered to be the most important natural resources for development in every community, and thereby proper development of health and intake of nutrition are required (Karak et al. 2017). Dietary diversity plays a huge role here as it is a way of conceptualizing dietary adequacy and optimal nutrient intake (Ali et al. 2019). The value of dietary diversity has been recognized as key to high-quality diets by nutritionists, and dietary diversity score (DSS) is a proxy indicator for measuring nutrient adequacy. The importance of dietary diversity for health and nutrition has become increasingly popular in recent years as they are relatively simple to measure and are thought to reflect nutrient adequacy. Links between socioeconomic status and child nutrition have also been long established by dietary diversity. However, lack of diversity has been recognized as a severe problem among poor population in most developing countries as diets are predominantly based on starch staples and often include few or no animal protein and only seasonal fruits and vegetables. The situation is more vulnerable for the infants and children as being the future assets of a nation; they need both energy and nutrient dense food to grow physically and mentally (Arimond and Ruel 2004). Undernourished children also have higher risks of mortality and morbidity (Ali et al. 2019). As far as child malnourishment is concerned, growth failures and infections are the predominant reasons. Poor nutrition in the first 1000 days of a child's life results into stunted growth which is associated with impaired cognitive ability. Undernutrition also increases the risk of diseases like diarrhea, measles, malaria, and pneumonia that can hinder a child's both mental and physical developments (Singh et al. 2019). The damage caused by undernutrition in children might result in poor academic achievements, low economic productivity, and associated illness during adulthood (Khamis et al. 2019). According to estimates of the United Nation Children's Fund (UNICEF), globally about 165 million children under the age of 5 years are found to be stunted, i.e., low height for age, 101 million children are found to be underweight, and about 52 million children are found to be wasted (weight for height) (Singh et al. 2019).

Food security can be simply defined as absence of hunger or provision of sufficient amount of food at global, national, community, or household level (Alam 2018). Despite decades of economic growth, the Food Security Act (NFSA) in India was passed in August 2013 as response to country's persistently high malnutrition rates (Kjelsrud et al. 2017). Introduction of Green Revolution in the 1960s along with other agricultural developments could not reduce the war with hunger in the country, and malnutrition still remains stubbornly high (Bouton 2019). With nearly 195 million undernourished people, India shares a global hunger burden, and nearly four out of ten children in the country do not meet full human potential due to chronic undernutrition or stunting which is a serious matter of concern (United Nations 2020). Protein-energy malnutrition (PEM) and vitamin A deficiency are found to be prominent among most of the preschool children (Bhattacharya 2012). The administrative division of India with 29 states and 7 union territories falls into 640 districts. Therefore, extensive heterogeneity in child malnutrition in the country has been observed due to the existence of various social and economic inequalities. According to reports of the National Family and Health Survey, the country presently consists of 38% of children under the age of five having stunted growth and 36% of children suffering from being underweight (Singh et al. 2019).

The District of Koch Bihar is a unique biosphere of West Bengal where most of the people are sunk into poverty, deprivation, and acute suffering (Bhattacharya 2012). There exists a wide disparity in sectoral and spatial development of the district (Karmakar et al. 2019). Locals mostly residing in rural parts of Koch Bihar cannot afford food for their daily living due to low purchasing power and higher prices of food products (Gaiha et al. 2010). Children mostly of the rural areas in the district are malnourished, and their health conditions are also found to be in a sorry state (Bhattacharya 2012). As the economy of Koch Bihar is agrarian-based, various investments in agriculture are being made as there exists a direct link between agriculture and food security. Productivity of grains is keys to food security for households of rural areas who have a poor access to food markets. Investments in agriculture for food security also give insurance to protect the chronic and transitory poor (Alam 2018). Nutrition is important at every age, and proper intake of calorie is required the most among children from the early stages of life as it heavily contributes for their proper growth.

This paper mainly focuses on the association of dietary diversity with child nutrition in Koch Bihar and also tries to look into the level of food security of the district to get a proper idea of the daily calorie intake of the local children as they are the future assets of the country. Hence, nutritional status of children is extremely an important topic of discussion as youngsters of today are going to be the citizens of tomorrow (Singh 2020).

10.2 Objectives

The present study focuses on child nutrition and food security from the family diet record at grassroots level in the study area. The overall goal of the research was to determine whether there is an association between child dietary diversity and nutritional status.

10.3 Study Area

The study has been conducted in the District of Koch Bihar which is located in between the latitudinal extension of 25°57′47″ to 26°36′20″ N and longitudes of 88°47′44″ to 89°54′35″ E (Sarkar, B. K. 2014). Physiographically, the district belongs to the *Barind* Tract of the Lower Gangetic Plain which lies between the peninsular plateau in the south and the Himalayas in the north. *Terai* (marshy) vegetation prevails on the northern side of Koch Bihar. The district is surrounded by Jalpaiguri District in the north, Goalpara District of Assam and Rangpur District of Bangladesh in the East, and International Borders of Bangladesh in the south and west (Alam 2018). The economy of Koch Bihar is mostly dependent on agriculture, and major crops like rice, wheat, pulses, tobacco, and jute are grown (Sarkar, B. K. 2014). The total population of the district is 2,819,086, and of the total population, the rural population is approximately 89.70%. The sex ratio of the district is 942 females per 1000 males which is lower than the state's sex ratio, i.e., 950 females per 1000 males (Ray et al. 2017). According to 2011 census report, the population under 6 years is 10.77% of the total population, and the sex ratio of 0–6 years population is 963 (Bhattacharya 2012). Among all the district of West Bengal, Koch Bihar contains nearly about 50% scheduled caste population to total population as per 2011 Indian census (Barman, B., & Roy, R. 2018). Scheduled caste (SC) population are mainly engaged in agricultural activities, but still the regional as well as total food security is found to be low here than other districts of West Bengal. As per records, 90% of the district area pertains to rural background where improper irrigational facilities, basic agricultural equipment, and lack of agricultural knowledge hamper every agricultural activity. The district lags in infrastructural developments as well. According to a study, approximately 650 km of roads in the district are found to be unmetaled, while 545 km of roads are metaled which indicates a pitiful situation of transport system (Sarkar, B. K. 2014). However, there are only 102 km of railway line present. In terms of 2011 census, the district ranks 16 in health index which is quite low compared to other districts of the state. The same scenario is observed for education index and income index of the district (Bhattacharya 2012). The overall scenario symbolizes the district to be backward in nature. Koch Bihar consists of 12 blocks, namely, Haldibari, Mekhliganj, Mathabhanga I, Mathabhanga II, Sitalkuchi, Koch Bihar I, Koch Bihar II, Tufanganj I, Tufanganj II, Dinhata I, Dinhata II, and Sitai (Ray et al. 2017).

10.4 Database and Methodology

The present study is based on primary data generated by comprehensive survey to have a clear picture about the nutritional status of the children residing in the District of Koch Bihar. As people, mostly residing in the rural parts of Koch Bihar, face immense troubles to meet the basic necessities of life, it is obvious that children don't get sufficient nutritious food for a healthy growth. This is a real matter of concern. The survey was carried out in the year 2014. The database is a source of research support that has helped to complete the research work. The present study is based on questionnaire survey as well as observation methods. A well-detailed questionnaire has been prepared during the survey to analyze the nutritional status of the children of Koch Bihar. Random purposive sampling has been implemented at the time of door-to-door survey. Out of the 12 blocks of the district, namely, Haldibari, Mekhliganj, Mathabhanga I, Mathabhanga II, Sitalkuchi, Koch Bihar I, Koch Bihar II, Tufanganj I, Tufanganj II, Dinhata I, Dinhata II, and Sitai, 12 sample

Table 10.1 Sample villages and demographic structure of the sample households

Name of the blocks	Name of selected village	Total household	Sample household
Koch Bihar I	Ghughumari	3268	163
Koch Bihar II	Pestharjhar	1269	63
Dinhata I	Dinhata	1721	85
Dinhata II	Sahebganj	1514	76
Sitai	Bharali	1738	87
Mathabhanga I	Pachagarh	1332	67
Mathabhanga II	Angarkata Paradubi	2177	108
Sitalkuchi	Nagar Lalbazar	1782	89
Tufanganj I	Chamta	1973	99
Tufanganj II	Bara Kodali	1221	61
Mekhliganj	Kamat Changrabandha	1751	88
Haldibari	Madhyam Hudumdanga	1590	80
Total		21,336	1066

Source: Primary Census Abstract, 2011 and Primary Survey, 2014

villages have been selected from each block of the study area. These 12 villages are randomly selected based on their accessibility such as closeness to the markets, roads, rivers, and railway stations. The sample villages are, namely, Madhya Hudumdanga, Angarkata Paradubi, Sahebganj, Nagar Lalbazar (near roads), Pachagarh, Ghughumari, Bharali (near markets), Kamat Changrabandha, Bara Kodali, Chamta (near river), Pestharjhar, and Dinhata (near railway station). There are a total number of 21,336 households in the district, out of which 1066 households as samples have been taken for survey. From Table 10.1, it can be studied that from Ghughumari Village of Koch Bihar I, out of 3268 households, 163 have been surveyed, while 63 households out of 1269 from Pestharjhar of Koch Bihar II have been taken as samples. From Dinhata and Sahebganj of Dinhata I and Dinhata II, 85 households out of 1721 and 76 households out of 1514 have been taken up for survey. Research work has also been carried out in the villages of Bharali, Pachagarh, and Angarkata Paradubi located in the blocks of Sitai, Mathabhanga I, and Mathabhanga II of Koch Bihar where out of 1738, 1332, and 2177 households 87, 67, and 108 houses have been surveyed, respectively. Further, study has been carried out in the Nagar Lalbazar, Chamta, and Bara Kodali of Sitalkuchi, Tufanganj I, and Tufanganj II where out of 1782, 1973, and 1221 houses, 89, 99, and 61 households have been surveyed. The study has also been conducted in the villages of Kamat Changrabandha and Madhyam Hudumdanga located in the blocks of Mekhliganj and Haldibari where out of 1751 and 1590 houses, 88 and 80 samples from households have been collected, respectively. The present study is based on the terms of evolutionary method of both qualitative and quantitative processes. Various statistical tools have also been used to justify the result of the study.

10.5 Results and Discussion

The relationship between nutrition, health, and learning is undeniably strong, and among three factors, nutrition impacts a child's development most (Chulack 2016). Malnutrition is a widely recognized major health problem in developing countries like India. Growing children are most vulnerable to its growing consequences (Anwar et al. 2013). India is a home to a largest number of undernourished children in the world and is nearly double that of sub-Saharan Africa (Sahu et al. 2015). Malnourished children from rural India face major health issues due to the lack of access to healthcare (Anwar et al. 2013). Chronic undernutrition also results in delayed physical growth, motor developments, and cognitive developments that ultimately result into poor academic performance and social skills among children.

West Bengal is a middle-income state, and children of this state suffer from severe malnourishment. It has emerged that child health is a grave issue (Dawn and Basu 2014). The District of Koch Bihar, which is our area of interest, is located in the extreme north of West Bengal. It has been found to have secured the 12th position in terms of age-sex ratio in 0–6 years of age group and 16th position in terms of health index in district ranking which is quite poor. People belonging to rural areas in the district face severe poverty and deprivation which in turn creates an impact on their health. As a result, the health condition of children of Koch Bihar turns out to be very fragile (Bhattacharya 2012). Poverty, low birth weight, unhygienic living conditions, lack of adequate nutritious diets, low level of parental awareness, and poor breastfeeding practices are the major factors that contribute toward child undernourishment in the district which is a serious matter of concern (Dawn and Basu 2014).

However, to get a comprehensible scenario of the nutritional status of the children residing in the district, some important factors have been taken up for detailed studies which have been discussed as follows:

10.5.1 Household Income

Household income refers to the combined gross income of all members of a household who are 15 years or older. Household income is an important economic measure as it helps in understanding an area's standard of living (Luo 2018).

To understand the economic condition and purchasing power of the people residing in the sample villages, monthly household income of the houses was collected during the which has been shown in Table 10.2. In the above table, it can be seen that the income level of sample villages has been arranged based on their amount of income in ascending order and has been categorized into three parts, i.e., below Rs. 4000, Rs. 4000–8000, and above Rs. 8000. From the table, it can be interpreted that 38.27% of the households lead their daily livelihood within the monthly income of Rs. 4000–8000, 37.8% of the households can afford the daily necessities of life under the income level of Rs. 4000, and only 23.92% of

Table 10.2 Village-wise distribution of income of the sample population

Name of the village	Income structure			
	Below 4000	4000–8000	Above 8000	Total
Angarkata Paradubi	42.59	34.26	23.15	100
Bharali	44.83	40.23	14.94	100
Dinhata	32.94	42.35	24.71	100
Sahebganj	40.79	32.89	26.32	100
Ghughumari	29.45	40.49	30.06	100
Madhyam Hudumdanga	35	40	25	100
Kamat Changrabandha	54.55	37.5	7.95	100
Pachagarh	31.34	38.81	29.85	100
Pesterjhar	38.1	39.68	22.22	100
Nagar Lalbazar	31.46	40.45	28.09	100
Chamta	34.34	36.36	29.29	100
Bara Kodali	45.9	34.43	19.67	100
Total	37.8	38.27	23.92	100

Sources: Based on Primary Survey, 2014

households earn a monthly income of Rs. 8000 and above. From the village-wise study, it can be seen that Ghughumari Village of Koch Bihar I (30.06%) records highest household monthly income of Rs. 8000. Here, villagers are mostly engaged into handicraft works which are sold as finished products in the market (Basak et al. 2019). Monthly income of Rs. 8000 and above have also been observed in two villages, namely, Pachagarh of Mathabhanga I (29.85%) and Chamta of Tufanganj I (29.29%), respectively, which indicates the villages to be in an economically developed state. Household income between the range of Rs. 4000–8000 has been mostly observed in four villages of the district, namely, Dinhata of Dinhata I block (42.35%), Nagar Lalbazar of Sitalkuchi (40.45%), Ghughumari of Koch Bihar I (40.49%), and Bharali of Sitai (40.23%), while Kamat Changrabandha Village of Mekhliganj is noted to be the most economically backward among all sample villages, as majority of the households (54.55%) earn a monthly household income of less than Rs. 4000. Lower household income, i.e., below Rs. 4000, has also been mostly observed in the villages Bara Kodali of Tufanganj II (45.9%), Bharali of Sitai (44.83%), Angarkata Paradubi of Mathabhanga II (42.59%), and Sahebganj of Dinhata II (40.79%). People residing in these areas mostly belong to marginalized groups and bear BPL character. As a result, nutritional status of the people is a very pitiful state which also results into prevalence of low dietary diversity (Bhattacharya 2012).

10.5.2 Occupational Structure

Occupational structure refers to an individual's profession, type of work (Alam 2018). Occupational structure is the distribution of working force among different occupations based on skill level and economic status. It acts as an important measure as occupation of an individual helps to understand the quality of food and calorie they consume that gives a clear picture of the level of food security people experience (Alam 2018) (Fig. 10.1).

Table 10.3 focuses on the occupational structure of the sample villages. The occupations of the surveyed people have been categorized into five types, based on accessible occupation I that are cultivators, daily labors, agricultural labors (A. labors), business, and services. A highest number of people engaged as cultivators are reported in Dinhata Village of Dinhata I (49.19%), while daily labors are towering in Pachagarh Village of Mathabhanga I (47.67%) and agricultural labors in Bara Kodali of Tufanganj II (12.64%), and a large number of people are associated with service sector in Chamta Village of Tufanganj I (16.79%). Food access is ensured when people, all households, and individuals have enough resources to access sufficient quality and quantity of food as well as diversity for a nutritious food (Alam 2018). In the District of Koch Bihar, agricultural labors largely face food security problems as they have minimum purchasing power due monopolistic power of the landlords, uncertain payments, and more (Mandal et al. 2018). In the study area, majority of them fall under the BPL category. This in turn affects the health status of their children as they face poor feeding practices which are the main cause of undernutrition (Khamis et al. 2019). They are devoid of nutrient dense food which in turn hinders their physical and mental development (Arimond and Ruel 2004). Lack of intake of nutritional food also leads to frequent illness and early mortality

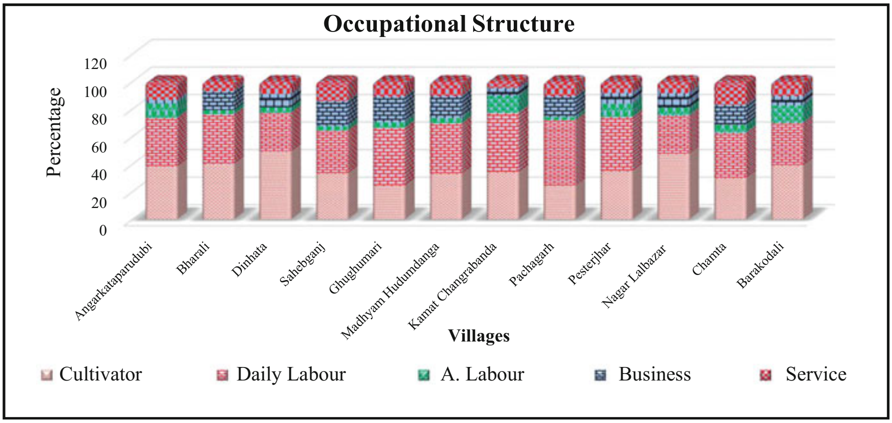


Fig. 10.1 Diagrammatic representation of occupational structure in the selected villages of Koch Bihar District. Sources: Based on primary field survey, 2014

Table 10.3 Village-wise distribution of occupational structure of the sample population

Name of the blocks	Occupational structure					
	Cultivator	Daily labor	Agricultural labor	Business	Service	Total
Angarkata Paradubi	38.42	35.26	10.53	2.63	13.16	100
Bharali	50	33.08	3.08	9.23	4.62	100
Dinhata	49.19	28.23	4.03	9.68	8.87	100
Sahebganj	33.33	31.18	3.23	18.28	13.98	100
Ghughumari	24.27	42.23	3.88	18.93	10.68	100
Madhyam Hudumdanga	33.02	36.79	3.77	16.04	10.38	100
Kamat Changrabandha	39.5	46.22	10.76	1.68	0.84	100
Pachagarh	24.42	47.67	2.33	15.12	10.47	100
Pesterjhar	34	39	11	8	8	100
Nagar Lalbazar	47.54	27.87	5.74	10.66	8.2	100
Chamta	29.93	32.85	5.84	14.6	16.79	100
Bara Kodali	39.08	31.03	12.64	6.9	10.34	100
Total	36.67	36.07	6.47	10.93	9.87	100

Sources: Based on primary field survey, 2014

during adulthood (Khamis et al. 2019). Consequently, children lack dietary diversity as they lack consumption of essential nutrients and diverse diets (Arimond and Ruel 2004).

10.5.3 Daily Consumption of Food Items

Understanding of the consumption pattern of households belonging to different income groups is essential to get a clear perspective of food security standard of an area (Roy and Malhotra 2018) (Fig. 10.2).

According to observations, rice and potato dominate as staple food in the sample villages. As per Table 10.4, the average daily consumption of rice is 512.3 g/head/day which is seen to be quite high. Along with rice, people also consume more potatoes (129 g/day/head) and vegetables (104.7 g/day/head) on a daily basis. However, the average consumption of protein such as red meat (31.2 g/head/day), white meat (37.5 g/head/day), eggs (0.1 g/head/day), and milk (35.2 g/head/day) is low due to lower purchasing power of the locals and rise in prices of the food products (Gaiha et al. 2010). Even intake of fats such as animal ghee (0.2 g/head/day) and cheese (0.1 g/head/day) as well as flour items like bread (0.9 g/head/day), sweets (0.6 g/head/day), and soft drinks (0.2 g/head/day) is very meager. This indicates that food securities in the surveyed villages are quite low as sufficient amount of quality food is not available. As a result, calorie consumption of children residing in the villages is quite poor. Lack of dietary diversity has also been noted as

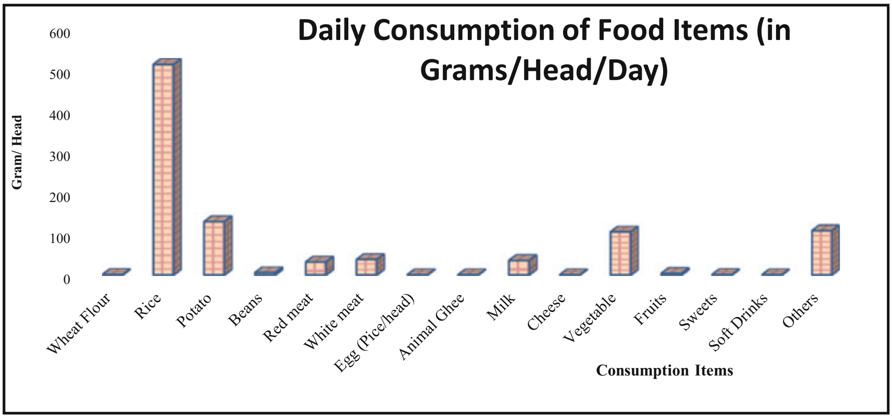


Fig. 10.2 Diagrammatic representation of daily consumption of food items (in grams/head) in the selected villages of Koch Bihar District (Sources: Based on primary field survey, 2014)

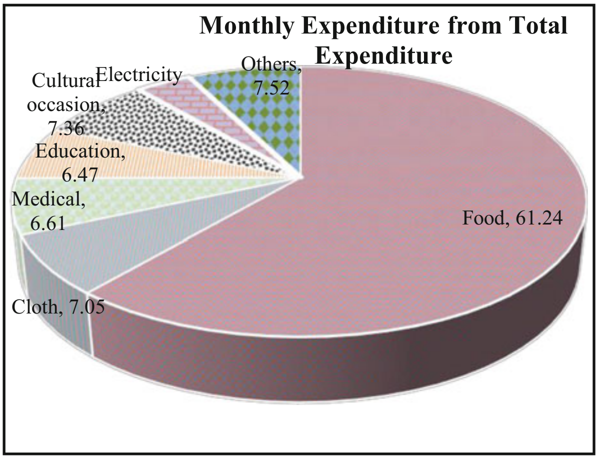
people depend more on starchy staples and few or no animal products which is quite vulnerable for young children (Arimond and Ruel 2004). Deficiency in consumption of nutritious food leads to malnourishment among children for which they are mostly stunted, underweight, and wasted (Bukania et al. 2014). Undernourished children are also likely to suffer from infections and other illness that create a negative impact on their health as well (Singh et al. 2019). Therefore, daily consumptions of nutritious food are required for the local children of the villages as undernourishment leads not only to poor physical growth but also below par mental developments as well as behavioral abnormalities (Martins et al. 2011).

Table 10.4 Village-wise distribution of daily consumptions in grams per head per day

Name of the blocks	Bread/ wheat flour	Rice	Potato	Beans	Red meat	White meat	Egg (piece/ head)	Animal ghee	Milk	Cheese	Vegetable	Fruits	Sweets	Soft drinks	Others
Angarkata Paradubi	2.1	471.3	145.4	0.0	44.6	47.8	0.0	0.5	58.4	0.0	121.9	6.9	2.1	0.0	117.6
Bharali	0.0	512.3	89.7	2.1	33.1	36.4	0.2	0.0	47.5	0.0	84.8	0.0	0.0	0.0	72.7
Dinhata	0.6	581.5	156.4	9.7	32.4	30.9	0.2	0.0	33.3	0.0	90.2	1.5	0.0	0.0	85.0
Sahebganj	1.0	496.3	136.8	8.8	27.1	30.8	0.3	0.3	34.6	0.0	115.6	6.4	0.0	0.0	117.0
Ghughumari	0.3	477.6	115.3	6.0	27.5	29.7	0.1	0.3	36.3	0.1	113.0	4.6	0.4	0.5	126.6
Madhya Hudumdanga	0.7	526.0	122.3	8.1	32.4	32.6	0.1	0.1	37.0	0.1	100.3	2.3	0.3	0.4	106.9
Kamat Changrabandha	0.0	524.0	87.9	4.2	16.8	60.9	0.2	0.0	0.0	0.0	82.1	1.5	0.7	0.2	86.8
Pachagarh	0.0	478.1	119.4	4.7	23.2	32.8	0.3	0.3	39.7	0.1	120.5	5.3	0.4	0.4	136.9
Pesterjhar	2.2	506.9	137.8	2.1	35.4	52.3	0.1	0.3	33.4	0.0	110.2	5.9	1.7	0.3	110.7
Nagar Lalbazar	2.1	592.4	175.9	10.9	32.2	31.2	0.1	0.0	22.6	0.0	96.2	0.9	0.0	0.0	93.0
Chamta	1.4	503.0	136.6	5.5	33.6	32.1	0.2	0.5	45.4	0.7	114.9	6.7	1.4	0.6	122.5
Bara Kodali	0.8	486.0	137.7	1.5	36.1	37.1	0.1	0.4	28.7	0.0	104.7	1.2	0.0	0.0	110.9
Total	0.9	512.3	129.7	5.4	31.2	37.5	0.1	0.2	35.2	0.1	104.7	3.7	0.6	0.2	107.6

Sources: Based on primary field survey, 2014

10.5.4 Monthly Expenditure



Expenditure refers to the payments made in exchange for goods and services (Aguiar and Hurst 2005). Making a budget is essential as it helps in managing money (Barr and McClellan 2018). Table 10.5 reveals the expenditure statistics of the sample villages. The expenditure on consumption covered in this study relates to expenditure on food items, clothing, fuel, ceremonies, health, education, and other nonfood items including imputed rental value of owner-occupied houses. From the table, it can be interpreted that in the study area, villagers spend a large portion of monthly expenditure on food (62.44%) than expenses on cloths (6.93%), medical treatments (6.40%), and cultural occasion (6.90%). Education and electricity (consumption of fuel) also share only 6.40% and 3.72% of the total monthly expenditure, respectively. According to science, food is converted into energy by oxygen for our body. As living conditions of the people of surveyed villages is not in a healthy state, people mainly try to spend their earning on food rather than on other necessities of life. Natives mainly depend on rice and potatoes for their daily living. This is quite detrimental for children as they don't get enough nutritious food and largely depend on starchy food items (Arimond and Ruel 2004). Nutrition insecurity can be observed among children as they are unable to access adequate quantities of nutritious food for their optimal growth and development (Govender et al. 2017). As a result, dietary diversity is quite low due to severe nutritional inadequacy (Heim and Paksi 2019). Poor income support also forces children not to attend school, and many a times it has been observed that they get engaged in agricultural activities along with their family members as family labors from a very small age (Acherjee and Deb 1998). As locals largely depend on agricultural productions for their living, investments in agriculture are being made to increase food security in the district so that no child goes to bed hungry and no physical and mental capabilities of the children should be stunted by malnutrition (Alam 2018).

Table 10.5 Village-wise distribution of percentage of monthly expenditure from total expenditure

Name of the blocks	Food	Cloth	Medical	Education	Cultural occasion	Electricity	Others	Total
Angarkata Paradubi	71.98	7.07	6.39	5.77	3.36	3.58	1.85	100
Bharali	68.85	5.33	5.00	5.83	5.02	4.85	5.11	100
Dinhata	63.50	6.47	6.15	7.69	5.67	3.74	6.78	100
Sahebganj	58.10	7.60	6.74	6.99	7.63	3.58	9.36	100
Ghughumari	51.45	8.03	7.32	7.75	10.37	3.78	10.29	100
Haldibari	56.22	7.20	6.85	7.77	8.88	3.73	9.36	100
Kamat Changrabandha	73.99	4.47	3.89	4.88	2.83	3.43	6.50	100
Pachagarh	51.63	8.19	7.19	7.07	12.04	3.85	10.02	100
Pesterjhar	68.60	6.71	6.36	4.55	5.04	3.49	5.26	100
Nagar Lalbazar	62.55	6.75	6.70	6.84	6.39	3.48	7.28	100
Chamta	56.98	8.01	7.71	6.82	8.13	3.47	8.87	100
Bara Kodali	65.39	7.27	6.52	5.37	6.41	3.70	5.35	100
Total	62.44	6.93	6.40	6.44	6.90	3.72	7.17	100

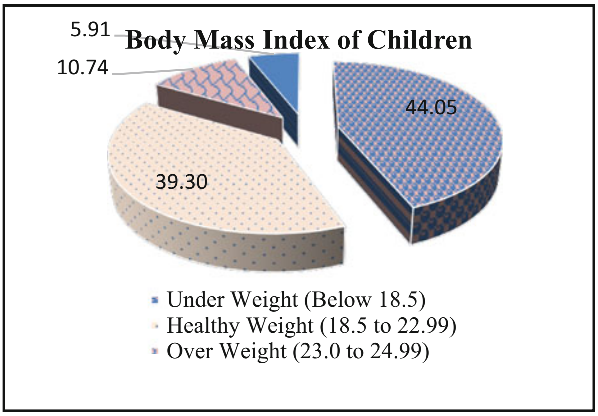
Sources: Based on primary field survey, 2014

10.5.5 Body Mass Index (BMI)

Body mass index (BMI) is the measurement of a person's body weight with respect to his or her height. It is more of an indicator than direct measurement of a person's total body fat (Evans and Colls 2009). Body mass index (Fig. 10.3) is calculated by the weight in kilograms divided by the height in meters squared. A BMI chart is usually followed to categorize a person as normal, underweight, overweight, or obese which has been represented as follows (Evans and Colls 2009):

Body mass index (BMI)	Weight status
Below 18.5	Underweight
18.5–24.9	Normal
25.0–29.9	Overweight
Over 30.0	Obese

Fig. 10.3 BMI of children



Malnutrition among children occurs when they are deprived of nutritious diets on a daily basis (Dawn and Basu 2014). This causes damage to the vital organs and functions in the human body (Holland 2018). Figure 10.3 reveals that 44.05% of children in surveyed villages are underweight as their BMI is calculated to be below 18.5, while 39.30% of the village children fall under the category of normal weight. It has also been noted that 10.74% of the children population is overweight and the remaining 5.91% are obese which is very minimum. As per BMI calculations, it can be interpreted that the maximum number of children in the surveyed villages of Koch Bihar District is malnourished. People residing in the villages are mostly landless laborers and are very much poverty-stricken. As a result, poor diet is prevalent among the children (Müller and Krawinkel 2005). Highest problem of child malnutrition has mainly been noted in the villages of Nagar Lalbazar, Pesterjhar, Pachagarh, and Kamat Changrabandha as majority of their family members are agricultural laborers and belong to below poverty line (BPL) level. Children are also seen to get engaged in agricultural activities along with their family members as family labors from a very small age due to poor income level (Acherjee and Deb 1998). Hence, along with proper intake of nutrients, food security is required as well for the development of the village children as severe malnourishment has also resulted into muscle wasting, loss of subcutaneous fat, and prominence of bony structures, particularly over the thorax which is a serious matter of concern (Bhattacharya 2012).

Malnutrition is a major public health problem that exists among children largely residing in rural parts of Koch Bihar (Bhattacharya 2012). They mainly hail from a poor socioeconomic background and thus devoid of nutritious diets (Singh et al. 2019). Lower monthly income of below Rs. 4000 has been observed in villages of Kamat Changrabandha in Mekhliganj, Bara Kodali of Tufanganj II, Bharali of Sitai block, Angarkata Paradubi of Mathabhanga II, and Sahebganj of Dinhata II block in Koch Bihar District. This indicates that the purchasing power of the village people is quite low. A maximum number of agricultural laborers have also been observed in Bara Kodali who get severely exploited by monopolistic power of the landlords for which lifestyle of these people is extremely backward (Mandal et al. 2018). Most of the village people falls under BPL level and thereby faces huge problems related to food security. They largely consume rice and potatoes for living and are devoid of protein intake. As a result, there is inadequate intake of calories among children (Singh et al. 2019). They mainly depend on starchy food materials for living for which they lack dietary diversity (Arimond and Ruel 2004). Low BMI in children has been largely noted among children residing in four villages, namely, Nagar Lalbazar, Pesterjhar, Pachagarh, and Kamat Changrabandha. Consequently, most children in the surveyed villages suffer from diarrhea, have stunted growth, and are underweight (Bhattacharya 2012). The level of food security in rural parts of Koch Bihar District is studied to be low, and consequently children lack nutritious diets. Hence, more focus is to be made on agricultural developments in the district. It is a multidimensional concept of which crop production, crop diversification, and commercialization of agriculture are the main components. Agricultural developments not only ensure food security but also play a dual role in abolition of hunger and create job opportunities for the rural households. Raising of crop productivity is also expected to increase the purchasing power of the poor which will further result into village children getting adequate amount of nutritional food on a daily basis which will lead to their genuine growth and development (Alam 2018).

10.6 Conclusion

Childhood is a critical time in growth and development of a person and is a key stage in the establishment of their physical and mental abilities. Nutrition plays a very important role in the development of children and a healthy diet and as a consequence synergistically enhances their work abilities (Graham 2016). The District of Koch Bihar lies in extreme north of West Bengal, and people are largely obsequious to poverty and sufferings. Children residing in rural parts of the district are devoid of nutritional food. They suffer severe problems related to food security and mostly depend on potatoes, sweet potatoes, and rice as their staple food for living. Due to low calorie intake, malnourishment exists, and largely children are found to be stunted and are underweight (Bhattacharya 2012). Children from the surveyed households are also like to have low dietary diversity as nutritional intakes are quite low (Chandrasekhar et al. 2017). Thereby, food security needs to be improved in the district as obtainment of sufficient quality and quantity of food will help the children in having nutritious diet on a regular basis which in turn will also increase their dietary diversity (Alam 2018). Lack of knowledge, faulty social beliefs, unhygienic living conditions, low level of parental awareness, and poor breastfeeding practices are also some of the factors for which children become vulnerable to malnourishment (Dawn and Basu 2014). Hence, prevalence of malnutrition in villages of Koch Bihar needs to be reduced with the help of following measures such as creating awareness among the village locals, improving educational level of mothers, raising household living standards, and reducing higher-order births by means of family planning (Bhattacharya 2012). As malnourishment is an existing problem among the underprivileged children, the Government of India has also introduced certain important policies and programs such as the Integrated Child Development Services (ICDS), Midday Meal Schemes (MDM) in government schools, National Health Mission (NHM), and more for its eradication (Narayan et al. 2019). The National Nutrition Strategy adopted by the Indian government also aims to reduce all forms of malnutrition by 2030 and achieve the Sustainable Development Goals related to nutrition and health. Therefore, proper nutritional diet of children is required for their normal growth and cognitive developments as undoubtedly they are the future builders of our nation (Bhattacharya, P. T. et al. 2016).

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Chapter 11
Resource Availability and Socio-economic Profile of Scheduled Caste (SC) Community in Agrarian Society: Approach Towards Sustainability

Asraful Alam and L. N. Satpati

Abstract Resource availability is important for sustainable livelihood and development. A resource is not merely a tangible object but also a functional relationship that exists between people's wants, capabilities and attitude towards worth of the environment. The objectives of this study are to study the availability of various resources in Koch Bihar for its natives and whether they are being sustainably utilized or not and the other one to study and investigate the socio-economic profile of the village people belonging to scheduled caste community in Koch Bihar District, West Bengal. The present study is based on both primary and secondary sources of data to have a clear picture about resource availability and its sustainable utilization by the natives of Koch Bihar District. The extensive household survey also focuses on the socio-economic background of the scheduled caste population residing within the district largely belonging to the farming community, and they are directly depending on the primary economic activity and natural resources.

Keywords Resource availability · Socio-economic profile · Scheduled caste (SC) · Koch Bihar and agrarian society

11.1 Introduction

Resources refer to those materials that occur naturally in the environment and have use value naturally or after being subjected to certain degree of modification and processes (Afra 2016). A resource is a means to an end (Thakur et al. 2015). Natural resources are important to all of us, and our future depends on them. Derived from

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French, etymologically resource can be defined as a naturally occurring material that a society perceives to be useful to its economic and material well-being (Okpara, J. O., & Idowu, S. O. 2013). The concept of resource was first promulgated by resource economist Erich Walter Zimmermann in the year 1943 who offered a synthetic assessment of human, cultural and natural factors which determine resource availability (Lin, B. et al. 2015). According to Zimmerman, 'Resources are highly dynamic functional concepts; they are not, they become, they evolve out of the triune interaction of nature, man, and culture, in which nature sets outer limits, but man and culture are largely responsible for the portion of physical totality that is made available for human use' (Bradley 2010). The availability of natural resources is a function of two things, i.e. the physical characteristics of the resources themselves and human, economic as well as technological conditions. The physical processes that govern the formation, distribution and occurrence of natural resources are determined by physical laws over which people have no direct control (Okpara, J. O., & Idowu, S. O. 2013). They consist of all things that do not fall under man-made creations, and thus what human beings see around them without their interventions is taken into account as natural resources (Afra 2016). They are often characterized by the amount of biodiversity and geo-diversity existent in various ecosystems. A resource is not merely a tangible object but also a functional relationship that exists between people's wants, capabilities and attitude towards worth of the environment. With application of human skills, people maintain their survival by processing out resources for their requirements (Poudel 2012). They constitute an important material basis for national development and social progress (Sun et al. 2018). Thereby, elements of environment become a resource when they attain certain aspects of human beings such as their needs and desires, sociocultural conditions, economic states and finally political circumstances, leading to development in the wealth of the country (Afra 2016).

Since dawn of human civilization, resources are viewed according to broad spectrum of man-environment interrelationship. Human activities in the past were totally determined by nature, and resources were extracted and utilized by human beings according to nature's limitations giving rise to 'deterministic' relationship of man and environment. However, with time, gradually man got success over nature's law and control. This resulted into over-exploitation of natural resources for which the concept of infinite sources of natural resources has been changed to perceived depletion; hence, the concept of 'possibilism' in man-environment relationship came into existence (Poudel 2012).The exploitation of ecosystem by humans has created a long-lasting consequence for future provision of resources. This has negatively affected the provision of food, rise in health hazards, risks of natural disasters and more (Lampert 2019). Hence, sustainable utilization of resources is required as Sustainable Development Goals provide new and enlarged understanding of sustainability to beat the social, economic and environmental challenges. According to the Brundtland Report, sustainable development is defined as the development that meets the need of the present without compromising the ability of future generations to meet their needs (Kroll 2020). Restoring and maintaining the health of the resources by incorporating resource efficiency also acts like a key element of sustainable development (Bakshi 2016). As India is a country with huge diversity, it is said to be rich in its natural resources (Frederick and Joseph 2016). However, sustainability of resources is mandatory in the country as the developmental model is characterized by heavy reliance on natural resources, thus putting extensive pressure on resources leading to increased costs, higher rate of forest degradation and reduced availability of agricultural lands. To overcome these adversities, the Government of India in the year 2006 adopted the National Environmental Policy with overall objective to conserve environmental resources through their efficient utilization, encourage intergenerational equity, ensure application of principles of good environmental governance and promote ways for environmental protection (Bakshi 2016).

The District of Koch Bihar is a unique biosphere of West Bengal where the economy is largely dependent on agriculture (Sarkar et al. 2014). It shares about 50.1% of the total SC population which is double than the State of West Bengal mostly belonging to farming community (Bhattacharya 2012). In Koch Bihar, out of a total geographical area of 3.387 ha, 2.46 lakh hectares is net cropped area, and irrigated area accounts for 106.00 thousand hectares. The major crop grown in the region includes paddy that occupies 60% of the cultivated area, 12% of the land is covered by tobacco, while 8.54% of the cultivated land is covered by jute and vegetables. The remaining land is occupied by potato, wheat and other crops (Alam 2018). The marginalized groups such as the scheduled castes are mainly characterized with below the poverty line (BPL), as a result of which people are into poverty, deprivation and acute suffering (Bhattacharya 2012). Therefore, to ensure food security of the locals, various agricultural developments have been taken into account by sustainably utilizing the available resources in the district as raising agricultural productivity will not only abolish hunger of the poor marginalized groups but will also increase their purchasing power for a better living (Alam 2018).

11.2 Objectives

The main objectives of the paper include:

1. To study the availability of various resources in Koch Bihar for its natives and whether they are being sustainably utilized or not
2. To study and investigate the socio-economic profile of the village people belonging to scheduled caste community and resource availability in the study area

11.3 Methodology

The present study is based on both primary and secondary sources of data to have a clear picture about resource availability and its sustainable utilization by the natives of Koch Bihar District. The survey also focuses on the socio-economic background of the SC population residing within the district largely belonging to the farming community. The database is a source of research support that has helped to complete the research work. For proper study of environmental recourse sustainability, self-reliance and social and economic condition of the people residing in Koch Bihar, data have been collected through fieldwork with the help of a well-structured questionnaire.

According to Table 11.1, 12 villages with a total of 194 household samples have been surveyed from three blocks of the district, namely, Haldibari, Mathabhanga II and Koch Bihar II respectively. From the table, it can be studied that four villages, namely, Madhya Baksiganj (19 households), Uttar Baksiganj (22 households), Dakshin Samilabas (10 households) and Dakshin Pran Majumder (10 households) of Haldibari block, have been surveyed where resource availability is found to be low, and maximum SC population concentration is observed in Dakshin Pran Majumder (100%). Moderate availability of resources has been observed in Mathabhanga II where 4 villages, namely, Sutarpara (13 households), Subharpathar (10 households), Angarkata Paradubi (25 households) and Phulbari Dewanbas (10 households), have been surveyed, respectively, and maximum SC population has been noted in the village of Phulbari Dewanbas (100%), while resource availability is studied to be high in Koch Bihar II of Koch Bihar District. Four more villages, namely, Basdaha Natibari (25 households), Kalapani (25 households), Chuadanga (15 households) and Ghargharia Prathamkhanda (10 households), have been taken into account, and high concentration of SC population has been observed in Ghargharia Prathamkhanda bearing a value of 96%. Stratified random sampling technique has been applied during the time of survey. It is also to be noted that secondary data sources have been being collected from different governmental agencies such as the Office of District Magistrate, Koch Bihar, for various developmental studies of the district, municipal corporations of the surveyed blocks, research reports, journals and District Census Handbook of Koch Bihar District. The present study is based on the terms of evolutionary method of both qualitative and quantitative processes. Various statistical tools have also been used to justify the result of the study.

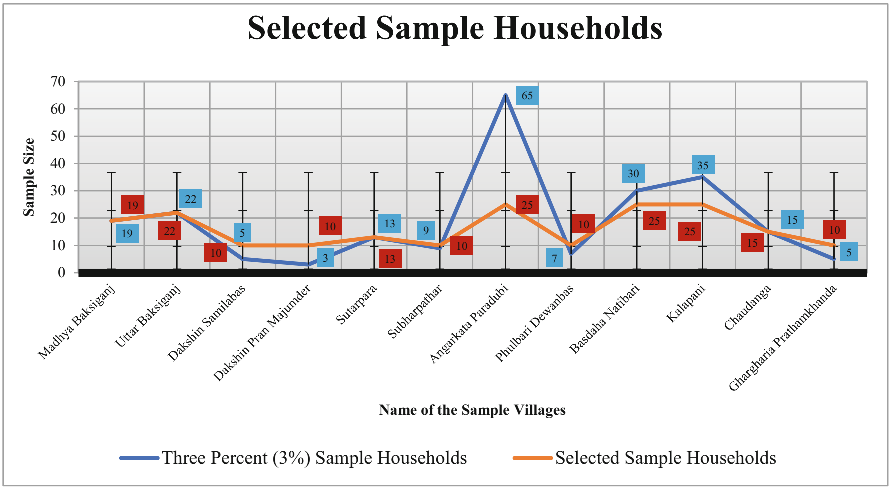


Table 11.1 Sample blocks and sample population

Resource availability zones	Name of the sample blocks and villages		Total households	Total population	Total SC population	% of SC	3% sample households	Total sample households
Low resource availability	Haldibari	Madhya Baksiganj	646	2684	824	31	19	19
		Uttar Baksiganj	737	3229	1650	51	22	22
		Dakshin Samilabas	152	789	692	88	5	10
		Dakshin Pran Majumder	101	432	432	100	3	10
Moderate resource availability	Mathabhanga II	Sutarpara	428	1884	719	38	13	13
		Subharpathar	288	1397	643	46	9	10
		Angarkata Paradubi	2177	9475	6620	70	65	25
		Phulbari Dewanbas	226	1150	1148	100	7	10
High resource availability	Koch Bihar II	Basdaha Natibari	990	4385	1197	27	30	25
		Kalapani	1165	5480	2763	50	35	25
		Chuadanga	488	2017	1504	75	15	15
		Ghargharia Prathamkhanda	164	641	616	96	5	10
Total		12 villages	7562	33,563	18,808	64	227	194

11.4 Details of Methodologies Applied During Survey

Table 11.2 shows various methodologies adopted while conducting the present study related to resource availability and its sustainable utilization by the natives of Koch Bihar District in a very detailed way. Research work has also been conducted based on the socio-economic condition of the SC community as the district comprises

Table 11.2 Detailed methodology table

Selection of the study area	Target group for methodology	Details of the methodology	Sample size	Name of the sample blocks and villages
District blocks	Study area		Whole district	
	Resource availability	Blocks are selected based on resource availability, which has been calculated by AHP (weightage methods), and from each category (high medium and low), one block has been selected as a sample block	Three blocks	Haldibari
				Mathabhanga II
				Koch Bihar II
Villages	Concentration of scheduled caste population	Villages are selected based on concentration of SC population and four (4) villages from each block with the help of mean + SD, 1SD, mean − SD and mean − 2SD	12 villages	Madhya Baksiganj
				Uttar Baksiganj
				Dakshin Samilabas
				Dakshin Pran Majumder
				Sutarpara
				Subharpathar
				Angarkata Paradubi
				Phulbari Dewanbas
				Basdaha Natibari
				Kalapani
				Chuadanga
				Ghargharia Prathamkhanda
Households	Only SC households	Out of the total SC households, 3% of the households have been basically selected where minimum of 10 households and maximum of 25 households from each village and only specific villages are selected which have 100 households	194 households from 12 villages	

about 50.1% of the total scheduled caste population who are largely engaged in agricultural activities and bears a state of BPL characteristics (Bhattacharya 2012). Three blocks of the district, namely, Haldibari, Mathabhanga II and Koch Bihar II, respectively, have been taken into account during the conduct of the survey. The particulars applied for proper study of resource availability and socio-economic state of the SC community residing in Koch Bihar District is discussed as follows.

11.4.1 Resource Availability

Resources are the backbone of every economy and provide two functions, namely, raw materials for production of goods and services and environmental services, respectively (Mensah, J., & Enu-Kwesi, F. 2019). For a detailed study of resource availability in Koch Bihar, analytic hierarchical process (AHP) method has been applied. The concept of AHP was first developed by Prof. Thomas L. Saaty in the year 1970 (Kunz 2012). AHP is a general theory of measurement and is used to derive ratio scale from both discrete and continued paired comparisons. These comparisons may be taken from actual measurements or from fundamental scale that reflects relative strength of preferences (Saaty 1987). The existing 1–9 scale in AHP was first introduced by Saaty to analyse the pairwise comparisons that range from equally preferred to extremely preferred (Zhang et al. 2009). The scale is represented as follows:

Criteria ranking based on AHP method

Level ranking	Importance
1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Very strongly preferred
8	Very to extremely strongly preferred
9	Extremely preferred

As per study, it has been observed that resource availability is highly preferred in Koch Bihar II block of Koch Bihar District with a total share percentage parameter weightage of 9. It has also been noted that resource availability is moderately preferred in Mathabhanga II with a total share percentage parameter weightage of 3, while preference of resource availability is low in Haldibari bearing a total share percentage parameter weight of 1.

11.4.2 Concentration of Scheduled Caste Population in the Surveyed Villages

Located in the northern portion of West Bengal, the District of Koch Bihar shares a large percentage of SC population (Mandal et al. 2018). For a detailed study of concentration of this marginalized section, a total of 12 villages have been surveyed from the blocks of Haldibari, Mathabhanga II and Koch Bihar II. It is also to be noted that four villages from each of the three blocks have been selected based on the concentration of SC population. The 12 villages that have been selected during the conduct of survey are Madhya Baksiganj, Uttar Baksiganj, Dakshin Samilabas and Dakshin Pran Majumder belonging to Haldibari block, Sutarpara, Subharpathar, Angarkata Paradubi and Phulbari Dewanbas of Mathabhanga II and finally Basdaha Natibari, Kalapani, Chuadanga as well as Ghargharia Prathamkhanda of Koch Bihar II. It is also to be taken into account that the concentration of SC population in the surveyed villages has been calculated by applying the methods of mean + SD, 1SD, mean − SD and mean − 2SD, respectively.

11.4.3 Selection of Households

In the present study, only the SC households have been surveyed to get a clear idea of the socio-economic condition of the people belonging to this community. A total of 194 households have been surveyed from the 12 selected villages. It is to be noted that out of the total SC households, 3% of them were basically selected. From each village, minimum of 10 households and maximum 25 households are taken into account, and only specific villages have been selected that bear about 100 households. Stratified random sampling technique has been adopted during the time of the survey.

Hence, these are the detailed methodologies with the help of which the entire survey has been conducted.

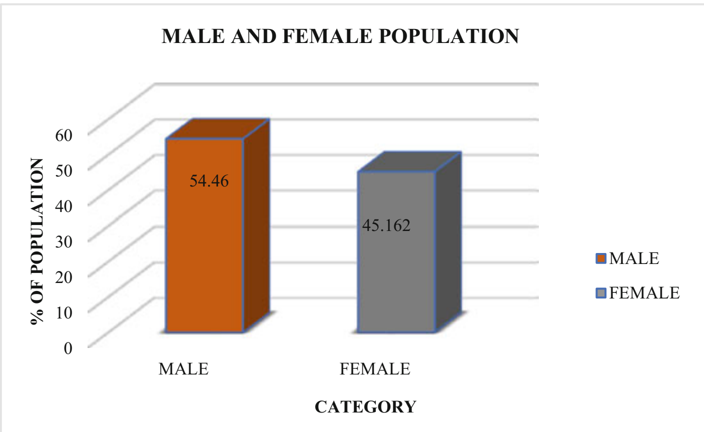
11.5 Study Area

The study has been conducted in the District of Koch Bihar which is located in between the latitudinal extension of 25°57′47″–26°36′20″ N and longitudes of 88°47′44″–89°54′35″ E. The district is situated in the foothills of the Eastern Himalayas and forms a part of Himalayan Tarai of West Bengal (Sarkar et al. 2014). The district is surrounded by Jalpaiguri District in the North, Goalpara District of Assam and Rangpur District of Bangladesh in the East and international borders of Bangladesh in the South and West (Alam 2018). Although the district boundary is artificial in the majority of the portions, there are some natural borders created by rivers Jaldhaka and Kaljani to the North, Gadadhar and Sankosh to the

East and Dharla to the South (Mandal et al. 2018). The economy of Koch Bihar is mostly dependent on agriculture, and major crops like rice, wheat, pulses, tobacco and jute are grown (Sarkar et al. 2014). The total population of Koch Bihar District as per 2011 Census is 2, 819,086, of which 2,529,652 resides in rural areas and 289,434 in urban areas (Mandal et al. 2018). According to the Census of India 2011, among all the district of West Bengal, Koch Bihar contains nearly about 50% scheduled caste population to total population (Barman 2015). Though the scheduled caste (SC) population are mainly engaged in agricultural activities, still the regional as well as total food security is found to be low here than other districts of West Bengal. Almost people depend on rain-fed agriculture, and the SC community largely falls under BPL category for which they face acute deprivations and sufferings (Bhattacharya 2012). The district is characterized to be backward in all respects from the state average like percentage share of rural inhabitants, SC population, literacy rate and percentage share of BPL, agricultural labour, wage rate and work participation rate (Mandal et al. 2018). Even the district lags in infrastructural developments. The District of Koch Bihar is characterized by moderate type of climate and comprises of 12 blocks, namely, Haldibari, Mekhliganj, Mathabhanga I, Mathabhanga II, Sitalkuchi, Koch Bihar I, Koch Bihar II, Tufanganj I, Tufanganj II, Dinhata I, Dinhata II and Sitai (Ray, M., & Rahaman, M. 2017).

11.6 Results and Discussion

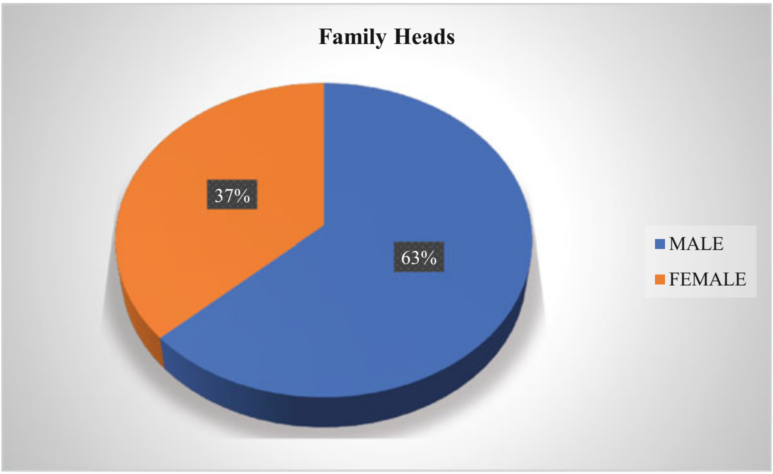
11.6.1 Demographic Profile



Demography is the scientific study of human population (Raghavan et al. 2020). It mainly helps us to understand the size, status and behaviour of the population (Tarsi and Tuff 2012). India is the second most populous country in the world after China and has recorded a total population of 136.6 crore people in 2019 (United Nations

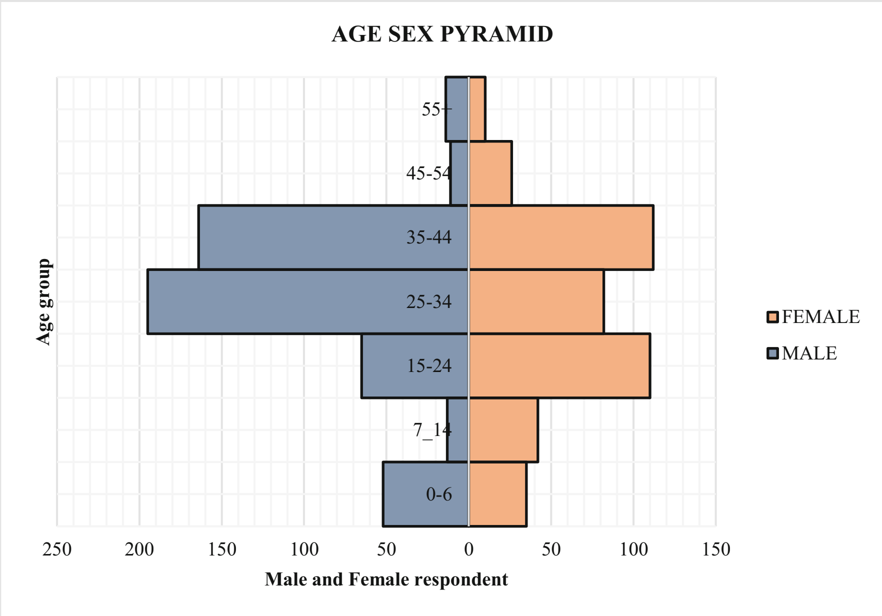
2020). However, the status of women is not favourable for which India is known to be one of the most gender unequal countries worldwide (Gailits et al. 2019). As per Census 2011, gender ratio of India is 943 females per 1000 males (United Nations 2020). This is the reason why our Indian family system is largely patriarchal in nature (Bhangaokar, R., & Kapadia, S. 2019). In a patriarchal family setup, it is the male members of household, i.e. husband, elder brother and father, who play a huge role in decision-making for the rest of the family. Still with time, this patriarchal setup is changing slowly towards equalitarian interaction among the educated, among urban middle classes and also among some rural setups which act as a positive indicator for development of a society (Mullatti 1995). From the above diagram, it can be studied that 54.46% of the surveyed population in the 12 sample villages are males, while 45.16% of the surveyed population are females. As males outnumber females in India and condition of women is quite unfavourable in our society, hence, our country is counted as one of the most gender unequal countries (Gailits et al. 2019).

11.6.2 Family Heads



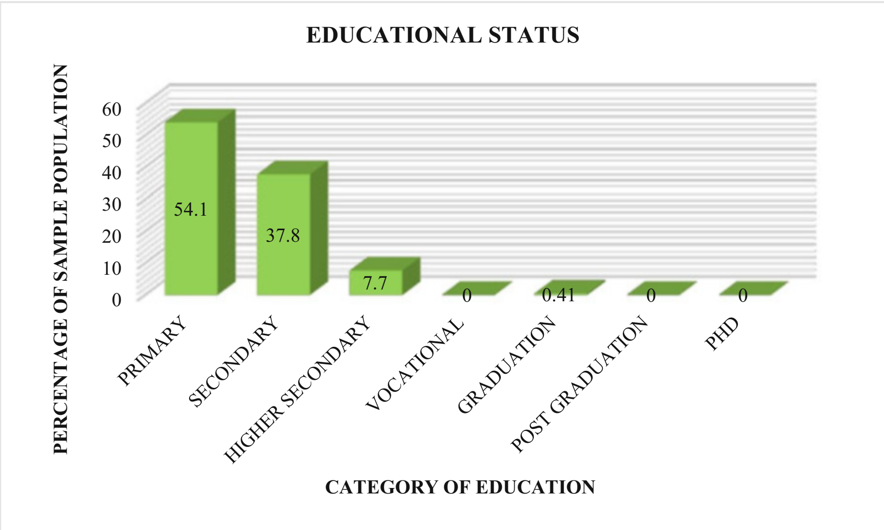
The term family is derived from Latin word *Familia*, denoting a household establishment and also referring to a 'group of individuals living together during important phases of their lifetime and bound to each other by biological or social and psychological relationship' (Chadda et al. 2013). As the Indian family system is patriarchal in nature, it is the male members who take the major decisions regarding their household and are also considered as the family heads (Kapadia 1982). The male-centred society has resulted into low involvement of women in the family decision-making (Singh and Sebastian 2018). As per reports, only 4% of the households are headed by married women in India (Nagarjana 2015). From the above diagram, it can be studied that about 63.41% of the sample respondents are males who are treated as head of the family in the surveyed villages of Koch Bihar District as this is the traditional custom of a patriarchal society. It has also been observed that about 36.9% of the females in the villages act as family heads. According to study, it has been found that about three-fourths of the women act as head of the family when they are widowed and two-thirds of those who get separated from their husbands (Nagarjana 2015).

11.6.3 Age-Sex Structure



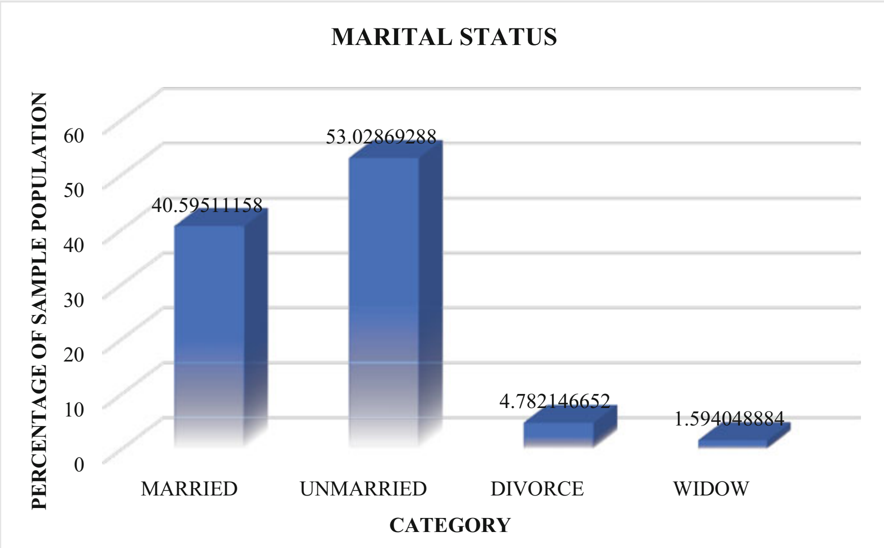
A population pyramid illustrates both age structure and gender structure of population resident within a particular region and country at a particular point in time. The number of males and females is shown in numbers or percentages of the total number of people of the country (Block 2014). Developing countries like India consists of age-sex pyramid with a wide base as younger population growth rate is more compared to high-income countries (Pezzulo et al. 2017). The above age-sex pyramid has been prepared on the basis of population data collected during the course of survey from the 12 sampled villages. From the diagram, it can be studied that the sampled villages of Koch Bihar District contain a large proportion of young and mature population falling within the age group of 25–34 and 35–44 (Diagram: Age Sex Pyramid), suggesting a relatively high birth rate (number of births per individual within the population per unit time). It has also been noted that the bars narrow at each age interval, depicting that a significant number of individuals die at every age. Here death rate (number of deaths per individual within the population per unit time) is relatively high for the population falling under the age group of 55+ which indicates that the average survival time for an individual of aged populations is less compared to other males and females falling under different age groups which indicates an imbalance in the sex ratio. This is the traditional nature of our Indian society, and that is the reason why India is known to be one of the most gender-biased countries in the world (Gailits et al. 2019).

11.6.4 Educational Status



Education plays an important role in one's life. It is the key to success in the future and helps to secure various opportunities in life (Al-Shualbi 2014). Education is also a major indicator of human development. Education gives us knowledge of the world around us and also helps us change into something better. It assists every individual to have a better perspective towards life (Al-Dubai et al. 2013). Thereby, education is deemed a real success behind any future success (Al-Shualbi 2014). According to study, it has been noted that the effective literacy rate of the SC population in Koch Bihar District has increased from 64.35% in 2001 to 73.57% in 2011 as per census reports which indicates higher achievement in the educational sector (Barman 2015). From the above diagram, it can be studied that about 54.1% of the sample population in the surveyed villages of Koch Bihar have primary level education. It has also been observed that 37.17% of people have education till secondary level, while only 7.7% of the population attain higher secondary level of education. What has been noted is that the number of respondents pursuing further studies is very handful in number. Only 0.42% of the surveyed respondents have attained education till graduation level. A considerable number of village respondents are also found to be just functionally literates, and most of the people are illiterate. By this result, it can be concluded that less progressiveness towards education exists in the surveyed villages of Koch Bihar. The villagers need to attain higher education as it will help in creating potential future for them in the coming future (Jónasson 2016).

11.6.5 Marital Status



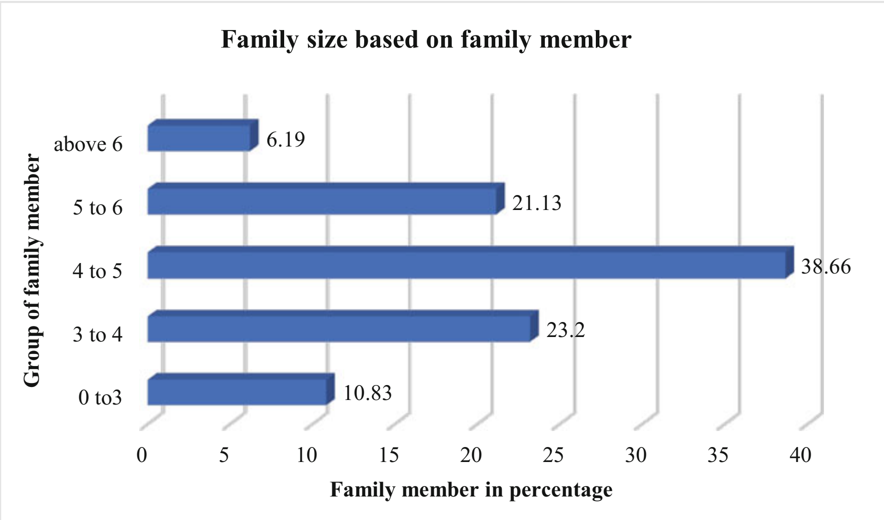
In India, traditionally and from time immemorial, marriage has been a sacred bond for people (Ghoshal et al. 2019). It is one of the most important social institutions. Civil status or marital status is the distinct options that show one's relationship with the significant other. Marriage is the beginning of family and is a lifelong commitment that widens a person's horizons. It defines oneness. Marriage is also considered as a superior bond because couples become like teammates and move together in comradeship facing the challenges, excitements, disappointments, surprises and uncertainties of life. Survival on earth seems to be more meaningful after marriage (Singh and Sebastian 2018). From the above diagram, it can be interpreted that 53.02% respondents in the sample villages of Koch Bihar District are unmarried, while 40.95% of the respondents are married. It has also been found that about 1.6% of the surveyed respondents are widows. As per studies, it has been observed that about 4.5% of respondents mostly women are divorcees as they faced domestic violence on a regular basis for which it was not possible to continue their marriage any further (Chishti 2016).

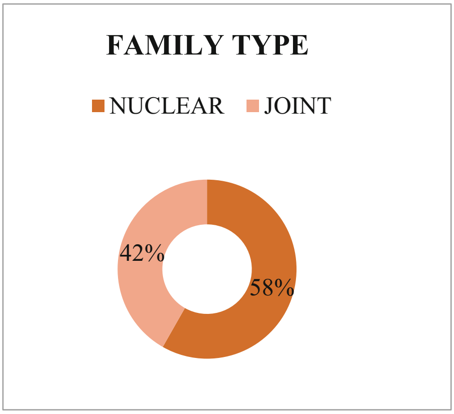
11.6.6 Socio-economic Status

Socio-economic status is defined as the measure of one's combined economic and social status and tends to be positively associated with better health. It mainly takes three indicators into account, i.e. education, income and occupation (Baker 2014). It is a total measure of an individual's work experience or of a family's economic and social position in relation to others. The primary objective is to include indicators for measuring socio-economic status as it helps to understand the inequalities that exist in the society and adjust the socio-economic differences accordingly (Mattson et al. 2017).

To assess the socio-economic condition of the SC population residing in the 12 selected villages of Koch Bihar District during the time of the survey, some of the major indicators have been taken into account which are discussed as follows.

11.6.7 Family Size





Both in pre-modern and modern societies, the institution of family has been recognized as the most basic unit of social organization (Eboh and Akpata 2017). Hence, family size is one of the important indicators to define the socio-economic status of a particular community (Agarwal 1985). From above family type figure, it can be studied that about 58.24% of respondents living in the surveyed villages belong to nuclear-type family, while only 41.75% of the respondents live in a joint family system. As per above figures, it can also be interpreted that about 38.66% of the respondents bears 4–5 family members in their houses, and only 6.19% respondents have more than six family members. Rural areas are showing greater signs of fragmentation of families by giving rise to nuclear family type and joint families declining at a much faster rate as village people are getting much influenced by the urban lifestyle (Shaikh 2017).

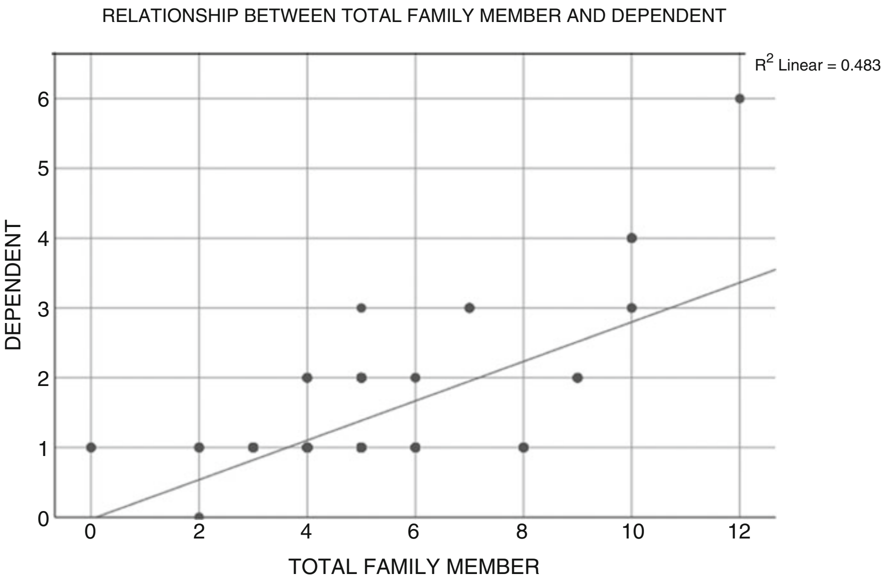
11.6.8 Dependency Ratio

Dependency ratio is the measurement of the number of dependents aged 0–14 and over the age of 65 compared to working population mainly falling between the age group of 15 and 64 years (Pirani 2014). This demographic indicator gives insight into the number of people of non-working age in contrast with the number of people of working age (Hayes et al. 2020). A low dependency ratio means that there are sufficient people working who can support the dependent population, while the higher the dependency ratio, the greater the burden (Table 11.3).

Table 11.3 Correlation on dependency of sample population

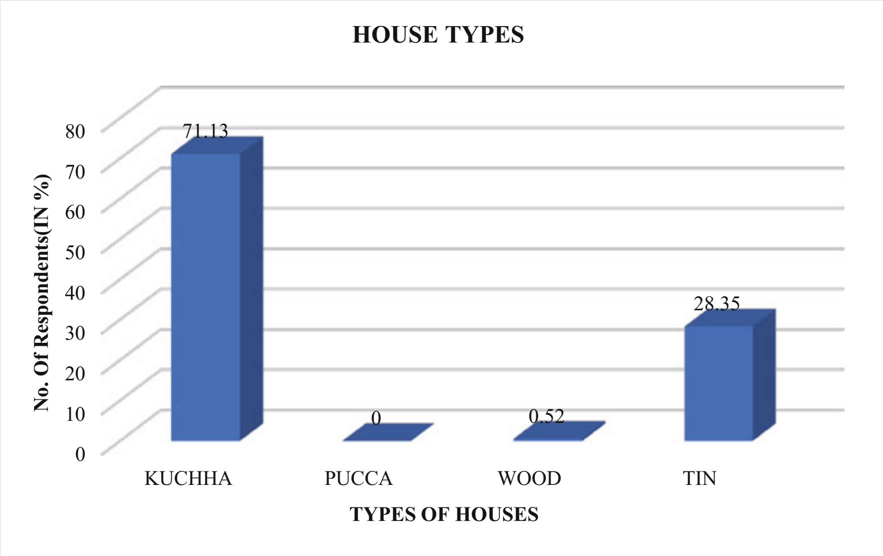
		Total family member	Dependent
Total family member	Pearson correlation	1	0.695[a]
	Sig. (two-tailed)		0.000
	N	194	194
Dependent	Pearson correlation	0.695[a]	1
	Sig. (two-tailed)	0.000	
	N	194	194

[a]Correlation is significant at the 0.01 level (two-tailed)



A sample of 194 respondents has been selected from 12 different villages of 3 blocks of Koch Bihar District, namely, Haldibari, Mathabhanga II and Koch Behar II, respectively, to determine whether most of the family members are dependent on the earning members or not. The value of the correlation statistics is 0.695. The *p* value that appears in the 'two-tailed' row is calculated to be (0.000). The result is found to be significant because the value (0.483) is less than the designated *p* value (normally 0.05). In this case, as the *p* value is greater than the value of significance, we would reject the null hypothesis because it asserts that most of the family members are dependent. As per our study, when the total number of family members is increasing, the number of dependent population is also rising, but as the line is nonlinear in nature, it represents that the total increase of population is proportionally not similar to the increase of dependent population.

11.6.9 Housing Pattern



Along with food and cloth, housing is one of the basic necessities of mankind. It is the fulcrum which rests all the basic necessities required for a better living (Reddy et al. 2017). As the type of houses are solely determined by income of an individual or family, hence housing pattern acts as an important measure in determining socio-economic status of a particular area (Islam and Mustaquim 2014). From the above diagram, it can be studied that majority of the respondents, i.e. 71.13%, reside in 'kutcha' houses, while 28.35% of the respondents have houses made of tin. According to study, it is quite alarming to notice that pucca houses which are considered to be all weather-durable and sustainable are absolutely nil (0%) in the 12 selected villages of Koch Bihar District. 'Kutcha' houses which are not considered to be sustainable are found higher in proportion in the surveyed villages (Reddy et al. 2017). This indicates that the income level of the respondents in the surveyed villages of Koch Bihar District is quite low for which economic backwardness is faced by the locals (Islam and Mustaquim 2014).

11.6.10 Housing Condition

Housing condition is an important way of assessing the socio-economic condition of the people living in it. The number of dwelling rooms in a house is an important indicator that comes under housing condition as it denotes congestion in the house. It also depicts both privacy in the house and quality living of people residing in it (Reddy et al. 2017).

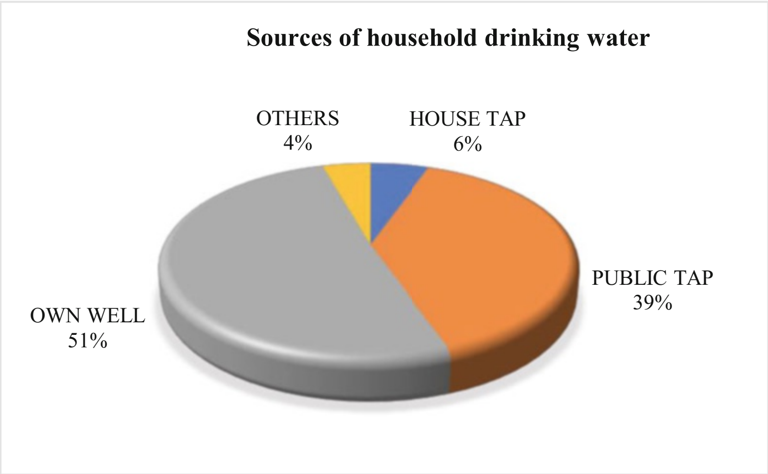
According to Table 11.4, it can be studied that the result of test value is 0.000 which is less than the designated p value 0.05. This indicates a significant relationship between the two variables. The available rooms in the surveyed houses are satisfactory for each and every family member of the respondents. Therefore, we can come to a conclusion that the total number of family members and the number of rooms in the surveyed houses have a positive relationship as household crowding is avoided (United Nations, 2017).

11.7 Social Amenities

Social amenities or public amenities refer to the things which are shared by public or residents of a particular area. They are the infrastructural facilities which are shared and thereby become a convergence point for the local and surrounding communities. Access to basic amenities like drinking water, sanitation, electricity, housing, drainage and others plays a crucial role in well-being of people as they contribute to physical and material comfort as well as quality of life (Kumar 2014).

Some of the basic amenities that have been taken into account to assess the quality life of the surveyed population in the 12 selected villages of Koch Bihar District are discussed as follows.

11.7.1 Source of Drinking Water



Water is an essential resource for life on the earth's surface covering more than 70% of the planet (Hossain 2015). However, with time, it has become a dwindling resource due to various anthropogenic activities. In India, development has resulted in the increase in demand of water in both urban and rural areas. Hence, the focus is

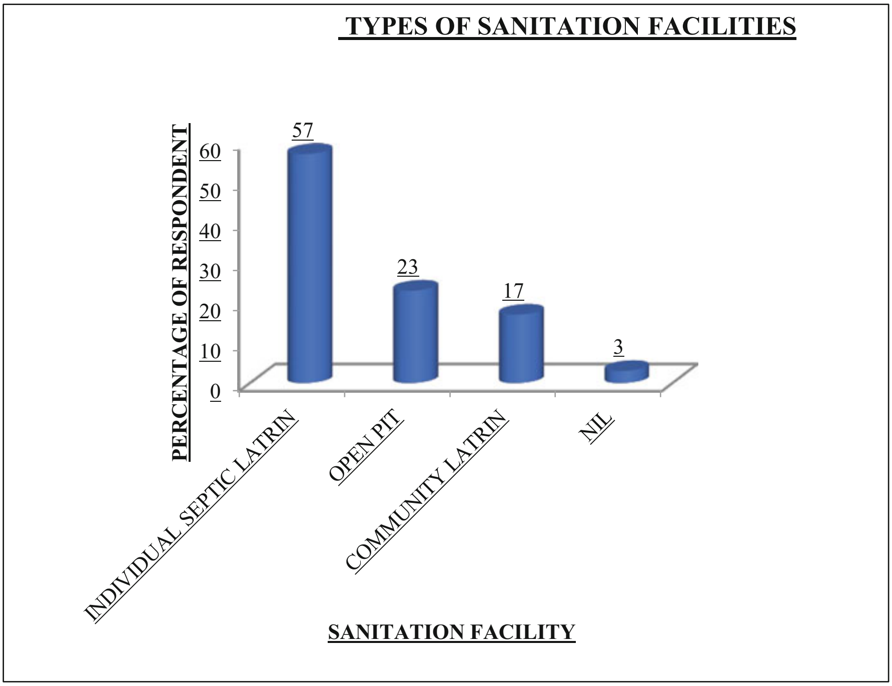
Table 11.4 Chi-square showing relationship between family members and number of rooms in the house

Chi-square tests			
	Value	df	Asymptotic significance (two-sided)
Pearson chi-square	218.258[a]	40	0.000
Likelihood ratio	129.060	40	0.000
Linear-by-linear association	35.185	1	0.000
N of valid cases	191		

[a]Forty-eight cells (87.3%) have expected count less than 5. The minimum expected count is 0.01

required to be made on both source and pattern of domestic water consumption as it plays a key role for existence of life on earth (Singh et al. 2013). From the above diagram, it can be interpreted that about 51% of the surveyed respondents in the selected villages of Koch Bihar District have their own wells which serve the purpose of domestic consumption of water. It has also been observed that about 39% of the respondents use public taps as it is widely available to the natives. Public taps act as one of the basic amenities for the local people. According to study, only 6% of the respondents have house taps. This depicts the economic backwardness of the village people for which they cannot provide themselves with personal comforts and thereby mostly depends on tube wells, public taps and hand pumps (Venkatesha et al. 2020).

11.7.2 Sanitation Type



Availability of clean water and adequate sanitation facilities are the critical measures for proper health and sustainable socio-economic development (Ravindra et al. 2019). In developing countries like India, sanitation is a major concern, and only 32.70% of rural households have access to toilets (Banerjee et al. 2017). Hence, proper sanitation conditions are a necessity in the country as it ensures both safe living and proper maintenance of hygiene (Nagpal et al. 2019). From the above figure, it can be studied that about 57% of the surveyed respondents in the 12 selected villages of Koch Bihar District have individual latrines which depict a decent sanitation condition in the study areas. According to study, it has also been observed that about 23% of the respondents while only 17% of the surveyed respondents have access community latrines which indicate low socio-economic status of the rural people. What is more alarming is that 3% of the respondents do not have access to any kind of sanitation facilities and thereby defecate in open areas. As people in rural areas still do not have access to proper sanitation facilities, hence government should take the initiative of constructing toilets so that natives do not need to defecate in open and proper hygiene can be maintained in the local areas (Banerjee et al. 2017).

11.7.3 Working Status

In India, differences exist in nature of employment opportunities on the basis of areas and regions (Kapur 2019). People in rural areas are mostly engaged in farming activities, but during the last two decades, rapid changes have been observed in the structure of rural employment, and people were mostly seen to engage themselves in non-farm sectors (Reddy et al. 2014). Presently, the primary aim of rural individuals is to obtain well-paid employment opportunities so that they are able to sustain their living conditions in an appropriate manner (Kapur 2019).

Table 11.5 shows the different occupational structure of the 194 surveyed respondents from the 12 different villages. According to study, each respondent in the 12 different selected villages is engaged in different occupational activities. The sample is mainly collected to determine whether different occupations are significantly related to the surveyed respondents or not. The people in the surveyed villages are mainly engaged in four occupations, namely, agriculture, family business, industrial sector and government sector, respectively. The value of the multiple linear regressions is noted to be different for the four variables. The p value that appears in the same row in the significance is also different for every variable. For the agricultural activity, the value of significance is 0.000 which is less than the designated p value normally (0.05). As a result, for this case, the null hypothesis is

Table 11.5 Multiple linear regressions on working status

Model		Unstandardized coefficients		Standardized coefficients			95.0% confidence interval for B		Correlations			Collinearity statistics	
		B	Std. error	Beta	*t*	Sig.	Lower bound	Upper bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	3.172	0.136		23.346	0.000	2.904	3.440					
	Agriculture	1.281	0.081	0.757	15.898	0.000	1.122	1.440	0.758	0.757	0.756	0.998	1.002
	Family business	−0.453	0.873	−0.025	−0.519	0.604	−2.175	1.269	−0.043	−0.038	−0.025	0.999	1.001
	Industry	−0.120	0.715	−0.008	−0.167	0.867	−1.529	1.290	−0.030	−0.012	−0.008	0.999	1.001
	Govt. sect.	0.047	0.873	0.003	0.054	0.957	−1.675	1.769	−0.015	0.004	0.003	0.999	1.001

[a]Dependent variable: total family member

rejected that asserts respondents are dependent on agricultural activities for earning which indicates that most of the respondents are totally engaged in agricultural activities. It has also been observed that the significance values for family business (0.604), industrial sectors (0.867) and government sectors (0.957) have a greater significance value than the designated *p* value (0.05). In this case as the *p* value is less than the value of significance, we would accept the null hypothesis for it asserts that the respondents are not dependent on family business, industry and government sector for earning. Hence, the multiple regression analysis evaluates that the respondents in the chosen sample villages are mostly engaged in agricultural activities as a statistically significant relationship exists between agricultural activities and the respondents compared to other. From this, we can deduce that people residing in the 12 selected villages of Koch Bihar District largely belong to poor category and are therefore mostly dependent on the field productivity, soil capacity, climatic conditions and technical know-how to raise agricultural productions for maintenance of their livelihood (Sarkar and Ghosh 2017).

11.7.4 Income and Expenditure Status

Income is the money that an individual receives usually in exchange of providing good and services or through investing capital. Income is primarily used to fund day-to-day expenditures (Kagan et al. 2019). The relationship that exists between income and expenditure is often known as consumption scheduled. It is mainly used to assess the economic trends in the household sector.

Table 11.6 mainly tries to show the relationship between income and expenditure. The *p* value that appears in the same row of ‘Asymptotic significance (two-sided)’ column is 0.000. Hence, a statistically significant relation exists as significant value is normally 0.05. As a result, we would reject the null hypothesis that asserts that two variables are dependent on each other. To put it simply, the data suggests that the two variables, i.e. income and expenditure, are associated with each other and expenditure is totally dependent on income (Kagan et al. 2019).

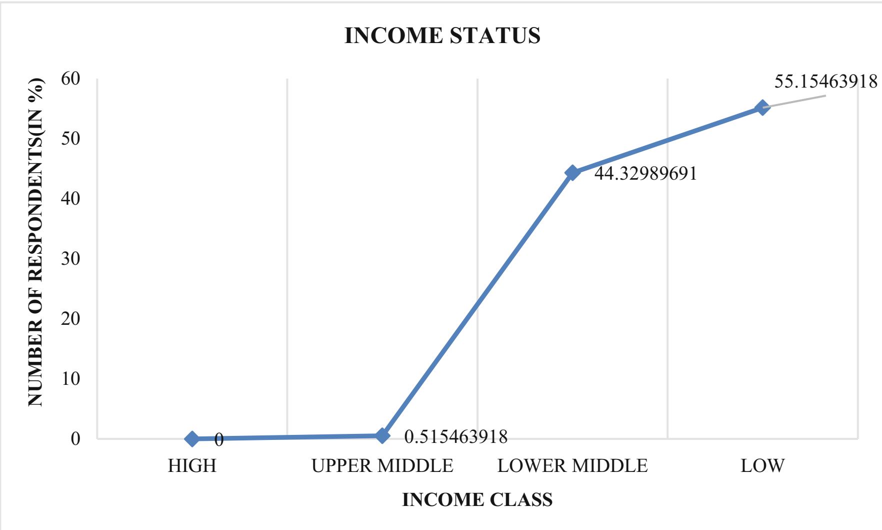
Table 11.6 Chi-square test on income and expenditure

	Value	df	Asymptotic significance (two-sided)
Pearson chi-square	3390.434[a]	1025	0.000
Likelihood ratio	864.682	1025	1.000
Linear-by-linear association	49.123	1	0.000
N of valid cases	180		

[a]One thousand and ninety-two cells (100.0%) have expected count less than 5. The minimum expected count is 0.01

11.8 Income Status of the Rural Respondents of Koch Bihar District Belonging to SC Community

The District of Koch Bihar is a unique biosphere where majority of people are engaged in agrarian activities (Bhattacharya 2012). However, the district is studied to be backward in nature as various troubles such as landlessness, fragmentation of agricultural lands due to rise in population pressure, and lack of job opportunities are faced by the village locals. As a result, most people are sunk into poverty and face huge loss of income (Mandal et al. 2018).



The above figure depicts the income status of the people in the 12 selected villages of Koch Bihar District. From the diagram, it can be easily interpreted that about 44% of the respondents belong to low middle-income groups, while 55% of the respondents belong to low-income groups. It has also been noted that people belonging to high-income as well as upper middle-income groups are quite negligible. This depicts the economic backwardness of the surveyed villages for which the village locals are objected to lack of opportunities, poverty, deprivations and sufferings (Bhattacharya 2012).

For a proper understanding, a regression analysis has been shown on income spent on consumption of different necessities by the villagers of Koch Bihar District (Table 11.7). To conduct this present study, a sample of 194 respondent has been selected from the 12 different villages who are found to be engaged in different

Table 11.7 Regression analysis on income spent on consumption of different necessities

Model		Unstandardized coefficients		Standardized coefficient		
		B	Std. error	Beta	*t*	Sig.
1	(Constant)	203.919	81.401		2.505	0.013
	Food	1.002	0.001	0.947	1016.603	0.000
	Cloth	0.963	0.018	0.052	52.167	0.000
	Medicine	0.669	0.108	0.007	6.219	0.000
	Education	1.004	0.029	0.038	34.743	0.000
	Entertainment	1.035	0.023	0.056	44.151	0.000

[a]Dependent variable: total expenditure

occupational activities to fulfil their as well as daily needs of their family. In the sample mainly helps to determine whether respondents' income spent on consumption of different necessities are significantly related or not. From this study, an association has been observed on expenditure of food, clothing, medicine, education and entertainment. The *p* value appears in the same row, and significance values are different for every variable. According to study, the significance value for food is 0.000 which is less than the designated *p* value (normally 0.05), and the other four variables, i.e. cloths (0.000), medicine (0.000), education (0.000) and entertainment (0.000), also bear significance values less than the *p* value (0.05). Hence, this indicates that the income spent on the abovementioned five variables are significantly related to total expenditure.

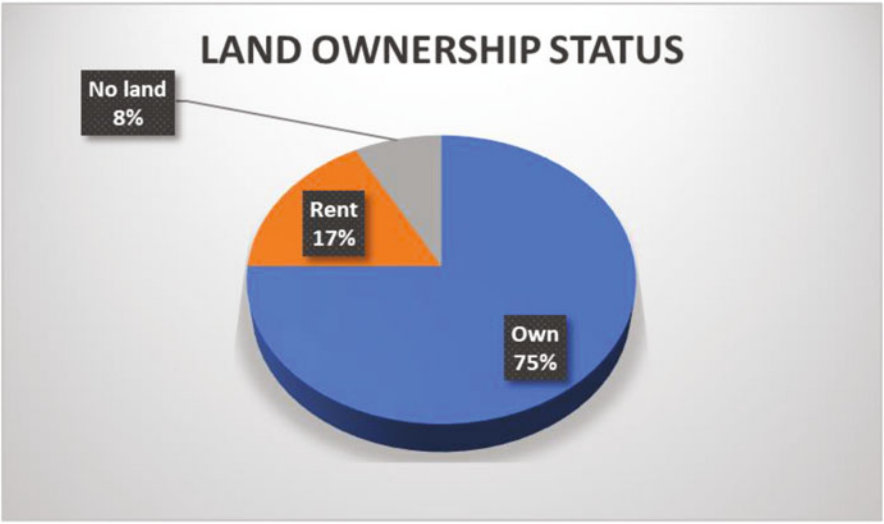
11.9 Land Utilization and Ownership

Access to land is of fundamental importance in rural India. Households mainly depend on agriculture for their daily living. Land plays a dual role in rural India; from its value as a productive factor, landownership confers collateral in credit markets, security during occurrence of natural hazards or life contingencies and social status (Mearns 1999). Presently, there are marginal landowners in most of the rural Indian households mainly growing cereals on small patch of lands and are largely reliant on groundwater for irrigation (Rukmini 2015).

The District of Koch Bihar that lies on the Himalayan Tarai region of West Bengal is mainly agricultural in nature, and the economy is dependent on the same for which (Sarkar et al. 2014). Land plays a key role in the district as agricultural developments are given great importance because it not only abolishes hunger of the local people but also helps to generate their income level for a better livelihood (Alam 2018).

11.9.1 Status of Landownership in Rural Parts of Koch Bihar District

Status of Landownership In Rural Parts Of Koch Bihar District



The above figure shows the landownership status of the respondents residing in the 12 surveyed villages of Koch Bihar District. From the diagram, it can be clearly interpreted that 75% of the respondents have their ownership on landholdings, while 17% of the respondents pay rent as they utilize land of others. It has also been noted that 8% of the respondents live below the poverty line, as a result of which they do not possess any rented or own land. These people mostly engage themselves as landless labourers and work on other land. However, these labourers face depressed circumstances during work due to monopolistic powers exercised by the landlords, minimum and uncertain wages, seasonal nature of agriculture and lack of employment opportunities (Mandal et al. 2018).

11.10 Utilization of Land in Villages of Koch Bihar District

As land is an important resource in Koch Bihar, it is utilized in various ways. For a proper analysis of land utilization in the district, a multiple regression analysis table has been constructed which is discussed as follows (Table 11.8):

The multiple regression analysis table has been constructed to show the relationship between the respondents and the land utilization based on five parameters,

Table 11.8 Multiple linear regression on different land utilization categories

Model		Unstandardized coefficients		Standardized coefficients			Correlations		
		B	Std. error	Beta	*t*	Sig.	Zero-order	Partial	Part
1	(Constant)	116.439	8.158		14.272	0.000			
	Total land (bigha)	11.449	5.924	0.157	1.933	0.055	0.003	0.141	0.134
	Grazing land	−5.239	24.516	−0.016	−0.214	0.831	−0.050	−0.016	−0.015
	Forest	−77.135	38.000	−0.149	−2.030	0.044	−0.137	−0.148	−0.140
	Mixed	24.514	39.031	0.048	0.628	0.531	−0.018	0.046	0.043
	Settlement	−87.179	18.667	−0.356	−4.670	0.000	−0.291	−0.326	−0.323

[a]Dependent variable: respondent ID

namely, total land, grazing land, forest, mixed and settlement, respectively. As per study, the significance values of total land (0.055), grazing land (0.831) and mixed land (0.531) are found to be greater than the designated *p* value normally (0.05) which means that these three parameters are not significantly related to the total population. On the other hand, the significance values of forest (0.044) and settlement (0.000) are studied to be less than the *p* value (0.05) from which we can interpret that forest and settlement are significantly related to the respondents. Hence, from this we can say that people of Koch Bihar have more access to settlement and forests as the district and its surrounding areas comprise large forest areas providing benefits to its locals compared to total land, grazing land and mixed land (Sarkar et al. 2014).

11.11 Availability of Different Resources for Utilization of People in Koch Bihar

In rural areas, households depend on different local common pool resources for their daily livelihood (Narain et al. 2008). Village people largely utilize land for farming as it is a way of earning for them. Even, small-scale farming, fishing, raising livestock and non-farm activities are some of the common livelihoods that these populations survive on (Mphande 2016). The availability of resources also contributes towards sustainable rural development process for which it is counted as important element in lives of the village people (Patil 2019).

As the District of Koch Bihar is blessed with various resources, its availability to the surveyed respondents has been studied with the help of a multiple linear regression analysis table which has been discussed as follows:

In Table 11.9, seven variables have been taken to find out the efficiency of availability of resources in the 12 selected sample villages of Koch Bihar. From the test result, it can be studied that the significance value of land cover (0.009) and land use (0.031) is less than the designated *p* value (0.05), which means that the 12 villages are efficient in both of these resources. A low *p* value (<0.05) indicates to reject the null hypothesis. On the other hand, livestock (0.709), constructed materials (0.239), water resource (0.080) and wood (0.345) have greater significance values than *p* value (0.05) which depicts that the surveyed villages have deficient availability of these four resources. Efficiency in availability of both land cover and land-use resources have been observed in the district as located at the foothills of the Eastern Himalayas, the District of Koch Bihar has large forest areas, and the economy of this district is largely dependent on agriculture (Sarkar et al. 2014). Most of the people residing in rural parts of Koch Bihar are engaged in agricultural activities, and important crops such as paddy, tobacco, jute, potatoes, mustard, wheat and more are grown here. Moreover, agriculture in Koch Bihar not only ensures food security but is also the major a means of livelihood for the locals (Alam 2018).

Table 11.9 *p* Values in multiple linear regression analysis for the study of the availability of different resources

Descriptive statistics

	Mean	*Std. deviation*	*N*
Total sample population	16.17	6.590	12
Land cover	11.83	5.750	12
Livestock	1.92	1.564	12
Mineral use	0.00	0.000	12
Water resource	3.00	4.710	12
Land use	13.33	6.513	12
Constructed material	0.42	1.443	12
Reuse the resource	0.00	0.000	12
Wood	1.67	2.015	12

Coefficients[a]

Model		*Unstandardized coefficients*		*Standardized coefficients*	*t*	*Sig.*
		B	*Std. error*	*Beta*		
1	(Constant)	3.701	1.531		2.417	0.060
	Land cover	0.724	0.173	0.632	4.191	0.009
	Livestock	0.191	0.484	0.045	0.395	0.709
	Water resource	−0.287	0.131	−0.205	−2.192	0.080
	Constructed material	0.231	0.173	0.228	1.337	0.239
	Land use	1.517	0.508	0.332	2.988	0.031
	Wood	0.410	0.393	0.125	1.042	0.345

[a]Dependent variable: total sample population

11.12 Relation Between Total Land in Surveyed Villages of Koch Bihar and Land Available for Agriculture

Table 11.10 is constructed on the basis of chi-square test to determine the relationship between total land and land available for agricultural activities. To conduct this study, a sample of 194 respondents has been selected from 12 different villages of Koch Bihar to determine the relation between total land in the district and land available for agricultural purpose. The value of the Pearson chi-square statistics is 650.408. The *p* value appears in the same row in the 'Asymptotic significance (two-sided)' column (0.000). The result is significant because the value is found to

Table 11.10 Chi-square test showing relation between total land and land available for agriculture

Chi-square tests			
	Value	df	Asymptotic significance (two-sided)
Pearson Chi-square	650.408[a]	315	0.000
Likelihood ratio	336.000	315	0.199
Linear-by-linear association	142.585	1	0.000
N of valid cases	194		

[a]Three hundred and eighty-one cells (99.2%) have expected count less than 5. The minimum expected count is 0.01

be less than the designated *p* value normally (0.05). In this case, as the *p* value is greater than the significance value; we would thereby reject the null hypothesis that asserts the two variables are dependent on each other. To put it simply, the result is significant, and the two variables are associated with each other. Therefore, we can say that the selected sample respondents have enough agricultural lands to that of total land and this is the reason why Koch Bihar is agrarian in nature and the entire economy of the district is dependent on it (Sarkar et al. 2014).

11.13 Human Improvement Indicator

Development can be defined and measured in a great variety of ways. The Human Development Index used by the United Nations Development Programme represents an attempt to emphasize on human welfare rather than on progress of the national economy (Nubler 1991). In HDI, the level of human development is conceptualized as having three components, i.e. health, education and economic conditions. These are quantified at the country level by using four indicators, namely, life expectancy at birth, mean and expected years of schooling and the logarithm of gross national income per capita (PPP in US $).The UN has been publishing the 'Human Development Reports' regularly since 1990, providing the values of the HDIs for approximately 180 countries around the world and ranking them accordingly (Ghislandi et al. 2019).

As the human improvement indicators helps to justify the overall condition of an area, a multiple regression analysis table has been constructed to study the human development condition in the 12 selected villages of Koch Bihar District (Table 11.11).

To understand the human development conditions in the 12 selected villages of Koch Bihar, three parameters have been taken which are dependent population, literate population and healthcare facilities. With the help of this test, we can come to a point whether dependent population, literacy and healthcare facilities are significant to the total number of respondents or not. The above test shows that the significance value of dependent population (0.000) and literates (0.000) are less than *p* value (0.05) which means dependents and literacy are significant to the total

Table 11.11 Multiple linear regression showing different human improvement indicators

Descriptive statistics

	Mean	*Std. deviation*	*N*
Total	4.77	1.858	194
Dependent	1.32	0.757	194
Literate	1.82	1.532	194
Healthcare	1.02	0.142	194

Coefficients[a]

Model		*Unstandardized coefficients*		*Standardized coefficients*	*t*	*Sig.*	*Correlations*		
		B	*Std. error*	*Beta*			*Zero-order*	*Partial*	*Part*
1	(Constant)	2.103	0.701		3.001	0.003			
	Dependent	1.521	0.126	0.620	11.087	0.000	0.694	0.659	0.593
	Literate	0.313	0.063	0.258	4.975	0.000	0.435	0.340	0.244
	Healthcare	0.083	0.648	0.006	0.129	0.898	−0.041	0.009	0.006

[a]Dependent variable: total

population (Table 11.11). The villages are moderately strong as these two parameters are significantly related based on the collected data. On the other hand, the significance value of healthcare (0.898) is greater than the designated *p* value normally (0.05) which means that healthcare is not significantly related to the total population. The public health facilities in the district are not within proximity for which villagers have a tendency to go to the unqualified medical practitioners for general ailments. Even during time of emergencies, ambulance services are not available, and the village locals need to depend on private rented vehicles. Therefore, infrastructural developments related to healthcare facilities are required in Koch Bihar for the benefit of the villagers (Bhattacharya 2012).

From the above study, it can be determined that Koch Bihar is still backward in nature. It lacks proper facilities and infrastructural developments for which people residing in the village areas mostly belonging to the scheduled caste community lack job opportunities and are objected to severe poverty and deprivations. Therefore, proper developmental plans are required to be taken up for this district so that the poor can have a better livelihood and can access to all the basic necessities required for day-to-day living (Alam 2018).

11.14 Conclusion

The District of Koch Bihar is an exclusive biosphere of West Bengal which is filled with natural resources. Located in the foothills of the Eastern Himalayas, Koch Bihar and its surrounding regions are covered with forests, and the district is agrarian in nature. As a result, variety of crops such as wheat, rice, pulses, tobacco and jute are grown in this region (Sarkar et al. 2014). The most unique factor of the district is that it consists of about 50.1% of scheduled caste population which is double than the State of West Bengal. However, people belonging to scheduled caste community largely belong to low-income and low middle-income class groups, as a result of which they are highly sunk into poverty (Bhattacharya 2012). Though agriculture is the main occupation in the district, as per study, there are still many people belonging to the scheduled caste group who do not have lands of their own and are engaged as labourers in other person’s land where they are found to be severely exploited due to the monopolistic power exercised by the landlords. Even, the wages paid to them are low and uncertain. Due to such exploitations and lack of job opportunities, presently these labourers are seen to be migrating to different states of India like Rajasthan, Delhi, Maharashtra, Tamil Nadu, Bihar and Arunachal Pradesh for a better living (Mandal et al. 2018). Other than availability of land for agricultural purposes, it has also been observed that people lack in availability of other important resources, namely, livestock, building materials, water resources and woods, which can contribute towards a better living for the village locals. Socio-economic characteristics are important tools to measure human development (Islam et al. 2014). The poor income status of the village people belonging to the scheduled caste community has contributed towards an impoverished lifestyle of the locals as they are largely found to be residing in kutcha houses which are not considered to be sustainable in nature (Kumar et al. 2017). They even lack basic social amenities such as proper sanitation facilities, and people are still found to be defecating in the open as villages lack proper latrine facilities which are pretty unhygienic in nature giving rise to major health hazards (Ambesh and Ambesh 2016). Education is one of the important components of people to enhance lifestyle, but due to the lack of opportunities and poor income structure of the rural people belonging to SC community, majority of them have education till primary level which reflects their backwardness (Islam and Mustaquim 2014). The economic backwardness of Koch Bihar has also contributed towards poor infrastructural developments, and people mostly belonging to the rural areas still do not have access to proper medical facilities (Bhattacharya 2012). Thereby, the district is characterized to be backward in every respect (Mandal et al. 2018). As a result, proper developmental measures are required to be taken for progress of this region. Being agrarian in nature, various initiatives such as agricultural developments are being taken into account for this district as agricultural productivity not only ensures food security but will also create job opportunities for the rural households. Higher income will give way to a better lifestyle to the village people belonging to the scheduled caste community (Alam 2018). The district also lacks proper planning. Therefore, as Koch Bihar is blessed with various resources, proper developmental measures are required by sustainably utilizing them as it would help in enhancing job opportunities in the district. This will assist the village people mostly belonging to the scheduled caste community to come out of poverty and lead a better life with access to every amenity required for survival (Alam 2018).

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Part III
Sustainable Food and Nutrition Security

Chapter 12
Understanding the Multidimensions of Food and Nutrition Security in Odisha: An Integrated Approach of Availability, Accessibility, and Utilization

Sanjit Sarkar

Abstract Understanding food security is complex and multidimensional. Due to its complexity and lack of availability of data, it becomes a troublesome task to measure "food security" more comprehensively. This study aims to understand food security in Odisha by integrating its multiple components of food availability, accessibility, and utilization. Using a set of 21 indicators collected from multiple sources of secondary data, the present study aims to understand multidimensions of food and nutrition security in Odisha. A composite food security index was constructed using Principal Component Analysis (PCA) to summarize the indicators. The analyses show that the total production of food grains is higher than the total requirement with a compound annual growth rate (CAGR) of 4.1% per annum. As shown by the composite index, out of 30 districts, 8 have been categorized as "food secure," 14 districts fall in "moderately food secure," and 8 are found to be "food insecure." Hence, the government initiatives to implement the state nutrition policies and allocation of resources need to be done based on targeting priority districts and vulnerable regions.

Keywords Food security · Nutrition · Malnutrition · Priority districts · Vulnerable groups

12.1 Introduction

In the recent past, the State of Odisha has shown progressive development in various dimensions after years of deprivation. The state's recent estimation on Gross State Domestic Product (GSDP) showed a growth rate of 7.14% during 2017–2018. This impressive economic growth furthermore accompanied with the industrial and

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infrastructural development and improved public health and social indicators. The agricultural production, especially the principal crop, i.e., rice, showed a steady growth during the past few years. In the year 2016–2017, the state has produced 98 lakh metric tons of paddy which was more than its estimated requirement. In spite of the economic progress and adequate production of rice, the state could not have performed satisfactory to combat with food and nutrition security during Millennium Development Goals (MDG) period (e.g., by 2015s). However, the state has determined a strong vision to eliminate food and nutrition insecurity by 2036 to achieve Sustainable Development Goals (SDG). In this perspective to achieve SDG, it is extremely important for the state to look into the fact of diversified production pattern for principal crops, to understand the diet habit and viability to access the foods, and to identify regional disparity of food insecurity incidence for better policy implementation and monitoring.

Food security is multidimensional (Maxwell and Frankenbetger 1992; Maxwell 1995), and the definition of "food security" has undergone several changes in the last few decades. Before the 1970s, the concept of "food security" used to define based on national food availability and food stock only, while the viewpoint has changed afterward from national food availability to accessibility and entitlement of food at household and individual level (Sen 1981; FAO 1983). Furthermore, nutritional values and utilization of foods also become an integral part of food security in the recent time (Nahla et al. 2016; WFP and IHD 2011). Hence, the term "food security" has been better labeled as "food and nutrition security" indicating nutrition security is an essential and integrated element of food security. Nonetheless, the widely accepted definition of food security was given by World Food Summits (FAO 1996) as "Food security, at the individual, household, national, regional and global levels, is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." This definition is further refined in "The State of Food Insecurity in the World" (FAO 2001) where social acceptance and access of food are also incorporated along with economic and physical access which means even if food is available, the food should be socially acceptable and permissible to eat by their ethnical and religious status. In this definition, there are three main dimensions of food security—food availability, accessibility, and utilization. Food availability refers to the physical availability of nutritious, socially, and culturally acceptable food in a region. Accessibility refers to the affordability and ability to acquire the available foods, which depends on the purchasing power capacity of households and physical viability to access the food or food sources. Utilization refers to the biological assimilation of the food, i.e., how the food is better translated into nutrient values in the body of individuals. Better utilization of food into the human body protects from the incidence of undernutrition like low body mass index (BMI) among adults, underweight, wasting, and stunting among children. Poor hygiene and sanitation and contaminated water are often associated with low utilization of food and inversely impact on household's food and nutrition security (MSSRF and WFP 2010). Another aspect that is often discussed in the domains of "food and nutrition security" is "stability" which means regular flow and sustainability in all the mentioned dimensions throughout the year.

With this complex definition, it becomes a huge hurdle for researchers to demarcate "food secure" or "food insecure" pockets in a geographical region due to its multifaceted set of indicators ranging over four dimensions of food security and due to scantiness of data, particularly at subnational and micro level. In the past, most of the studies those focused on measuring food security in India were based on nutrition intake criteria among its people (i.e., calorie intake-based) using National Sample Survey (NSS) data (Tandon and Landes 2011; Deaton and Drèze 2009). None of these studies could capture multidimensional aspects of food security. Of course, there are few studies which acknowledged accessibility dimension either by assessing the access to and impact of public distribution system (PDS) or by some other ways in measuring the food security at household level (Dev 1996; Kadiyala et al. 2012; Chakravarty and Dand 2006). But everywhere "utilization" aspects of food security were ignored by these studies. Very first time in India, the World Food Programme (WFP) in collaboration with MS Swaminathan Research Foundation (MSSRF) and the Institute of Human Development (IHD) attempted to publish a series of food security atlas for India and its selected states including Odisha (WFP n.d., https://www.wfp.org) where they have analyzed food security using multidimensional framework of food availability, accessibility, and utilization. Nevertheless, the Food Security Atlas for Rural Odisha (2008) has limitations as it was prepared only for rural counterpart and does not provide summative picture for the state as a whole (WFP and IHD 2008). In this background, the present study efforts to fulfill the research gap by analyzing the border spectrum of food security and its regional disparity following the multidimensional framework.

12.2 The Study Area

The present study analyzed food security condition for Odisha, a state of India located in the northeastern part of the country, having locational extent that lies between 17°49′N–22°34′N latitudes and 81°27′E–87°29′E longitudes with 1,55,707 sq km of areal extent (Fig. 12.1). As per 2011 Census, the state is having a total inhabitation of 4.19 crore people, out of which 84% people are living in rural Odisha. The Odisha is one of the tribal dominated states in India where 40% of the total population belongs to scheduled caste and scheduled tribe people. The sex ratio of the state is not so skewed, but still there is a lack of 21 females per 1000 male counterpart. Concentrations of habitants are mostly semi-compacted type due to its extensive plateaus and table lands which comprise more than 70% of the total geographical area. On an average, 270 persons live in 1 km^2 of area in the state. Physiographically, the state has been divided into four zones, i.e., northern plateau, central table land, Eastern Ghats, and coastal plains. Because of the diverse physiographic characteristics and spatial concentration of tribes, the state has shown a unique pattern of development where much of the development has taken place in the coastal plain than other parts of the states. As a fact of coastal-centric development, concentration of population has increased in the coastal plain resulting in the

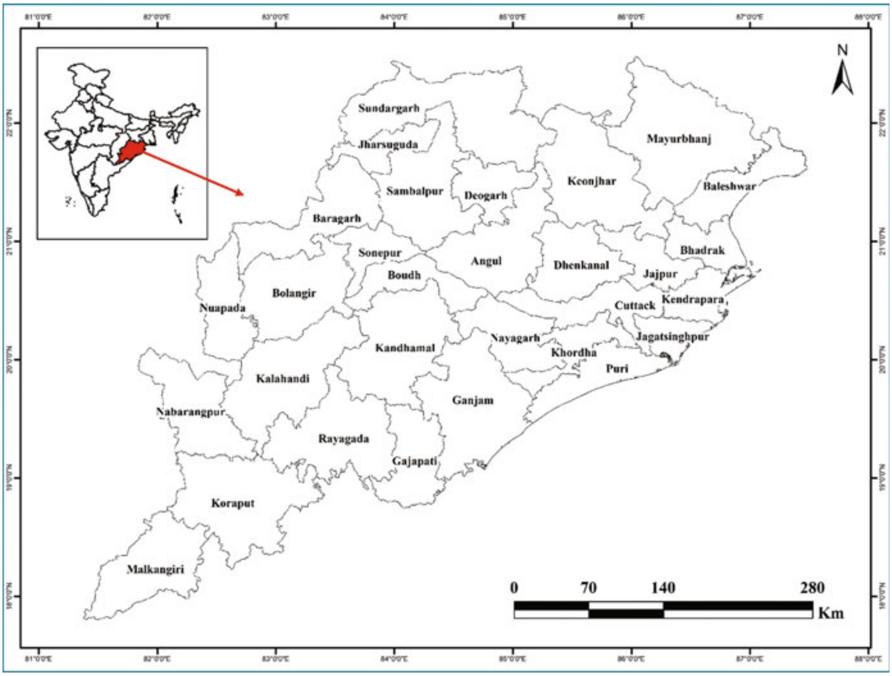

Fig. 12.1 Location map of the study area

net sown area for agriculture to reduced significantly and inversely affecting the sustainable agricultural production.

12.3 Data and Methodology

The present study utilized secondary sources of data from various governmental departments of Odisha, published reports, census of India, and other relevant sources. To measure multidimensional aspects of food security, we computed composite index for each of the dimensions of food availability, food accessibility, food utilization, and overall food security. A composite index summarizes multiple indicators of various concern dimensions and compares aggregate performance among geographical regions. As it represents aggregate result of multiple indicators, it can't represent variation of individual indicators. Indeed, this is an effective tool in policy analysis and is used universally to measure geographical variation in various social, economic, and developmental indicators. In this study, the indexes were computed at sub-state level, i.e., at district level, to assess the performance of districts in each dimension of food security. The indicators chosen for computing food security index are given below (Table. 12.1):

Table 12.1 List of indicators used for composite indexes

Dimensions		Variable name	Variable label	Ref. year	Data sources
Food security index	Availability	x1	Food grain productivity per hectare yields in kg	2011–2015	Directorate of Agriculture and Food Production, Odisha
		x2	Per capita production of food grains	2011–2015	Directorate of Agriculture and Food Production, Odisha
		x3	Percentage of non-forest area to geographical area	2015	Land Utilization Statistics, Directorate of Agriculture and Food Production, Odisha
		x4	Percentage of net sown area to total geographical area	2015	Land Utilization Statistics, Directorate of Agriculture and food production, Odisha
		x5	Percentage of irrigated area to net sown area	2015	Directorate of Agriculture and Food Production, Odisha
	Accessibility	y1	Percentage of habitat villages connected with paved road	2011	Census village facility data
		y2	Road density index	2015	Panchayati Raj and Drinking Water Department, Rural Development Department, and Department of Works, Government of Odisha
		y3	Percentage of habitat villages having FPS within 5-km distance	2011	Census village facility data
		y4	Percentage of SC and ST population	2011	Census of India
		y5	Female literacy rate	2011	Census of India
		y6	Percentage share of female to agriculture	2011	Census of India
		y7	Gross district domestic product at current price	2011	Directorate of Economics and Statistics, Government of Odisha
		y8	Head count ratio	2011–2012	Directorate of Economics and Statistics, Government of Odisha
		y9	Percentage of households having bank AC	2011	Census of India

(continued)

Table 12.1 (continued)

Dimensions		Variable name	Variable label	Ref. year	Data sources
	Utilization	z1	Percentage of household access to improved drinking water	2011	Census
		z2	Percentage of households having latrine within household premises	2011	Census
		z3	Percentage of households using LPG as cooking fuel	2011	Census
		z4	Percentage of stunted children under the age of five	2015–2016	National Family and Health Survey-4
		z5	Percentage of wasted children under the age of five	2015–2016	National Family and Health Survey-4
		z6	Percentage of underweight children under the age of five	2015–2016	National Family and Health Survey-4
		z7	Percentage of anemic children under the age of five	2015–2016	National Family and Health Survey-4

12.3.1 Principal Component Analysis (PCA)

We applied Principal Component Analysis (PCA) method to construct indexes to assess the situation of availability, accessibility, utilization, and overall food security of districts. The PCA is a data reduction technique which transforms correlated original variables into new set of uncorrelated variables. In reality original variables are so correlated with each other that only first few variables, called principal components, may be sufficient to explain the variation of the data. The PCA extracts principal components using orthogonal transformation and based on the amount of variation they account for in the original set of data. This is the reason that the PCA is a preferable method to construct composite index when variables are possibly correlated (Jolliffe 2002; Thattil et al. 2015;Vyas and Kumaranayake 2006). Variables included in constructing indexes are as follows: variables x1–x5 are included for availability index, variables y1–y9 are included for accessibility index, and variables z1–z12 are included for utilization index. For overall food security

Table 12.2 Applicability tests of principal component analysis (PCA)

	Availability index	Accessibility index	Utilization index	Food security index
Kaiser-Meyer-Olkin measure (KMO)	0.466	0.776	0.674	0.561
Bartlett's test of sphericity				
Chi-square	63.884	194.744	203.208	675.113
p-Value	0.000	0.000	0.000	0.000

index, all the variables considered for availability, accessibility, and utilization indexes are included in the PCA model.

12.3.1.1 Pre-PCA Tests

As a fact of preset condition of PCA, variables need to be correlated with each other which is confirmed by inspecting correlation matrix. Besides looking correlation, we also examined Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy to assess the applicability of Principal Component Analysis in the data (Table 12.2). Both the test results for accessibility index and utilization index confirm suitability to use PCA. KMO test results for availability index and food security index are little poor—just above miserable—but Bartlett's test of sphericity with an associated p value of <0.001 indicates that we can proceed (Beaumont 2012).

12.3.1.2 Normalization of the Data

The indicators used in these indexes have different measurement units which required to be nominalized prior to aggregation of the data. One advantage of using PCA is that it normalizes the data and converts all variables of different measurement units into same scale. Several methods are available to normalize the data like ranking, standardization (Z-score), min-max, distance to a reference country, etc. In this analysis, we applied standardized (Z-score) method using the following formula:

$$\text{Standardization } (Z\text{-score}) = (X_{\text{i}} - \text{Mean})/\text{SD}$$

where X_{i} = value of the indicatorsSD = Standard deviation

12.3.1.3 Selection of Components

We calculated index values based on the number of components which together account maximum variation of data. Thus, the number of components to be retained for the analysis is decided based on the *eigenvalue* with more than one. Following this rule, we have retained two components for the availability, accessibility, and utilization index but four components for overall food security index. The detail of components and their contribution in explaining the variation of data is given in Table 12.3.

12.3.2 Aggregation of Multiple Components to Construct Composite Index

Composite index values for each dimension are calculated by summing the selected components. But Table 12.3 summarizes that each component is not equally important in measuring the dimensions of food security. Hence, a weighted sum was applied to calculate index values. The proportion of variation explained by each component to the cumulative variation of selected components is taken as weight (Table 12.4). Thus, single composite score for each dimension using multiple components is calculated using the following way:

Composite index value = $(C_i \times W_i) + \ldots + (C_n \times W_n)$where C_i = score value of "i"th component and W_i = weight for "i"th component.

Table 12.3 Variation of data explained by different components

	Availability index	Accessibility index	Utilization index	Food security index
	Variation explained			
Comp 1	44%	59%	59%	48%
Comp 2	35%	15%	18%	16%
Comp 3	–	–	–	09%
Comp 4	–	–	–	05%
Cumulative variation explained by selected components together	79%	74%	77%	78%

Table 12.4 Weights for each component

	Comp 1	Comp 2	Comp 3	Comp 4
	Weight (W_i) (%)			
Availability index	55.7	44.3		
Accessibility index	79.7	20.3		
Utilization index	76.6	23.3		
Food security index	61.5	20.5	11.5	6.4

12.4 Results and Discussion

12.4.1 Land Utilization and Food Production Basket

The Land Utilization Statistics of Odisha (Table 12.5) shows that more than one-third (37%) of the geographical area is under forest cover and net shown area available for cultivation is 35% in 2014–2015 which shrunk by 2% in the last 15 years. In the same period, area under nonagricultural use has increased from 6% in 2000–2001 to 8% in 2014–2015, an indication of transforming agricultural land into nonagricultural activities.

The food production basket in Odisha is not diversified. A chart has been prepared (Fig. 12.2), by taking average of 4 years of production data, to show diversification in food grain production in the state. It shows that rice is the principal crop in the state, comprised of 81% of the total food grain and followed by pulses (10%), maize (7%), and ragi (2%). The production of many nutritious millets—wheat, jowar, bajra, and small millets—is negligible, and their productions are limited in some parts of northern plateaus and southern table lands.

Table 12.5 Land utilization statistics of Odisha 2000–2001 to 2014–2015

Land utilization pattern	2000–2001 (%)	2014–2015 (%)
Forest area	37.33	37.33
Misc tree and groves	3.10	2.20
Permanent pasture	2.85	3.17
Land put to nonagricultural use	6.42	8.34
Barren and uncultivable land	5.41	5.39
Fallow land cultivable waste	7.46	8.27
Net area sown	37.43	35.30

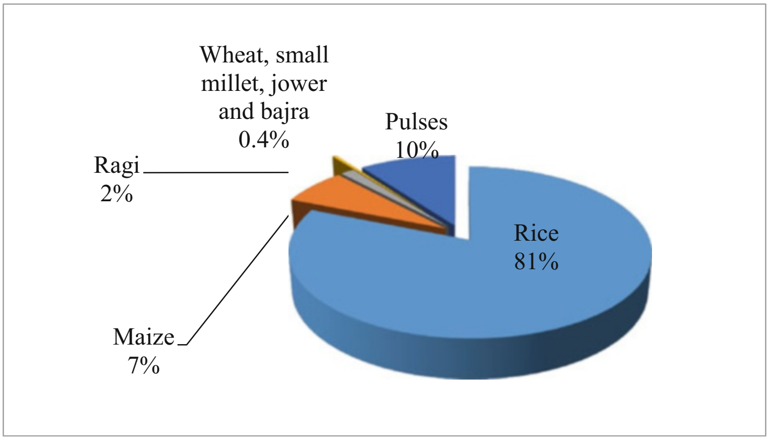

Fig. 12.2 Food grain production basket in Odisha (2011–2015)

12.4.2 Availability of Food Grains

As production is concern, the state is self-sufficient in both cereal and pulse production. Against a requirement of 7 million metric tons of cereals and 1 million metric tons of pulses, the state has produced 10.7 million and 1.1 million metric tons of cereals and pulses, respectively, in the year 2014–2015 (Table 12.6). In the case of growth rate, the state has achieved a cumulative annual growth rate (CAGR) of 4.1% for cereals and 3.9% for pulses during the period of 2000–2001 to 2013–2014, which is significant for sustained future production. Per hectare production of food grain in Odisha showed an average of 15 quintiles, whereas some districts in central Odisha showed productivity as good as more than 20 quintiles per hectare. Similarly, per capita availability of food grains in these same districts—i.e., 741 kg/capita in Subarnapur and 576 kg/capita in Bargar—are also much higher than the state average of 241 kg per capita. On the contrary, most of the districts particularly in central and coastal Odisha such as Gajapati, Jajpur, Kendrapara, and Nayagarh showed low productivity as well as low per capita availability of food grains due to high population concentration and shrinking of net sown area for the agriculture.

To comprehend the overall situation of food availability, an index was prepared by taking into account five proxy indicators related to productivity, availability, percent of non-forest area, percent of net-shown area, and percent of irrigated area. Figure 12.3 shows that seven districts out of 30—Bargarh, Subarnapur, Kalahandi, and Nabarangpur in northern Odisha and Balasore, Bhadrak, and Jagatsinghpur in central and coastal Odisha—were performed well in terms of food availability index. Contrariwise, most of the southern Odisha's districts like Angul, Nayagarh, Kandhamal, Ganjam, and Gajapati were low-performing districts.

12.4.3 Accessibility of Foods

The second dimension of food security is accessibility of food and nutrition, precise focus to be given to vulnerable population and subpopulation like poor, tribes, and displaced people. A set of proxy indicators (y1–y9) has been used to capture broad spectrum of accessibility, i.e., physical, economic, and social accessibilities. The indicators like road connectivity and proximate distance from PDS center provide physical viability to access to food. Physical accessibilities are found good in districts like Puri, Cuttack, Jajpur, and Jharsuguda where more than 80% villages are connected with paved road. On the other hand, most of southern Odisha's districts like Kandhamal, Ganjam, Koraput, and Malkangiri showed less than 50% of habitat villages are connected with paved roads. Not only deprived in physical accessibility, these southern Odisha districts are characterized with low level of female literacy rate and high concentration of scheduled caste and scheduled tribe population. Because of social and economic backwardness and physical constraints to serve the region, the southern parts of Odisha remain as the disadvantageous

Table 12.6 Requirement and production gap of cereals and pulses in Odisha (2001–2014)

Year	Cereals '000 MTs			Pulses '000 MTs			Major natural calamities (no. of districts affected)
	Consumption requirement	Production	Sufficiency (+)/ deficiency (−)	Consumption requirement	Production	Sufficiency (+)/ deficiency (−)	
2001–202	5950	7536	1586	845	697	−148	Floods (24)
2002–2003	6028	3586	−2442	856	458	−398	Drought (29)
2003–2004	6108	7114	1006	867	623	−244	Floods (23)
2004–2005	6188	6964	776	879	625	−254	Floods (5)
2005–2006	6269	7426	1157	890	794	−96	Floods (15)
2006–2007	6353	7432	1079	902	866	−36	Floods (27)
2007–2008	6435	8346	1911	914	908	−6	Floods (15)
2008–2009	6520	7640	1120	926	994	68	Floods (21)
2009–2010	6606	7745	1139	938	963	25	Flood and heavy rain (17), drought/pest attack (18)
2010–2011	6693	7771	1078	950	999	49	Flood and heavy rain (6), drought (17), unseasonal cyclonic rain (24)
2011–2012	6781	6695	−86	963	921	−42	Drought (21), flood (21)
2012–2013	6871	10,362	3491	976	1037	61	Drought (4), flood (5)
2013–2014	6962	8574	1612	989	1058	69	Severe cyclonic storm "Phailin" (19)
2014–2015	7054	10,733	3679	1002	1057	55	Flood (27), cyclonic storm "Hudhud" (15)

Source: Odisha Agricultural Statistics (2013–2014), Annual Report on Natural Calamities (2012–2013), Government of Odisha

[a]Consumption requirements for cereals and pulses were estimated based on 500 g/adult unit and 50 g (dal)/adult unit per day, respectively

[b]Total population was converted into adult equivalent by adjusting with 88% of the total population

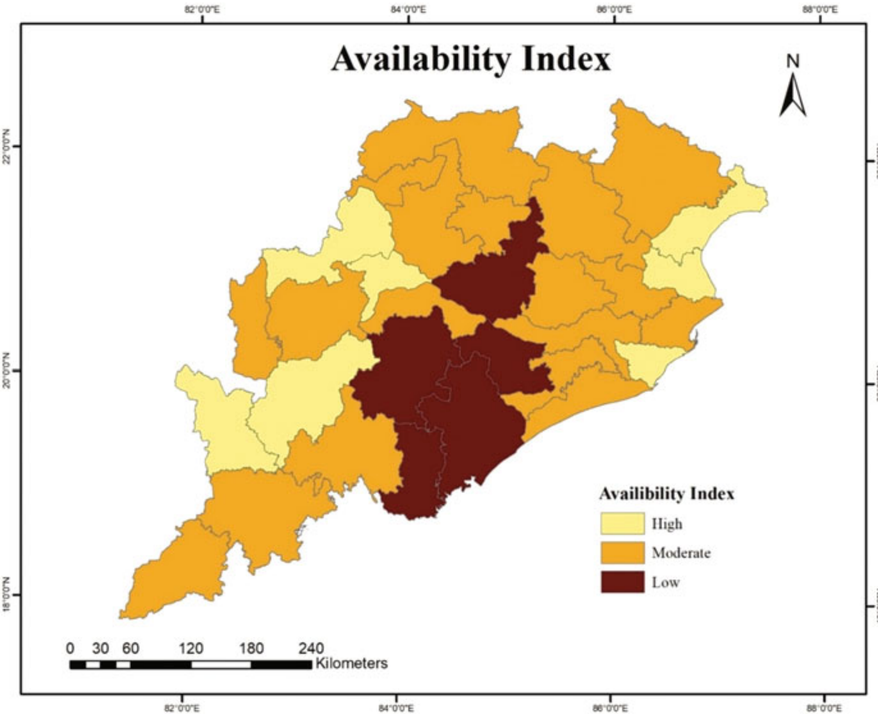

Fig. 12.3 Intrastate variation of availability index in Odisha

position to provide secure accessibility and entitlement of foods. The overall accessibility index (Fig. 12.4) shows that almost all the southern districts of Odisha and some districts of southern part of central Odisha, Balangir and Sonepur, alerted with low level of accessibility index. Higher level of accessibility index is found mostly in coastal districts of Odisha, particularly in Puri, Jagatsinghpur, Kendrapara, Bhadrak, and Baleswar.

Another aspect of accessibility of food that has also been studied in this paper is access to nutrition and has been extracted from the National Sample Survey Report to understand a macro-scenario of nutrition intake among various vulnerable people and subpopulation. Figure 12.5 shows that there is a huge gap between poor (button 35% of MPCE) and rich (top 35% of MPCE) in calorie consumption in both rural and urban areas. Nevertheless, the poor households remain deprived in calorie consumption compared to rich irrespective of their residential status, yet rural poor are more vulnerable than urban poor as consumption of calorie among rural poor is far below (1902 kcl/day) than the required level of 2400 kcal/day, whereas urban poor consume 1917 kcl/day which is almost nearer to the required level of 2100 kcal/day for them.

Table 12.7 shows the trend of percent share of food expenditure out of the total household expenditure by different fractile groups during 2004–2005 to 2011–2012.

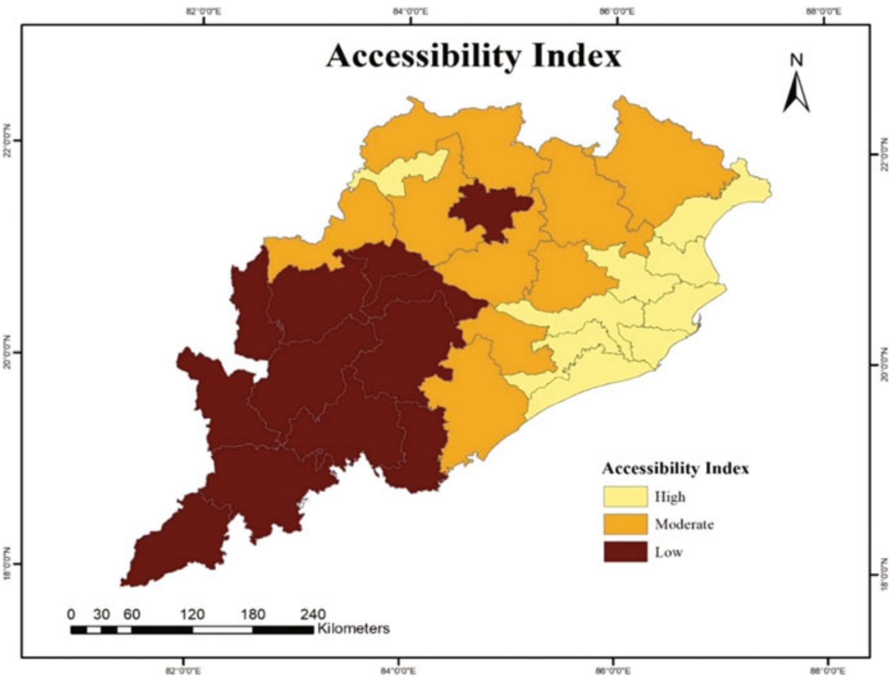

Fig. 12.4 Intrastate variation of accessibility index in Odisha

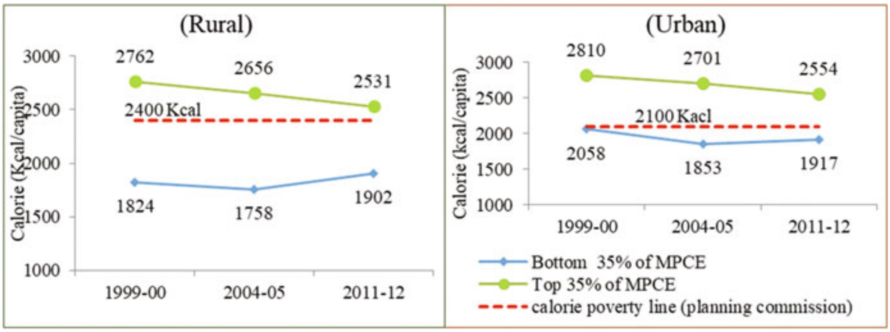

Fig. 12.5 Poor and rich gap in access to calorie by residence in Odisha, 1999–1900 to 2011–2012 (Source: Nutritional Intake in India (2011–2012), NSS 68th round)

The decrease in percent share of food expenditure out of the total household expenditure among lower fractile MPCE groups during 2004–2005 to 2011–2012 indicates that purchasing capacity, i.e., accessibility to food, has increased not only among rich but also among poor. A contrast trend is observed among upper most fractile classes where percent share of food expenditure has increased from 2004–2005 to 2011–2012 in both rural and urban areas. It happened probably due

Table 12.7 Percent share of food expenditure to total household's expenditure by household economic status

	Rural				Urban			
	% share of food expenditure		% share of cereal expenditure		% share of food expenditure		% share of cereal expenditure	
MPCE fractiles	2004–2005	2011–2012	2004–2005	2011–2012	2004–2005	2011–2012	2004–2005	2011–2012
1st	72.4	62.7	43.6	23.6	70.3	62.3	37.0	25.5
2nd	69.9	62.0	38.9	22.9	66.5	62.4	32.1	20.6
3rd	69.5	61.4	37.8	21.9	63.0	59.1	26.9	21.2
4th	66.9	60.0	33.6	20.8	59.1	56.6	23.9	16.3
5th	65.9	63.5	31.3	20.2	56.8	54.5	21.5	17.4
6th	64.5	61.2	29.0	19.6	53.2	56.9	18.8	18.0
7th	61.4	60.7	27.0	18.6	49.5	54.1	15.2	14.7
8th	59.8	59.3	24.0	17.0	47.8	45.6	12.7	10.4
9th	57.4	57.7	21.4	16.4	48.0	48.2	12.4	10.2
10th	54.1	54.5	17.8	14.2	39.8	41.8	9.0	6.9
11th	50.2	55.1	12.7	12.9	34.9	38.3	7.4	4.8
12th	35.7	44.2	8.8	9.4	24.4	29.5	3.1	3.5
All	61.6	57.2	28.3	16.7	49.9	45.4	16.8	10.5

Source: Nutritional Intake in India (2011–2012), NSS 68th round

Table 12.8 Trend and current status of nutritional indicators among children (under 5 years) and adults (15–49 years) in Odisha and India

Indicators	Odisha		India	
	2005–2006	2015–2016	2005–2006	2015–2016
Children (under 5 years)				
Stunting	45.0	34.1	48.0	38.4
Wasting	19.6	20.4	19.8	21.0
Underweight	40.7	34.4	42.5	35.7
Anemia (<11.0 g/dl)	65.0	44.6	69.4	58.4
Adult (15–49 years)				
Low BMI (BMI < 18.5 kg/m^2)				
Women	41.4	26.4	35.5	22.9
Men	35.7	19.5	34.2	20.2
Overweight (BMI $\geq$ 25.0 kg/m^2				
Women	6.6	16.5	12.6	20.7
Men	6.0	17.2	9.3	18.6
Anemia				
Pregnant women	68.1	47.6	57.9	50.3
Women	61.1	51.0	55.3	53.0
Men	33.9	28.4	24.2	22.7

Source: National Family and Health Survey 3 and 4

Note: Stunting, height for age; wasting, weight for height; underweight, weight for age; anemia for pregnant women at <11.0 g/dl and for women and men at <12.0 g/dl

to inclination toward non-cereals and fat-rich-based foods from cereal-based cheap foods among upper economic class people.

12.4.4 Utilization of Food and Nutrition Outcome

The third and most important dimension of food security is utilization or assimilation of food's nutrients into the body for better nutritional outcomes. Overall, the state has shown (Table 12.8) progressive improvement in reducing undernutrition among its people in the last 10 years. The prevalence of stunting, underweight, and anemia among children under 5 years has declined by about 11%, 6%, and 20%, respectively, during 2006–2007 (NFHS-3) and 2015–2016 (NFHS-4). Yet, the current prevalence is still high where 34.1% of children under 5 are stunted, 34.4% are underweight, and 44.6% are anemic in the years 2015–2016. Not only among children but the prevalence of undernutrition among adults, measured by body mass index, is also reduced in the same period of time (i.e., 2005–2006 to 2015–2016) from 34.2% to 19.3% among men and from 35.5% to 22.9% among women. On the other hand, obesity among adults, which is another form of malnutrition, has shot up drastically. The prevalence of obesity has increased from 6% in

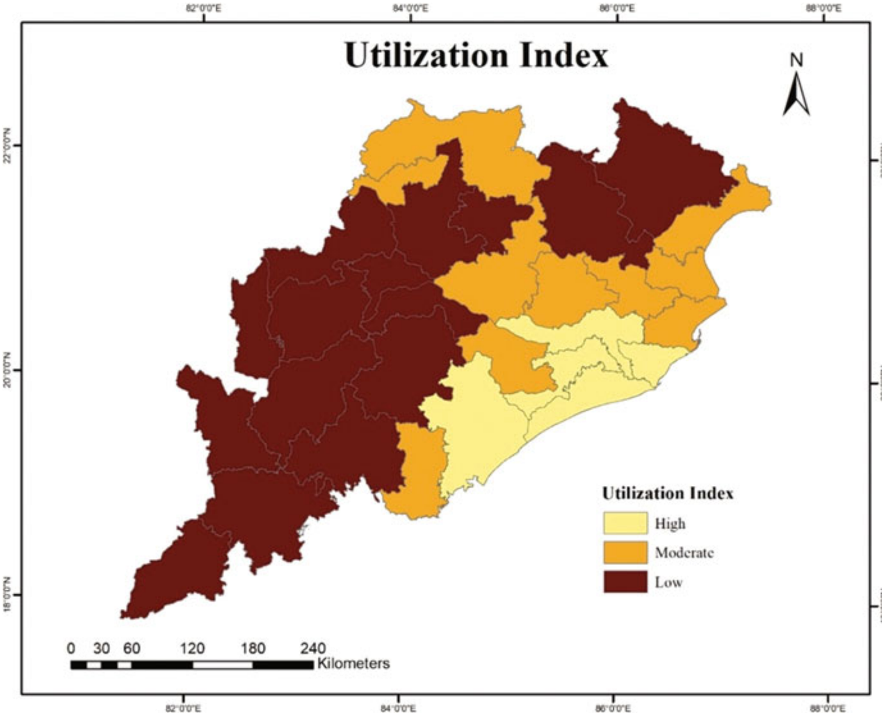

Fig. 12.6 Intrastate variations of utilization index in Odisha

2005–2006 to 17.2% in 2015–2016 among men and from 6.6% to 16.5% among women in the same period.

The prevalence of undernutrition among people is an outcome of chronic food insecurity condition which resulted because of inefficient utilization of nutrients in the human body. Efficient utilization of nutrients in the body further depends on access to hygiene and sanitation. Considering the domains, a set of indicators (z1–z7) have been used to compute the utilization index. The utilization index values shown on the map (Fig. 12.6) depicts that only five districts of coastal and central Odisha, namely, Puri, Cuttack, Khordha, Ganjam, and Jagatsinghpur, are performing high. Ten districts, mostly located in northern Odisha, showed moderate performance in utilization index. Almost all districts of southern Odisha, except Ganjam, showed poor performance in the composite index.

12.4.5 Food Security Index

Finally, food security index which is a composite index was prepared using all the indicators that have been used for all the three dimensions. The result shows that

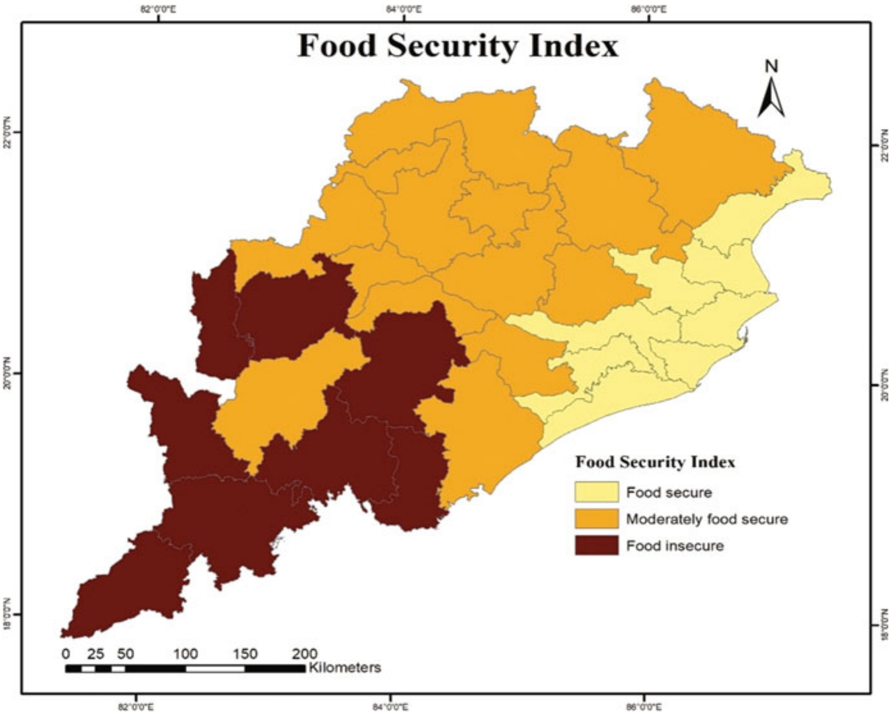

Fig. 12.7 Intrastate variations of food security index in Odisha

eight districts out of 30 districts are food secure, 14 districts are moderately food secure, and eight districts are found to be food insecure. There is a clear picture of spatial variation in the food security condition in the state. Figure 12.7 shows that food secure districts are mainly concentrated on coastal and central Odisha, whereas moderately food secure districts are clustered in the northern Odisha, and food insecure districts are particularly located in the southern part of Odisha.

12.5 Conclusion

The spatial pattern of food security condition of the state can be well explained by the variation of many economic, social, and physical underlying factors. Most of the southern districts of Odisha are categorized as "food insecure" in spite of the fact that these districts produce significant amounts of food grains including maize, ragi, and small millets. For example, maximum share of the state's maize production is contributed by four districts of southern Odisha, namely, Koraput, Rayagada, Kalahandi, and Nabarangpur. Similarly, ragi, jowar, and bajra are mainly produced in Ganjam and Koraput districts. Kalahari and Ganjam together contribute most of the pulses produced in the state. Hence, availability is no longer an issue for these districts, but accessibility and low level of utilization of food are major barriers to ensure food security. Road connectivity and accessibility to fair price shop are far worst in southern districts compared to central and coastal districts. Higher concentration of SC and ST population and poor hygiene and sanitation conditions made these districts as high prevalent districts for undernutrition, which is a reflection of low utilization of food. Another aspect that has emerged from this study is that the state is progressing toward double burden of malnutrition, a public health disorder that occurred when most of the people are undernourished and at the same time huge chunk of people are suffering from obesity too.

The Government of Odisha has shown keen interest to improve the nutritional status and ensure food security for the state. With this vision, the Government of Odisha in collaboration with national and international NGOs has implemented numbers of intervention program to enhance nutrition and food security in the state. The state has been one of the frontline performers in the implementation of various centrally sponsored nutrition schemes such as ICDS, MDM, and TPDS under the National Food Security Act (NFSA). The coverage of the NFSA was so widespread that by 2016, the state had reached 3.23 crore beneficiaries against a target of 3.26 crore as per union government norms. Not only in general but the government has taken a series of positive initiatives for vulnerable population and backward regions to battle with food insecurity. Initiatives have been taken to enhance the production and consumption of climate resistance crops in the southern parts of Odisha by implementation of the "Odisha Millets Mission." The Odisha Millets Mission is a special drive for the promotion of millets in tribal areas of Odisha. Considering high nutritive benefits of millets, this mission is focused to increase millet consumption in the households by making awareness about nutritive benefits of millets and also being keen to include millets in State Nutrition Program and public distribution systems to eliminate micronutrient deficiency, particularly in tribal areas. Overall, the state is progressing toward nutrition and food security, but the regional disparities in the rate of progress are not satisfactory. This intrastate disparity of food insecurity could be addressed by targeting the interventions to specific districts, regions, and vulnerable subgroups.

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Chapter 13
Determinants of Childhood Stunting in India: Comparative Evidence from Bihar

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Abstract A comparative assessment of socioeconomic determinants of stunting between India and Bihar is displayed in this study. The data from the National Family Health Survey-4 is used in this study to examine the comparative scenario of stunting between Bihar and India. Primary evidence of childhood stunting from Bhagalpur District has used to represent the eastern Bihar in our study. The bivariate and binary logistic regression models are used to accomplish the study objectives. A comparison in child growth between WHO standard and the sample from Bhagalpur District of Bihar has been also done. There is an over 10% difference in stunting prevalence between India and Bihar. We find that older children, children of higher birth order, children practicing unsafe disposal of stool, children born to lower educated mothers, and belong to poor households have significantly higher odds of stunting in Bihar as well as India. Child height for age only aligned with WHO standards in early childhood (0–12 months) for Bhagalpur District, but the likelihood of child stunting rises as age increases. Thus, we recommend effective program interventions keeping the socioeconomic and demographic vulnerabilities of children into consideration, reducing children stunting to attain the Sustainable Development Goals by 2030 in Bihar as well as India.

Keywords Height for age · Child growth · Nutrition · Undernutrition · Malnutrition · NFHS

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13.1 Introduction

Nutritional status plays a significant role in children's physical and mental development informative stage of life (Kumar et al. 2010). Stunting is one of the key indicators of chronic malnutrition and is closely associated with failure of ideal linear growth potential (Fenske et al. 2013). Postnatal child death is significantly associated with child height and the presence of diseases; a stunted child is more likely at risk of death (Bozzoli et al. 2009). The United Nations' estimates that about 45% of death of children under 5 years are due to malnutrition in India (UNICEF 2014). Stunting is linked with poor cognitive development and physical growth in the early stage of life and lower school achievement than non-stunted children in late adolescence (Grantham-McGregor et al. 1991). Furthermore, the meager psychological functioning of stunted children is probable to affect their quality of life as well as social and personal spheres throughout their whole life (Walker et al. 2007). Given the physical, mental, and economic significance of healthy child growth, reduction of the proportion of under-5 malnourished children through lessening hunger and poverty by 2015 was the important key indicator of MDG Goal 1. SDG 2 targeted to end all forms of malnutrition and hunger by 2030.

Recent estimates of the WHO suggested that globally the prevalence of stunting has been reducing from 32.4% to 21.3% during 2000–2019. Nevertheless, about 144 million children under 5 years of age were found to be stunted in 2019 (WHO 2020). Regionally, South Asia alone shares about 38.9% of the world's stunted children (WHO 2020). Furthermore, about 38% of children under age 5 years are stunted in 2015–2016 (IIPS and ICF 2017). Among the neighboring countries of India, Bangladesh and Nepal are advanced in reducing the prevalence of stunting than India and Pakistan; more progress is found among highly educated and wealthy household (Frongillo Jr et al. 1997; Krishna et al. 2018). In India, severe stunting of children noticeably declined, and remarkable progress of declining stunting are found in the central, eastern, and northern regions, especially among the poorest household (Nie et al. 2019). A persisting gap in the prevalence of stunting exist among the states ranging from 48% in Bihar to 20% in Kerala in 2015–2016 (IIPS and ICF 2017). A noticeable high stunting prevalence is found in empowered action group (EAG) states. Bihar is one of the members of this high policy focus of India. Malnutrition was extremely concentrated among the poorest in the areas with the ICDS program and other government-sponsored nutritional programs during 1992–2006 in India (Pathak and Singh 2011).

There are socioeconomic, regional, and demographic differentials in child malnutrition in India. The rural-urban gap in stunting is highly observed in Assam, Maharashtra, Gujarat, and Punjab (IIPS and ICF 2017; Banerjee et al. 2017). The district-level prevalence of stunting and wealth disparity is more closely correlated than other nutritional status such as underweight and overweight (Khan & Mohanty 2018). The wealth disparity in stunting has noticeably been observed among districts in Bihar and other disadvantageous states in India (Liou et al. 2020). Young et al. (2016) suggested that child malnutrition is one of the major public health challenges in Bihar; poor breastfeeding practices, household hunger, low-income status, poor dietary practices, and illiteracy are major causes of malnutrition in Bihar. Meenakshi (2016) suggested that the triple burden of malnutrition increased in India. As per food, the quality of food is highly correlated with child nutrition. A study by Sharma (2019) finds a limited improvement in the child's nutritional status during recent decades; malnutrition continued to be high among poor households. Khan and Mohanty (2018) show the prevalence of stunting child heterogeneously spread in India and highly clustered in districts belonging to Uttar Pradesh, Bihar, Jharkhand, and Madhya Pradesh. The districts with high poverty, low education, and low mother's BMI have a higher risk of stunting. A detailed literature review on the correlates of stunting in India is discussed in the following.

13.1.1 Review of Literature: Socioeconomic and Demographic Correlates

Many previous studies examined socioeconomic correlates of malnutrition especially stunting in India and elsewhere (Rengma et al. 2015; Kanjilal et al. 2010; Jena et al. 2019; Singh et al. 2018; Singh et al. 2019; Khadse and Chaurasia 2020; Sultana et al. 2019). Interstate inequality exists in India; the disproportionate burden of stunting existed among children from poor socioeconomic status. Despite the high prevalence of stunting in rural areas, the urban poor are more vulnerable in terms of child stunting. The state domestic product (NSDP) is negatively associated with the risk of stunting in India (Kanjilal et al. 2010). Lower-middle developed countries have been moving toward the dual burden of malnutrition due to changing socioeconomic conditions, demographic transition, food habits, and noncommunicable diseases during recent two decades (Rengma et al. 2015). Jena et al. (2019) found that severe acute malnutrition is more prevalent among male child, 6–12 months of age group, and rural and socioeconomically backward groups. Inadequate breastfeeding practice and poor child care are significant factors of severe acute malnutrition in Odisha. Singh et al. (2019) presented that district-level variation and socioeconomic inequalities in malnutrition present in India are mainly concentrated among districts of western, central, and eastern regions with high birth order and underdeveloped. Children belong to a low socio-economic background with illiterate women mother, less likely to maintain water, sanitation, and hygiene (WASH) practice in households, making children more vulnerable to malnutrition. Khadse and Chaurasia (2020) showed that stunting is heavily concentrated among socially backward groups, especially in scheduled caste and rural communities. The mother's body mass index (BMI), breastfeeding practice, and mobility of children are the strong predictors of stunting. The probability of stunting increased with increasing child's age, illiteracy, poor wealth status, and first birth at an early age. Mothers with normal BMI are less likely to have stunting children (Sultana et al. 2019).

Studies by Fenske et al. (2013) covered all possible factors of child stunting such as socioeconomic, maternal, and regional characteristics as well as nutritional, healthcare facility, and infection-related factors in India. This study confirms that child's age and sex are non-modifiable factors and highlights that maternal education, household wealth, ideal BMI of the mother, and proper utilization of healthcare facilities are significant protective factors of child stunting. Nie et al. (2019) observed that severe stunting of children has been noticeably declined and remarkable progress of declining stunting has been found in the central, eastern, and northern regions, especially among the poorest household. The prominent factors of declining child stunting are mother's BMI and education, and autonomy level has a relatively significant contribution to the decline in the level of stunting. Bozzoli et al. (2009) presented that postnatal child death is significantly associated with child height and the presence of diseases. Energy availability, female literacy, health expenditure, and gross national product (GNP) are closely associated with child stunting (Frongillo Jr et al. 1997).

Besides these socioeconomic, demographic, and regional factors, maternal health-related characteristics play crucial roles in the likelihood of childhood stunting. As stunting is the result of chronic malnutrition, stunting during the neonatal stage of life is closely associated with a maternal causes such as malnutrition of the mother and nonexclusive breastfeeding, but after the appearance of stunting during the postnatal period is mainly caused by poor nutritional dietary practice (Singh et al. 2018). Lack of early breastfeeding, insufficient food supply, and security, micronutrient deficiency, poor wealth and healthcare status, low standard of living, illiteracy, and poor quality of child care are leading factors of malnutrition in South Asia (Akhtar 2016). Similarly, the ideal BMI of mothers and proper utilization of healthcare facilities are significant protective factors of child stunting (Fenske et al. 2013). In addition, disease prevalence of children during childhood period, maternal factors such as nutritional status of mother and breastfeeding practice, and environmental factors are significant predictors of child stunting. The preceding birth interval and birth order of the children have significant effects on childhood stunting in South Asian countries, especially in India (Rana et al. 2019; Rana and Goli 2018).

In India, most of the studies examined socioeconomic correlates of stunting, socioeconomic inequalities in malnutrition, intersocial and intrasocial group differentials, prevalence and correlates of malnutrition, and also at district and regional level patterns of malnutrition. Among the EAG states, Bihar is one of the populous states of India which has a very high level of childhood stunting. Bhagalpur District, being a socioeconomically prominent district of western Bihar, remains to have high prevalence of childhood stunting. This is the first ever study in India that has focused on a comparative analysis of socioeconomic determinants of stunting between India and Bihar, using both primary and secondary data. Therefore, in this paper, we examine a comparative assessment of the socioeconomic determinants of stunting between India and Bihar. Further, we present primary evidence of childhood stunting from Bhagalpur District representing the eastern Bihar.

13.2 Data and Methods

13.2.1 Data Sources and Sample Selection

Data from the National Family Health Survey-4 (NFHS-4) is used in this study for a comparative analysis of India and Bihar. The NFHS is a large-scale multi-round survey, conducted throughout the country in 2015–2016. The Ministry of Health and Family Welfare (MOHFW), Government of India, designated the International Institute for Population Sciences (IIPS), Mumbai, as the nodal agency responsible for providing coordination and technical guidance for the survey. This nationally representative survey is an Indian version of the Demographic and Health Surveys (DHS), providing consistent and reliable estimates of fertility, mortality, family planning, child's nutritional status, morbidity, utilization of maternal and child healthcare services, anemia, utilization and quality of health and family planning, and other related indicators at the national, state, and regional levels. The data from the NFHS is extensively used in various policy and program formulations; as of now, four rounds have been conducted during the years 1992–1993, 1998–1999, and 2014–2016. The NFHS-4 covered a nationally representative sample of 601,509 households, comprising 699,686 women of reproductive age (aged 15–49 years), 103,525 men (aged 15–54 years), and 259,627 children (0–5 years). In our study, the unit of analysis is births which took place 5 years preceding the survey. The selected sample for this study included children with valid height measurements. The study used a total sample of 225,002 and 22,275 births for India and Bihar, respectively (IIPS and ICF 2015–2016).

The evidence from the Bhagalpur District has been presented based on the sample collected during March–April 2019. A sample of 512 under-5 children has been collected from 512 households of four sample blocks of Bhagalpur District. Out of 16 blocks of Bhagalpur District, four blocks and nine sample villages were selected for the survey. A multilevel sampling method for selecting blocks, place of residence, villages, and households has been applied. Nine villages have been selected purposively such as Fatehpur, Mansarpur, Bhiti, and Rajpur of Sabour C.D. block, Asandpur of Jagdishpur C.D. block, Agarpur of Goradih C.D. block, and Karela, Nurpur, and Mahandpur of Nathanagar C.D. block. These blocks are situated in the southern part of the District of Bhagalpur. Within these blocks, households with at least one child born within the last 5 years were selected randomly for the primary survey.

13.2.2 Variable Description

13.2.2.1 Outcome Variable

The outcome variable for this study is stunting, which refers to height for age. It expressed a low height relative to age and resulted from a slowing in skeletal growth. Stunting can be caused by poor dietary intake over time as well as poor health condition and reflects a failure to reach growth potential. Children whose height-for-age *Z*-score are below minus two standard deviations (−2 SD) from the median of the reference population are considered short for their age (stunted) or chronically undernourished (WHO 2007).

13.2.2.2 Predictor Variables

We included explanatory variables at the child, mother, and household levels. We selected the confounders after an extensive review of existing literature. Child's age at months 0–5, 6–11, 12–23, 24–35, 36–47, 48–59, sex of the child (male and female), child's birth order (1, 2, 2–3, and 4+), child's breastfeeding timing (immediately, within 1 h, after 1 h, missing), diarrhea status (no, yes, and missing), and child's stool disposal (unsafe, safe, and missing) are considered the child level. At the mother level, the confounders selected were consumption of vitamin A (no, yes, and missing), mother's age at child's birth (years) (<19, 20–24, 25–30, and 30+), mother's education (no education, primary, secondary, and higher), mother's nutritional status (normal, underweight, overweight, obese, and other), antenatal care during pregnancy (0, 1–3, 4+, and missing), social groups (scheduled tribe, scheduled caste, other backward class, and other castes), and religion (Hindu, Islam, and other). Wealth index (poorest, poorer, middle, richer, and richest) and area of residence (urban and rural) were selected at the household level. The wealth index is used to measure the household's socioeconomic status in NFHS and similar surveys; the details of the wealth index can be found in the NFHS report (IIPS and ICF 2015–2016).

13.2.3 Statistical Analyses

The univariate, bivariate, and multivariate statistical analyses were carried out for this study. The univariate descriptive statistics have been computed to understand the sample characteristics. The percentage of stunted children has been estimated for showing the prevalence of stunting across different socioeconomic, demographic, and regional factors. The binary logistic regression model has been applied to examine the determinants of stunting prevalence in India and Bihar. For the estimation of prevalence and correlates of stunting in Bihar, we used state-level wealth quintiles and state weights to account the state-level heterogeneity and poverty level. A comparison in childhood growth for age has been made between WHO standard and the evidence from Bhagalpur District of Bihar. The WHO growth standard for height for age is a standard for the linear growth of children constructed based on height for 0–24 months' children and 25–60 months' children. Further, LMS-based methods used to merge both age groups to model for the whole age range (0–-60 months of children) and power transformation of age applied to stretch the age scale (WHO 2006). For the data analyses, the STATA 15.1 software was used.

13.3 Results

13.3.1 Sample Characteristics

Table 13.1 presents the sample characteristics of the children under the age of 5 by background characteristics in India and Bihar (2015–2016). Our study included a total of 225,002 births in India and 22,275 births in Bihar which took place in the last 5 years before 2015–2016. Overall, the percentage distribution of children under the age of 5 had a similar distribution in India and Bihar across sociodemographic characteristics. Almost half (48%) of which were female, and 42% of the sample at the national level reported to breastfeed immediately. More than one-third (38%) of these births were first in order, and 14% were four or more in order. Approximately half (46%) of the mothers were between 20 and 24 years of age, with normal nutritional status (52%), and three-fourths (76%) residing in rural areas. The highest education attended by most (46%) of the mothers was secondary education. Almost four in five mothers (78%) belong to the Hindu religion, and 44% belong to the other backward caste, while 24% belong to other or general caste. The majority (39%) of mothers received four or more antenatal care during pregnancy. Among the sample births, 66% of the children's stool is disposed in an unsafe way, while 55% of the children's mothers consume vitamin A during pregnancy. Almost half of the children lived in households with poor socioeconomic status.

13.3.2 Prevalence of Stunting

The prevalence of stunting in children under the age of 5 by selected socioeconomic and background characteristics is presented in Table 13.2 for both India and Bihar (2015–2016). The prevalence of stunting was compared between India and Bihar by different background characteristics. Overall, at the national level, almost two in five children are stunted (38%), whereas in Bihar almost half of the children were stunted (48%). The prevalence of stunting in children varies significantly with socioeconomic characteristics in both India and Bihar. In both India and Bihar, the prevalence of stunting was significantly higher in children who were aged 36–47 months, four

Table 13.1 Descriptive statistics of children among under the age of 5 by background characteristics in India and Bihar (2015–2016)

Background characteristics	India		Bihar	
	Percent (weighted)	Unweighted *N*	Percent (weighted)	Unweighted *N*
Child's age (months)				
0–5	8.2	18,898	8.1	1778
06–11	10.3	22,973	10.7	2442
12–23	20.3	45,273	20.4	4553
24–35	20.1	45,105	19.6	4334
36–47	21.1	47,407	21.5	4754
48–59	20.1	45,346	19.8	4414
Sex of the child				
Male	51.9	116,360	51.5	11,490
Female	48.1	108,642	48.5	10,785
Birth order of the child				
1	38.3	83,046	28.1	6272
2–3	47.6	106,012	47.1	10,495
4+	13.1	35,944	24.7	5508
Child's breastfeeding timing				
Immediately	41.6	95,980	35.1	7960
Within 1 hour	24.4	54,664	27.0	6116
After 1 hour	29.8	64,478	33.4	7278
Missing	4.3	9880	4.4	921
Diarrhea status				
No	90.6	204,007	89.3	20,100
Yes	9.4	20,781	10.5	2137
Missing	0.1	214	0.2	38
Consumption of vitamin A				
No	43.7	104,984	41.5	9388
Yes	55.2	117,055	56.9	12,578
Missing	1.2	2963	1.6	309
Child's stool disposal				
Unsafe	66.1	147,765	83.3	18,722
Safe	33.5	76,247	16.1	3450
Missing	0.3	990	0.6	103
Mother's age at child's birth (years)				
<19	16.8	34,409	16.3	3632
20–24	45.6	98,842	43.6	9722
25–30	28.1	66,108	28.2	6301
30+	9.5	25,643	11.9	2620
Mother's education				
No education	29.7	68,978	56.5	12,461
Primary	13.1	32,835	12.6	2764
Secondary	45.8	102,191	26.9	6126

(continued)

Table 13.1 (continued)

Background characteristics	India		Bihar	
	Percent (weighted)	Unweighted *N*	Percent (weighted)	Unweighted *N*
Higher	10.4	20,998	4.0	924
Mother's nutritional status				
Normal	52.2	121,275	50.3	11,182
Underweight	23.0	49,262	27.9	6223
Overweight	10.6	22,400	5.1	1134
Obese	2.8	5520	1.0	218
Other[a]	11.5	26,545	15.8	3518
Antenatal care during pregnancy				
0	12.0	28,461	29.1	6140
1–3	23.8	58,464	28.2	6584
4+	38.6	79,444	9.8	2231
Missing	25.6	58,633	32.9	7320
Social groups				
Scheduled tribe	10.3	44,440	3.8	702
Scheduled caste	21.7	42,540	21.7	4948
Other backward caste	44.3	88,803	59.4	13,313
Other caste[b]	23.7	49,219	15.1	3312
Religion				
Hindu	78.7	163,089	81.8	18,511
Islam	16.5	35,241	18.1	3741
Other[c]	4.8	26,672	0.1	23
Wealth index				
Poorest	25.1	58,330	23.4	4830
Poorer	22.1	53,162	22.5	4906
Middle	19.9	45,136	20.8	4713
Richer	18.3	37,815	18.8	4424
Richest	13.6	30,559	13.4	3402
Area of residence				
Urban	23.8	53,483	10.4	2308
Rural	76.2	171,519	89.6	19,967
India	100.0	225,002	100.0	22,275

Data source: National Family Health Survey-4 (2015–2016)
N refers to sample size
[a]Other refers to currently pregnant women
[b]Other caste includes other than ST/SC and other backward castes
[c]Other religion includes Christian, Sikh, Buddhist, Jain, Jewish, Parsi, others, and no religion

Table 13.2 Percentage of stunted children among children under the age of 5 by background characteristics in India and Bihar (2015–2016)

Background characteristics	India	Bihar
Child's age (months)		
0–5	19.9	18.9
06–11	23.0	29.2
12–23	42.7	52.1
24–35	42.7	54.6
36–47	43.3	55.8
48–59	40.0	52.7
Sex of the child		
Male	38.8	48.0
Female	37.9	48.8
Birth order of the child		
1	33.3	45.0
2–3	38.9	47.7
4+	50.4	53.6
Child's breastfeeding timing		
Immediately	37.0	48.4
Within 1 hour	39.6	49.8
After 1 hour	39.1	47.8
Missing	39.1	44.0
Diarrhea status		
No	38.3	48.7
Yes	39.0	45.7
Missing	45.7	49.8
Consumption of vitamin A		
No	38.6	44.9
Yes	38.2	50.9
Missing	40.1	50.7
Child's stool disposal		
Unsafe	42.4	49.8
Safe	30.4	41.3
Missing	38.6	38.0
Mother's age at child's birth (years)		
<19	40.4	48.5
20–24	37.7	46.8
25–30	37.2	49.3
30+	41.7	52.1
Mother's education		
No education	50.8	54.9
Primary	43.4	49.9
Secondary	32.8	37.4
Higher	20.8	25.0
Mother's nutritional status		

(continued)

Table 13.2 (continued)

Background characteristics	India	Bihar
Normal	37.2	46.6
Underweight	45.6	52.9
Overweight	27.0	32.1
Obese	24.5	34.3
Other[a]	43.3	52.4
Antenatal care during pregnancy		
0	46.5	48.4
1–3	39.9	44.6
4+	30.5	34.9
Missing	45.1	55.7
Social groups		
Scheduled tribe	43.9	49.6
Scheduled caste	42.7	56.2
Other backward caste	38.7	47.9
Other caste[b]	31.4	38.6
Religion		
Hindu	38.5	48.3
Islam	39.8	48.8
Other[c]	31.6	46.4
Wealth index		
Poorest	51.5	57.6
Poorer	43.5	54.2
Middle	36.5	49.4
Richer	29.2	43.7
Richest	22.2	29.7
Area of residence		
Urban	31.0	40.0
Rural	41.2	49.4
India	38.4	48.4

Data source: National Family Health Survey-4 (2015–2016)
[a]Other refers to currently pregnant women
[b]Other caste includes other than ST/SC and other backward castes
[c]Other religion includes Christian, Sikh, Buddhist, Jain, Jewish, Parsi, others, and no religion

and above birth order, breastfed within 1 hour of birth, and practicing unsafe stool disposal and whose mother is underweight, had no antenatal care during pregnancy, aged less than 18 years, had no education, belong to the poorest wealth quintiles, and lived in rural areas.

The result suggests that there is over 10% difference in stunting prevalence between India and Bihar, among mothers who consume vitamin A tablet, mothers' practices of safe disposal of children's stool, mothers' delivery of the baby in age 25–30 years, and mothers who belong to the scheduled caste and poorer, middle and richer wealth quintiles. There is also a significant difference over 20–30% observed by the age of the child, mother's educational level, and wealth quintiles and over 10% by the area of residence and social groups in both India and Bihar. The results show that the prevalence of stunting is 10% higher in Bihar than the national level. The bivariate analysis shows a significant difference, almost on an average of 5–10%, in the prevalence of stunting across the background characteristics in both India and Bihar level. Among the children under the age of 6 months, there is a difference of 1% in stunting prevalence between India and Bihar; it increased with an increase in the age of children and reached the highest difference of 13% at age 36–59 months. Among the mothers who breastfeed their child immediately among them, there is a difference of 11% in stunting prevalence, and it reduces to 9% among those who breastfeed after an hour. Concerning the birth order of the children, the result shows that prevalence of stunting increase with an increase in birth order in India and Bihar as well. The difference in stunting prevalence among the first and four and above birth order is 17% in India and 9% in Bihar.

13.3.3 Determinants of Childhood Stunting

Table 13.3 displays the determinants of stunting using binary logistic regression for both India and Bihar, respectively. The prevalence of stunting was compared between India and Bihar with different background characteristics. Furthermore, the prevalence of stunting among the different background characteristics was compared separately for India and Bihar. At the India level, the child is strongly linked to the probability of being stunted by increasing age. Children aged 36–-47 months are three times more likely (OR: 3.08, 95% CI: 2.95–3.22) to be stunted than children aged 0–5 months. Children whose mothers were less educated were more likely to be stunted than their counterparts (OR: 1.68, 95% CI: 1.68–1.76); similarly, if the child's mother was underweight, they were more likely to be stunted (OR: 1.25, 95% CI: 1.22–1.28). The result also indicats that mother's social group and socioeconomic status linked strongly with odds of child stunting, and children from scheduled caste more likely to be stunted with an odd of 1.33 (95% CI: 1.29–1.37) as well as children who belonged to the poorest households (OR: 1.95, 95% CI: 1.87–2.04).

The odds of childhood stunting is significantly varied across the background characteristics in both India and Bihar. The odds of stunting were significantly higher among older children, children of higher birth order, and children practicing unsafe disposal of stool. Similarly, both in India and Bihar, significantly higher odds of stunting were found among children whose mothers were less than 19 years of age during the childbirth, had no education, were underweight, had no antenatal care visits during pregnancy, belong to the scheduled caste and tribe groups, follow Islam religion, and belong to the poor economic status than their counterparts. The significant difference in the probability of stunting is found by the age of the child, mother's educational level, social group, and wealth status. The sex of the child, diarrhea status, consumption of vitamin A, antenatal care during pregnancy, and place of residence are not significantly associated with stunting prevalence in Bihar.

Table 13.3 Adjusted odds ratios of stunting among under the age of 5 by background characteristics in India and Bihar (2015–2016)

	India			Bihar		
Background characteristics	Odds Ratio	95% Conf. interval		Odds Ratio	95% Conf. interval	
Child's age (months)						
0–5 (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
06–11	1.26***	1.20	1.32	1.94***	1.67	2.26
12–23	3.04***	2.92	3.17	4.64***	4.05	5.32
24–35	2.98***	2.86	3.11	5.03***	4.38	5.78
36–47	3.08***	2.95	3.22	5.24***	4.54	6.04
48–59	2.57***	2.46	2.69	4.57***	3.95	5.28
Sex of the child						
Male (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
Female	0.90***	0.89	0.92	1.00	0.95	1.06
Birth order of the child						
1 (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
2–3	1.22***	1.19	1.25	1.12**	1.04	1.21
4+	1.51***	1.46	1.56	1.29***	1.16	1.43
Child's breastfeeding timing						
Immediately (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
Within 1 hour	1.05***	1.02	1.07	0.99	0.92	1.06
After 1 hour	1.04***	1.02	1.07	0.94	0.87	1.00
Missing	0.95**	0.91	1.00	0.75***	0.65	0.87
Diarrhea status						
No (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
Yes	1.06***	1.03	1.09	0.95	0.86	1.05
Consumption of vitamin A						
Yes (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
No	1.00	0.98	1.02	0.95	0.90	1.01
Child's stool disposal						
Safe (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
Unsafe	1.14***	1.11	1.17	1.12**	1.03	1.21
Mother's age at child's birth (years)						
<19	1.14***	1.11	1.17	1.10**	1.00	1.19
20–24 (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
25–30	0.91***	0.89	0.93	0.98	0.91	1.06
30+	0.87***	0.85	0.91	0.93	0.83	1.03
Mother's education						
Higher (ref.)	1.00	⍰	⍰	1.00	⍰	⍰
Secondary	1.26***	1.21	1.31	1.34***	1.13	1.58
Primary	1.53***	1.46	1.60	1.77***	1.47	2.12
No education	1.68***	1.61	1.76	1.90***	1.59	2.26
Mother's BMI						
Normal (ref.)	1.00	⍰	⍰	1.00	⍰	⍰

(continued)

Table 13.3 (continued)

Background characteristics	India			Bihar		
	Odds Ratio	95% Conf. interval		Odds Ratio	95% Conf. interval	
Underweight	1.25***	1.22	1.28	1.19***	1.11	1.27
Overweight	0.80***	0.77	0.82	0.73***	0.64	0.84
Obese	0.75***	0.70	0.80	0.78	0.58	1.05
Other[a]	1.19***	1.16	1.23	1.20***	1.11	1.31
Antenatal care during pregnancy						
0	1.12***	1.09	1.16	1.07	0.96	1.20
1–3	1.09***	1.06	1.11	1.08	0.97	1.20
4+ (ref.)	1.00			1.00		
Social groups						
Scheduled tribe	1.15***	1.12	1.19	1.18	0.99	1.40
Scheduled caste	1.33***	1.29	1.37	1.62***	1.46	1.79
Other backward caste	1.22***	1.19	1.25	1.30***	1.19	1.42
Other caste[b] (ref.)	1.00			1.00		
Religion						
Hindu (ref.)	1.00			1.00		
Islam	1.08***	1.05	1.11	1.09**	1.00	1.18
Other[c]	0.88***	0.85	0.91	0.83	0.35	1.99
Wealth index						
Richest (ref.)	1.00			1.00		
Richer	1.16***	1.12	1.21	1.41***	1.26	1.56
Middle	1.41***	1.36	1.46	1.64***	1.47	1.83
Poorer	1.66***	1.59	1.73	1.87***	1.67	2.10
Poorest	1.95***	1.87	2.04	1.99***	1.77	2.25
Area of residence						
Urban (ref.)	1.00			1.00		
Rural	0.93***	0.91	0.95	1.01	0.92	1.12

Data source: National Family Health Survey-4 (2015–2016)
***$P < 0.01$, **$P < 0.05$; Ref. stands for reference category
[a]Other refers to currently pregnant women
[b]Other castes include other than ST/SC and other backward castes
[c]Other religion includes Christian, Sikh, Buddhist, Jain, Jewish, Parsi, others, and no religion

13.3.4 Child Growth in Bhagalpur District

Figure 13.1 shows the comparison in child growth between the WHO growth standard and Bhagalpur District of Bihar separately for boys and girls. During the infancy phase (0–12 months), the child growth of the Bhagalpur District almost followed the WHO growth standards both for boys and girls. However, there was a decline in the height for age after 12 months onwards of the child's age in Bhagalpur District in comparison to WHO growth standard showing prevailing stunting among

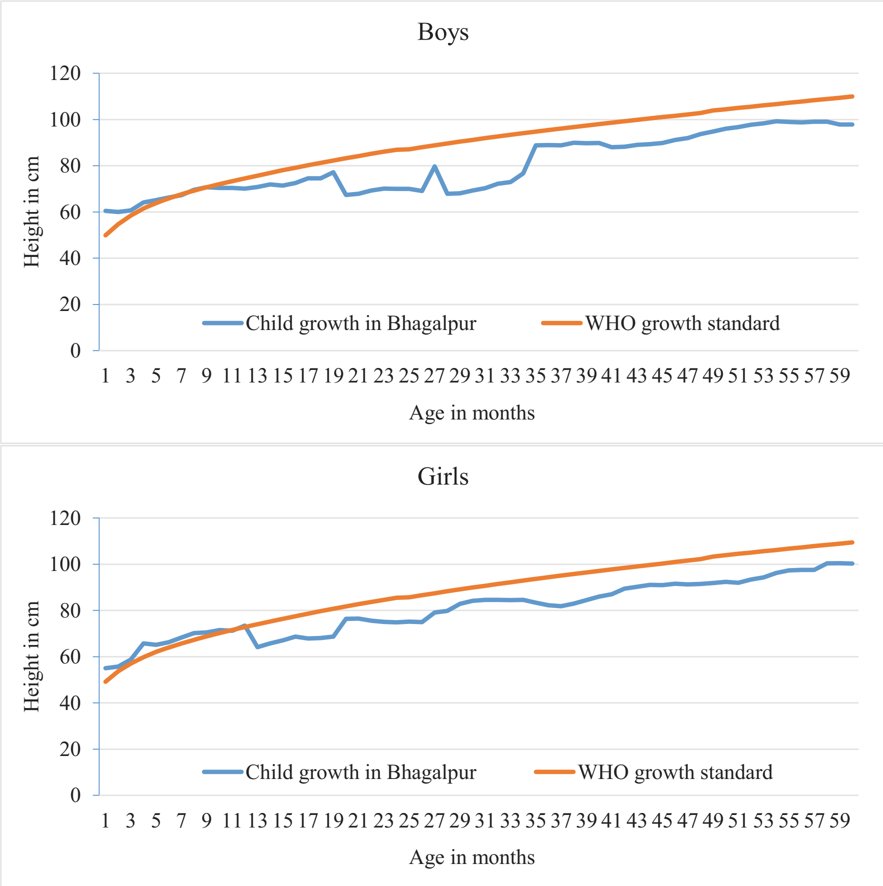

Fig. 13.1 A comparison in child growth between WHO standard and the sample from Bhagalpur District of Bihar (2019). Note: World Health Organization's child growth standard (WHO 2006)

boys and girls till late childhood. For the boys between the ages of 20 and 35 months, the height was shorter than girls compared to WHO growth standards.

13.4 Discussion

Childhood growth is an acute problem in India. The latest estimate from NFHS-4 suggests that almost two in five children are stunted (38%) at the national level in 2015–2016, whereas every second child in Bihar is stunted (48%) (IIPS and ICF 2017). The findings from this study indicate that the demographic factors such as child's age, mothers' age at childbirth, and birth order; social factors like mothers' education, place of residence, and religion; economic factors, i.e., wealth quintiles;

and other mother-related factors such as mothers' height and weight and access to the maternity care affect the likelihood of childhood stunting in India and Bihar. The risk of child stunting is higher in Bihar than the national average for the majority of the socioeconomic and demographic factors, which implies the disadvantageous position of Bihar. The evidence from Bhagalpur, an eastern district of Bihar, shows that as the age of the children increases, the likelihood of child stunting increases.

Our finding indicates the significant differences in the prevalence of stunting across the demographic factors such as child's age and birth order in both Bihar and national levels. Children's age is a cabalistic predictor of childhood stunting. This finding is consistent with many previous studies. As child's age increases, the risk of being stunted increased (Kamal 2011; Rakotomanana et al. 2017; Ntenda and Chuang 2018; Gebru et al. 2019). In our study, we found that children who were aged 36–47 months have a significantly higher prevalence of stunting in both India and Bihar. However, the effects of child's age on stunting in Bihar are higher than the national average. The study also confirmed that multiple birth order and childhood stunting were found statistically significant for both India and Bihar. Multiple birth order involves child defects like shrunk, low weight, premature birth, and cerebral paralysis which can suppress child growth (WHO 2006; Magadi 2011; Adekanmbi et al. 2013). The significant difference has been found in the first birth order in stunting prevalence between India and Bihar. On the other hand, the difference of multiple birth order in stunting prevalence is very insignificant between India and Bihar. This study finds that mothers whose age was less than 19 years at the time of delivery have a high risk of stunting among their children than mothers whose age was above 20 years at the time of delivery for both Bihar and India levels. Similar findings were found in the previous studies (Kismul et al. 2018; Fall et al. 2015). A higher risk of childhood stunting in Bihar for these demographic factors indicates that Bihar suffers the disadvantageous situation in terms of early age at marriage, early age at childbearing, and high birth order which call for family planning program interventions.

Social determinants such as mothers' education, religion, and place of residence have significant effects on child stunting in India and Bihar. The inverse relationship between mothers' level of education and childhood stunting is found in both India and Bihar. A similar finding was also reported by Gebru et al. (2019). Women from highly educated households and high wealth quintile households have less stunted children (Kimani et al. 2015; Frost et al. 2005). Our results indicate that children who reside in urban areas are less prevalent of stunting than rural areas for both India and Bihar. A similar pattern was also found in low-income and middle-income countries (Paciorek et al. 2013). This study also demonstrated that the prevalence of childhood stunting is higher among those who follow Islam compared to other religions in both India and Bihar. A similar result was found in Bangladesh (Levay et al. 2013; Mkandawire and Hendriks 2018). This might be due to poor socioeconomic status of Muslim households (Chowdhury et al. 2016). By all the social factors, the likelihood of child stunting is higher in Bihar than the national average, possibly because of social backwardness and economic disadvantage, especially in education and ruralization of the population in Bihar.

The economic factors play a crucial role in childhood stunting. The findings from this study demonstrated that there is a strong positive association between wealth quintiles and child stunting for both India and Bihar. Children from the poorest wealth quintiles had higher odd of stunting than the wealthiest quintiles. The degree of difference is higher in Bihar than the national average. This finding is consistent with previous studies (Semba et al. 2008; Hong and Hong 2007).

Other mother-level factors such as mothers' height and weight and access to maternity care for the child are also important predictors for the childhood stunting in both India and Bihar. The findings reflect on the mother's height for childhood stunting (Singh et al. 2017). The effect of the mother's height on childhood stunting is due to genetic transfers and endowments (Bosch et al. 2008; Subramanian et al. 2009; Özaltin et al. 2010). Our study showed that children whose mothers are underweight had higher odds of childhood stunting than the normal mother for both India and Bihar (Teshome et al. 2009). Moreover, findings indicate that mothers who had no antenatal care during pregnancy have a higher prevalence for both India and Bihar. Another key result is the age of the mother for childhood stunting for the State of Bihar and the national level.

In this study, the evidence from Bhagalpur District on child growth showed that child's height for age in early childhood aligned with the WHO standards. However, we found that from the end of the infancy to late childhood, the likelihood of stunting increases in the Bhagalpur District. Our study revealed the evidence of children's age in the change of child growth. The possible explanation for such a situation from Bhagalpur District on child growth may be the impact of dietary pattern change with age, which might play a complex role in the nexus of dietary intake, food security, and economic status. Studies had found that during the infancy, children are more dependent on the breastfeeding along with other food intakes that positively influence the children's growth conditions (Syeda et al. 2020; Muldiasman et al. 2018). It is important to consider the dietary practice and children age as increase in the age of the children, specifically during the mid-childhood, the introduction of semi-solid and solid food is essential for the overall growth of children. Perhaps the insufficient supplementary food during childhood elevates the risk of childhood stunting in Bhagalpur. Previous researches have also shown that if children do not have considerable protein and carbohydrate in their dietary practices, they are more likely to be stunted (Esfarjani et al. 2013; Krasevec et al. 2017). As per the NFHS-4 report (2015), about 46.6% of children aged under 5 years were stunted in Bhagalpur District, and almost 55% of mothers were illiterate. Mothers' educational status was found to affect the children's nutritional status. Educated mothers were more concerned and aware of the children's dietary and health conditions than uneducated mothers (Mzumara et al. 2018; Nshimyiryo et al. 2019). On the other hand, household wealth status also has a significant effect on child's nutritional status because poor households may distribute a low per capita food availability (Howe et al. 2009; Boyle et al. 2006). Similarly, earlier studies have also shown that children from the poorest wealth status household were having substantially higher stunting (Tiwari et al. 2014; Habimana and Biracyaza 2019).

The study was based on the DHS data, a cross-sectional survey that only provides a snapshot of children stunting in Bihar. Using cross-sectional data, the causal relationship between two variables is not possible. Child growth trajectory from Bhagalpur District needs a cohort data. Further study is recommended for conducting a cohort study for understanding child growth trajectories. However, we have tried to assess the factors determining childhood stunting in India and Bihar.

In conclusion, our study highlighted the differences among the determinants of childhood stunting between samples from the whole of India and Bihar. In addition, the evidence from the Bhagalpur District, an eastern district of Bihar, has shown the insightful findings. The major implications of the findings of this study are the following: First, demographic disadvantages, i.e., early marriage and early child-bearing, lower use of contraceptive methods, and resultant higher fertility rate, are the major demographic drivers of childhood stunting. Family planning should be promoted, and the age of marriage needs to be raised in the State of Bihar. Second, Bihar is one of the resource-poor states of India that also has educational underdevelopment. These drawbacks of the state hold the progress in reducing the prevalence of childhood stunting. Hence, awareness on child-feeding practices and provision of supplementary foods need to be ensured in the state. Third, along with the samples from India and Bihar, the evidence from Bhagalpur also confirms that as the age of the children increases, the risk of childhood stunting also elevates. This finding indicates that strengthened child care and supplementary food are required for the middle-aged and relatively older children. Summarily, the findings from the present study will help in the development of potential interventions and actions associated with mothers' role in children's malnutrition at the state level in Bihar and Bhagalpur District. Thus, with effective policy and program interventions and keeping the findings into consideration, childhood stunting may be reduced to achieve the Sustainable Development Goals by 2030 in Bihar as well as India.

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Chapter 14
Sibling Effect on Intra-household Child Malnutrition in India: An Analysis Among Different Sociodemographic Groups from the National Family Health Survey

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Abstract This study examines the effect of number and composition of boys and girls and socioeconomic group on malnutrition in the two or less sibling household. Bivariate analyses were used on National Family Health Survey (NFHS-IV) data on two or less children under 5 in India ($N = 53{,}599$). Data were pooled at national level, and multinomial logistic regression (MLR) was used to assess the relationship between composition biodemographic and socioeconomic characteristics, with malnutrition outcomes (stunting, wasting, underweight). The results point to a substantial variation in the malnutrition of children from lower age at birth to higher age. Another finding from MLR observed that one male or one female composition household suffer less from malnutrition than two female or two male composition family. As with malnutrition, having more sibling of a brother or sister significantly increases the risk of stunting, wasting, and underweight. Besides, women with higher education and belonging to the richest wealth quintile and other social groups have better nutritional status of children than their counterparts. In conclusion, for better outcome on nutritional status, the government should be concerned about gender, number of sibling, and socioeconomic status at intra-household level.

Keywords Nutritional status · Under-5 children · Stunting · Wasting · Underweight · India

14.1 Introduction

Health condition and nutritional well-being of children are increasingly attracting global attention. Worldwide, more than one-third of children under 5 death is estimated to be at 5.3 million due to undernutrition in 2018, which indicates a

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considerable disease burden on children (WHO and UNICEF 2019). An estimated of 21.9% or 149 million children under 5 years of age suffer from stunting and about 7.3% or 49 million of children from wasting. On the other hand, approximately 5.9% of the total children, or 40 million children worldwide, were overweight in 2018 (WHO and UNICEF 2019).

Proper nutrition permits children to be productive and grow, learn, play, and participate, while malnutrition robs children from their future. At childhood, healthy growth, proper organ development and function, a robust immune system, and neurological and cognitive development directly are ensured by nutrition. Child malnutrition negatively impacts the cognitive development and the economic status of an individual family by impeding an individual's capability to lead healthy lives (Grantham-McGregor et al. 2007; Walker et al. 2007; Martorell and Zongrone 2012). In public health research, it was observed that the maximum number of children under 5 death happens in those families who are attributable to undernutrition (Liu et al. 2012; Black et al. 2008). Despite progress in several fronts, India's struggle to eradicate malnutrition continues to be a difficult one as level of malnutrition among children remained consistently high.

14.1.1 Indian Scenario

In the last three decades, development experts suggested that the accelerated growth of the Indian economy does not ensure a healthy lifestyle. The country suffers from worse child malnutrition; even the condition is much more adverse than the sub-Saharan African countries. Based on this view, India made little or no progress in bringing malnutrition label down. According to the UNICEF, 90% of the world's undernourished children (0–59 months) are living in Africa and Asia, and approximately one-third of the total child live in India. Similarly, 20% of the total under-5 children in India are suffering from wasting, which is equal to the 33% of the world's children. In India, 43% of children are underweight, and 48% (i.e., 61 million) are stunted due to chronic undernutrition (UNICEF 2008).

Studies from South Asia (India) examine that multiple siblings and higher birth order increase the vulnerability risk for child malnutrition (Mondal and Sen 2010). Birth spacing affects the younger children, and the probability of stunting increases for those who are born in close spacing (Pathak et al. 2004; Basit et al. 2012). A study from India observed that a large number of siblings affect the girl child more than the boys in terms of malnutrition (Biswas and Bose 2011). Previous research show the rate of malnutrition was more remarkable for girls than boys in India, boys are less likely than girls to be stunted when all birth order of living siblings are girls, and vice versa (Raj et al. 2014).

Macro-level studies show nutrition condition of children depends on the educational status of parents, economic situation, place of residence, religion, caste, and different policy interventions and market outcomes (Pathak and Singh 2011). But at intra-household level, variance of nutritional status depends on sibling structure, composition of children, and other sociodemographic factors. This study is too important because in every society, the nutrition of children depends on intra-household food allocation. Many times the interfamilial distribution of nutrients favors boys over girls (Banerjee 1983). Some prior researchers worked on child nutrition but not similar to this and used data that are more than a decade old. Thus, the purpose of this study is to examine the association of two or less than two sibling indicators (age at birth, birth order, child composition, and socioeconomic groups) with child malnutrition, whether these associations are similar for composition of boys and girls in India.

14.2 Methods

14.2.1 Data Source and Sample Size

The present study is based on secondary data. The National Family Health Survey (NFHS-4) data 2015–2016 has been used. Worldwide popular Demographic and Health Surveys (DHS), known as NFHS in India, was conducted under the state ownership of the Ministry of Health and Family Welfare (MoHFW), Government of India, coordinated by the International Institute for Population Sciences (IIPS). NFHS is a large-scale, multi-stage survey conducted in a representative sample of households all over India. Four rounds of the survey were conducted since NFHS-1 in 1992–1993, NFHS-2 in 1998–1999, and NFHS-3 in 2005–2006, and NFHS-4 round was continued in 2015–2016. The survey provides data for all 640 districts and 36 states and union territories (UTs) as per the 2011 Census Classification. It provides information on fertility, mortality, family planning, maternal and child health indicators, child nutrition, domestic violence, etc. at the national and state levels.

In NFHS-4, the total sample collected for women was 699,686 and men 112,122. Household information in a representative sample of 265,653 children below age 5 were collected from across India. This study selected children below 5 years of age and those families who have only two or less children, and more than two-child families have been excluded, and as a result, the total sample remaining was 53,599.

14.2.2 Variables

The definition and the coding of the variables used in this study were defined in two parts: outcome variables and predictor variables.

14.2.2.1 Outcome Variables

In this study, the type of malnutrition children have was categorized into three outcome variables: (1) no stunting/wasting/underweight, (2) one stunting/wasting/underweight, and (3) two stunting/wasting/underweight. This analysis used the same definition to measure stunting, wasting, and underweight as the NFHS-4 (IIPS and Macro International 2017). It deviates from the NFHS-4 method of calculating malnutrition of children at the intra-household level, choosing only those families who have two or less children.

14.2.2.2 Predictor Variables

The choice of the predictor variable was made only after careful consideration and an extensive review of the literature on factors associated with the malnutrition of children below age 5 (UNICEF 2019; Raj et al. 2014). For this study, the respondent's socioeconomic and demographic backgrounds were considered (i.e., mother's age at birth, child composition, nature of child dominancy, the economic category that they belong to, the religion that they practice, their social group, level of education attainment). The social groups are census classification of the population made based on social status and geographical remoteness of an individual or community. In Indian social communities, four primary caste hierarchies are considered for social classification; these are scheduled caste (SCs), scheduled tribes (STs), other backward classes (OBCs), and general or other castes.

14.2.2.3 Statistical Analysis

All the statistical analyses in this study were performed using Stata 14 (Stata Corp LP, College Station, Texas, USA). Univariate and multinomial logistic regression (MLR) models were used to estimate the association between predictor and outcome variables. To fulfill the objectives and test the hypothesis of the study, proportional use of hygienic and unhygienic method has been carried out using multinomial logistic regression. In this study, the universal analysis includes multinomial logistic regression which is used when the extraneous variables are numeric and nominal in nature and the outcome variable is categorical with at least categories. In this regard, the dependent variable, that is, nutritional status, is checked by stunting, wasting, and underweight, and these three variables are separately checked by no stunting/wasting/underweight children, one stunting/wasting/underweight children, and two stunting/wasting/underweight children. The mathematical equation of multinomial logistic regression is as follows:

$$Z_1 = (P_1 P_3) = a_1 + \sum \times b_{1j} X_j.$$
$$Z_2 = (P_1 P_3) = a_2 + \sum \times b_{2j} X_j.$$

where

- $a_{i\ i=1,2}$: Constants
- $b_{ij\ i\ =\ 1,2;\ j\ =\ 1,2...n}$: Multinomial regression coefficients
- P_1: Estimated probability of no stunting/wasting/underweight children at below 5 year age
- P_2: Estimated probability of one stunting/wasting/underweight children at below 5 year age
- P_3: Estimated probability of two stunting/wasting/underweight children at below 5 year age

14.3 Results

Table 14.1 shows the descriptive statistics of the study sample of 53,599 children. The status of child malnutrition is categorized into three groups: no malnutrition (no stunting or wasting or underweight), one malnutrition, and two malnutrition among children within the family of two children. The child malnutrition is reported as no stunting (46%), one stunting (37%), and two stunting (17%); no wasting (69%), one wasting (26%), and two wasting (5%); and no underweight (50%), one underweight (33%), and two underweight (16%). Approximate half of the last two children (48.3%) were born to a mother aged 20–24, where less than 10% of children were born to mothers aged <18 and 35–49.

The percentage of only one son (46%) and only one daughter (41.3%) were much higher followed by two boys or two girls. Among social groups, the sample distribution resembles the general population distribution. Hinduism is the dominant religious group in India, followed by Muslims and others, with the same observation in the study. Wealth quintile has been categorized into five categories: poorest (29.1%), poorer (23.4%), middle (20.1%), richer (16.8%), and richest (10.7%). Here the educational attainment was grouped into four categories, i.e., no education (33.9%), primary education (14.4%), secondary education (43.5%), and higher education (7.1%).

The MLR estimates the biodemographic and socioeconomic factors associated with stunting among last two children under 5 years of age in India (Table 14.2). Children living in India consistently experienced the highest rate of stunting, wasting, and underweight. The risk of one stunting children significantly decreases with increases in the maternal age at birth (20–24 OR = 0.84; 25–34 OR = 0.71; 35–49 OR = 0.59; against <18 OR = 1). Similar results were found against two stunting children also. The odds of one child stunting were less for one male and one female families (OR = 0.86, 95% CI = 0.79, 0.93) and two male dominant families (OR = 0.87, 95% CI = 0.77, 0.97) as compared to the two female child family., Similarly for no stunting against two children, had lower risk of stunting. For girls but not boys, the number of brother increases the risk for one child stunting (1 vs. 0 brother OR = 1.4, 95% CI = 1.3, 1.52; 2 vs. 0 brother OR = 1.4, 95% CI = 1.3,

Table 14.1 Percentage distribution sample of the last two children by nutrition, biodemographic, and socioeconomic variable

Variable	Sample size	Percentage
Nutrition variables		
Stunting		
No stunting	24,465	45.8 [45.4,46.3]
1 stunting	19,876	36.7 [36.3,37.1]
Both stunting	9258	17.5 [17.1,17.8]
Wasting among two-child family		
No wasting	37,202	68.7 [68.3,69.1]
1 wasting	13,624	26.3 [25.9,26.7]
Both wasting	2773	5.1 [4.9,5.3]
Underweight among two-child family		
No underweight	27,529	50.2 [49.8,50.6]
1 underweight	17,854	33.8 [33.4,34.2]
Both underweight	8216.0	16 [14.7,16.3]
Biodemographic variables		
Mother's age at birth		
<18	3937	8.3 [8,8.5]
18–19	9050	18 [17.7,18.3]
20–24	25,370	48.3 [47.8,48.7]
25–34	14,115	23.8 [23.4,24.1]
35–49	1127	1.7 [1.6,1.8]
2-child compositions		
2 females	12,884	23.8 [23.4,24.2]
1 male + 1 female	27,488	51.7 [51.2,52.1]
2 males	13,227	24.5 [24.1,24.9]
Son dominant		
No daughter	10,963	20.9 [20.5,21.2]
Only 1 son	24,035	46 [45.6,46.4]
Only 2 sons	14,581	26.7 [26.3,27.1]
Only 3 sons	4020	6.4 [6.2,6.6]
Daughter dominant		
No son	10,617	20.3 [19.9,20.6]
Only 1 daughter	21,642	41.3 [40.9,41.7]
Only 2 daughters	14,050	26 [25.6,26.4]
Only 3 daughters	7290	12.5 [12.2,12.7]
Socioeconomic variables		
Wealth index of the family		
Poorest	16,198	29.1 [28.7,29.5]
Poorer	13,383	23.4 [23,23.7]
Middle	10,577	20.1 [19.7,20.4]
Richer	8081	16.8 [16.4,17.1]
Richest	5360	10.7 [10.4,11]
Level of education		

(continued)

Table 14.1 (continued)

Variable	Sample size	Percentage
No education	18,756	33.9 [33.5,34.3]
Primary	8476	14.4 [14.1,14.7]
Secondary	22,943	43.5 [43.1,44]
Higher	3424	7.1 [6.9,7.4]
Religion		
Hindu	38,690	78.6 [78.2,78.9]
Muslim	8723	17 [16.7,17.3]
Christian	4392	2 [1.9,2.1]
Other	1794	2.4 [2.3,2.6]
Castes		
SC	10,631	22.8 [22.5,23.2]
ST	11,029	11.5 [11.2,11.8]
OBC	21,531	47 [46.6,47.4]
Others	8658	18.7 [18.3,19]

The confidence intervals are indicated in the parenthesis

1.52; 3 vs. 0 brother OR = 2.32, 95% CI = 2.05, 2.61). The odds of one child stunting increase as the number of sister increases (1 vs. 0 sister OR = 1.26, 95% CI = 1.16, 1.36; 2 vs. 0 sister OR = 1.43, 95% CI = 1.3, 1.57; 3 vs. 0 sister OR = 1.84, 95% CI = 1.65, 2.04). Similarly, two-child stunting increases as the number of sister or brother increases (Table 14.2). The odds of being one- child or two-child stunting are significantly lower for children who were born in higher socioeconomic status as compared to children who were born in low economic status household. The effect of stunting is significantly lower for those children who are born to educated mother as compared to the illiterate (see Table 14.2). Childrens live in Christian and other religious families have significantly lower risk for stunting as compared to children living in families practicing Hinduism. Analysis shows the odds of child stunting are less for ST (1 child stunting OR = 0.89; 2 child stunting OR = 0.72), OBC (1 child stunting OR = 0.96; 2 child stunting OR = 0.87), and other castes (1 child stunting OR = 0.77; 2 child stunting OR = 0.61) as compared to the SC family (OR = 1).

Table 14.3 shows the number of wasting children by biodemographic and socioeconomic variables. In this analysis maternal age at birth is only effective at 10% significant level for higher age group (25–34 and 35–49) in both one and two wasting children. Analysis from this study shows having more male siblings (1 vs. 0 brother OR = 1.16, 95% CI = 1.07, 1.26; 2 vs. 0 brother OR = 1.25, 95% CI = 1.23, 1.38; 3+ vs. 0 bother OR = 1.2 95% CI = 1.07,1.36) and having more female siblings (1 vs. 0 sister OR = 1.18, 95% CI = 1.09, 1.28; 2 vs. 0 sister OR = 1.20, 95% CI = 1.09, 1.31; 3+ vs. 0 sister OR = 1.31 95% CI = 1.18, 1.46) increase the risk for one wasting children for the total sample. Similar results were observed for two wasting children also. The odds of one wasting children continue to decline as the level of wealth quintile increases, the risk such that children who

Table 14.2 Multivariate model showing association with stunting among children under 5 years of age in India (2015–2016)

Factors	No stunting versus one stunting (95% CI)	No stunting versus two stunting
Maternal age at birth		
18–19 versus <18	0.96 [0.88,1.04]	1.01 [0.91,1.13]
20–24 versus <18	0.84*** [0.78,0.91]	0.83*** [0.75,0.92]
25–34 versus <18	0.71*** [0.65,0.77]	0.61*** [0.55,0.69]
35–49 versus <18	0.59*** [0.5,0.7]	0.41*** [0.33,0.5]
Child composition		
1 male + 1 female versus 2 females	0.86*** [0.79,0.93]	0.68*** [0.62,0.75]
2 males versus 2 females	0.87** [0.77,0.97]	0.74*** [0.65,0.85]
Brother		
1 versus 0	1.4*** [1.3,1.52]	2.12*** [1.91,2.35]
2 versus 0	1.86*** [1.69,2.05]	3.7*** [3.28,4.17]
3+ versus 0	2.32*** [2.05,2.61]	4.68*** [4.04,5.43]
Sister		
1 versus 0	1.26*** [1.16,1.36]	1.69*** [1.52,1.87]
2 versus 0	1.43*** [1.3,1.57]	2.44*** [2.18,2.74]
3+ versus 0	1.84*** [1.65,2.04]	3.11*** [2.73,3.55]
Wealth quintile		
Poorer versus poorest	0.85*** [0.81,0.9]	0.82*** [0.77,0.87]
Middle versus poorest	0.74*** [0.69,0.78]	0.62*** [0.57,0.67]
Richer versus poorest	0.63*** [0.59,0.67]	0.45*** [0.41,0.49]
Richest versus poorest	0.53*** [0.49,0.58]	0.33*** [0.29,0.38]
Level of education		
Primary versus no education	0.94** [0.88,1]	0.87*** [0.81,0.94]
Secondary versus no education	0.78*** [0.74,0.82]	0.67*** [0.63,0.72]
Higher versus no education	0.64*** [0.58,0.7]	0.43*** [0.37,0.51]
Religion		
Muslim versus Hindu	1.07** [1,1.13]	0.99 [0.91,1.07]
Christian versus Hindu	0.78*** [0.72,0.85]	0.7*** [0.62,0.78]
Other versus Hindu	0.86*** [0.77,0.96]	0.73*** [0.62,0.85]
Social group		
ST versus SC	0.89*** [0.83,0.95]	0.72*** [0.66,0.79]
OBC versus SC	0.96 [0.91,1.01]	0.87*** [0.82,0.93]
Other versus SC	0.77*** [0.72,0.82]	0.61*** [0.56,0.67]
_cons	0.97 [0.85,1.1]	0.35*** [0.3,0.41]

The confidence intervals are indicated in the parenthesis
®Reference category. *P* value: *** = <0.01, ** = <0.05, * = <0.1 (Goli et el. 2020)

Table 14.3 Multivariate model showing association with wasting among under 5 years of age in India (2015–16)

Factor	No wasting versus one wasting	No wasting versus two wasting
Maternal age at birth		
18–19 versus <18	1 [0.92,1.09]	1.1 [0.92,1.31]
20–24 versus <18	0.98 [0.9,1.06]	1.04 [0.89,1.23]
25–34 versus <18	0.91* [0.84,1]	0.9 [0.75,1.08]
35–49 versus <18	0.87* [0.73,1.02]	0.73* [0.52,1.03]
Child composition		
1 male + 1 female versus 2 females	0.96 [0.88,1.04]	0.9 [0.76,1.06]
2 males versus 2 females	1.05 [0.94,1.18]	1.01 [0.82,1.26]
Brother		
1 versus 0	1.16*** [1.07,1.26]	1.53*** [1.29,1.8]
2 versus 0	1.25*** [1.13,1.38]	2.06*** [1.7,2.49]
3+ versus 0	1.20*** [1.07,1.36]	1.93*** [1.52,2.45]
Sister		
1 versus 0	1.18*** [1.09,1.28]	1.36*** [1.16,1.59]
2 versus 0	1.20*** [1.09,1.31]	1.57*** [1.31,1.87]
3+ versus 0	1.31*** [1.18,1.46]	1.54*** [1.25,1.89]
Wealth quintal		
Poorer versus poorest	0.86*** [0.82,0.91]	0.84*** [0.76,0.94]
Middle versus poorest	0.82*** [0.77,0.87]	0.86*** [0.76,0.97]
Richer versus poorest	0.78*** [0.73,0.84]	0.85** [0.74,0.98]
Richest versus poorest	0.73*** [0.67,0.8]	0.78*** [0.65,0.93]
Level of education		
Primary versus no education	0.96 [0.91,1.03]	1.01 [0.9,1.13]
Secondary versus no education	0.95** [0.9,1.0]	0.93 [0.83,1.03]
Higher versus no education	0.89** [0.81,0.99]	0.84* [0.68,1.03]
Religion		
Muslim versus Hindu	0.83*** [0.78,0.88]	0.74*** [0.66,0.85]
Christian versus Hindu	0.45*** [0.41,0.49]	0.35*** [0.29,0.43]
Other versus Hindu	0.75*** [0.67,0.84]	0.77** [0.61,0.96]
Social group		
ST versus SC	1.21*** [1.13,1.29]	1.31*** [1.16,1.49]
OBC versus SC	1.02 [0.97,1.08]	0.97 [0.88,1.08]
Other versus SC	0.92** [0.86,0.99]	0.89* [0.77,1.02]
_cons	0.37*** [0.32,0.42]	0.05*** [0.04,0.06]

The confidence intervals are indicated in the parenthesis
®Reference category. *P* value: *** = <0.01, ** = <0.05, * = <0.1 (Goli et el. 2020)

belong to the poorer group have 0.86 time less chances of being wasted as compared to the poorest (OR 1), and it continues to decline at 0.73 (CI = 0.67, 0.8) in richest group. Similarly the risk of two wasting children decreases with better economic conditions (see Table 14.3). In educational qualification, the risk for wasting (1 or 2 wasting) is less for those children who were born in higher educated household.

The odds of being one wasting children were significantly lower for Muslim (OR = 0.83), Christian (OR 0.45), and others (OR = 0.75) as compared to the Hindu. The risk of two wasting children significantly very low for Christian household (OR = 0.35), followed by Muslim (OR = 0.74), others (OR = 0.77), and Hindu family (OR = 1). The number of one child wasting increases in ST (OR = 1.21) but decreases for other caste children (OR = 0.92) as compared to SC. Similar finding is found in two wasting children also, where ST children had more prevalence and other caste had less than SC.

Table 14.4 represents the MLR of underweight children in below 5 years of age among different exposure groups in India. The risk of underweight children (in both one and two children) is significantly less in mothers with higher age. The family who has one son and one daughter and two sons has lower prevalence of underweight as compared to two female children (Table 14.4). The sibling structure shows having more boys (1 vs. 0 OR = 1; 2 vs. 0 OR = 1.66; 3+ vs. 0 OR = 1.83) and girls (1 vs. 0 OR = 1.21; 2 vs. 0 OR = 1.34; 3+ vs. 0 OR = 1.64) increases the risk of underweight of children. Similar kind of result observed in terms of the risk of two

underweight children and sibling structure of the household (Table 14.4). The risk of being underweight (one or two children) was significantly lower for higher-income group. The result shows women's educational attainment and nutrition of children have positive association that means with increases in the level of education, the risk of underweight decreases. Religious-wise analysis to predict one- and two-child underweight reveals that the odds of Muslim, Christian, and other religions were significantly lower as compared to the Hindu religious group (Table 14.4).

14.4 Discussion

The finding from this study tries to capture the importance of different biodemographic and socioeconomic effect on intra-household child malnutrition in India. In this context, a synthesis of our result along with the review of relevant literature suggests the significance of policy and practice. Based on the study of comprehensive literature review and robust empirical analysis, the study advanced a number of intriguing finding. Low maternal age at birth indicates the high prevalence of child malnutrition as compared to women who delivered baby at higher age. In view of previous evidence that the women who married earlier were not provided proper nutrition to their children, perhaps due to less control to access on their food (Raj et al. 2009; King 2003). In this study child composition significantly effect on stunting and underweight, the two female dominated household being more suffering by one or two child stunting or underweight then one male and one female or two male family. On the other hand the two male composition family is more prone to malnutrition than one male and one female combination family. Prior research

Table 14.4 Multivariate model showing association with underweight among children under 5 years of age in India (2015–2016)

Factor	No underweight versus one underweight	No underweight versus two underweight
Maternal age at birth		
18–19 versus <18	0.97 [0.89,1.06]	1.07 [0.96,1.2]
20–24 versus <18	0.89*** [0.83,0.97]	0.89 [0.8,0.99]
25–34 versus <18	0.75*** [0.69,0.82]	0.66*** [0.59,0.74]
35–49 versus <18	0.61*** [0.51,0.71]	0.48*** [0.39,0.59]
Child composition		
1 male + 1 female versus 2 females	0.88*** [0.81,0.96]	0.73*** [0.66,0.81]
2 males versus 2 females	0.93 [0.83,1.04]	0.79*** [0.69,0.91]
Brother		
1 versus 0	1.32*** [1.22,1.43]	1.95*** [1.76,2.17]
2 versus 0	1.66*** [1.51,1.82]	3.11*** [2.75,3.52]
3+ versus 0	1.83*** [1.63,2.07]	3.72*** [3.2,4.33]
Sister		
1 versus 0	1.21*** [1.12,1.32]	1.58*** [1.42,1.76]
2 versus 0	1.34*** [1.22,1.47]	2.12*** [1.89,2.39]
3+ versus 0	1.64*** [1.48,1.82]	2.66*** [2.33,3.05]
Wealth quintile		
Poorer versus poorest	0.8*** [0.75,0.84]	0.75*** [0.7,0.8]
Middle versus poorest	0.69*** [0.65,0.74]	0.56*** [0.52,0.61]
Richer versus poorest	0.6*** [0.56,0.64]	0.46*** [0.42,0.5]
Richest versus poorest	0.52*** [0.48,0.56]	0.32*** [0.28,0.37]
Level of education		
Primary versus no education	0.96 [0.9,1.02]	0.89*** [0.83,0.96]
Secondary versus no education	0.8*** [0.76,0.85]	0.7*** [0.65,0.74]
Higher versus no education	0.62*** [0.56,0.68]	0.46*** [0.39,0.54]
Religion		
Muslim versus Hindu	0.94* [0.89,1]	0.83*** [0.77,0.9]
Christian versus Hindu	0.47*** [0.43,0.51]	0.27*** [0.23,0.31]
Other versus Hindu	0.74*** [0.66,0.83]	0.62*** [0.53,0.73]
Social group		
ST versus SC	1 [0.93,1.07]	0.93 [0.86,1.02]
OBC versus SC	0.99 [0.94,1.04]	0.93** [0.87,1]
Other versus SC	0.78*** [0.73,0.84]	0.66*** [0.6,0.72]
_cons	0.84*** [0.74,0.95]	0.3 [0.25,0.35]

The confidence intervals are indicated in the parenthesis
®Reference category. *P* value: *** = <0.01, ** = <0.05, * = <0.1 (Goli et el. 2020)

suggest children with two or more surviving same-sex sibling have worse effect on health outcome. The high son preference in India and low value of girl are evident that the harmful effect of having surviving older siblings of the same sex alone is worse for girls than it is for boys (Rohin 2003; Raj et al. 2013). As with malnutrition, having more siblings (brothers or girls) significantly increases the risk of stunting, wasting, and underweight (Raj et al. 2014). Intra-household inequality shows the nutritional inequality among different socioeconomic groups of people in India. The prevalence of stunting, wasting, and underweight is much higher among children who survive in economically poor family rather than in economically strong family. Similar finding has been well documented in prior research (Mazumdar 2010; Pathak and Singh 2011). These findings indicate that children from better-off families have benefited from the economic growth to a larger extent than children from poor families. Education also plays an important role for nutritional status of children. Moreover, evidence from the study suggest that mother's education and nutrition have a well-established positive relation; if educational level of mother increases, then the risk of stunting, wasting, and underweight decreases. Our finding corroborates with the previous studies by Subramanyam et al. (2010)) and Bharati and colleagues (Bharati et al. 2007). Religious-wise variation of malnutrition shows stunting prevalence among Christian and other religious children is significantly lower, whereas other nutritional perimeters (wasting and underweight) show more number of Hindu children suffering from malnutrition, followed by Muslim, Christian, and other religious children. Children who born in the general caste family have less prevalence to stunting, wasting, or underweight, followed by SC, ST, and OBC children.

Finding from this study documents differential effect of sibling on child malnutrition for boys and girls in India. The risk of malnutrition increases for girls as compared to boys. Having more siblings in case of both, boys and girls, increases the risk of malnutrition. Mother's age at birth has more effect on stunting and underweight but less in wasting. The malnutrition problem also observed across different socio-economic group, in some group (higher economic, Christen and other religion, general caste) the nutrition status of children much batter but in other group passing through with worse condition. Result of this study suggests different treatment and nutritional access for girls relative to boy based on number and sex of sibling; on the other hand, it also focuses on economically poor people or the backward caste or religious group in India.

14.5 Conclusion

In policy perspective, similar to the previous studies (Santhya and Jejeebhoy 2007; Rohin 2003) which suggested shifting of age at marriage (more than 18) and equal child preference or higher value of girls are important for child health benefits, we suggest that it is even more important for the improvement of child's nutritional status. Similarly, providing initiative to the economically poor section and backward group is also vital for better health outcome of children (Pathak and Singh 2011). Thus, major steps need to be taken to stop early marriages and negligence of girl child. On the other hand, the government should be focused on reducing economic disparity and increasing women's education level with the technical support of the UNICEF. The increase in education level certainly helps girls to postpone marriage. The improvement in education or age at marriage will directly help in improving the nutritional status of children (Fajth and Vinay 2010). However, India needs to strengthen its multi-sectorial program to address child malnutrition. Along with ongoing direct and indirect flagship, social welfare, women and child welfare, and nutritional and health programs work for all [viz., public distribution system (PDS), National Nutrition Mission (NNM), National Policy for Women Empowerment, Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGA)]. A country with 100% proper child nutrition can positively impact our economies, health, education, equality, and social development. Actually, with malnutrition problem, we will not able to achieve other Sustainable Development Goals like education, health, and gender equality.

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Chapter 15
Does Immunization Coverage Influence on Childhood Dual Burden of Malnutrition in India? What Does Demographic Health Survey Tell?

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Abstract The objective of the study was to assess the patterns of the dual burden of malnutrition among children <5 years, including its determinants and multilevel variations in the context of immunization coverage in India. All four rounds of NFHS were employed to accomplish the analyses. The overall undernutrition and stunting vulnerability were observed in the low immunization states, whereas the prevalence of high overweightness was found in the states of having high level of full immunization. The overall absolute and annual changes of stunting and underweight were decreasing, while overweight was increasing irrespective of categorization of the level of immunization across the Indian states. The sex-adjusted annual change reflected the constant rate of decline of stunting and underweight for both male and female children irrespective of the level of immunization. It is found that the odds of being underweight increased with age of children and place of residence, while the odds of being overweight were high for mothers with higher education, among Christian, and other caste group. Focusing on Sustainable Development Goals (SDGs) 2.2, the Indian government should take more necessary public health interventions and policies to prevent the dual burden of malnutrition among under-5 children.

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15.1 Introduction

The double burden of malnutrition (DBM) (undernutrition and overnutrition) is oozing out as a critical problem across the globe and standing as a substantial public health concern for the low- and middle-income countries. The double burden of malnutrition refers to the coexistence of undernutrition and overnutrition in the same population across the life course (Shrimpton and Rokx 2012). With the potential of influencing the health and economy, its coexistence in many regions is prevalent in the same country, community, and many times even household. The early undernutrition, i.e., among the mothers during pregnancy and the children in early childhood, entails a profound influence on the later overnutrition, exacerbating the risk for noncommunicable diseases (Darnton-Hill et al. 2004; James et al. 2000). As per the WHO, 42 million children under 5 years of age were overweight, also 156 million were stunted (low height for age), and 50 million were affected by wasting (low weight for height) in the year 2014 (WHO 2014). Poor nutrition status among children such as overweight and obesity are gradually grappling in the lower- and middle-income countries in which these are serious issues responsible for more than half of deaths among children under 5 (WHO 2014). There has been enough emphasis given on the importance of nutrition pertinent to its role in the development of physical, mental, and emotional of children in the formative years of their lives (Kumar et al. 2010). Nutrition during pregnancy is detrimental for the growth of the fetus, and under inadequate nutrition, the child under 2 years of age gets exposed to the risk of stunting, overweight, and noncommunicable disease in the adulthood (Black et al. 2013). The first 2 years of a child are considered very critical for development as it lays the foundation for the future health as an adult, and without ensuring the growth and proper development of the child, the future nation-building and economic development cannot be successfully achieved.

In order to confront the issue of malnutrition, there have been various suggested strategies such as exclusive breastfeeding, immunization, regular growth monitoring, prevention of infection, etc. (Sahu et al. 2015). The vital role of immunization among children for fighting early childhood diseases has also been well documented, but the poor coverage of vaccination in the rural and remote area also exists in the developed and developing countries (Fernandez et al. 2011; Pelletier et al. 1995). Under the unavailability of vaccination, the susceptibility of children to die under 5 years of age rises (Bryce et al. 2005). Despite being the most effective disease preventable solution, most parents do not realize the importance of vaccine and do not get benefitted from the healthcare services.

Earlier malnutrition has been conceived and approached as separate public health issues, but their coexistence and intrinsic relationship are vital issues of concern. Though many developing countries are experiencing rapid economic development, there have been existing disparities in the status of nutrition as well as the rising overnutrition/overweight cases. Hence, the present study delves into understanding the prevalence of dual burden of malnutrition according to the coverage of vaccination among under-5 children in Indian states. In India as well as in other developing countries, the coexistence of undernutrition and overnutrition is a serious public health challenge. Understanding the determinants related to childhood malnutrition assists both public and private stakeholders in policy formulation. Hence, a comprehensive study to examine the relationship between multilevel factors and childhood malnutrition is in demand.

15.2 Materials and Methods

15.2.1 Data Source

The study utilized the data of all four rounds of the National Family Health Survey (NFHS) which is known as Demographic and Health Surveys (DHS) at the global level. The NFHS is the nationally representative survey, which provides the information on population, health, and nutrition for the country as a whole. The present study focuses on the nutritional status of children aged 0–59 months. To present the trend of nutritional status of children, the four rounds of NFHS data, viz., NFHS-1 (1992–1993), NFHS-2 (1998–1999), NFHS-3 (2005–2006), and NFHS-4 (2015–2016), were used. However, the trend of the level of undernutrition, overweight, and stunted was presented for only those who were aged 0–36 months, as the information on the nutritional status of children aged 0–59 months were not available in NFHS-1 and NFHS-2. For analysis purpose, kids and persons' files of the NFHS data were utilized.

15.2.2 Sampling Design

The NFHS follows the multistage stratified sampling design. For the selection of primary sampling units (PSUs), the census data were used as sampling frame. These PSUs consisted of villages in rural area and census enumeration blocks (CEBs) in urban areas. PSUs with fewer than 40 households were linked to the nearest PSUs. Moreover, in the rural area, villages were selected based on probability proportion to size (PPS). Six equal substrata were created in each stratum based on the information of estimated number of the households in each village and percentage of population belonging to scheduled castes (SCs) and scheduled tribes (STs). Within each explicit stratum, each PSU was sorted according to the literacy rate of women aged 6+ years. Finally, sample PSUs were selected using PPS sampling. In urban areas, CEBs were sorted according to the SC/ST population, and sample CEBs were drawn using PPS sampling.

15.2.3 Describing Outcome Variables

The dependent variable of the study was underweight and overweight of children aged 0–59 months. As mentioned earlier, the present study focused on nutritional status of children age 0–59 months. Therefore, the study has focused on three important indicators of nutrition, i.e., stunting, underweight, and overweight. The NFHS data provides the different z-scores of nutrition, viz., HAZ (height-for-age z-score), WHZ (weight-for-height z-score), and WAZ (weight-for-age z-score).

Z-score is defined as the deviation of the value observed for an individual from the median of the reference population divided by the standard deviation (SD) of the reference population, i.e.:

$$z - \text{score} = \frac{\text{Observed value} - \text{Median of the reference population}}{\text{SD of the reference population}}$$

Stunting is defined as the number of children whose HAZ is below minus two standard deviation (HAZ< -2) according to WHO growth standards (WHO 2006). Underweight is defined as the number of children whose WAZ is below minus two standard deviations (WAZ< -2), whereas overweight is defined as the number of children whose WHZ is above plus two standard deviations (WHZ > 2).

The levels of nutritional indicators were presented by different states/union territories (UTs) based on their immunization status. The immunization status is calculated for children aged 12–23 months using the NFHS-4 data. Children aged 12–23 months is considered to be fully immunized if he had received the vaccination of BCG, measles, three doses of polio, and three doses of diphtheria (WHO 2017). After that, on the basis of the level of full immunization, the states were classified into three equal categories, i.e., low immunization states (less than 57.6% immunization level), medium immunization states (57.7–67.5%), and high immunization states (67.6–85%).

15.2.4 Describing Predictor Variables

The independent variables were age group (0–12 months, 12–59 months), sex (male, female), mother's education (no education, primary, secondary, higher), sector (urban, rural), religion (Hindu, Muslim, Christian, others), caste groups (scheduled caste, scheduled tribe, other backward classes, general, others), and household size.

15.2.5 Statistical Modeling and Analysis

The multiple logistic regression model was employed to study the important covariates of underweight and overweight. Binary logistic regression is a type of regression analysis where the dependent variable is a dummy variable (coded 0, 1):

$$Y_{ij} = \frac{e^U}{1 + e^U}$$

where:
Y = Nutritional indicator divided into two categories, i.e., 0 (no) and 1 (yes)
j = Nutritional indicator, i.e., underweight and overweight
e = Exponential
U = Regular linear regression, i.e.:

$$U = \alpha + \beta_1 x_1 + \ldots + \beta_k x_k + u \cdots ; k = 1, 2, \ldots, 7$$

The odds ratio of underweight and overweight were calculated for the aforementioned covariates.

The absolute and annual changes in stunting, underweight, and overweight were also calculated using NFHS-3 and NFHS-4 data for male and female children (aged 0–59 months). The following are the formulas to calculate the absolute and annual changes:

$$\text{Abosulte change} = \frac{\text{Ni}_{2015-2016} - \text{Ni}_{2005-2006}}{\text{Ni}_{2005-2006}} \times 100$$

$$\text{Annual change} = \left(\frac{\text{Ni}_{2015-2016} - \text{Ni}_{2005-2006}}{\text{Ni}_{2005-2006} \times \text{Noy}}\right) * 100)$$

where:

1. Ni represents nutritional indicator, i.e., stunting, underweight, and overweight.
2. Noy is the number of years between two rounds.

The number of children aged 0–59 months for the study is 268,873 (NFHS-4). The Stata 16 software was used for bivariate and multivariate analysis.

15.2.6 Ethical Considerations

The whole data for this study were taken from the MEASURE DHS archive (available from http://www.measuredhs.com). Prior to the conduction of survey, the DHS obtained ethical clearance from government recognized Ethical Review Committees/Institutional Review Boards of the respective countries as well as the

Institutional Review Board of ICF International, USA. The Indian version of DHS also obtained approval from the National Ethics Committee in India. Written informed consent was taken from each respondent who participated in this survey. This study was considered to be exempted as the data were completely anonymized, and therefore, the researchers did not need to obtain further ethical approval to use the data.

15.3 Results

15.3.1 Trends in the Prevalence of Stunting, Underweight, and Overweight

Figure 15.1 shows the nutritional status of children under 3 years of age during 1992–1993 (NFHS-1) to 2015–2016 (NFHS-4) in India. The prevalence of all three components of childhood malnutrition (i.e., stunting, underweight, and overweight) decreased over the last four successive surveys. Stunting specifically decreased from 54% in 1992–1993 to 34% in 2015–2016.The prevalence of underweight stood at 34% with a decline of 10% points during the reference period. However, insignificant reductions with almost stagnant prevalence in overweight were observed (from 3% to 2%) in the country.

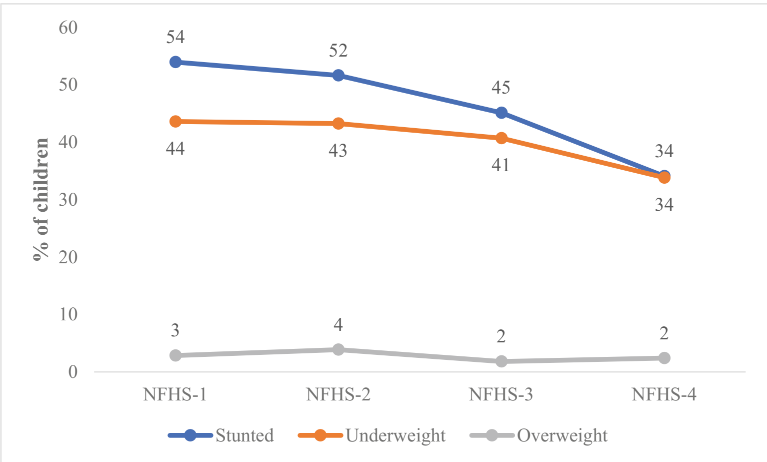

Fig. 15.1 Nutritional status of children under age 3 years, India, 1992–1993 to 2015–2016

15.3.2 *Description of Study Population by Level of Malnutrition and Its Associated Factors in 2015–2016*

Table 15.1 elucidates the descriptive statistics and bivariate association between the nutritional statuses with its predictors. The national estimated prevalence of underweight was 34.5%, while that of overweight was 2.3%. The sex composition of sampled population was almost equal. In the sample, majority of children were male (51.8%) and belonged to above 12 months of age (80.4%). Half of the children's mothers were educated up to the secondary level. Most of the sample population resided in the urban area (71.9%) and belonged to Hindu religion (80.2%). As far as caste is concerned, other backward classes (42.8%) stand out being the dominant

Table 15.1 Sample description and bivariate analysis ($N = 268{,}873$)

Variables	Descriptive statistics	Underweight	Overweight
Stunted	36.4		
Overweight	2.3		
Underweight	34.5		
Age groups			
0–12 months	19.6	1.00	1.00
12–59 months	80.4	1.514 ± 0.018***	0.345 ± 0.011***
Sex			
Male	51.8	1.00	1.00
Female	48.2	0.941 ± 0.008***	0.957 ± 0.03
Mother's education			
No education	29.2	1.00	1.00
Primary	13.9	0.809 ± 0.011	1.021 ± 0.05***
Secondary	45.9	0.559 ± 0.006***	1.182 ± 0.04***
Higher	10.9	0.322 ± 0.006***	1.757 ± 0.08
Sector			
Urban	71.9	1.00	1.00
Rural	28.1	1.154 ± 0.013***	0.841 ± 0.03***
Religion			
Hindu	80.2	1.00	1.00
Muslim	14.1	0.914 ± 0.012***	1.002 ± 0.04
Christian	2.3	0.398 ± 0.008***	1.555 ± 0.08***
Others	3.4	0.613 ± 0.015***	1.322 ± 0.08***
Caste groups			
Scheduled caste	20.6	1.00	1.00
Scheduled tribe	9.3	1.071 ± 0.016***	1.372 ± 0.07***
Other backward classes	42.8	0.903 ± 0.011***	1.042 ± 0.05
General	22.9	0.685 ± 0.010***	1.254 ± 0.06***
Others	4.4	0.581 ± 0.015***	1.574 ± 0.12***
Household size	5.8 ± 2.7	1.000 ± 0.001	0.968 ± 0.01***

population in the group. The average household size was estimated as 5.8 in the analysis.

***Significance at 1%, **Significance at 5%,*Significance at 10%. The last two columns of Table 15.1 show the bivariate association between children nutritional status and its predictors. It is found that the odds of being underweight increased with age of children and place of residence, while the odds of being overweight were high for mothers with higher education (OR = 1.757; SE = ±0.08), among Christians (OR = 1.555; SE = ±0.08), and other caste group (OR = 1.574; SE = ±0.12). Older children and children from rural areas are more likely to be underweight. On the contrary, children from more educated mother and other than Hindu were more likely to be overweight.

15.3.3 Nutritional Status of Children Under 5 Years by Level of Full Immunization, India (2015–2016)

Figure 15.2 presents nutritional status of children by level of full immunization in India. The low immunization states were having highest level of stunting (39.03%) and underweight (38.05%) and lowest level of overweight (1.82%) as compared to medium and high child immunization states. Uttar Pradesh reported highest level of stunting (44.44%) and Madhya Pradesh with highest level of underweight (42.78%), while Arunachal Pradesh reported highest level of overweight (4.88%) among the low immunization states. As far as the medium immunization states are concerned, Bihar was having highest level of stunting (45.99%), while Jharkhand had the highest level of underweight (47.84%). Tamil Nadu which lies in the medium immunization group reported the highest level of overweight (4.95%). High immunization states found to have least average level of stunting (29.94%) and underweight (29.53%) and highest level of overweight (2.67%). Among the high immunization states, Chhattisgarh had highest stunting (36.44%) and underweight (37.68%), while Sikkim found to have the highest level of overweight (8.57%). Overall highest levels of stunting, underweight, and overweight were observed in Bihar (45.99%), Jharkhand (47.84%), and Sikkim (8.57%), respectively.

15.3.4 Absolute and Annual Changes in Stunting, Underweight, and Overweight Between 2005–2006 and 2015–2016 of the NFHS, India

Table 15.2 presents the absolute and annual changes in the prevalence of stunting, underweight, and overweight between third (2005–2006) and fourth round (2015–2016) of NFHS for all children <5 years with their level of full immunization in Indian states and UTs. Overall, majority of states and UTs witnessed the reduction

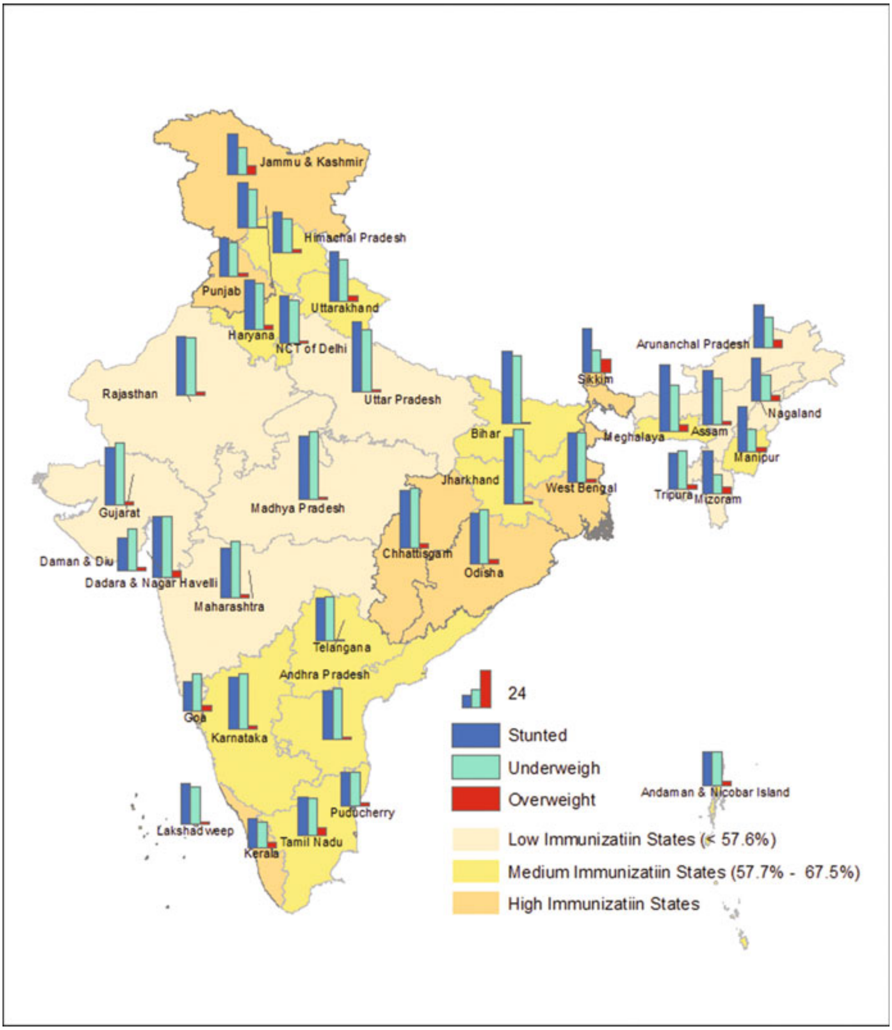

Fig. 15.2 Nutritional status of children under 5 years by level of full immunization, India, 2015–2016

in the level of stunting and underweight with annual changes the in prevalence of stunting that range from −1.38/year (Rajasthan) to −3.68/year (Arunachal Pradesh). Maximum states from low immunization group experienced the maximum annual change in the stunting (Maharashtra, Mizoram, Arunachal Pradesh, Tripura). The extent of annual change of underweight ranges from −0.22/year (Andhra Pradesh) to −4.12/year (Himachal Pradesh). On average, maximum annual change of underweight was found in the medium immunization states and UTs (−1.90/years), while the average maximum absolute and annual changes were found in the high immunization states and UTs. Bihar (34.81%/year) from medium immunization states and

Table 15.2 Overall absolute and annualized changes in stunting, underweight, and overweight between 2005–2006 and 2015–2016 of NFHS, India

States/UT	Stunted		Underweight		Overweight	
	Absolute change (%)	Annual change (%/year)	Absolute change (%)	Annual change (%/year)	Absolute change (%)	Annualchange (%/year)
Low immunization states	−23.1	−2.31	−12.9	−1.29	20.5	2.05
Gujarat	−29.4	−2.94	−11.3	−1.13	64.3	6.43
Madhya Pradesh	−19.2	−1.92	−28.2	−2.82	47.9	4.79
Maharashtra	−31.0	−3.10	−2.4	−0.24	−29.1	−2.91
Mizoram	−31.5	−3.15	−39.7	−3.97	−1.6	−0.16
Nagaland	−29.7	−2.97	−33.4	−3.34	−20.9	−2.09
Rajasthan	−13.8	−1.38	−8.6	−0.86	29.2	2.92
Arunachal Pradesh	−36.8	−3.68	−39.7	−3.97	42.7	4.27
Tripura	−34.9	−3.49	−38.5	−3.85	38.2	3.82
Uttar Pradesh	−21.7	−2.17	−7.1	−0.71	25.8	2.58
Uttarakhand	−29.8	−2.98	−30.3	−3.03	46.7	4.67
Assam	−25.4	−2.54	−17.8	−1.78	82.4	8.24
Medium immunization states	−22.3	−2.23	−19.0	−1.90	38.8	3.88
Haryana	−30.0	−3.00	−25.4	−2.54	117.1	11.71
Himachal Pradesh	−32.9	−3.29	−41.2	−4.12	78.5	7.85
Jharkhand	−14.1	−1.41	−14.6	−1.46	148.4	14.84
Karnataka	−24.4	−2.44	−6.1	−0.61	−2.6	−0.26
Andhra Pradesh	−27.2	−2.72	−2.2	−0.22	−45.2	−4.52
Manipur	−20.2	−2.02	−37.2	−3.72	34.5	3.45
Meghalaya	−24.4	−2.44	−40.8	−4.08	49.2	4.92
Delhi	−28.1	−2.81	3.1	0.31	−69.7	−6.97
Tamil Nadu	−19.3	−1.93	−20.1	−2.01	41.4	4.14

Bihar	−15.7	−1.67	−21.3	−2.13	348.1	34.81
High immunization states	−29.1	−2.91	−18.9	−1.89	56.1	5.61
Goa	−26.2	−2.62	−4.6	−0.46	−11.8	−1.18
Jammu and Kashmir	−26.5	−2.65	−34.8	−3.48	140.2	14.02
Kerala	−26.3	−2.63	−30.0	−3.00	162.7	15.27
Odisha	−27.8	−2.78	−15.7	−1.57	45.7	4.57
Punjab	−32.5	−3.25	−12.7	−1.27	55.6	5.56
Sikkim	−25.6	−2.56	−27.7	−2.77	4.4	0.44
West Bengal	−29.1	−2.91	−18.9	−1.89	17.0	1.70
Chhattisgarh	−30.9	−3.09	−19.8	−1.98	118.2	11.82

Kerala from high immunization states (15.27%/year) followed by Jharkhand (14.84%/year) from medium immunization group had the highest increase in the annual change of overweight nutritional status.

15.3.5 Sex-Adjusted Overall Absolute and Annual Changes in Stunting, Underweight, and Overweight Between 2005–2006 and 2015–2016, India

To determine the role of sex in the change of the nutritional status, we compared the prevalence of stunting, underweight, and overweight by sex among Indian states and UTs (Table 15.3). Irrespective of the level of the immunization, there was a decline in the prevalence of stunting, while there was not much difference in annual change between female and male in India. However, among male, the annual change of stunting ranges from −1.60/year (Manipur) to −3.56/year (Tripura), while for female the annual change of stunting ranges from −1.11/year (Jharkhand) to −3.48/year (Arunachal Pradesh). The low immunization group had maximum number of states with maximum change in the stunting. Most of the states also experienced a decline in the underweight in India. Among male children, the change in prevalence of underweight ranges from −0.01/year (Maharashtra) to −4.12/year (Mizoram). Similar to the stunting, low immunization group had maximum number of states with maximum change in the underweight. On the other hand, overweight increased in most states in both the sex group. The average change in the overweight for male children was highest in the medium immunization group (4.03%/year), while for female children, it was low immunization group (4.56%/year). States such as Bihar (48.18%/year), Jammu and Kashmir (15.70%/year) and Kerala (15.64%/year) had the highest change in the overweight for male children, whereas Jharkhand (38.93%/year), Haryana (25.80%/year), and Bihar (23.53%/year), which are medium immunization states, had the maximum change in the overweight in India.

15.4 Discussion

The present study is an endeavor to present the direct comparison of prevalence of stunting, underweight, and overweight in children below 5 years of age. This study is a first attempt to highlight the variations in the status of dual burden of malnutrition in accordance with the level of immunization observed in the country. Under the results, it became evident with the prevalence of stunting (34%), underweight (34%), and overweight (2%) that more than two-third under-5 children in India carries a potential nutritional deficiency (IIPS 2017). The high prevalence of dual burden of malnutrition among under-5 children is likely to highlight the unequal distribution of resources at the individual level (Wagstaff and Watanabe 1999; IIPS 2007; Van de

Table 15.3 Sex-adjusted overall absolute and annual changes in stunting, underweight, and overweight between 2005–2006 and 2015–2016, India

	Stunted				Underweight				Overweight			
	Male		Female		Male		Female		Male		Female	
States/UT	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)
Low immunization states	−22.86	−2.29	−23.27	−2.33	−10.84	−1.08	−15.11	−1.51	4.00	0.40	45.60	4.56
Gujarat	−30.32	−3.03	−28.42	−2.84	−13.01	−1.30	−9.08	−0.91	20.25	2.02	195.08	19.51
Madhya Pradesh	−17.76	−1.78	−20.69	−2.07	−26.49	−2.65	−28.60	−2.86	26.67	2.67	78.57	7.86
Maharashtra	−33.16	−3.32	−28.46	−2.85	−0.05	−0.01	−4.89	−0.49	−37.38	−3.74	−15.74	−1.67
Mizoram	−33.60	−3.36	−29.30	−2.93	−41.21	−4.12	−37.97	−3.80	26.87	2.69	−25.87	−2.59
Nagaland	−26.90	−2.69	−33.17	−3.32	−32.94	−3.29	−34.09	−3.41	−11.95	−1.20	−32.64	−3.26
Rajasthan	−12.73	−1.27	−14.97	−1.50	−6.49	−0.65	−10.93	−1.09	23.86	2.39	37.76	3.78
Arunachal Pradesh	−37.25	−3.73	−34.84	−3.48	−37.76	−3.78	−42.35	−4.23	55.13	5.51	29.15	2.92
Tripura	−35.64	−3.56	−34.03	−3.40	−33.21	−3.32	−43.18	−4.32	76.35	7.64	17.20	1.72
Uttar Pradesh	−21.21	−2.12	−22.18	−2.22	−4.67	−0.47	−9.56	−0.96	5.67	0.57	57.73	5.77
Uttarakhand	−32.68	−3.27	−26.23	−2.62	−28.95	−2.89	−29.75	−2.97	12.14	1.21	121.38	12.14
Assam	−23.90	−2.39	−27.27	−2.73	−9.28	−0.93	−25.65	−2.57	70.23	7.02	96.64	9.66
Medium immunization states	−21.93	−2.19	−22.78	−2.28	−17.77	−1.78	−20.27	−2.03	40.28	4.03	38.13	3.81
Haryana	−28.93	−2.89	−31.21	−3.12	−23.30	−2.33	−27.82	−2.78	69.89	6.99	258.02	25.80
Himachal Pradesh	−32.00	−3.20	−31.62	−3.16	−38.61	−3.86	−41.80	−4.18	114.71	11.47	43.75	4.38

(continued)

Table 15.3 (continued)

States/UT	Stunted				Underweight				Overweight			
	Male		Female		Male		Female		Male		Female	
	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)	Absolute change (%)	Annual change (%/ year)
Jharkhand	−17.27	−1.73	−11.13	−1.11	−15.19	−1.62	−13.15	−1.32	70.71	7.07	389.29	38.93
Karnataka	−21.40	−2.14	−27.67	−2.77	−5.47	−0.55	−6.77	−0.68	25.63	2.56	−20.41	−2.04
Andhra Pradesh	−23.73	−2.37	−31.11	−3.11	5.15	0.51	−10.09	−1.01	−17.42	−1.74	−65.81	−6.58
Manipur	−15.00	−1.60	−24.29	−2.43	−26.93	−2.69	−45.56	−4.56	32.03	3.20	36.55	3.65
Meghalaya	−20.74	−2.07	−27.65	−2.76	−39.67	−3.97	−41.84	−4.18	77.10	7.71	29.22	2.92
Delhi	−27.89	−2.79	−28.87	−2.89	4.05	0.41	1.07	0.11	−74.71	−7.47	−63.85	−6.39
Tamil Nadu	−20.67	−2.07	−17.47	−1.75	−19.93	−1.99	−19.96	−2.00	13.44	1.34	78.39	7.84
Bihar	−15.37	−1.64	−17.20	−1.72	−21.09	−2.11	−21.58	−2.16	481.82	48.18	235.29	23.53
High immunization states	−28.60	−2.86	−29.51	−2.95	−15.88	−1.59	−21.85	−2.18	34.45	3.44	94.62	9.46
Goa	−34.81	−3.48	−15.26	−1.53	−19.69	−1.97	8.44	0.84	−5.46	−0.55	−18.52	−1.85
Jammu and Kashmir	−19.25	−1.93	−33.54	−3.35	−28.33	−2.83	−40.46	−4.05	167.01	15.70	148.20	14.82
Kerala	−30.45	−3.05	−21.80	−2.18	−31.57	−3.16	−28.02	−2.80	166.43	15.64	161.42	15.14
Odisha	−25.65	−2.56	−29.85	−2.98	−12.46	−1.25	−18.24	−1.82	33.64	3.36	66.41	6.64
Punjab	−31.43	−3.14	−33.58	−3.36	−3.92	−0.39	−22.49	−2.25	52.50	5.25	62.24	6.22
Sikkim	−20.99	−2.10	−32.31	−3.23	−19.84	−1.98	−36.43	−3.64	46.89	4.69	−27.38	−2.74
West Bengal	−31.36	−3.14	−27.45	−2.75	−17.97	−1.80	−19.67	−1.97	−7.87	−0.79	72.73	7.27
Chhattisgarh	−29.55	−2.95	−32.37	−3.24	−15.28	−1.63	−23.45	−2.34	97.14	9.71	143.90	14.39

Poel et al. 2008). Stunting was found to be decreased by 20% points during NFHS-1 to NFHS-4, and the prevalence of the underweight decreased from 44% in NFHS-1 to 34% in NFHS-4. The prevalence of overweight stands at 2% with a constant rate of change.

There are enough evidences which reflect the association between the levels of immunization and nutritional status among under-5 children in India as well as around the globe (Oladeji et al. 2019; Kumari et al. 2020). In congruence to the issue, the present study highlighted the variation in the nutritional status among under-5 children in the context of the level of immunization. The risk of undernutrition and overnutrition seems to be spatially clustered within the country. High level of undernutrition vulnerability is found in the low immunization states, whereas the prevalence of high overweightness is observed in the states of having high level of full immunization. These data reflect that the status of immunization has played an instrumental role in determining the level of nutritional status among under-5 children. In agreement with our findings, previous studies have documented the association between lower level of immunization with high prevalence of underweights and vice versa (Fadare et al. 2019). The annual changes show that stunting and underweight were decreasing, while overweight was increasing in a gradient manner irrespective of categorization of the level of immunization.

Majority of the states (such as Uttar Pradesh, Madhya Pradesh, Bihar, Chhattisgarh, Odisha, etc.) reflecting the higher level of stunting and underweight are socioeconomically backward. In contrast, the high magnitude of overweightness is being found in the socioeconomically advanced states like Tamil Nadu and Kerala and hilly states like Sikkim, Arunachal Pradesh, Jammu and Kashmir, etc. Along with earlier studies, our study found that children belonging to low socioeconomic stratum were more likely to be more underweight, while those in the socioeconomically advanced group experience the high risk of overweight (Sachdev 2018; Nie et al. 2019). The low access of high nutrient content foods and low level of education of household may explain the high prevalence of undernutrition among under-5 children in the states like Uttar Pradesh, Madhya Pradesh, Bihar, Chhattisgarh, and Odisha (Ghosh-Jerath et al. 2017). On the contrary, states like Tamil Nadu and Kerala are economically advanced and highly educated and have urban inspired lifestyles which may be considered responsible factors for overweight and obesity (Bhuyan et al. 2020; Vikram 2018). The hilly states could have lower access of healthcare services that may explain high magnitude of overweightness in Sikkim, Arunachal Pradesh, Jammu and Kashmir, etc. (Bhargava et al. 2016). Studies also documented that factors such as differences in breastfeeding practices, the time of introduction to and quality of complementary foods, rural-urban environment, household standard of living, and family wealth status have been proven as the determinants for the variations in nutritional status across the states (Aguayo et al. 2016; Shivakumar et al. 2019; Corsi et al. 2016).

A significant contribution of the present study assesses the trends in the dual burden of malnutrition in the light of gender differences, which have not been examined in the previous studies. The son preference is high in the patriarchal societies like India (Milazzo 2018). Studies also revealed that female children are more likely to be underweight and stunted (Lone et al. 2020). The annual change reflects the constant rate of decline for both male and female children. It is expected to see the high rate of decline in undernutrition status for female children in comparison to their counterparts, as the male children already possess low level of underweight. Therefore, there is less scope for declining stunting and underweight among male children. Differences in the breastfeeding practices and high son preference could be responsible for these inequalities (Mohseni et al. 2019; Jose 2017).

15.5 Limitation and Strengths

There are some substantial strengths and limitations pertinent to the study. The major strength is that the study utilized the data from nationally representative samples comprising of both rural and urban areas of India. In addition to this, anthropometric measurements (height and weight) were captured by trained interviewers according to the internationally recommended standard protocol, which made it possible to estimate accurate *z*-score values for under-5 children. However, we failed to include the temporal dimensions into the analysis due to the cross-sectional nature of the data. The study failed to include factors such as breastfeeding practices and dietary patterns into the analysis, which may definitely have an impact in the variation of nutritional status among children.

15.6 Conclusion

The prevalence of undernutrition among children under 5 years is declining, mostly reflecting reductions in stunting. However, these declines are not uniform throughout the country. Conversely, the burden of overweightness continues to increase in many Indian states, which underscores the importance of future research to identify the forces attributed to the increasing rates of overweight. The country must continue to involve governments and international agencies in developing policies to reduce stunting and underweight while concurrently eliminating overweight. Given the extensive attention on the Sustainable Development Goals and Indian investment to bring down childhood undernutrition, this is upsetting. Since India is struggling to meet the Sustainable Development Goals (SDGs) 2.2 pertaining to end all forms of malnutrition by 2030, an extensive approach is a must in the country. The amalgamation of rises in overweight with a slowing decline in stunting and underweight reflects an even more anxious picture, and it is gradually capturing consideration for the central debates and discussions in public health.

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