Sapna A. Narula
S. P. Raj *Editors*

Sustainable Food Value Chain Development

Perspectives from Developing and Emerging Economies

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Dr. Narula dedicates this book:

To my parents
Late Sh Baldev Raj Arora
Smt. Raj Arora

Foreword by Dr. K. V. Raman

Farmers all over the world continue to seek support to enhance their food value chain by promoting diversified, sustainable, and climate-resilient farming systems which encourage the production and processing of safe, pure and healthy food and by strengthening marketing connections.

This book provides specific examples and case studies on strengthening and expanding food value chains in both developing and emerging economies to improve production and productivity, stakeholder coordination and collaboration, and exports, all within a context of increased climate resilience and reduced emissions.

The editors, Drs. S. Narula and S. P. Raj, have done an excellent job to reflect on the consensus views of several food value chain researchers and practitioners who have contributed chapters reflecting their experience with marketing success. This book is a useful reference for guidance on how food value systems are initiated and structured, how they function, and makes a strong case for increased effort and resources to develop a sustainable food value chain in the context of sustainable development goals aimed at reducing poverty and hunger.

Dr. K. V. Raman
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Foreword by David Cahill

The COVID pandemic has created economic and social disruptions, millions of people are facing the at risk to fall into extreme poverty, the number of undernourished people is currently estimated at nearly 690 million and they could go up by up to 132 million by the end of this year. Sustainable food value chains have been identified as one of the priority areas required to meet these food and nutritional security challenges. These challenges are especially relevant to developing and emerging economies. Technology and innovation play an important and pivotal role in the transformation of food systems and the development and application of these technologies needs to be tailored for context. Developing and emerging economies, for example, are primarily reliant on farmers who have small land holdings. Coupled with unorganised market structures this makes these economies more vulnerable to global disruptions such as pandemics and climate shocks. Their future must, therefore, not only be underpinned by advances in technology but also alignments in both policy and markets that support local needs.

It is with great pleasure that I note that Profs. Sapna A. Narula and S. P. Raj have had the foresight to bring together this timely and comprehensive compendium. Professors Narula and Raj have a deep understanding of the functions and importance of value chains through their distinguished research and teaching careers. This book has drawn together the global network of colleagues and their expertise that Profs. Narula and Raj have established and nurtured and set about answering the important questions of our time regarding food value chains in developing and emerging economies. Readers will find it a valuable and contemporary collection of empirical research, case studies, and theoretical papers that will not only inform but will present the foundation for future-proofing our food value chains. I am also sure that this book will be beneficial for researchers, policy-makers, industry practitioners and students in their quest towards an understanding of supply chain issues, especially at the local level.

With my best compliments,

Prof. David Cahill
Professor
School of Life and Environmental Science
Personal Chair in Biological Sciences
Deakin University
Former Director
TERI-DEAKIN Nano Biotech Centre

Foreword by B. K. Sikka

Over the last three decades, the progressive liberalization of cross-border transactions, advances in agricultural production technology and information services, and improvements in transport logistics and services have made agricultural supply chains more competitive and responsive in terms of consumer demands and; at the same time more resilient. Agricultural supply chains also saw a paradigm shift in terms of linkage between developing and developed countries through technological upgradation, policy support, global cooperation etc.

However, supply chains in developing and emerging countries are extremely different from those in developed countries. This is also very clear that supply chains in emerging economies are more vulnerable in terms of climate change, market inefficiencies and other disasters.

COVID-19 has placed unprecedented stresses on food supply chains, with bottlenecks in farm labour, processing, transport, and logistics, as well as momentous shifts in demand. Food supply chains have demonstrated remarkable resilience in the face of these stresses. The biggest risk for food security is not with food availability but with consumers' access to food: safety nets are essential to avoid an increase in hunger and food insecurity.

I am glad to see the efforts put in by the editors Professors Sapna Narula and S. P. Raj to cover some of these emerging issues in the four sections of the book. The book covers both case studies and empirical research in this area from countries such as Nepal, India, Australia, and Sri Lanka highlighting the opportunities and challenges.

The special focus of the book is the perspective on SDGs wherein the implications of the papers on various SDGs are highlighted.

I am sure the book is an interesting read for both researchers and practitioners and brings useful insights for agriculture supply chains in post covid world.

Prof. B. K. Sikka
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Preface

The book owes its origin to the two International Conferences that were organized by the Editors in New Delhi (International Conference on Agribusiness in Emerging Economies January 3–4, 2018) and (International Workshop on Strengthening Agribusiness Trade: Stakeholders Dialogue and Partnerships towards SDGs, November 14–15, 2019) and attracted a lot of interest from researchers across the globe. In the first conference around 300 participants from across the world joined; the conference was held in collaboration with the Martin J. Whitman School of Management at Syracuse University and the South Asia Center, a part of the Moynihan Institute of Global Affairs in the Maxwell School at Syracuse University. The conference was actively supported by the Indian Council of Agricultural Research, The International Food Policy Research Institute, Deakin University, RMIT University.

The second conference was organised under the aegis of TERI School of Advanced Studies in collaboration with the Western Sydney University, Indian Council of Agricultural Research, The National Academy of Agricultural Research Management and National Agricultural Higher Education Project. The conference was actively supported by Tata Cornell Institute, RMIT Australia, Deakin Australia, Australia Indian Business Council and UN Global Compact India.

The book addresses the gap that exists in sustainable value chain development in a regional context. Although various studies of food value chains are available in the literature, only a few address *sustainable* value chain development. This book adopts a holistic approach to sustainable agricultural value chain development and addresses significant aspects such as challenges, opportunities, best practices, technology and innovation, business models and policy formulation in the context of developing and emerging economies. The chapters focus on all the existing and potential actors in the value chain. The editors have invited leading researchers, policymakers, practitioners, and academicians to contribute to this book. This edited volume will be useful for scientists, researchers, students, research scholars, and practitioners as it builds the latest interdisciplinary knowledge in the area of sustainable value chain development. An important aspect of the book is case studies of recent and ongoing projects from various countries around the world.

The book is organized in the context of Sustainable Development Goals and has direct relevance and linkages with SDG 1 (poverty), SDG 2 (zero hunger), SDG 3 (good health and wellbeing), SDG 4 (quality education), SDG 5 (gender equality), SDG 12 (responsible consumption and production), SDG 13 (climate action) and SDG 17 (partnerships).

Review Process

The proposal for each chapter underwent at least two double blind peer reviews where a detailed concept note along with the extended chapter abstract was reviewed. Each chapter has also been double-blind peer-reviewed by anonymous reviewers from both academia and practice.

New Delhi, India Sapna A. Narula
Syracuse, USA S. P. Raj

Acknowledgments

The editors would like to thank all the authors who have contributed to this edition. To the anonymous peer reviewers who helped in strengthening the quality of the chapters by providing important comments to authors, we offer immense thanks.

We would also like to acknowledge the support provided by Dr. Muneer Ahmad Magry, Research Fellow, Deakin University, Australia, and Mr. Kaan Canyaz, Graduate Assistant, Syracuse University, US.

We would also like to thank our friends, family members and well-wishers for all their support.

Tremendous thanks and gratitude to the team at Springer, who were very helpful throughout the process of editing and compiling this book.

Dr. Sapna A. Narula
Dr. S. P. Raj

Disclaimer

The inferences/analyses, projections and recommendations made in this book are based on the best effort basis of the authors after the visits to fields, opinions of various stakeholders, review of various reports or secondary sources. The information and opinions contained in this book have been compiled or arrived from sources believed to be reliable, but no representation or warranty expressed is made to their accuracy, completeness or correctness. This book is for information purposes only. The information contained in this book is published for the assistance of the recipient but is not to be relied upon as authoritative or taken in substitution for the exercise of judgment by any recipient. This book is not intended to be a substitute for professional, technical or legal advice. All opinions expressed in this book are subject to change without notice. Neither authors nor any other legal entities to which they belong, accept any liability whatsoever for any direct or consequential loss howsoever arising from any use of this book or its contents or otherwise arising in connection herewith.

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Editors and Contributors

About the Editors

Sapna A. Narula currently serves Nalanda University, India where she is Professor and Dean of School of Management Studies. She is a distinguished academician in agribusiness and sustainability who has made immense contribution to the discipline through her teaching, research and consultancy efforts. During her career span of 22 years in university teaching, research and consultancy, she has also played a key role in advancing education for agribusiness through a number of initiatives targeted at raising awareness generation and capacity building amongst corporates, youth, managers, and policy-makers. She has played a key role in designing innovative academic programmes such as MBA/Business Sustainability, MBA/Agribusiness and MBA/Food Supply Chain Management. She has also spearheaded various sustainability initiatives which she promoted for youth such as Green Shift (2018), BLISS (Building Learning in Sustainability Science, 2014) and has been on the jury of many sustainability related awards/initiatives. She is currently serving as President of Global Network for Sustainable Development, Arizona, US as its President has been associated with the UN Global Compact Network of India, PRME (Principles of Responsible Management Education), Connecting Dreams Foundation and National Agricultural Higher Education Project (ICAR) in various advisory roles for the cause of sustainable development goals. She has also held key leadership positions in prestigious Universities in India and has delivered several keynotes, and distinguished sessions at many Universities abroad. She was a visiting professor in Department of Management, Deakin University, Australia (2018). A recipient of many awards notably Prosper. Net Scopus Young Scientist Award for Sustainable Development, 2011 delivered jointly by the German Ministry, United Nations University and Elsevier and a Young Scientist Award (2009) from Uttarakhand Council for Science and Technology, Government of Uttarakhand, she has worked on research projects funded by various national and international organizations EPSRC, DFID, IFAD., Bill and Melinda Gates Foundation. One of the research projects where she led sustainable livelihood work has also won UN Global Compact Innovative SDG Practices Award

2019. She has published her research extensively in journals (*Journal of Cleaner Production, Journal of Sustainable Mining, Business Strategy and Development, CSR and Environmental Management* among many others) and a paper written by her in the context of organic food has won the Outstanding Paper Award 2021.

S. P. Raj is chair of the marketing department and Distinguished Professor at the Whitman School of Management, Syracuse University. He holds the Irwin and Marjorie Guttag Endowed Professorship and serves as Director of the Snyder Innovation Management Center and chair of the Department of Marketing, Supply Chain and Retail Management. He has previously served as interim dean and as senior associate dean for the school. He was also a tenured full professor of marketing at Cornell University and a visiting faculty at the Kellogg School of Management, Northwestern University. He was the founding editor of the *Journal of Agribusiness in Developing and Emerging Economies*. Raj's research on marketing strategies, their influence on customer behavior, and managing new product development and innovation is cited extensively with over 2500 citations in the Social Sciences Citation Index and 7500 in Google Scholar. His work has been recognized with prestigious awards such as the John D. C. Little Award by the Institute for Management Sciences, a finalist for the William F O'Dell Award by the Journal of Marketing Research, the Donald R. Lehmann Award by the AMA and many Best Paper awards in conferences. His research was supported by the NSF/Corporate Center for Innovation Management Studies. He has published in leading journals such as *Marketing Science, Journal of Marketing, Journal of Marketing Research, Journal of Consumer Research, Research Policy, European Journal of Operational Research, Journal of Business Research, Journal of Product Innovation Management*, and *IEEE Transactions on Engineering Management*. He holds a Ph.D. and M.S. from Carnegie-Mellon University and a B.Tech. from the Indian Institute of Technology, Madras.

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Abbreviations

ASC	Aquaculture Stewardship Council
CE	Circular Economy
CEP	Comparative Export Performance Index
CES	Consumption Expenditure Surveys
CGIAR	Consultative Group for International Agricultural Research's
CSR	Corporate Social Responsibility
DDT	*Dichlorodiphenyltrichloroethane*
DOA	Department of Agriculture
ET	Evapotranspiration
EU	European Union
FAO	Food and Agricultural Organization
FCR	Food Conversion Ratio
FL	Food Loss
FVW	Food Vegetable Waste
FW	Food Waste
GOI	Government of India
HIMALI	High Mountain Agribusiness, and Livelihood Improvement
HVAP	High-Value Agriculture Project
ICAR	Indian Council of Agricultural Research
ICIMOD	International Centre for Integrated Mountain Development
ICRISAT	The International Crops Research Institute for the Semi-Arid Tropics
ICT	Information Communication and Technology
MoSPI	Ministry of Statistics and Programme Implementation
MSC	Marine Stewardship Council
NER	North Eastern Region
NFHS	National Family Health Survey
NNM	National Nutrition Mission
NSSO	National Sample Survey Office
NTFP	Non Timber Forest Products
PACT	Project for Agriculture Commercialization and Trade
PDO	Pacific Decadal Oscillations

SDG	Sustainable Development Goals
SSA	Sunflower seed albumin
UN	*United Nations*
UNCTAD	United Nations Conference on Trade and Development
UNDP	*United Nations Development Program*
USD	United States Dollar
USDA	United States Development Authority
WANA	West Asia and North Africa
WB	World Bank
WBCSD	World Business Council for Sustainable
WTO	World Trade Organisation
WWF	World Wildlife Fund

Introduction

Sapna A. Narula and S. P. Raj

1 Background

According to recent estimates, almost 12% of the global population had severe food insecurity in 2020, representing a staggering total of 928 million people—148 million more than the previous year (UN, 2021). The projected gap in meeting the UN's 2030 food and nutrition targets that existed pre-pandemic has only widened after COVID-19. More than half of the world's undernourished are found in Asia (418 million) and more than one-third in Africa (282 million) (FAO, 2021). It is believed that conflict, climatic variability and disasters, economic slowdown, and the COVID-19 pandemic have been major drivers of the increase in frequency and intensity of food insecurity and malnutrition over the last few years (FAO, 2021). Reaching the 2025 and 2030 global food and nutrition targets remains a daunting challenge: internal and external factors in developing regions are pushing up the cost of nutritious food while incomes remain low, making healthy diets out of reach.

Climate variability and extremes create multiple and compounded impacts on food systems (FAO, 2015). They negatively impact agricultural production and also impact food imports as countries try to compensate for domestic production losses. Climate-related disasters can significantly impact food value chains and negatively affect sector growth and food and non-food agri-industries (FAO, 2015). Their impacts are especially profound on four dimensions of food security: availability, access, utilization, and stability.

Sustainable and inclusive food systems are an urgent requirement to ensure a food-sufficient and secure world (FAO, 2020). Innovative mechanisms to reduce

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climate-related risks, strong market structures and institutions, widespread adoption of climate-smart and environmentally sound production techniques, and the rehabilitation of the natural environment will strengthen the resilience of food systems to increased climate variability. The persistence of socioeconomic inequalities across the food value chains magnifies the need to include marginalized populations in the mainstream food systems by enhancing their access to resources, technology, information, and innovation to empower them to become agents of change toward more sustainable food systems.

The global report on food and nutrition security has suggested six pathways:

- Scaling up climate resilience across food systems.
- Integrating humanitarian, developmental, and peace-building policies in conflict-affected areas.
- Interventions along food supply chains to lower the costs of nutritious foods.
- Tackling poverty and structural inequalities to ensure pro-poor and inclusive food systems.
- Strong food environment and changing consumer behavior to promote dietary patterns with positive impacts on human health and the environment.

2 Sustainable Food Value Chains

The annual **State of Food Security and Nutrition in the World Global Report** has identified sustainable food value chains as one of the major drivers in meeting food security targets, especially in developing countries (FAO, 2021). The global nature of agricultural trade provides myriad opportunities for even small and marginal farmers in developing and emerging economies. Although these countries have been able to meet their domestic needs, they have a long way to go before their produce becomes integrated into global supply chains. Agriculture in these countries is characterized by low-cost production and seasonal cropping. At the same time, it is constrained by the absence of strict food safety standards as well as a lack of efficient and novel methods of production, transport, cold storage, and technological infrastructure. These factors—coupled with the dominance of traditional market access systems—limit farmers' ability to gain a reasonable share of income. Further constraints such as climate change, rising input prices, competition from global products, and volatile food prices are critical challenges. Connecting small and marginal farmers in developing and emerging economies to global markets can increase their income opportunities and raise their standard of living (Magry & Narula, 2021).

The development of sustainable food value chains can enhance the opportunities for producers not only in global markets but also in domestic markets. Climate change is likely to pose challenges to agricultural value chains, resulting in resource scarcity and changes to crop acreage, production and productivity, land-use patterns, and livelihood diversification. Besides biophysical impacts on the food chains, such as quantitative and qualitative losses, weed and pest challenges, and land–soil–water resource degradation, huge exacerbations looming in the form of lost farmer profits, market inefficiencies, and post-harvest losses along every step of the food chain. The farmers of the region need to be prepared for these challenges and be part of building climate-resilient agricultural value chains that are inclusive and provide alternative livelihood options that are socially and environmentally sustainable. Demand–supply mismatches posed by climate events give rise to problems such as price inflation and inefficient markets; they need to be tackled by removing information asymmetry between producers and markets. Various stakeholders—ranging from local communities and academic institutions to civil society organizations, government bodies, and policymakers—need to work in an integrated manner to create climate-resilient and market-efficient food systems.

Food value chain studies have recently attracted the attention of researchers. They have observed that the creation of sustainable food value chains has led to economic and social empowerment of local communities in developing and emerging economies. There are numerous case studies involving a range of commodities from different regions and countries that showcase success stories at the community level. There is great potential for these business models to be replicated. At the same time, a variety of value chain activities still need to be studied and documented, such as capacity building, livelihood development, market information and intelligence, demand–supply match, extension education for farmers, and innovation and technological interventions. There is also a need to look for holistic value chains where all stakeholders, including farmers, have an equitable share and there is less food loss/wastage and more value addition.

The purpose of this book is to discuss the current state of food value chains in developing and emerging economies; at the same time, we discuss the opportunities and challenges presented by changing climate, global food regimes, domestic regulations, and consumer lifestyles and preferences. In this book, we address the following questions:

- What are the current state, scope, and potential of sustainable value chain development in developing and emerging economies?
- How can various challenges related to resource efficiency, climate change, food loss, and waste in agri-food supply chains be addressed?
- What are the best practices in selected regions regarding food value chain development? How can these be replicated and scaled up?
- What role could technology and innovation play in building sustainable food value chains?
- What can sustainable value chain development contribute to inclusive social and rural upliftment?
- How can new market institutions, mechanisms, and business models help develop these value chains?
- What best practices from developed countries can be adapted in the context of local conditions in India and other emerging economies?

This book has adopted a holistic approach for sustainable agricultural value chain development and addresses significant aspects such as challenges, opportunities, best practices, technology and innovation, business models, and policy formulation in the context of developing and emerging economies. The chapters focus on all the existing and potential actors in the value chain. Researchers, policymakers, and practitioners from the United States, Australia, Sri Lanka, Nepal, India, Estonia, and Africa have contributed to this volume. The edited piece covers a variety of topics from climate change, sustainable livelihoods, corporate social responsibility, social entrepreneurship, resource efficiency, food loss and waste, and food consumption patterns in the context of food value chains. This edited volume is useful for scientists, researchers, students, and practitioners, as it brings together the latest interdisciplinary knowledge in the area of sustainable value chain development. An important aspect of the book is the presentation of case studies describing recent and ongoing projects from different countries.

The book has been organized in the context of Sustainable Development Goals and the chapters inside provide direct relevance and linkages with SDG 1 (poverty), SDG2 (zero hunger), SDG 5 (gender equality), SDG 12 (responsible consumption and production), SDG 13 (climate action), and SDG 17 (partnerships).

Parts:

Four parts comprise the book:

Part 1: Sustainable Food Systems and Circular Economy: Tackling Resource Use, Efficiency, Food Loss and Waste Problems

Efficient use of resources across the value chain and the reduction of food loss and waste can lead to the overall resilience of the food system. One of the key features of a circular economy is the maximal utilization of agricultural resources with minimal waste and the productive reuse of by-products generated along the production and supply chain. This part's four chapters all touch upon issues of circular economy and resource efficiency across the value chain to reduce food loss and waste and promote efficient use of resources.

The Chapter "Challenges and Prospects of Tackling Food Loss and Wastes in the Circular Economy Context" by Bhat et al. addresses food loss and waste across the globe. The authors present data from various agencies to describe the food loss and waste scenario while building a case for food valorization. Globally, about 14% of the total food production is lost between harvesting and the retail market (FAO, 2020). According to the United Nations Environment Programme's (UNEP) Food Waste Index Report 2021, about 17% of global food production goes to waste, with nearly 61% of the waste attributed to households, 26% to food services, and 13% to the retail sector. The authors reiterate goals set by the EU Commission for efficient resource management and lowering of the carbon footprint (low carbon economy) by 2050 and the aims that have been set for the success of the green economy. Novel sustainable approaches to tackling food loss and food waste in the circular economy are deliberated, specifically taking into consideration the EU context and comparing high-income-generating countries with low- and middle-income-generating countries. This chapter proposes innovative means for minimizing loss/waste at the "on-farm" and "off-farm" levels as well as maximum utilization of by-products from agro-food industries. In addition, the potential and avenues of valorization of wastes and/or by-products, e.g., bioplastics are discussed. The authors recommend that developing zero-waste models based on novel food-processing technologies can contribute to the success of sustainable food value chain development in the circular economy context.

In the Chapter "Climate Change and Agroecosystems in the Hill and Mountain Regions of Northeast India", Dr. Chubamenla Jamir presents a detailed analysis of the impact of climate change on agro-ecosystems in the hill and mountain regions of Northeast India. Even though it occupies only about 8% of India's total land area and is home to 3.8% of the population, the northeast region requires significant attention because its mountain ecosystems are more vulnerable to climate change and the potential ramifications for both economic and social development are great. The chapter uses data to describe the nature and magnitude of exposure of agriculture to climate change in the region and the sensitivity of crops to climate change events. How climate change impacts crop productivity and how farmers and stakeholders along the agri-food supply chain are adapting to climate risk is also well presented in the chapter. The research identifies the biophysical and socioeconomic factors that make the agro-ecosystems vulnerable to climate change in the region. The author concludes that our understanding of climate risks in the region may be limited due to a paucity of temporal and spatial data and the difficulty in modeling the climate in hilly topography. Future climate projections indicate a rise in temperature and extreme and erratic rainfall, which will subsequently increase the magnitude of floods and drought in the region. The multidimensional poverty index in many districts of Northeast India also points towards a great impact on the livelihoods of the poor and on the overall sustainability of the agro-ecosystem. Hence, these issues need immediate redress.

In the Chapter "Towards Circular Economy of Food Systems: An Explorative Appraisal of Opportunities in Fish and Seafood Value Chains", using the circular economy framework with a focus on resource switch, resource efficiency, and resource circularity, Fadeeva and Rene explore the fish and seafood value chains, which have great potential from the sustainable consumption and production (SDG 12) perspective. The authors stress that further efforts are needed to accelerate and scale up circular economy applications in seafood value chains while ensuring a just transition for the millions depending on fisheries and aquaculture for their livelihoods. First and foremost, the authors advise, this requires firm policy direction and regulatory security at global, regional, and national levels for production (both wild-caught and farmed) and their processing value chains, along with strong institutional, knowledge, and operational capabilities to ensure data-driven, transparent, and predictable implementation. Secondly, further efforts are necessary to create a strong market pull for transformative change in the value chains, starting from consumer demand for sustainable fish and seafood and, ultimately, market rejection of unsustainable products. Such market pull can also leverage finance, R&D, and other resources into a sustainable and circular transformation of fish and seafood value chains. Thirdly, efforts need to focus on creating a vibrant ecosystem to support fish farmers, fishing communities, and processors—many of them micro-, small, or medium enterprises—as they adopt best circularity practices, including training and capacity building, and quality and assurance systems development.

Sengupta and Hari in the Chapter "Resource Efficiency for Sustainable Agriculture and Food Value Chains in India: The Case of Food Loss & Waste" then build on the concept of food system transformation and its imperatives for sustainable development. The authors highlight that food systems for a better future cannot just be about enhanced production; they must also reduce environmental stress, constrain emissions, and mitigate the impact of climate change. There is growing momentum that food and land systems need to undergo major transformations to deliver on a number of SDGs. Picking up the case of India, the chapter stresses holistic and innovative approaches to reducing food loss and waste across crops. The private sector in the food and agricultural business, they note, has to set food loss and waste targets and develop action plans. The authors highlight the absence of national-level plans in South Asian countries and recommend governments provide an enabling environment at the national, state, and local levels. The chapter also presents a framework for the application of resource efficiency (principles of circular economy) in designing actions to reduce food loss and waste and measure efficacy.

Part 2: Technology and Innovation for Food Value Chain Development

New technologies and business models offer promising potential for revolutionizing food supply chains around the world, especially in developing countries, by overcoming information asymmetries across the traditional supply chains and empowering small and marginal farmers with market information and use of information technologies to optimize their efforts—from farm inputs to harvest, by assessing factors such as weather and soil conditions. This part opens by enhancing our theoretical understanding of value chain development and then moves to a discussion of successful technologies and business models, such as tunnel technology in Nepal and an ongoing project on social entrepreneurship in India. The chapters also discuss the barriers to the implementation of these technologies at the field level and how farmers can best benefit from these initiatives.

The first chapter in part "Agricultural Value-Chains in Developing Economies: A Theoretical Framework" aims at providing a conceptual framework for understanding value chains and to inform our understanding of complex systems, such as the food supply system, which is critically important to human life on this planet. The chapter advances our theoretical understanding of how value chains evolve from farmers to complex, well-developed global supply chains. The chapter is important in describing the utility of value chains from both producers' and consumers' perspectives. Against a theoretical backdrop, the chapter describes how various stakeholders in the chains interact with each other to provide sustainable livelihoods and overall resilience of the system. The chapter contributes to our understanding of the complex relationships necessary to design and manage various value chain interventions. The case of value chains in developing and emerging economies is compared with those in developed countries. The chapter highlights that the cost of interventions must be carefully calculated and compared with the benefits that a particular policy intends to provide. Hence the need for cost–benefit analysis across the chain, including costs of externalities.

In the Chapter "Tunnel Farming as an Adaptation Tool Against Climate Change Effect Among Smallholder Farmers in Nepal", Dinesh jammarkattel et al. spotlight the case of tunnel farming in Nepal, a low-income agricultural country where smallholder farming is the mainstay for a majority of the population. Of the two-thirds of the population engaged in agriculture, 90% are smallholders who cultivate nearly 70% of the total farms that are less than 1 ha in size. Most of these smallholders practice subsistence farming and live below the poverty line of $1.90 a day as defined in SDG 1. The authors discuss climate change and its threat to the 767 million smallholder farmers across the globe, who are vulnerable to even small changes in climate. They stress the need for raising the adaptive capacities of these farmers to face current and upcoming changes.

The authors offer Kathmandu Valley in Nepal as a case study to explore the effectiveness of tunnel technology as a successful adaptation. Presenting trend analysis of the last 30 years of time-series data of temperature and rainfall to understand climate variability at the study site reveals significant variation in the temperature and rainfall, which might have affected the smallholder farmers in numerous ways. The descriptive analysis reveals that tunnel technology significantly increases the crop productivity and income of smallholder farmers tackling climate change hazards. The tunnel protects crops from severe climatic conditions such as extreme rainfall and high temperature, enabling farmers to grow year-round, and contributing to better crop productivity, higher income, and a more sustainable livelihood. Tunnel technology could be considered an effective adaptation strategy contributing to SDG 1 (poverty elimination), SDG 2 (zero hunger), and SDG 13 (climate action).

The significance of food systems transformation and value chains has already been highlighted in this part's first chapter. In a post-COVID world, the concern for nutritional security has been flagged as critical for the populations of South and Southeast Asia. Chickpea has been identified as a commodity that can contribute immensely to meeting sustainable development goals (SDGs) through the alleviation of poverty and ensuring good health.

The authors Sandhu et al. outline in the Chapter "Chickpea Nutritional Status and Value Chain for Sustainable Development" the significance of chickpea as an important crop for sustainable land use and food and value chain development. It sustains soil health and saves natural resources while also fixing atmospheric nitrogen to improve soil fertility. It requires less fresh irrigation water compared to cereal crops. The strategies outlined—from production to processing, to value addition, to consumption—are likely to help sustain current yields and expand availability. The chapter highlights the potential of chickpea in ensuring nutritional security for a large number of predominantly agrarian people around the world, ways and means to enhance the production of nutrient-dense chickpea, and avenues for value addition. The authors stress research on nutritionally dense varieties of chickpea and also the development of processed foods.

Part 3: Towards Responsible Food Consumption

Consumers can catalyze significant market changes through demand for more sustainable products and also through their behavior patterns. This part focuses on sustainable consumption and production (SDG 12). The chapters in this part cover consumer behavior, changing dietary patterns, and demand for organic food. The part combines empirical work, case studies, and success stories in the field that are in line with responsible consumption goals.

Part 3 contains two chapters:

The Chapter "Changing Food Consumption Pattern and its Implications on Achieving Zero Hunger in India (SDG-2)", written by Saxena and Kolady, examines the shifts in food consumption patterns in India and highlights their implications from the perspective of SDGs. The evidence from consumption expenditure surveys of the National Sample Survey Office (NSSO) reveals a gradual shift in food consumption patterns among Indian households. The study revealed striking empirical differences in the consumption patterns of Indian households across rural and urban sectors, geographical regions, and income categories. Broadly, food consumption patterns are shifting away from cereals and other staple food items and towards high-value food commodities such as fruits, vegetables, milk, non-vegetarian products, and processed foods. Recently, average calorie intake among Indian households is witnessing a reversal in what has long been a declining trend. This is a desirable sign and warrants the identification of underlying factors influencing such trend reversal. The expenditure elasticities of high-value agricultural commodities (HVACs) like milk, non-vegetarian products, fruits, etc. were higher than staple food, i.e., cereals. Further, wide inter-regional variations in the household demand for food necessitates the match of demand and supply at local levels and the removal of bottlenecks in the production of food commodities to fulfill the demand in each region. The study offers significant implications for research on changing consumption patterns in the Asia–Pacific region, led by UNEP and other multilateral agencies. The study is also important from the perspective of addressing food and nutritional concerns as part of national SDG agendas and food security missions.

The next paper in this part, Chapter "The Impact of Strategic CSR on Small Holder Farmer: A Study of Agri-Input Firms in India", explores trends in corporate social responsibility practices of the Indian agribusiness sector. The authors emphasize that large agribusiness corporations have a responsibility to contribute to the sustainability and climate resilience of food systems in emerging countries. The Indian agribusiness sector is now under increased public scrutiny for environmental degradation (which is extensive, due to excessive use of fertilizers, pesticides, and the burning of agricultural waste, etc.) and for human resource exploitation of farm laborers. This will have a direct effect on the quantum of agricultural produce sold in domestic and foreign markets. To combat these challenges, agribusiness companies are using corporate social responsibility (CSR) activities to build up their brand value. Through these CSR funds, there exists huge potential to transform farming systems and farmer livelihoods in India and other emerging economies. The integration of farmers into food supply chains dominated by multinational corporations can also lead to technological and economic empowerment.

The authors, Mathur and Poddar, conclude that agribusiness companies are investing more in SDG 3 (healthy well-being) and SDG 4 (education sector), followed by SDG 8 (livelihood generation). Companies are pursuing strategic CSR rather than traditional philanthropic CSR. The paper provides a framework for companies to use their CSR investments to encourage responsible consumption.

Part 4: Linking Small Farmers to Markets: Markets, Institutions, and Trade

The chapters in this part focus on the critical role played by markets and institutions in making food value chains more productive in delivering value to farmers and consumers. This part includes chapters on the market development of non-timber forest products (NTFPs) in Jharkhand state of India, international trade trends in agricultural commodities in India, and market structure and institutions in India as well as the small island nation of Sri Lanka.

Part four contains four chapters.

In the Chapter "Marketing Constraints of Non-timber Forest Products: Evidence from Jharkhand, India", Magry et al. take up the case of non-timber forest products (NTFP) and explain their essential role in the livelihoods of tribal and rural communities in Jharkhand. With the help of socioeconomic data collected from tribal communities in the Khunti District of Jharkhand, the authors explore the market channel of NTFPs in the region. The authors share data on market channel, information flow, market asymmetries, and awareness levels of tribal communities regarding markets and prices. Based on a survey of the stakeholders, the authors highlight the constraints in the region in collecting and marketing of Lac, Mahua, and Tamarind, where heretofore there has been a paucity of data in this field, due to the region's difficult location and accessibility of respondents. The authors are the first to have examined NTFPs here in the context of value chains and to have highlighted the constraints in the marketing channel. The study offers major implications for policymakers and proposes interventions to connect NTFPs to markets. The work is extremely significant for SDG 1 (no poverty), SDG 2 (zero hunger), SDG 5 (gender equality), and SDG 8 (decent work and economic growth).

Based on the data analysis, the authors recommend that India needs to focus on stable trade policy, particularly for commodities with greater trade potential, and that sanitary and phytosanitary measures (SPS) should strictly adhere to the international standards. Export-oriented supply chains should be efficiently managed, they note, reducing the costs and making exports more competitive. With the government's focus on doubling agricultural exports and an agricultural export policy in place, India needs to find effective solutions to become a global leader in agricultural exports. Needless to say, effective logistics management and quality management is critical to strengthening global trade linkages. Farmers need to be continuously aware of the changing trade and regulatory environments and demand patterns.

In the Chapter "Impact of Marketing Reforms on Farm-Market Linkages", Prabhat Kumar et al. discuss agricultural marketing reforms in India and the market interventions that are needed to support the farmers navigating traditional barriers while at the same time modernizing the market systems. Various policy intiatives taken by Govt. of India to remove market efficiencies and develop value chains are discussed e.g. eNAM scheme, FPOs (Farmer Producer Organisations). The authors talk about the positive impact of these initiatives on farmers: (1) farmers can benefit immensely from market reforms at the policy level and from other interventions aimed at reducing information asymmetries and market intermediaries and (2) small landholders in these countries could benefit from better organization (e.g., through producer organizations) and support from innovative financial measures.

Chapter "Smallholder Agriculture in Developing and Emerging Economies: The Case of Sri Lanka", by Rohitha Rosario, provides detailed understanding of Sri Lanka's smallholder farming scenario, especially in the context of COVID-19. The chapter builds on the significance of the smallholder agriculture sector in Sri Lanka and small farmers' involvement in producing coconut, sugarcane, vegetables, prawns, and ornamental fish. The author discusses the impact of COVID-19 on food supplies in Sri Lanka and how farmers coped at the local level. The chapter also discusses modern agricultural marketing systems and how contract farming reduces the vulnerabilities of smallholder agriculture. Highlighting smallholder institutions such as farmers' co-operatives, agrarian and Mahavali farmers organizations, farmer companies, and smallholder development societies, this chapter enhances our understanding of the institutional setup in Sri Lanka while also pointing out constraints on sustainability. The authors outline strategies to enhance the sustainability of smallholder farms including separation of ownership from farm management, collaboration with agribusiness partners, and multi-product institutions.

Agricultural exports from India have undergone significant change in terms of trends, composition, and diversification. In the Chapter "Structure, Performance and Competitiveness in Indian Agricultural Exports Expanding Trade and Strengthening Global Trade Linkages", Saxena et al. examine trends in exports of agricultural commodities, export performance, commodity and geographical diversification, and established trade-growth linkages. The authors indentify commodities which have a great potential for exports and have also categorized the commodities based on their competitiveness. Useful recommendations have been made in order to enhance the export cpmpetitiveness of agricultural commodities from India.

3 Conclusion and the Way Forward

The work based on multiple commodities such as lac, mahua, tamarind, chickpeas, seafood, fruits, and vegetables presented in the book provides useful evidence about market inefficiencies and pre- and post-harvest losses across the food value chains in developing countries. The small size of farms, surplus produce, lack of technical know-how, absence of market information and alternative markets are some of the barriers to improve farmer incomes. Climate change and disasters, to be sure, are also making it very difficult for these small and marginal farmers to reach their yield and earning potential due to frequent market disruptions.

The authors provide evidence of climate change disrupting the supply chains in many agro-ecosystems, e.g., Kathmandu Valley of Nepal, Sri Lanka, NTFPs in Jharkhand state of India, and also northeast regions of India. They reiterate the paucity of data related to climate change in these regions. On the consumption side, the authors reveal that food consumption habits of different classes are also changing, putting additional stress on value chains.

From the case of tunnel technology in Nepal, it is quite evident that innovations hold promise for small and marginal farmers, whether to strengthen the flow of information, enhance productivity, or manage disasters. Local and indigenous technologies can also play a significant role in strengthening food systems. The case of the use of eNAM in India as exhibited in the final chapter provides a successful example of building an electronic national market platform in a huge agrarian economy like India. Various policy initiatives on market-farm linkages, reduction of post-harvest losses, and encouraging innovations are needed for smaller countries like Nepal, Bangladesh, and Sri Lanka, perhaps building on the experiences of policy initiatives in India. The national-level circular economic models in food value chains would also help in building overall resilience of the system as in the case of the seafood value chain. At the same time, it is important to assess and estimate the losses at each step of the value chain.

Significant implications for SDG 12 emerge out of the authors' contributions. Shifting dietary patterns in various domestic markets may require the development of new value chains for organic food, coarse grains, functional foods, protein-based food, seafood, and standard-compliant food. The overall circularity and resource efficiency of the value chains can only be achieved with demand–supply linkages. The development of sustainability standards across food chains helps build trust and aids consumers in making informed decisions. It also raises awareness and knowledge among producers about the markets and consumers. Multinational food corporations have a significant role to play in this regard, linking both ends of the chain, raising the capacities of farmers, building resource efficiency, and sharing innovative tools and techniques in production and logistics. The example of India's mandatory corporate social responsibility spending offers prospects for multinational companies to invest in food supply chains through CSR funds.

Viewed as an integrated whole, the chapters in this volume point to a way forward in meeting SDG imperatives related to food and nutritional security that balances social, economic, and environmental sustainability.

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Sustainable Food Systems and Circular Economy: Tackling Resource Use, Efficiency, Food Loss and Waste Problems

Challenges and Prospects of Tackling Food Loss and Wastes in the Circular Economy Context

Rajeev Bhat, Minaxi Sharma, Reelika Rätsep, Dunja Malenica, and Katrin Jõgi

1 Introduction

The success of ensuring global food security relies on strengthening the food and feed production systems. Unsustainable food production coupled with climate change, food loss, and food wastage issues has significantly affected regional food security. Though much is often used synonymously, there has been a clear distinction between waste and loss in a food supply chain. The monitoring of food supply chains in context of food loss and food waste is must for the overall sustainability of food security of any nation. As per the available data, nearly one-third of global food production gets wasted throughout the supply chain. The United Nations 2030 *Agenda for Sustainable Development* specifies cutting down food waste generated (at retail and consumer levels) as well as reducing food loss along the production as well as the supply chain. Apart from this, European Union's common strategies incline towards sustainable management of raw materials that are aimed towards contributing to an elegant inclusive growth. With grave concerns about environmental drifts and stress created by food loss and wastage, reuse and recovery strategies have become a necessity, thus providing ample scope for effective valorization of food industrial wastes and by-products. Sustainable management and efficient valorization strategies can benefit not only the environment but can also open up new business prospects. Of course, the EU Commission's European Green Deal is expected to play a vital role in regional COVID-19 recovery and focuses mainly on reducing net carbon emission by ~55% (by 2030), gaining economic growth along committing to climate

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neutrality by 2050. Further, the basic goal of food industrial waste utilization is to exploit reasonable recompenses to maximal levels, thus contributing to the decline in wastes that goes as landfill as well as reducing pressure on the environment (Bilal & Iqbal, 2019; Coman et al., 2019; Fabi et al., 2020; Saqib et al., 2019; Tsang et al., 2019). Further, consumers' behavior toward dealing with the food waste and acceptance of novel value-added products obtained as a result of post-recovery processes are vital factors. Appropriate planning and developing practical models can significantly contribute towards efficient and methodologic management of food industrial wastes/by-products. It is essential to comprehend that various driving factors influencing consumers and the dependent industry can have a positive impact on the regional economy. Of course, in a global scenario, the major contributors to carbon footprint relevance to food waste are those occurring from cereals (34%) followed by livestock-derived products (33%) (FAO, 2013). Besides, recent estimates from the EU have indicated that nearly 70% of food waste comes from the household, food services, and retail sectors, while the production and processing sectors contribute 30% (FUSIONS, 2016). According to FAO (2020), about 14% of the total food production is lost between harvesting and the retail market. Besides, as per the United Nations Environment Programme's (UNEP) Food Waste Index Report 2021, ~17% of global food production goes to waste with nearly 61% contributed from the household, 26% from food services, and 13% from the retail sector. One of the goals set by the EU Commission is to gain success in efficient resource management and lower the carbon footprint (low carbon economy) by 2050 and aim for the success of the green economy concept. In this regard, the concept of circular economy is one of the much-acclaimed notions of recent years. One of the key features on which the concept of the circular economy relies is resource recovery with maximal utilization of agri-food industrial wastes and by-products. In short, the principle of circular economy aims to shorten the gap between production and the natural ecosystem cycle, while in a linear economy the basic raw materials which are transformed into a final, desired product are disposed of. The EU platform dealing with food loss and food waste has been working closely with academic institutions, government and private sectors, industry personnel, and other public stakeholders with a focus towards supporting and redefining appropriate measures directed at reduction of food waste, which is also addressed as a fragment of the farm-to-fork strategy (EU Commission, 2020a, 2020b). Technological innovations have been focused on meeting the requirements and demands of local food industries, stakeholders, government, and other key players. Besides, there is a wide range of challenges sustained to tackling food loss and waste in the circular economy context. Developing appropriate business models and policy formulations and accomplishing various socio-economic needs of society can significantly contribute to the success of the circular economy. It is a well-acclaimed fact that a circular economy can contribute to the management of waste generation to optimal levels and thereby significantly contributing to sustainable economic gains. On the other note, the concept of bioeconomy focuses more on utilizing bio-resources or adopting various types of bioprocess technologies to produce novel value-added products that can have potential applications in food, pharmaceuticals, health, cosmetics, and other industries. Further, the main focus of the bioeconomy relies on identifying various growth opportunities in bio-based sectors, all with a sustainable approach.

In the food industries, both solid and liquid wastes lead to environmental pollution, and proposing any novel concepts to lower the environmental footprint can be real value addition. Hence, sustainable utilization and recovery of valuable compounds from food industrial wastes and by-products (with a biorefinery approach) assumes prime importance in the current global scenario. Adoption of biorefinery platforms would allow producing value-added products such as biofuels, bio-fertilizers, useful chemicals bioplastics, and much more while reducing the accumulation of huge volumes of waste. These can be beneficial for producers, industrialists, as well as the environment (de Paula et al., 2018; Russo et al., 2019). In this view, the present chapter proposes various sustainable approaches that can be adopted to ensure efficient valorization of wastes/by-products in the entire agri-food supply chain, and in the context of circular economy. In the context of the United Nations sustainable development goals (SDGs), this chapter theme addresses predominantly SDG 12 (Responsible Consumption and Production). Vital features that will be covered in this chapter will revolve around proposing innovative means for minimizing the food loss and wastes at the "on-farm" and "off-farm" levels, with a comparison drawn between developed and developing economies. Besides, prospects of effective valorization of wastes and/or by-products mainly obtained from the fruits, vegetables, dairy, and meat-processing industries will be deliberated in detail.

2 Waste and Loss at the "On-Farm" Level and Possible Drives

Food loss and waste have been considered as a matter of inadequate allocation of administration, legislation, and distribution of resources. As per the Food and Agriculture Organization (FAO), every year nearly 1.3 billion tons of edible food are wasted globally, which could have easily fed three billion people (http://www.fao.org/food-loss-and-food-waste/flw-data, access date: 24 March 2021). Food loss and wastes amount to US$680 billion in industrialized nations and US$310 billion in developing countries (https://www.unep.org/thinkeatsave/get-informed/worldwide-food-waste; access date: 24 March 2021). In the European Union (EU) alone, 88 million tons of food waste are generated every year. Food waste conceals significant economic costs, estimated to be around €143 billion in the EU (Fusions, 2016). Until the present day, the major part of the reported food wastes and losses occur at the post-farm gate, while comparatively little attention has been paid to pre-farm gate (on-farm) losses. Significant amounts of edible produce are lost at the on-farm level, especially those of fresh produce. In the EU and other regions, the percentage of loss can reach 1even as much as 0–50% of total production due to bottlenecks and peculiarities of the production system. The most common factors affecting the formation of wastes and losses are unfavorable climatic conditions, inefficient agricultural practices, difficulties with contracting, lack of relevant knowledge, and thus deficient reporting (categorizing) of such losses. Especially in developing countries, the extent of such losses is the lack of information, as being often difficult to measure and due to some figurative losses derived from reduced yield as a consequence of inefficient farming practices. There is a significant gap in establishing clear definitions of "food losses" at the farm level, and a need to conceptualize and employ systems that would help to measure and monitor these properly and continuously. According to the Waste Framework Directive 2008/98/EC, Article 3, "waste" means any substance or object which the holder discards or intends to discard. The entirety of a food product is classified as food, including those parts not intended to be eaten. Importantly, the definition of food excludes pre-harvest produce. Mainly, the discrepancy in the "on-farm food waste" can be attributed to the geographical and contextual differences depending largely on the previously mentioned factors. On one hand, the technologies and knowledge may not be consistent and inaccessible to all farmers around the globe. On the other hand, the technologies and knowledge without a willingness to do something differently from usual or going the "new way" can be worthless.

According to the FAO (http://www.fao.org/3/mb060e/mb060e02.pdf, access date; 13 September 2021) in medium- and high-income-generating countries, edible foods intended for human consumption are wasted by throwing them away. Wastage of food by consumers in Europe and North America is 95–115 kg/year, while in South/Southeast Asia and sub-Saharan Africa, it is meager at 6–11 kg/year. Besides, it has been observed that food loss in high-income-generating countries (industrialized countries) is much higher when compared to developing countries. In developing countries, nearly 40% of the loss occurs during post-harvest and processing levels, while in industrialized regions, nearly 40% of the loss occurs at the retail and consumer levels. The economic loss incurred (at the consumer level) on food wastes in industrialized regions is ~222 million tons, which is considered to be equivalent to 230 million tons, the total net food production in sub-Saharan Africa. According to the UN Environment Programme (https://www.unep.org/thinkeatsave/get-informed/worldwide-food-waste, access date; 13 September 2021), in developing countries, food wastes occurring during the early stages of the supply value chain are linked directly with the finance and technical constraints related to harvesting and storage techniques. Hence, it has been opined that strengthening the supply chain is vital that can be ensured by the support of the farming community, improving the infrastructure, transportation facilities as well as food packaging can significantly reduce the amounts of food loss/food waste. Further, in medium- and high-income-generating countries, food waste and food loss occur during later stages of the supply chain. Apart from this, consumers behavior plays a significant role in industrialized countries. Creating awareness among consumers, industrial personnel, and retailers can be helpful to minimize food losses and waste.

The Food and Agriculture Organization of the UN (FAO, 2019) has empirically considered food losses occurring along the food supply chain starting from harvest/slaughter/catch, ending with retail, while waste is starting from the retail up to the consumption level. Moreover, in terms of economic value, around 14% of food produced globally is lost during the post-harvest stages. The same document claims that, for example, the observations on fruits and vegetables made in sub-Saharan Africa report a very broad range of on-farm losses. This is due to the vast differences in reasons of socio-economic and distribution of resources in rural food-producing areas, and because of the backwardness of the agricultural development in both, machinery and knowledge. The levels of losses have been described to be higher for fruits and vegetables when compared to cereals and pulses due to the differences in conditions for post-harvest handling, storage, and shelf-life of specific produce (http://www.fao.org/3/ca6030en/ca6030en.pdf, accessed date: 24 March 2021; https://www.actioncontrelafaim.org/wp-content/uploads/2018/01/technical_paper_phl__.pdf, accessed date: 24 March 2021).

Food waste highlights the inequity of different parts of the food chain. The "vicious circle" has taken the lead as retailers minimize risk by demanding persistent volumes of perfect produce, and producers, in turn, minimize their financial risks by withholding "imperfect" (odd-shaped, malformed, etc.) and surplus food. However, these patterns are gradually changing hand-in-hand with the increase in consumers' awareness regarding waste disposal and its impacts on the environment, health, and global sustainability. When throwing edible foods away, it means the misapplication and disproportionate occurrence concerning the use of energy, labor, water, land, capital, and all the other inputs that were needed for food production and distribution. It has a clear effect on the income of the farmers and producers, including the costs of leaving the produce unharvested. Moreover, food waste is an important major indirect cause of biodiversity loss due to uneaten, wasted food in conjugation with inefficient agriculture practices and agricultural expansion into wild areas (e.g., deforestation), as well as unsustainable fishing and aquaculture, which possess an important economic impact worldwide. At the same time, the decay of food products is a source of methane, which can defeat the attempts to improve the sustainability of the food chain from farm to fork.

However, as indicated earlier, there is no such thing as waste in the context of circular economy, because waste is turned into a new source of resources, which should possibly give a newly added value product irrespective of the field of the subject. The employment of "digital agriculture" has increased the importance and usage of precision farming methods, which results in minimizing losses at very early stages, though it is still not applicable and reachable in every single part of the world. The inedible plant parts could be collected and turned into bioplastics, animal feed, or to obtain any other value-added products that allow for the recycling and reuse of the valuable biomass/feedstock (Ben-Othman et al., 2020; Hussain et al., 2020; Jõgi & Bhat, 2020; Malenica & Bhat, 2020; Usmani et al., 2020a).

3 Fruits and Vegetable Wastes and By-Products Management—Innovations and Opportunities

Fruits and vegetables, an essential part of human nutrition, is a significant source of valuable bio-functional nutrients (Coman et al., 2019). Fruits and vegetable-dependent industries generate huge amounts of biodegradable wastes and by-products during various stages such as pre- and post-harvest levels, storage, processing, transportation and distribution, and retail outlets up to consumption (http://www.fao.org/3/a-i3901e.pdf; accessed on 31 January 2021). Fruit and vegetable wastes (FVW) can also be generated before reaching consumers and this might be due to customized overproduction and non-fulfillment of retailer quality requirements. The generation of a huge volume of FVW can pose serious environmental issues because of its high biodegradability and incurring economic loss for industries, which need to adopt safe disposal procedures (Plazzotta et al., 2017).

However, on the other note, food industrial wastes and by-products can be high priced materials. FVW encompasses highly valued bioactive compounds such as vitamins, minerals, dietary fiber, and other bioactive ingredients (polyphenols, carotenoids, anthocyanin, etc.) (Hussain et al., 2020; Sharma et al., 2021). Recent studies on the recovery of these value-added bio-functional components from FVW have gained high consideration, mostly owing to their beneficial role on human health (Coman et al., 2019).

FVW can be a good bio-based resource that holds high scope to be re-utilized in various industrial applications such as food, bio-energy, pharmaceuticals, cosmetics, and in livestock feed industries (FAO, 2014; Ghosh et al., 2016; Sagar et al., 2018). FVW is an extensively researched substrate explored for the extraction of various kinds of bioactive nutrients as shown in Table 1. FVW valorization strategies have been successfully explored to obtain antioxidants, polyphenols, and pigments such as carotenoids, chlorophyll, anthocyanin, and betalains (Rodriguez-Amaya, 2016; Usmani et al., 2020b) which can be of use during the development of functional foods. Among a wide range of fruit wastes explored, an industrial by-product of citrus (peel wastes) is one of the highest explored commodities to obtain pectin, flavonoids (hesperidin), carotenoids, essential oils, etc. (Chedea et al., 2010; Farhat et al., 2011; Masmoudi et al., 2008). FVW is also reported to be a good source of valuable polysaccharides and dietary fiber and has been extracted from orange peel, apple pomace, carrot peels, etc. Pectin has been used as a gelling agent in various food formulations such as jams, jellies, and confectionery (Christiaens et al., 2015; Perussello et al., 2017), while dietary fiber provides rich benefits to human-gut health (Hussain et al., 2020). Essential oils from citrus peel waste and grape seeds have been exploited as flavoring agents (Plazzotta & Manzocco, 2019) which can be used as an added ingredient in various food formulations. Besides, extracts of FVW have also been reported to exhibit anti-inflammatory anti-microbial activities, which can find pharmaceutical and cosmeceutical applications (Boukroufa et al., 2015; Plazzotta & Manzocco, 2019; Plazzotta et al., 2017).

Table 1 A general overview of some factors and reasons for on-farm food waste/loss

Factors affecting on-farm losses	Reason of the loss
Categorisation of loss/waste	Lack of relevant knowledge/means/incentives for categorizing, difficult to measure, lack of knowledge in the on-farm communication, time-consuming bureaucracy
Unfavourable climatic and/or growing conditions	Natural calamities like flooding, drought, hurricane, wind as well as soil erosion, occurrence of new disease or pests attack, unpredictability and uncertainty
Inefficient agricultural practices	Lack of relevant knowledge, outdated equipments, lack of resources, financial crisis, labour problems
Difficulties with contracting	Small amounts of produce, quality issues, rapid changes in the market and consumer demands
Sensitivity of the crops produced	Rapidly deteriorable produce (e.g. leafy greens, soft/fresh fruits and vegetables)

3.1 Valorization of FVW

Distinctive approaches can be effectively applied for recycling, reuse, and recovery of valuable bioactive components from FVW. Management can be achieved by controlling losses throughout the supply chain from farm to fork. Due to high moisture content, FVW are easily perishable, which leads to microbiological contamination and environmental pollution (Banerjee et al., 2017; Bas-Bellver et al., 2020; Coman et al., 2019; Pham Van et al., 2018; Plazzotta et al., 2017). Therefore, current disposal methods of FVW include landfilling and disposing of them in water bodies, and this needs to be replaced by waste management strategies. Besides, the use of FVW as a valuable source of bio-energy to produce biofuel, biogas, biohydrogen, and ethanol through biotechnological applications has been quite successful. Extracted bioactive compounds from FVW can be used for the development of novel functional and nutraceutical-based food products and as animal feed.

Some of the well-researched strategies include composting an individual or a mixture of FVW; processing FVW and industrial by-products into value-added flour that can be supplemented with normal wheat flour in bakery-based products; extraction of bioactive compounds (via the use of conventional or innovative extraction methods such as supercritical CO_2, ultrasound, microwave, pulsed electric field, high pressure, etc.); isolation of essential oils with established bioactivity for food, pharmaceutical, and cosmetic applications; extraction of structuring agents (fiber, cellulose, cellulose fibers, lignin); and the extraction of natural pigments (carotenoids, anthocyanin, betalains, chlorophyll) (Bustamante et al., 2016; Choi et al., 2015; Elain et al., 2016; Górnaś & Rudzińska, 2016; Roversi et al., 2016; Sharma et al., 2021). Besides, the conversion of FVW into biogas using anaerobic digestion and biofuel production has also been a success story (El Mekawy et al., 2015; Lin et al., 2013; Shen et al., 2013). The extraction of bio-functional ingredients from FVW remains one of the best strategies studied in recent years is depicted in Fig. 1.

3.2 *Innovations and Opportunities to Manage FVW*

Concerning food applications, various models have been proposed. Coman et al. (2019) have described two approaches for the use of FVW and their utilization in food formulations: (a) direct incorporation of FVW waste/by-products into an existing food product and (b) incorporation of bioactive compounds after extraction and then purification from FVW. However, the incorporation of bioactive nutrients into food products encounters several confronts and this can be dependent on extraction and purification steps, cost-effectiveness, use of green extraction techniques, and solvents. Besides, other challenges include the production of low amounts of bioactive compounds after processing huge biomass, non-confirmation of cent percent recovery of bioactive compounds, structural deformation in bioactive compounds, and much more (Coman et al., 2019; Sagar et al., 2018).

Adopting stable and rational strategies aimed towards generating zero FVW, recycling, and reusing them can support the circular economy strategies as well as can contribute positively to the environment. Nevertheless, life cycle assessment and understanding waste management hierarchy (*Reduce, Reuse, Recycle,* and *Recovery*) presume high importance (Clemente et al., 2015; Demirbas, 2011; Galanakis, 2012; Ghosh et al., 2016; San Martin et al., 2016; Schneider, 2013).

3.3 *Food Industrial Wastes as a Raw Material to Produce Bioplastics*

Global plastic production has reached its highest in recent years (359 million tons in 2018) (Plastic Europe, 2020). Currently, bioplastics represent less than 1% of all plastic materials produced globally (European Bioplastics, 2020). The global production capacity of bio-based plastics has been forecasted to attain 3.45 million metric tons by 2020. Starch-based plastics, polyhydroxyalkanoates (PHA), bio-based polyesters, and bio-based epoxy resins are foreseen to be major bio-based plastics of the future (Shen et al., 2010). The main source for plastic production is mainly fossil based, but due to rising consumer consciousness, environmental awareness, and administrative pressure towards adopting the circular economy model, alternative bio-based sources for plastic production are being considered. Rooted dependence on fossil fuels (coupled with unstable oil prices), currently used technologies, and existing infrastructure make petroleum the best economically feasible choice for plastic production (de Paula et al., 2018; Norgren & Edlund, 2014). Currently, the

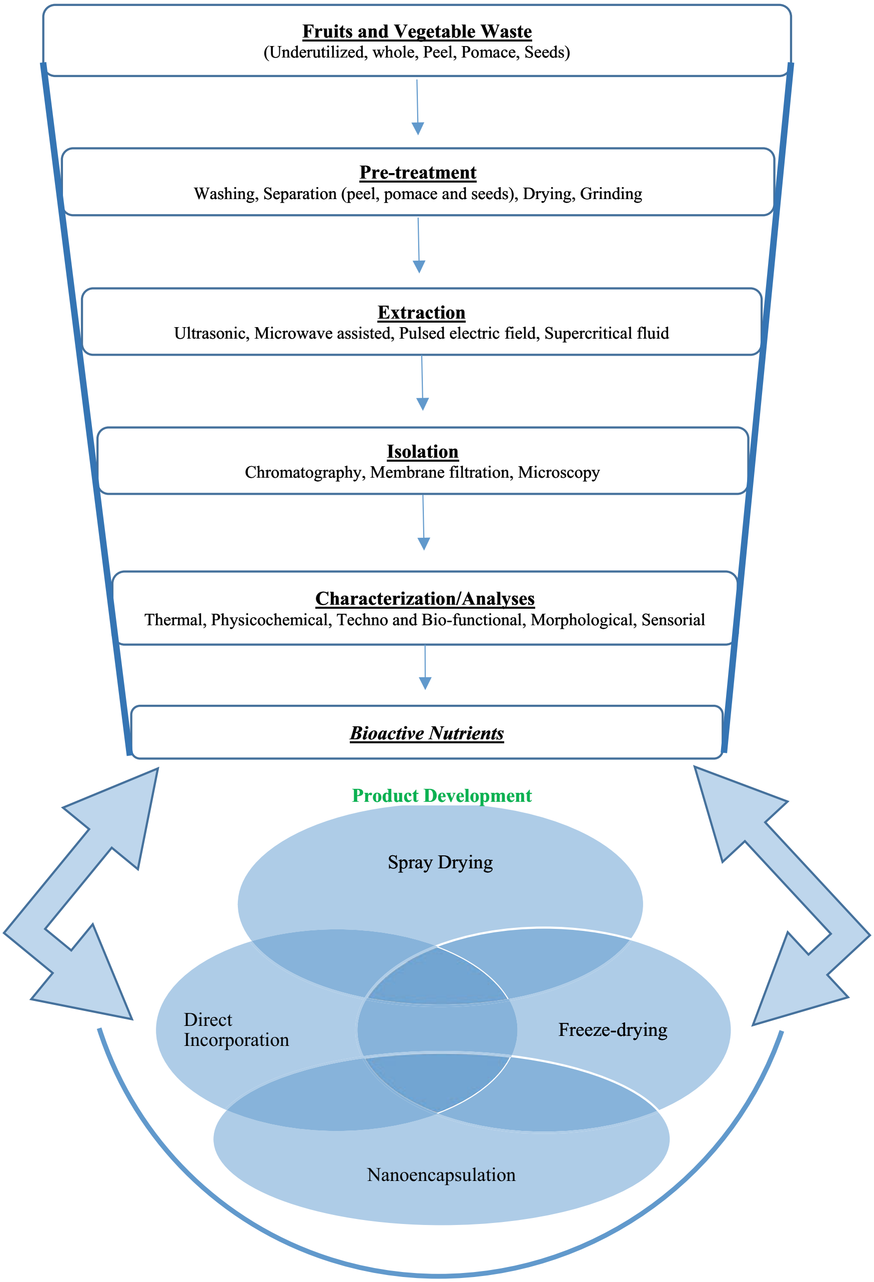

Fig. 1 Strategies for Fruit and vegetable waste (and by-products) management and valorization

industrial expenses for bioplastic production are much higher than that of petroleum-derived plastics. Of course, industrial production of bioplastics such as PHA is estimated to be 5–10 times more expensive than that of petrochemical-derived polymers (Tsang et al., 2019). When considering raw material costs, studies on energy analysis of bioplastic processing have shown that processing bioplastic and conventional petrochemical materials in injection molding processes results in similar energy demand (Schulze et al., 2017). In the majority of the instances under industrial conditions, bioplastics are biodegradable and compostable (Knorr et al., 2017). To elevate the cost-effectiveness of bioplastics, different methods have been proposed to reduce production costs. One option would be the use of agri-food wastes as raw materials for bioplastic production (Jõgi & Bhat, 2020). Some examples of the production of bioplastics from agricultural wastes include PHA production via microbial fermentation of wheat straw, sugarcane molasses, rapeseed meal, wheat bran, etc. (Bengtsson et al., 2010; Cesário et al., 2014a, 2014b; Colombo et al., 2016; Jõgi & Bhat, 2020; Zahari et al., 2015). Bioplastics have been also synthesized from parsley stem, spinach stem wastes, cocoa pod husks, rice hulls, etc. (Bayer et al., 2014).

The economic viability of bio-based products linked with a circular economy can be highly dependent on the facilities that integrate biomass conversion processes based on industrial demands to derive value-added products. Growing usage of renewable resources for producing bioplastics will not only help in transitioning towards the circular economy but will also have a positive environmental impact such as lowering greenhouse gas emissions, reducing landfills by non-biodegradable plastics, and thereby conserving natural ecosystems along with promoting investments and thus contributing for economic gains.

3.4 Food Industrial Wastes as Food and Feed

Keeping in mind the circular economy and bioeconomy concepts, the production of novel food and feed using agri-food-based industry wastes and by-products can be economically beneficial mainly owed to the low cost of raw materials (Malenica & Bhat, 2020; Yitbarek, 2019). The present days' food and feed production is already being challenged, especially in low- and middle-income countries with the major influencing factors being the shortage of fertile land, water scarcity, climate changes, increased price of food and feed materials, food-fuel-feed competition, rapid urbanization, industrialization, etc. (Achilonu et al., 2018; Bakshi et al., 2016; Halmemies-Beauchet-Filleau et al., 2018; Mirzaei-Aghsaghali & Maheri-Sis, 2008; Tayengwa & Mapiye, 2018; Valdez-Arjona & Ramírez-Mella, 2019).

The utilization of fruits and vegetable wastes (FVW) has been extensively studied by researchers, and as indicated earlier, FVW represents a highly underexploited resource of valuable bioactive compounds/phytonutrients (Coman et al., 2019; Zhu et al., 2019). FVW is well recognized to exhibit potential bioactivities (anti-inflammatory, anti-microbial, anti-mutagenic, cardioprotective activities, etc.)

(Achilonu et al., 2018; Correddu et al., 2020; Sagar et al., 2018; Skinner et al., 2018; Valdez-Arjona & Ramírez-Mella, 2019). This renders them a valuable, cheap source of raw material to be explored in food and feed applications. FVW can be processed into flour and used as a raw material for the development of novel functional food products. It can also be used for the production of natural food additives and natural food colorants. The extracts can also find application as a natural preservative, texturizing agents, emulsifier, bulking, and firming agent (Donno et al., 2018; Faustino et al., 2019; Gengatharan et al., 2015; Kowalska et al., 2017; Majerska et al., 2019). FVW has been explored for producing alcoholic beverages, vinegar, herbal tea, jellies, jam, juices, as well as to enhance the shelf-life of dairy and meat products (Benvenutti et al., 2019; Chakraborty et al., 2018; de Azevedo et al., 2018; Madhav & Pushpalatha, 2006; Majerska et al., 2019; Saraç & Dogan, 2016; Singh et al., 2009; Way et al., 2019) (Tables 2 and 3).

When it comes to the production of animal feeds, FVW has been explored for mainly ruminants, poultry, swine, and aqueous feeds. These can be added to animal feed as one of the main ingredients (directly) or as dietary supplements to reach a certain purpose or as a part of multifunctional ingredient (Kasapidou et al., 2015). Some of the FVW, owing to high protein content, can be added as fresh/fed directly, for example, cabbage waste, baby corn husk, empty pea pods, and pea vines (Bakshi et al., 2016). Regarding ruminant feed, pumpkin wastes have been considered as a potential feed resource, which has good nutritional value, and this was observed to enhance the milk production and meat composition in ruminants (Valdez-Arjona & Ramírez-Mella, 2019).

Concerning ruminants, apple pomace has been successfully incorporated into the diet of ruminants and is believed to help in silage fermentation and enhance ruminants' productivity (Fang et al., 2016). Dried citrus peel is often added to ruminants' diets to replace cereal substrates (Wadhwa & Bakshi, 2013). Banana peel has also been explored as a ruminant feed substitution owing to its high protein, fiber, and mineral compositions (Hassan et al., 2018). Pomace obtained from sea buckthorn, grape, and rapeseed has also been considered as a supplement to the ruminant diet (Hao et al., 2018; Manso et al., 2016; Musayeva et al., 2016).

Regarding poultry feed, apple pomace has been proven to enhance the productivity and performance of chicken (Aghili et al., 2019). Banana peels when included in the poultry diet showed improved growth, development, and reproduction in chickens and provided additional energy (Achilonu et al., 2018). There have also been studies involving the addition of grape pomace in the chicken diet (Aditya et al., 2018; Kara & Güçlü, 2012). Pumpkin waste is often used as poultry feed and is opined to prevent degenerative diseases and oxidative stress (Achilonu et al., 2018). The utilization of tomato pomace in the poultry diet is reported to improve the color of egg yolk (Yitbarek, 2019). Sea buckthorn pomace is also being added to poultry feed and a positive effect on chicken performance has been shown (Mushtaq et al., 2017; Orczewska-Dudek et al., 2018).

Regarding other monogastric animals, in the diet of pigs: banana peels, dried citrus pulp, mango peels, apple pomace, sea buckthorn pomace pumpkin waste, and tomato pomace have been successfully incorporated with no adverse effects observed

Table 2 Some examples of valorization of fruits and vegetable wastes/by-products for the recovery of bioactive compounds

Waste sources	Bioactive compounds	References
Apple pomace	Pectin	Wang et al. (2007)
Apple seeds	Phenolic compounds	Gunes et al. (2019)
Acerola (*Malpighia glabra* L.) peels	Anthocyanins, phenolics, vitamin C	Sancho et al. (2015)
Apricot kernel	Protein	Sharma et al. (2010)
Avocado peel	Polyphenols, Dietary fibre	Rotta et al. (2016), Tremocoldi et al. (2018)
Avocado seeds	Polyphenols, Procyanidins, Flavonoids	López-Cobo et al. (2016), Saavedra et al. (2017), Tremocoldi et al. (2018)
Beetroot pomace	Betalains Polyphenols, vitamins, dietary fibre, flavonoids	Čanadanović-Brunet et al. (2011), Kushwaha et al. (2018), Saponjac et al. (2016), Vulić et al. (2014)
Carrot wastes, carrot peel and powder	Polyphenols Carotenes Carotenoids	Clementz et al. (2019), Encalada et al. (2019), Nguyen and Scarlett (2016), Vodnar et al. (2017)
Garlic husk	Phenolic acids and dietary fibre	Chhouk et al. (2017), Kallel et al. (2014)
Grape skin	Phenols	Pinelo et al. (2006)
Gooseberry peels, Guava peel and pulp	Polyphenolic compounds, melanin, dietary fibre	Chitturi et al. (2013)
Lemon by-products	Pectin	Masmoudi et al. (2008)
Litchi pericarp	Phenolics flavonoids, anthocyanins	Jiang et al. (2013)
Mango peel	Phenolic compounds Polyphenols, Flavonoids, Carotenoids	Garcia-Mendoza et al. (2015), Sáyago-Ayerdi et al. (2019)
Orange peel	Carotenoids	Chedea et al. (2010)
	Limonene	Farhat et al. (2011)
Tomato pomace	Lycopene	Lavecchia and Zuorro (2008)
Tomato skin	Carotenoids	Strati and Oreopoulou (2011)

(Bakshi et al., 2016; Fang et al., 2016; Nuernberg et al., 2015). Carrot flakes and dehydrated carrots are often given to horses as treats (Bakshi et al., 2016). The diet of a rabbit has been supplemented by some of the FVW including bilberry pomace, tomato pomace, and carrot pomace (Dabbou et al., 2019; Grioui et al., 2019). It is evident from these reports that food industrial wastes and by-products, mainly those of FVW, are valuable raw materials that can be used for developing food and feed, thus supporting reuse and recovery theory.

Table 3 Valorization of dairy wastes/by-products to obtain valuable bio-functional ingredients

Dairy waste/by-products	Target ingredients	Potential applications	References
Whey	Whey powder, whey protein concentrate, whey protein isolate	Food emulsifyer, foaming agent, water binding and gelling agent abilities; Also useful in edible film coatings	Ramos et al. (2012), Yadav et al. (2015)
Whey	Lactose	Milk sugar, further can be utilized for lactic acid production and various oligosaccharides	Audic et al. (2003)
Whey	β-Lactoglobulin and α-Lactalbumin	Emulsifying and gelling agent, Carrier for fat-soluble vitamins and lipids, Regulator of serotonin, lipid oxidation, Antimicrobial activity and immunomodulatory agent	De Wit (1990)
Whey	Bovine serum albumin	Carrier for fatty acids	Korhonen (2009)
Whey	Immunoglobulins	Antimicrobial activity, anti-toxin and antiviruses agents; Milk replacers in infant milk formulations	Mohanty et al. (2016)
Whey	Lactoferrin and lactoperoxidases	Antimicrobial and antifungal agent	Hernández-Ledesma et al. (2011)
Whey	Bioactive proteins	Ingredients used in feed and pet food formulation; Antimicrobial agents	Mohanty et al. (2016)
Whey	Biopolymers (exopolysaccharides)	Food viscosant and gelling agent	Prazeres et al. (2012)
Whey	Enzymes (e.g., lipase, α-amylase)	Adjuvant in biotechnological applications	Yadav et al. (2015)
Whey	Lactic acid	Various biotechnological applications	Panesar et al. (2007)
Whey	B-lactoglobulin+	They can bind iron by siderophores Antipathogenic activity	Wihodo and Moraru (2013)

(continued)

Table 3 (continued)

Dairy waste/by-products	Target ingredients	Potential applications	References
Whey and by/products	Lactose	For ethanol production using wild lactose-fermenting yeasts	Guimarães et al. (2010)

On the other note, due to high nutritional values, dairy by-products such as whey can be utilized in food and feed formulations, as film-forming agents to develop edible film packaging (Plazzotta & Manzocco, 2019). Casein waste obtained during the purification processing of milk proteins can also be utilized in the formation of bioplastics, edible films, adhesives, coating and emulsifying agents, etc. (Ryder et al., 2017).

With this available information in the database, it is evident that food industrial wastes and by-products can be explored to produce value-added human food and animal feeds, thus supporting the circular bioeconomy concepts. However, future studies are warranted to ensure that overall safety and quality issues are regulated as per international norms.

4 Conclusions and Outlook

One of the major challenges witnessed in the global food industry is adopting a reliable and cost-effective sustainable management strategy to tackle food wastes and by-products generated post-processing. Circular management strategies coupled with pre-ordained progress in innovative techniques, aimed toward wastes and by-products transformation, can lead to significant outcomes and can have an impact on the regional economy. Developing "zero waste" models based on novel food-processing technologies can contribute to the success of sustainable food waste management. Depending on the raw material types (plant- or animal-based wastes and by-products), there is ample scope to effectively valorize the food wastes. In this regard, valorization of fruit and vegetable wastes and by-products not only represents and opens up wide opportunities for developing sustainable feed and food systems but can also contribute to regional food security as well as circular economy. Besides this, the dairy waste utilization arena is also expected to be worth exploring to exploit the bio-functionalities also worth exploring for its potential applications in food and pharma industry.

The coming decades will recognize the adoption of 'state-of-the-art' research methodologies that are set within the background of embracing some of the emerging trends of innovative green processing and extraction techniques. These are expected to be aimed toward the conversion of industrial wastes and by-products to produce value-added compounds, renewable resource materials, biofuel, and chemicals—all with a biorefinery approach. Given the current global situation which is facing the ongoing growth of the population, the COVID-19 pandemic, scarcity of fertile land, and much more sustainability challenges, consequently, it is expected that there might be an increased demand for food and feed. Hence, the need to look for opportunities to explore sustainable food and feed materials arises. Fortification and development of novel food and livestock feed via the use of industrial wastes and by-products (mainly those of fruit and vegetables) will open up a new arena of research activities that can benefit the regional bioeconomy. Though developing novel food and livestock feed pose good opportunities, safety regulations need to be carefully monitored to gain much-anticipated success. Scientific and technological innovation strategies can be expected to promote new business setups based on waste and by-product valorization. Nevertheless, once the recurring challenges of heterogeneity of wastes and by-product composition are overcome, the enormous potential is there to transform food industrial wastes and by-products into value-added compounds which are of low cost, safe, economically feasible, and environmentally friendly. So conclusively, it is opined that tackling food loss and wastes coupled with valorization technologies and a green approach can provide plenty of opportunities and stability aimed towards realizing the success of a circular bioeconomy.

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Climate Change and Agroecosystems in the Hill and Mountain Regions of Northeast India

Chubamenla Jamir, Charvi Kapoor, and Pratyaya Jagannath

1 Introduction

The North Eastern Region (NER) of India comprises of the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, covering a total area of 255,168 kms. The region, part of the Eastern Himalayas, is one of the most biodiversity dense regions in the world but is also witnessing very high rate of species loss. Although it occupies only about 8% of India's total land area and 3.8% of the population (Census of India, 2011), it is home to about 37% of the cultivated crop types of India. The region is being considered as the origin of 20 major agricultural and horticultural crops, signifying the rich biodiversity listed 160 domesticated and 355 wild cultivars of different crop types found in the region (Upadhayay & Sundriyal, 1998). The traditional shifting cultivation (locally called *Jhum*) is the predominant form of agroecosystem in the hills and mountainous terrain of the region. The main crop is rice, occupying more than 60% of the cropping area. In fact, in certain states like Nagaland and Mizoram, *Jhum* rice comprises of more than 75% of the cropping area and it is mostly grown during the monsoon season. Therefore, agriculture in the region has high dependence on monsoon precipitation.

The developing countries are highly vulnerable to climate change due to high dependency on climate sensitive livelihoods such as rainfed agriculture, water, and forestry (Moorhead, 2009). Further, even in highly vulnerable countries, there is differential vulnerability to climate change and that the marginalized communities having limited resources and low capacity to adapt or cope with climate risks are most adversely affected by climate change.

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Several studies have reported significant climate change in the NER of India; erratic rainfall; increasing occurrences of seasonal drought and flood; and frequent delays in the monsoon (Choudhury et al., 2019). This is critical as the agriculture and allied sector that supports livelihood for 70% of the region's population (Feroze et al., 2010) is dominantly rainfed; the area has high rural population concentration from 50 to 80% who are largely dependent on agriculture, forest and natural resources for livelihood (Choudhury & Sundriyal, 2003). This coupled with difficult mountainous terrain, low infrastructure and low coping capacity makes the NER highly vulnerable to climate change (Ravindranath et al., 2011; Sharma et al., 2009). Over 60% of the cropped area is under rainfed agriculture in the region and therefore the agroecosystems are highly vulnerable to climate variability and climate change. Further, increase in heavy rainfall has led to landslides and floods during the monsoon season that affects the food supply chain and the market mechanism in the region. A district level vulnerability assessment conducted by Ravindranath et al. (2011) have shown that majority of the districts in North East India are subjected to climate induced vulnerability and is projected to be vulnerable in the near future too. Climate change is therefore an area of concern in the region, especially for the climate sensitive rainfed agriculture; any changes in the monsoon rainfall is likely to have serious implications for agricultural crops.

2 Agroecosystems in NE India

Agriculture sustains on biodiversity, climate, land, water, weather and other environmental and ecosystem resources (Rasul & Kollmair, 2010). Therefore while defining agricultural systems, it is important to understand it in the larger environmental context. Agroecosystem is defined as a functionally and spatially coherent unit of agricultural activity, comprising of both the related biotic and abiotic components and their interactions (Harper, 2020). They are complex systems in which many species interact with various ecological and management processes at varying spatial scales (Loeuille et al., 2013; Bohan et al., 2013; Fig. 1).

The agroecosystems in NE India are influenced by the mostly montane topography of the region. Thus we can broadly divide the agroecosystems in the region into two broad types; (i) upland and (ii) lowland type. The shifting cultivation, locally called as the *Jhum*, is an upland type of agriculture production system that is the predominant type among the farmers of upland communities in this region. Mixed cropping with a fallow period is a characteristic feature of this cultivation. The other types of upland agroecosystems include terraced cultivation, the Aji cultivation system, etc. The wet rice cultivation system is practiced throughout the hilly terrain both at lower and higher elevations. The modified version of wet rice cultivation is practiced by the Apatani tribe of Arunachal Pradesh, locally this cultivation is known as 'Aji'. This 'Aji' system is a combination of rice and fish composed of millet on the bunds with separation in each plot. The Apatani tribes also practice upland dry farming, growing millets, maize and vegetables with jhum cultivation

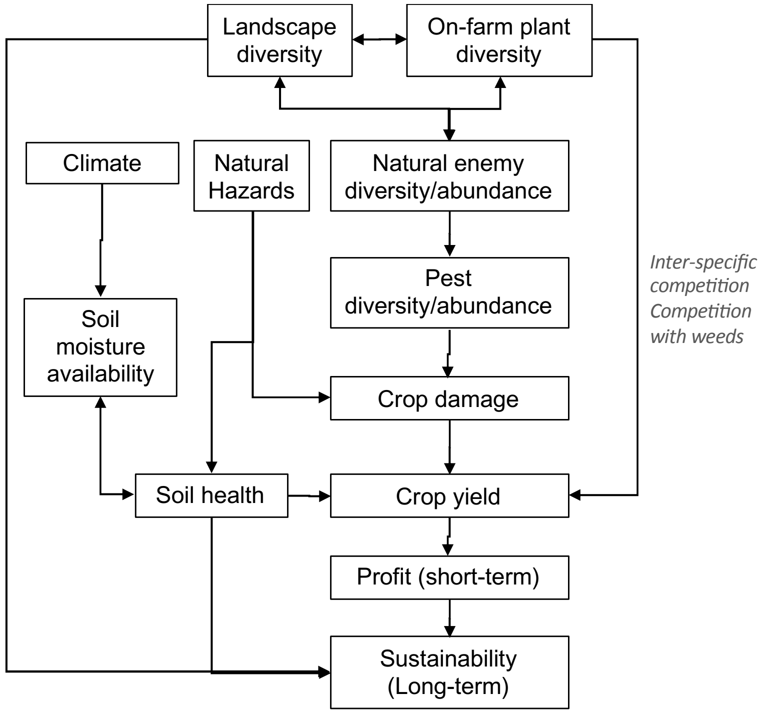

Fig. 1 Relationship between biotic and abiotic components in agroecosystems. Adapted from Bohan et al. (2013)

(Maikhuri & Ramakrishanan, 1990). The Monpas and Sherdukpens of Arunachal Pradesh, plain tribes and communities of Assam, Tripura and Imphal valley also exclusively depends on wet rice cultivation. In the valleys where water is an issue, mono-cropping and mixed cropping of seasonal crops are practiced where seeds are directly spread instead of plantation as in wet rice cultivation system. Terrace cultivation is introduced in the region by the government itself to discourage the practice of jhum cultivation among the farmers. Apart from these major cultivation systems; farmers in the region also practice some secondary forms like home gardens and plantation crop cultivations. This helps the farmers to link their family with the forest ecosystem and include animal husbandry (Majumder et al., 2011).

The degradation of the resource base combined with the increased stresses and uncertainties arising from global warming and the increased melting of ice and snow (the primary source of water for irrigation during the dry season) have posed a serious development and environmental challenge to South Asia (Rasul & Kollmair, 2010). The soils of the NER are rich in organic matter that are suitable for agriculture and climatic conditions conducive for rich vegetation. However, the factors of low cropping intensity, undulating topography, and subsistence farming characterize the agricultural production system. The productivity of agricultural land is much lower

Table 1 Food grain production in NE region

State	Production		Increase 2003 to 2014 (%)	Requirement as per 2014 population ('000 t)	Deficit/surplus (%)
	TE 2001–03 ('000 t)	TE 2012–14 ('000 t)			
Arunachal Pradesh (14,53,124)	234.7	376.4	60.37	256.1	46.97
Assam	3984.0	5409.0	35.77	5773.8	−6.32
Manipur	378.7	628.5	65.96	504.2	24.66
Meghalaya	228.5	278.8	22.04	549.0	−49.21
Mizoram	131.6	80.6	−38.72	202.1	−60.09
Nagaland	384.4	582.7	51.59	366.9	**58.83**
Sikkim	98.4	102.7	4.41	112.6	−8.73
Tripura	579.5	730.4	26.05	680.0	7.42
NE Region	6019.8	8232.8	36.76	8444.7	−2.51

Source Department of Agriculture, GoI 2014
Note TE = Triennium average

than the potential yield due to several factors such as low fertilizer consumption and low irrigated area (11% of the net sown area). Moreover, studies have shown that in this region, 96% of the agricultural implements are traditional. Currently, the region produces only 3.1% of national food grains production and continues to be a net importer of food grains even for its own consumption (Table 1) (Roy et al., 2019). Maintaining agro-biodiversity is essential for agricultural and environmental sustainability and consequently food security in the region (Majumder et al., 2011).

2.1 *Jhum* Cultivation

The entire NE region apart from the state of Sikkim, practice the shifting cultivation (*Jhum*) in many different methods. Initially, the vegetation in a patch of land is cleared by felling of trees, followed by putting the patch on fire and making it suitable for cultivation. Both paddy and maize are cultivated in the patches along with few vegetables. *Jhum* cultivation, being the predominant form of agriculture, continues to be the major land-use type in the region. In the past it has been the focus of culture, traditions and folklore and at present it continues to play a significant role in influencing the livelihood and economy in the region. In recent decades, this system has been criticised for its negative ecological impact and there has been numerous debates on whether this form of land-use be encouraged or abandoned. However, several researchers have documented the benefits of *Jhum* and have suggested that it is the most evolved agroecosystem practices and that these forms of traditional

Table 2 Status of shifting (*Jhum*) cultivation in NE states

States	Annual area under shifting Cultivation (Ha)	Fallow period (years)	Minimum area under Jhum at a given time ('000 Ha)	No. of household ('000)	Jhum landholding (Ha)
Arunachal Pradesh	70,000	3–10	210	54	1.29
Assam	69,600	2–10	139	58	1.20
Manipur	90,000	4–7	360	70	1.29
Meghalaya	53,000	5–7	265	52	1.01
Mizoram	63,000	3–4	189	50	1.26
Nagaland	19,000	5–8	191	116	0.16
Sikkim	NA	NA	NA	NA	NA
Tripura	22,300	5–9	112	43	0.51

Sources 1. Report of the Inter-Ministerial National Task Force on Rehabilitation of Shifting Cultivation Areas, 2008; 2. G.B. Pant Institute of Himalayan Environment and Development, Almora, Uttarakhand

agro-practices are significant for the farmers in the hill regions and highlighted the urgency of incorporating scientific knowledge in their management practices in order to sustain such agroecosystems especially in the face of global environmental change.

All the land under *Jhum* is upland and has a slope. There is no scope for artificial irrigation apart from the precipitation available in the area. Among all the *Jhum* practicing NE states, Nagaland has the maximum number of households (about 116 thousand) following the system (Table 2). However, the land availability is lowest among all the NE states for Nagaland with only 0.16 ha per household. It is interesting to note that inspite of this low per capita availability the presence of strong customary laws and community ownership the equitable distribution of land is ensured in the society. Since in Nagaland, the agriculture is predominantly *Jhum*, with the strong customary laws, clearing of land for equitable distribution results in extensification of agricultural land often leads to reduction in the fallow period from 20–30 years to 3–4 years (Choudhury & Sundriyal, 2003) (Fig. 2).

2.2 Apatani Wet Rice Cultivation (Rice + Fish System)

The Apatani wet rice cultivation is practiced by the local tribe Apatani in the state of Arunachal Pradesh. This is considered as a highly developed valley cultivation system where wet rice is cultivated together with fish (Singh et al., 2012; Rai, 2005). Often finger millets are grown on the bunds separating the plots and at times red algae is used making the terraces appear reddish. This system of cultivation is done to prevent soil erosion and conserve water. Here farmers use indigenous varieties of

Fig. 2 Jhum cultivation in Mokokchung district of Nagaland. Rice inter-cropped with maize. Image taken by the author

rice and fish (Common carp). As with all the hilly terrains, nutrient leaching and top soil erosion is a challenge for sustaining the soil quality. The farmers recycle crop residues and use other organic waste to maintain the soil nutrient and fertility (Dash et al., 2012). This form of agriculture produces good returns for the farmers; Saikia and Das (2008) estimated an economic return of about 65.8% in these integrated rice-fish systems.

2.3 Terraced Agroecosystem

This system is initiated by the local governmental agencies as an attempt to provide bench-terraced land free to local farmers as an alternative to jhum cultivation. The cropping pattern here is similar to jhum, but needs a heavy input of organic and/or inorganic fertilizers. The cropping can be done on the same site for 6 to 8 years, after this, the same site maybe abandoned because of poor soil fertility and weed problems. The loss of soil fertility reduces the effective land area for cropping (Ramakrishna, 1992).

3 Climate Risk to Agriculture in Northeast India

As per the updated Köppen-Geiger climate classification (Beck et al., 2018; Peel et al., 2007), most part of the NER falls under the humid subtropical climate (Cwa) while some parts of the region have mountain/highland (Cwb), tropical wet (Am) and tropical wet and dry climate (Aw). Due to the complexity of the topography and the mountainous terrain, studying climatic characteristics in the mountains is more difficult than in the plains. Albeit there are considerable number of evidences showing NER as highly vulnerable to climate change owing to its geo-ecological fragility, humid monsoon climate, and socio-economic conditions (REF). Most parts of the NER receives large amount of annual rainfall and therefore the vegetation, agriculture and soil are largely influenced by the rainfall pattern in the region. Thus any changes in the rainfall pattern will have high implications on the biodiversity and the agroecosystems in the region. In addition to the rainfall pattern, the climate risk of the region is also influenced by local variables such as elevation, and proximity to water (von Braun, 2020). Most parts of NER are on higher elevations with steep slopes which makes the agriculturally important top soil prone to erosion and the low elevation areas such as the Brahmaputra river plains prone to floods due to run-off from the hills and proximity to the river.

The following sub-sections gives an overview of the key weather and climate risks to agroecosystems in the region and identifies the extreme episodic events that most often threaten agriculture.

3.1 Erratic Rainfall Pattern

The NER receives relatively higher amount of rainfall than the rest of India (Das et al., 2009; Guhathakurta et al., 2011). Long-term analysis of rainfall in the region do not suggest any significant trend for the region as a whole (Choudhury et al., 2012; Jain et al., 2012; Dash et al., 2012). A time-series analysis (1871–2008) of monthly, seasonal and annual rainfall in the NER by Jain et al. (2012) suggested no significant trend but observed some seasonal trends for some seasons and for some hydro-meteorological sub-divisions.

Climate change has contributed to unpredictable or erratic rainfall pattern in the NER (Sharma & Rai, 2012). Year to year variability in monsoon rainfall has been observed in most parts of the region (REF). In addition to the irregularity in the rainfall pattern, there are also reports of changes in the rainfall seasonality with rainfall starting quite early in the region, heavy rainfall events (extreme rainfall), frequent flash floods, and prolonged dry periods (Table 3). For instance, in the year 2005, there were reports of prolonged dry periods with many springs and streams drying up accompanied by large scale landslides in the state of Mizoram (ICIMOD, 2008). During the past decade, the NER has experienced frequent occurrences of extreme climate events which had high deviations from the normal conditions (Table 3). The region also witnessed unseasonal heavy rainfall, delayed onset and early withdrawal of monsoon and severe hailstorms.

Dash et al. (2012) reported a significant decline in moderate and low rainfall days but an increase in heavy rainfall days over NER. The state of Meghalaya receives one of the highest recorded rainfalls not just in the region but globally too. Significant variation in the rainfall pattern has been reported in both the West and East Garo Hills of the state of Meghalaya (SAPCC). This increasing rainfall variability and increase

Table 3 Occurrences of extreme climate events in the past decade in NER (adapted from Saikia & Hazarika, 2020)

Year	Extreme event	Location
2009	One of the most severe drought	Across NER
2012	Most severe floods	Assam, Meghalaya, Arunachal Pradesh, Mizoram
2013	Drought like situations	In many districts across NER
2014	Flood	Assam, Meghalaya
	Drought	Manipur
2015	Unseasonal heavy rainfall (209% higher than normal in February–March)	Arunachal Pradesh
2015–16	Warmest years in 117 years (1910–2016)	Across NER
2016	Delayed onset of Monsoon by 10 days; 49% rainfall deficit	Meghalaya
	Severe flood (July–August)	Assam
2017	Severe floods	Assam, Manipur, Tripura
2018	Severe hailstorm (March)	Meghalaya
	Flood (July)	Nagaland
	Tornado (July)	Nagaon (Assam)
	Deficit rainfall	Arunachal Pradesh, Manipur, Meghalaya
	Very Early withdrawal of Monsoon	Across NER
2019	Delayed arrival of monsoon (5–6 days)	Across NER
	Deficit June rainfall	Sikkim, Nagaland
2020	Unseasonal heavy rainfall (May)	Across NER

in occurrences of extreme rainfall events have led to an increase in the occurrences of floods in the region during the past 20 years (IGSSS). Extreme rainfall events when coupled with deforestation are drivers of flooding events in the region (Jamir et al., 2008; Yadav & Sarma 2013). Future climate projections suggest a decline in the overall rainfall across the region under all the RCP scenarios.

Changes in the rainfall seasonality adversely affected sowing and harvesting of crops and harvestable grains were damaged. Changes in rainfall can affect the crop yield (Lobell & Burke, 2010; Birthal et al., 2014; Kumar et al., 2011) including rice (Saseendran et al., 2000). Further, a study conducted in Meghalaya (Dkhar et al., 2017) has reported that rainfall in June has a significant and positive impact on rice yield while rainfall during the month of August (reproductive stage of the crop) causes yield losses.

Although monsoons exhibit inter-annual variability, this normal variability is affected by climate change. There may not be significant trends observed in long-term time-series data over the region but the inter-annual variability in monsoon rainfall and the occurrence of extreme events have increased along with changes in the seasonality. Monsoon rainfall is shifting towards the post-monsoon period.

The NER is a landslide prone region owing to its geology and steep topography. Extreme rainfall events (including cloud outbursts) will therefore increase the risk of landslides and agriculturally important top soil erosion.

3.2 Droughts

Droughts are often a manifestation of occurrences of prolonged below normal rainfall and increasing atmospheric temperatures. As mentioned in the earlier sections, most available literature on long-term climate trend analysis for NER as a whole have not reported any significant trend in rainfall and temperature regimes (Choudhury et al., 2012; Das & Goswami, 2003; Jain et al., 2012). Albeit significant change in seasonal rainfall and temperature in certain parts (Das & Goswami, 2003; Mirza et al., 1998) and rapid changes for shorter duration has been observed (Jhajharia et al., 2012; Padmakumari et al., 2013). Choudhury et al. (2012) observed a rapid decrease of 355 mm in monsoon rainfall during 1974 to 2014 and attributed these trends to the natural interdecadal variability of monsoon rainfall over the region which are strongly associated with the Pacific Decadal Oscillations (PDO). During the years, 2005 and 2006, several districts in the state of Assam experienced intense drought-like conditions due to below normal monsoon rainfall. This led to crop failure and affected large number of agriculture based livelihoods and huge economic costs to the state. Other states of the region also received rainfall below their normal rainfall during this period. Again, in the year 2013, several districts across the NER experience drought-like conditions (Table 3). Ironically, Meghalaya, one of the rainiest places on earth has been experiencing a decrease in rainfall and increasing occurrences of droughts. During the past decade, deficit rainfall leading to severe droughts has been observed frequently across most parts of the NER (Table 3). Droughts have a significant impact on rice yield (Auffhammer et al., 2011), and thus with the increasing occurrence of drought in NER, rice crops which is the predominant crop in the region will be impacted.

3.3 Floods

Floods are a regular phenomenon especially along the Brahmaputra river plains in Assam and the low-lying west Garo Hills (bordering Assam) causing huge losses to crops, infrastructure, economy and livelihoods (Jamir et al., 2008). The past decade has seen very frequent and some of the most severe floods across different parts of NER (Table 3) even in those places where flood was unheard of. The erratic pattern of floods is an emerging risk in the region, especially for farmers along the Brahmaputra river banks and those in the low-lying areas. Brahmaputra river basin is highly climate vulnerable. Increase in heavy rainfall events in the surrounding hill during monsoon leads to very high run-off and subsequent flooding in the region. Although there are projections for 19.6% decrease in overall flow from the upper Brahmaputra basin in future (Immerzeel et al., 2010) but the downstream river flows are projected to increase in size (Gain et al., 2011). Global climate models (GCMs) indicate increase in discharge in the lower Brahmaputra River as a result of projected increase in precipitation downstream which will subsequently lead to more frequent floods of higher magnitude. The flood magnitude is projected to increase in the states of Tripura, Mizoram, Manipur, parts of Meghalaya and Nagaland while it will decrease in Arunachal Pradesh, Assam, Sikkim and parts of Meghalaya (Chowdhury & Ghosh, 2019).

In the year 2004, there were two extreme cloud outbursts- one in western Arunachal Pradesh and the other in the hills of western Meghalaya which led to two devastating flash floods in Sonitpur and Goalpara districts of Assam, both bordering Arunachal and Meghalaya respectively. There were large number of casualties and damage caused to properties and natural systems. Often several such extreme events go unrecorded due to lack of adequate hydro-meteorological services. Further, there are increases in flash floods in the lower plains of the region due to accelerated glacier melt and glacial lake formation (Aggarwal et al., 2017). The receding glaciers observed in Sikkim have been well documented (Garg et al., 2019) and this increases the risk of lake outburst events and subsequent flooding (Garg et al., 2019). For instance, in June 2007, due to an outburst of a glacial lake in North Sikkim and the flash flood following it, the sea buckthorn (an economically important Nitrogen fixer) along the Lachen Chu was washed away (Sharma & Rai, 2012).

3.4 Temperature

Analysis of long-term surface air temperature data for the NER show an increasing trend in both the maximum temperature ($T_{\max}$) and Minimum temperature ($T_{\min}$) (Choudhury et al., 2012; Dash et al., 2012; Jain et al., 2012; Laskar et al., 2014). The temperature is projected to increase further in the future with projections of 2 °C rise by 2050 (Kumar et al., 2011; Dutta, 2014). Projections based on RegCM3 simulations by Dash et al. (2012) indicates frequent warm event in the region. Out of the four seasons, monsoon season has the least increasing trend, Aggarwal et al. (2017) attributed to the cooling from advection of moisture during the monsoon period. Consistently increasing trends have been observed in both $T_{\max}$ and $T_{\min}$ in the states of Sikkim and Arunachal Pradesh which are on relatively higher altitudes; snow cover on higher altitudes insulates the atmosphere from soil moisture (Zhao et al., 2022) . Future climate projections for the region suggest a rise in temperature across all the region with annual increase in temperature ranging between 0.01 and 0.07 °C across different representative concentration pathways (RCPs) (Kumar & Dimri, 2018). Both $T_{\max}$ and $T_{\min}$ are influenced by different climatic variables (Bhutiyani et al., 2007); cloudiness decreases insolation and surface albedo which impacts $T_{\max}$ but not so much on $T_{\min}$ (Maxino et al., 2008).

4 Impact of Climate Change on Agroecosystems

Climate change may affect agroecosystems in many ways; changing temperatures and CO_2 levels, erratic precipitation, and changes in humidity and soil properties impacts plant growth and development, nutrient cycles, plant-weed interaction, and pest and disease occurrence (Ramesh et al., 2017; Xu et al., 2016; Gurjar et al., 2018). Although elevated CO_2 levels tend to have fertilization effects on agroecosystems, the response depends on the magnitude of these changes, response of individual crop species, and the prevailing environmental conditions. The fertilization effect of elevated CO_2 concentration on plant growth is possible only under optimum environmental conditions. Thus for a better understanding of the climate risks and its impacts on agroecosystems in the region, it is important to consider not just exposure to climate risks but considers other environmental constraints including water resources, pests to agriculture and the feedback mechanisms (Fischer et al., 2002) (Fig. 3).

4.1 *Impact on Crop Productivity*

Climate change has significant adverse effects on production of crops (Haile et al., 2017; Parry et al., 2004) and it is projected to have more severe impacts in the future especially in the Global South (Cline, 2007). Climate extremes related to both temperature and rainfall during the crop growing seasons are of greater risk (Lesk et al., 2016). Weather extremes exacerbate the year-to-year fluctuations of food availability (Haile et al., 2017), and thus may further increase price volatility

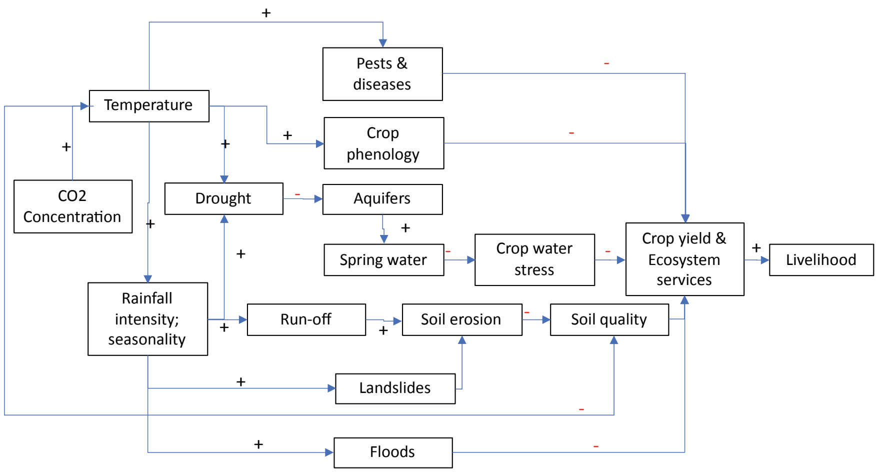

Fig. 3 Impact of climate change on agroecosystems in the Northeast region (NER) of India

with its adverse impacts on food accessibility especially for consumers in the lower income bracket (von Braun, 2020).

The NER is a climate sensitive region owing to the fact that a large section of livelihood is dependent on climate sensitive rainfed agriculture, forest resources and ecosystem services (Sharma et al., 2007; Kumar et al., 2022). The cumulative effect of increasing temperature and declining rainfall has had detrimental implications on the lives of the communities in the region. Climate change induced stresses such as floods, droughts and erratic rainfall and natural hazards such as earthquakes and landslides have caused degradation of ecosystems leading further to stressed agriculture and biodiversity. Evidences of climatic changes can be seen in the form of increasing occurrences of floods, decline in the ground water availability and agricultural productivity (Jhajharia et al., 2009).

Elevated $T_{\max}$ and $T_{\min}$ during rice cultivation period are reported to impact grain-yield in general and rice yield in particular due to reduced growing period (Saseendran et al., 2000; Babel et al., 2011). An increase in $T_{\min}$ has a significant impact on rice yield (Peng et al., 2004; Nagarjan et al., 2010) most likely due to increased respiration losses during the vegetative phase and reduced grain-filling duration and endosperm cell size during the ripening phase (Welch et al., 2010). Elevated $T_{\max}$ shows a negative impact during all growth phases due to reduced photosynthesis caused by chloroplast damage (vegetative phase), spikelet sterility caused by reduced pollen production (reproductive), and increased energy consumption caused by higher respiration demand (ripening) (Wassmann et al., 2009). In rice, a threshold of 35 °C, above which spikelet sterility becomes common under humid conditions (Wassmann et al., 2009; Yoshida et al., 1981). Welsh et al. (2010) reported that $T_{\max}$ do not have negative impacts if the temperature values do not cross this threshold value. There are also reports of shift in sowing and harvesting period of crops and migration of the species which can be attributed to changing temperature trends in the region (Sharma & Rai, 2012).

The production of large cardamom which is a traditional commercial crop in the state of Sikkim has been declining over the past decade (Sharma & Rai, 2012) leading to income loss and impact on livelihood. These findings are in line with local communities' perceptions and experiences that changing climate is negatively impacting the provision of various ecosystem services and their livelihoods (Sharma & Rai, 2012). In the regions with higher elevation, such as in Sikkim and Arunachal Pradesh agriculture still remains a major source of livelihood but the agriculture production is increasingly becoming vulnerable to major climatic hazards such as erratic rainfall, snowfall, and prolonged drought. In Assam where tea is a very important commercial crop, increased average monthly temperature and monsoon rainfall intensity decreased the yield of tea (Duncan et al., 2016; Dutta, 2014).

Kumar et al. (2011) projected for the year 2030 under A1b scenario substantial yield losses in rice, wheat and maize crops which are very important crops in the region. Under elevated temperatures the growing degree days are cumulated faster and therefore the crop duration is reduced resulting in less time for biomass accumulation and subsequently yield reduction. In irrigated conditions where the crops are not under water stress, this negative impact is compensated by the elevated CO_2

concentration, at least till the temperature crosses the optimum threshold. However, such CO_2 fertilization is not effective for rainfed rice. In the case of potato, an increase in the yield was observed under elevated temperature regime. Such cases are likely where the temperature is lower than the optimum conditions for potato crops and therefore the crop will benefit from a slight increase in temperature.

Rainfall variability impacts the production of rainfed crops. In Meghalaya, high intensity storms occur frequently during the beginning (coinciding with paddy transplanting and weeding) and end (harvest time) of the monsoon season. Studies have shown that the crop phenological stage that's most sensitive to adverse impacts from any stress including climate stress is the reproductive phase. In Meghalaya, September is the fruiting and milking stage for rice crops and therefore any high intensity rainfall/ storm will reduce the crop productivity. There are also reports of late arrival of monsoon rain on the germination and growth of seedlings of the rainfed rice in the region (IGSSS, 2016). Hailstorms in the month of March and April in the higher elevations of the NER are also a high risk especially for vegetable production (IGSSS, 2016).

4.2 Impact on Water Resources

A key impact of the rising atmospheric temperature is the impact on glacier volume. Due to global warming the Himalayan glaciers are melting and retreating at an average rate of 15 m per year however, important glaciers such as the Gangotri glacier have been retreating at a rate of 28 m per year. Increased melting of the glaciers increases the flow of rivers in summer leading to floods in the initial few decades but as glaciers continue to recede, the melt water reduces drying up the rivers. Rivers that receive a substantial amount of water from melting of Himalayan glaciers such as the Ganga and the Brahmaputra are likely to be at risk from such drying up consequences. Such drying up of rivers due to reduction in glacial water inflow will lead to serious consequences for agriculture and livelihood along the Brahmaputra river plains in the NER. However, projected increase in rainfall and accelerated summer flows due to increased melting may give rise to more intense flooding and flood hazards.

Although Brahmaputra river plays an important role as a source of freshwater over substantial low-lying areas of NER, most parts of the region have mountainous terrain with a major dependence on spring water (Table 4). Springs, which are natural outlets of unconfined aquifers, are critical for both ecosystem and livelihood in the mountain regions. While most springs in Northeast India are freshwater, fit for direct consumption, some springs contain desirable minerals that add to the quality and taste of exotic culinary. Spring waters are often directly piped to the urban areas without the need for any treatment, besides meeting the needs of rural domestic water and irrigation, due to its pristine nature.

Several studies have documented in detail the spring hydrology in the Himalayas (Tiwari, 2008; Agarwal et al., 2012; Grover, 2015; Pant and Rawat, 2015; Jeelani

Table 4 Dependence of the rural communities on springs in NER (adapted from Gupta and Kulkarni, 2018)

State	Total no of villages	Percentage of villages having springs
Arunachal Pradesh	5589	37.3
Assam	2639	11.4
Manipur	2581	54.4
Meghalaya	6839	55.7
Mizoram	830	54.6
Nagaland	1428	44.7
Sikkim	451	94.2
Tripura	875	16.1

et al., 2018) but these are mostly in the western Himalayas and details on the impact of climate change on the springs have not been well specified (Panwar, 2020). Changes in rainfall patterns such as increase in rainfall intensity, changes in seasonality, and reduction in winter rainfall, coupled with deforestation and other anthropogenic activities have led to the drying up of natural springs across the NER (Chaudhary et al., 2011; Tambe et al., 2012). For instance in the state of Sikkim, 80% of the rural households depend on spring water for their livelihood (Tambe et al., 2009). The spring recharge in Sikkim is mainly controlled by rainfall (Panwar, 2020). Rainfall trend analysis shows that during the years 2006 to 2010, warmer temperatures and reduction in rainfall during the winter (Tambe et al., 2011) shows a good correlation with the drying up of the natural springs in the state (Tambe et al., 2012). Studies on spring in the rest of the NER are limited, but given the declining trend of monsoon and winter rainfall at local scales and the increasing water demand due to anthropogenic activities, the springs in rest of the region are also likely to be affected. Drying up of springs in most of the states have been reported although detailed causative factors have not been identified (Sharma and Rai). The drying up of springs in Sikkim has reduced the soil moisture for crops (e.g. large cardamom) and led to higher competition for water resources among users (Sharma & Rai, 2012). Given the high dependence of rural communities on springs in the region (Table 4) any impacts on spring water will have significant implications on vegetation, agriculture and livelihood activities in the region.

Agriculture in NER is predominantly rainfed and therefore rainfall and spring water are the major sources of water for the rainfed upland agriculture such as the Jhum. Changes in the rainfall pattern and spring water availability is therefore a major constraint for agroecosystems in the region. The increase in winter temperature and the recurrent drought events will intensify the impacts on crops and this coupled with the anthropogenic factors such as land-use change will pose a serious challenge to agroecosystems in the NER in future.

4.3 Impact on Soil

One of the key impacts of rainfall in the region is on the soil, both in the hills as well as in the plains. In the plains, especially the flood plains, recurrent floods and heavy river flow and run-off during the monsoon season have led to the issue of siltation and erosion of agricultural land. For instance, Majuli Island which is the largest riverine island in the world is constantly subjected to flood, erosion and siltation impacting agriculture production and the livelihood of farmers (Das, 2014). Under the changing climate scenario, the increased stream-flow in the Brahmaputra river during the monsoon season has increased the erosion of Majuli Island towards upstream and accretion (due to siltation) towards downstream. Erosion and accretion can be observed at various places along the Brahmaputra river bank.

In the hills, the steep slope makes it vulnerable to soil erosion. Increased frequency of high intensity rainfall with high run-off will further increase the run-off and erosion losses of agriculturally important top soil and nutrient content in it. The soil in most parts of NER, being relatively acidic is a challenge to crop productivity in the region (Kumar, 2015). Under elevated CO_2 concentration there is increased root and soil microbial respiration leading to the formation of carbonic acid (H_2CO_3). On the other hand, rising air temperatures increases evaporative loss of soil moisture and as the deeper water with higher salts rises up to the rootzone it leads to salinization of soil. Further, the increase in atmospheric temperature also reduces the soil carbon content as the soil organic carbon content increases with temperature. Thus the observed increase in air temperature in the region is likely to have implications on the soil quality. Under changing climate scenario, high intensity rainfall events will lead to enhanced soil nutrient loss through the process of leaching (Kumar et al., 2011). Most of the agricultural practices in the NER are de facto organic; the use of synthetic fertilizers and pesticides is almost non-existent if not negligible in the upland agriculture. Thus, without any artificial inputs for enhancing soil quality, soil nutrient loss and deterioration of soil quality would have high implications on crop productivity in the region.

4.4 Impact on Pests and Diseases

Reduced precipitation and irregular rainfall pattern impacts rice cultivation and winter crop production. These impacts are compounded by increase of pest and pathogen prevalence due to climate change which reduces crop yield. An emergence in the invasive species and increase in diseases/pests have been observed in the region (Lamsal et al., 2018; Roy et al., 2019; Sharma & Rai, 2012). Several studies have reported that changes in long-term climatic conditions such as increased temperature in the temperate regions and areas of higher elevation have led to an increase in emergence of invasive species and incidence of diseases/pests (Lamsal et al., 2018; Rai & Singh, 2020). *Mikania micrantha* (also known as mile a minute weed) is invasive alien plant species (IAPS) documented globally for its adverse environmental as well as socio-economic impacts. The occurrence of this species has been reported in the past as an exotic perennial weed affecting Jhum cultivation at lower elevations of NER (Swamy & Ramakrishnan, 1987) but in the past decade there has been a high growth in abundance in the region mainly attributed to climate change (Rai & Singh, 2020). In Sikkim, during the past two decades, cardamom and citrus production have often fallen prey to various viral and fungal diseases (Sharma & Rai, 2012). Gurjar et al., (2018) reported an increased risk of late and early blight disease in potatoes in Meghalaya which was attributed to early rainfall and foggy conditions. There is a good correlation between increase in air temperature and occurrences of potato blight diseases (Sparks et al., 2014). The warm moist conditions due to early rainfall and elevated temperatures could be making the environmental conditions favourable for blight in the hills. The temperature and rainfall changes leading to phenological changes have led to increase in the number of invasive species, diseases and pests for agricultural crops (ICIMOD, 2008).

5 Vulnerability of Agroecosystems to Climate Change

The exposure of the entire NER to various climate risks such as very intense rainfall, floods and droughts makes the region highly vulnerable to climate change (Tse-ring et al., 2010). In addition to this, various bio-physical and socio-economic factors makes the agroecosystems in the region vulnerable to climate change. Ravindranath et al. (2011), noted that majority of the districts in North East India are subject to climate induced vulnerability currently and in the near future. The various climate risks and key vulnerabilities across the NER are summarised in Table 5.

The low-lying regions in the NER are highly vulnerable to floods due to multiple factors; heavy rainfall in the high altitude leading to increased run-off, increased sediment deposition due to high soil erosion in the high altitudes and increased river flow (Sharma et al., 2009). These areas are agriculturally more productive compared to the hills and have better accessibility due to which there is presence of higher anthropogenic activities and large scale immigration including influx from the surrounding hills. The environmental degradation and population pressure in the low-lying regions thus adds on to the already existing vulnerability in the region. While in the hills these pressures may not be as much, but they are faced with low mobility and infrastructural limitations that hampers the accessibility to socio-economic services and productive livelihood assets due to which the adaptive capacity is very low.

Table 5 Climate change related key vulnerabilities and related risks in NER

Component	Key vulnerabilities	Vulnerable system/region
Exposure	Erratic rainfall	Across NER
	Extremely heavy rainfall-leads to very high run-off in high altitudes and floods in lower altitudes/along the river banks	Hills
	Elevated night time temperatures (T_{min})—Critical for rice yield	Rice crops
	Floods and flash floods	Flood plains and the hills
	Droughts	Across NER
	Population pressure—Increases the exposure to climate risks	Lower altitude
Sensitivity	Fragile ecosystems and biodiversity	Across NER; Forests, wetlands
	Poor and marginalised people—Politically, economically and socio-culturally	Across NER
	Steep topography—Leads to high run-off and soil and nutrient erosion	Hills
	Proximity to the water source such as rivers and lakes—High risk of floods	Brahmaputra river plains in Assam and Meghalaya; Lothak lake in Manipur
	Land degradation—High rate of soil erosion, frequent landslides, makes the biodiversity fragile	Across NCR; critical in Majuli island
	High dependence on natural resource base—high dependence on forest resources, springs, and rainfed agriculture	Jhum cultivation areas; Areas in the higher elevations or remote areas
Adaptive capacity	Limited data and restricted access to existing data to understand the vulnerability context	Across NCR
	Low per capita development assets—low socio-economic services and productive livelihood assets	Across NCR
	Inaccessibility—Poor mobility; reduces access to technologies	Hills

Table 6 Interlinkages between climate change, impacts and SDGs in NER

Climate Change	Impacts	SDG target	Reference
Erratic rainfall pattern	Crop yield loss	SDG 1 (No poverty), SDG2 (Zero hunger), SDG8 (decent work and economic growth), SDG13 (climate action)	Duncan et al. (2016), Dutta (2014)
Early rainfall and foggy conditions	Increase in pests	SDG 15 Life on earth	Sharma and Rai (2012); Gurjar et al. (2018)
High intensity rainfall	Loss in soil nutrient	SDG6 (Clean water and sanitation), SDG 15 Life on earth	Kumar et al. (2011)
Warmer temperatures and reduction in rainfall during the winter	Drying up of the natural springs Impact on livelihood	SDG 6 Clean water and sanitation SDG 3 Good health and well being	Tambe et al. (2011, 2012)

6 Climate Change and Sustainable Development in the Region

The impacts of climate change on agroecosystem in the region are manifold. This will have trade-offs with a number of developmental practices in the region. For instance, erratic rainfall pattern leads to yield losses. This will reduce the income of farmers and will hamper the efforts by the government in reducing poverty.

There is a strong interlinkage with many SDGs (Table 6). Taking appropriate and immediate steps to reduce climate vulnerabilities would be helpful in achieving sustainable agriculture for communities. Sustainable agriculture would lead to improved livelihoods and increasing incomes and reducing poverty levels. This would improve consumption patterns and help fight malnutrition and hunger issues, thus having a positive impact on health. Climate action reduces the drudgery of women caused due to extreme weather events, bringing in gender equality. Climate action will be possible through strong policy support and local and global partnerships.

7 Conclusion

In this chapter, we examined the climate risks and its impacts on agroecosystems in the NER. In the higher altitudes, increasing frequencies of extremely heavy rainfall leading to soil erosion, run-off and landslides are likely to be the key climate risks impacting the crop productivity and agroecosystems as a whole. While in the lower altitudes and along the river banks, floods may pose a greater risk to the agroecosystems. Other factors such as rise in temperature (T_{min}) impacts crop productivity directly through impacting the crop physiology and indirectly through impact on the soil quality and the abundance of pests, diseases and invasive species across the NER.

Climate change and its impacts on agroecosystems in the NER are evident through long-term climate data analysis as well as the documented impacts of climate risks. Our understanding of the climate in this region may not be as robust compared to many other regions due to limited temporal and spatial data and the difficulty in modelling the climate in the hilly topography effectively. However, there have been substantial efforts in the past decade where time-series climate data has been analysed to understand the temporal and spatial pattern of climate change and variability in the region. Most of these studies have not established statistically significant rainfall and temperature trends while studying the NER as a whole but they have reported substantial trends while studying specific locations. The significant trend has been reported in both the higher and lower altitudes. This could be due to the fact that there is a huge variability in the climatic patterns across the region and between the plains and the hills. Nevertheless, all studies indicate high risk of climate extremes in the region and that these risks are increasing in terms of magnitude and frequency. The impacts of these risks on agroecosystems are already well documented. In addition to the exposure to extreme climatic conditions, the region's vulnerability is magnified due to the existing bio-physical (steep topography, fragile ecosystems, etc.) as well as socio-economic (poor infrastructure and mobility, poverty, marginalised communities) conditions.

Future projections show further rise in the temperature, and extreme and erratic rainfall which will subsequently increase the magnitude of flood and drought in the region. This will further intensify the already existing impacts of climate change on the agroecosystems and natural resource base in the region. Since substantial section of the population in the NER, especially in the rural areas depend on agriculture and ecosystem services for their livelihood, climate change will therefore impact the livelihood sustainability in the region. The multidimensional poverty index for many districts in the region is high (Alkire et al., 2018), suggesting an urgent need for policies and strategies for economic growth and development of the region. Reducing the vulnerabilities and developing appropriate adaptation tools and strategies for agroecosystems will help in the realization of the UN Sustainable Development Goals (SDG), especially the SDG 1 (No poverty), SDG2 (Zero hunger), SDG6 (Clean water and sanitation), SDG8 (decent work and economic growth) and SDG13 (climate action).

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Towards Circular Economy of Food Systems: An Explorative Appraisal of Opportunities in Fish, Seafood Value Chains

Zinaida Fadeeva and Rene Van Berkel

1 Introduction

Globally food systems are under severe pressure to meet the growing demand due to population growth expansion of the middle class, accelerated urbanization and industrialization, and changes in lifestyles and eating habits (Bricas, 2019; Islam & Karim, 2019). The prospect of global population reaching 10 billion by the end of this century puts further demands not only on the productivity and efficiency of food systems but also on their impact on health, the environment and ecosystems as a whole (Bene et al., 2015; Future of Food, 2021). Fish and seafood provide more than 20% of animal protein to 3.3 billion global citizens and up to 50% in countries like Bangladesh, Cambodia, Indonesia, the Gambia, Sri Lanka, Sierra Leone, and small island states, whereas the sector is estimated to provide jobs and livelihoods for up to 11% of the current population, more than 820 million people (FAO et al., 2019). Over 34% of assessed global fish stocks were assessed as overfished in 2017, and a further 58% are being fished at or near their sustainable maximum, and hence their production cannot be expanded further (Palomares et al., 2020; Our Ocean, 2016).

While the sustainability of the food system has been approached from multiple angles, Circular Economy (CE) offers a particularly useful perspective by pointing

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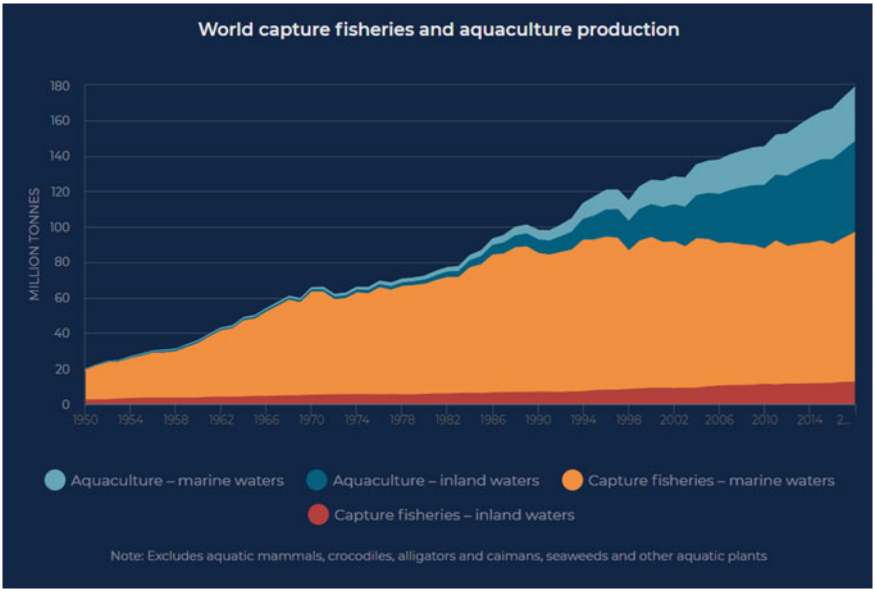
at the cycles of technological (or man-made) and biological materials that, respectively, require to be kept in continuous circulation in production and consumption systems or be returned in a sustainable fashion into natural systems (Franco, 2017). Specific to food systems, from a sustainability perspective, further emphasis is needed on the sustainability of the ecosystems that support primary production (Guerrero et al., 2019). Principally, CE offers a framework that helps to bring food production and consumption closer to the natural—regenerating and regenerative—cycles with wastes and byproducts feeding back into natural primary production in ecosystems or into technological cycles of man-made production and consumption (Ellen MacArthur Foundation, 2022; Muscat et al., 2021).

To illustrate the relevance of CE for achieving sustainable food systems, fish and seafood value chains are focused upon. Developing countries have become the largest suppliers of fish. China leads in terms of fish catch, followed by Peru, Indonesia, the USA and India. Asia accounts for 92% of global aquaculture, to which China, Indonesia, India, Vietnam and the Phillipines contribute the most and drive growth (Naylor et al., 2021). China, South and Southeast Asia are projected to remain to be the biggest suppliers of farmed fish in the future (FAO, 2016; Ottinger et al., 2016). Fisheries have been and are of critical importance also for meeting the dietary requirements in developing countries, particularly in coastal areas, delivering up, for example, up to 60% of dietary proteins in Gambia, Sierra Leone, Ghana, and Maldives and between 50 and 60% in Cambodia, Bangladesh, Indonesia and Sri Lanka (Bene et al., 2015).

From a sustainable nutrition perspective, aquaculture and fisheries are recognized game changers for sustainably meeting the protein needs of an expanding global population (Sadhukhan et al., 2020). This is due to the feed conversion ratio (FCR)—the amount of food required to produce a certain amount of produce—which is lower for fish and seafood compared to other proteins, particularly animal proteins (Fry et al., 2018). This requires consideration of all stages in fish and seafood growing (in natural and/or controlled (or farmed) environments), fishing or harvesting, processing, transport and consumption, as well as the processing of all waste, effluents and emissions from each stage (Thrane, 2009).

According to the Food and Agriculture Organization (FAO, 2020), the global consumption of fish and seafood has increased between 1990 and 2018 by 122% as the rise in capture fisheries increased by 14% and global aquaculture production by 527%, all within the same period. Consumption of fish and seafood amounted, in 2017, to 7% of the global intake of all proteins and 17% of animal proteins. In some countries this proportion reaches up to some 50% (FAO, 2020).

Aquaculture's contribution to total production is increasing sharply (Fig. 1), a trend that is critical to increasing production while reducing negative impacts on ecosystems and biodiversity from overfishing, provided aquaculture operations and management are sustainable.



Source: FAO - http://www.fao.org/3/ca9229en/ca9229en.pdf#page=20

2 Production Challenges and Impacts

The sustainability of fishery and aquaculture and their value chains relates to both the sustainability of the ecosystems on which these depend as well as on the ability to contribute safely to a nutritious diet for people (Gardner et al., 2017; Jennings et al., 2016). A typical food supply chain starts with primary producers/catchers of fish and seafood and the suppliers of packaging materials, technology and equipment and other materials used by processing companies that, in turn, send processed produce through distributors to domestic and international consumers (McLeod et al., 2015). Availability of cold chain and specialized storage facilities plays a significant role in shaping supply chains and their reach and value-added at different processing stages.

Despite its large diversity there are common issues of concern along the different value chains. *Produce losses* are of concern in all stages, resulting in fish and seafood getting wasted during catch or harvest, on receival or during processing, storage, distribution, retail and meal preparation (Lewis & Boyle, 2017). Losses of produce along the supply chain are estimated up to 35%, with some variations between regions (FAO, 2020), and are attributed to inefficiencies, lack of knowledge, inadequate access to technology, absence of quality assurance systems, and suboptimal policy frameworks. Both deficient and excessive diets impact health and associated health epidemic (Lancet Commission, 2020).

Primary production in open fisheries and farmed aquaculture requires water, land and energy that may adversely impact the health of the hosting aquatic and terrestrial ecosystems (Future of Food, 2021). Waste generation and water contamination are a main and common concern, alongside location specific concerns of overfishing and destruction of ecosystems and poor labor conditions (Duda & Sherman, 2002; Garcia, 2003). Non-selective fishing gear takes non-targeted fish and juvenile fish, benthic animals, mammals and birds that are discarded (Boopendranath, 2012). Water and energy consumption and generation of organic waste, wastewater and odor are significant at the processing stage. Food waste is again of concern at the consumption stage. Of particular concern is the need to preserve fish and seafood along the value chain. Most commonly by keeping it uninterrupted during processing, storage, transport, distribution and retail in a cold chain (cooling or freezing) to prevent spoilage. The cold chain itself requires resources, particularly energy. Generally, waste from processing fish and seafood has a high concentration of organic matter and water, which add to the complexity, and hence expenses, of its treatment and environmentally sound disposal (Jayathilakan et al., 2012).

Energy is a major cost factor for fish and seafood value chains (Gudmundsson et al., 2006). Energy is required for the production of inputs into aquaculture, i.e., fish meal, fish oil, etc., as fuel for fishing boats, for preservation and processing—on boats and on-shore, and for cold storage, distribution and retail of fish products (Muir, 2015). Energy is furthermore needed for all processing methods, including for the management of waste and wastewater. Growing diversity in fish and seafood processing (e.g., smoking, drying, canning, seasoning, etc.) All adds to energy consumption. Distribution, especially through long-distance cold chains is energy intensive. Cost considerations have started to spur efficiency and innovation in supply chains of fish and seafood products (FAO, 2020).

3 Circular Economy

The increased attention to efficiency and circularity in the use of natural resources is an acknowledgement of the deficiencies of currently prevailing linear economic model based on extract—produce—use—dispose (or take—make—throw model) (Lazarevic & Valve, 2017). This is 'wasteful' and 'extractive', as opposed to 'efficient' and 'circular', which requires change towards retaining material and energy within production and consumption cycles. As an alternative, the Circular Economy (CE) aims not only to minimize environmental impact across all stages of materials and energy use, but seeks new business opportunities, rejuvenation of natural systems and increased wellbeing of people (Ellen MacArthur Foundation, 2020).

From a CE perspective, it is important to note the differences between biological and technical materials, each having its own value and recovery cycles (Ellen MacArthur Foundation, 2020). Renewables, or bio-based materials, can be returned to nature into biological cycles at the end of their use at a sustainable rate that is comparable with natural processes, provided they are safe and not contaminated. Man-made materials require technical cycles that need to perpetually contain these materials in the economic systems through reuse, repair, remanufacture and recovery. CE requires changes in products, services, processes, and systems by which these are manufactured, distributed and used. Such changes are made by economic actors—producers, distributors, retailers and consumers—under guidance and with information from the government and other stakeholders.

Businesses and industries need to put the circular economy into practice for which three main operational strategies are available (Van Berkel & Fadeeva, 2020). Maximizing the use of renewables and non-harmful inputs—as material and as energy sources; Improving the efficiency of use of all materials and energy along all stages of production and consumption systems; and maximizing the perpetual cycling of end-of-life/secondary materials.

These strategies exploit the mutual reinforcing synergies between efficiency and circularity and the importance of choice of appropriate input materials (Fadeeva & Van Berkel, 2021). Efficiency serves to slow down and reduce the throughput of materials and circularity achieves closure of the above referred technical and biological cycles, i.e., zero leakage of technical materials to the environment and return of biological materials at an appropriate rate and in a suitable form for reabsorption into nature. CE also emphasizes the importance of different levels and types of actions and highlights roles that different partners play to achieve circularity and the need for careful coordination of actions among stakeholders and value chain partners.

Others have emphasized new business models as the discerning element of CE. For example, the World Business Council for Sustainable Development (WBCSD, 2017) scoped CE in terms of five business models: circular supply; resource recovery; extended life of products; product service combinations; and sharing platforms. These open new business opportunities in combination with three enabling technologies: digital (in particular Internet of Things, big data, etc.), biotechnology (in particular, bio-energy, bio-materials, biocatalysts, etc.) and physical technologies (in particular 3D printing, nanotechnology, robotics, etc.). Along similar lines, other scholars have suggested CE business models in slightly different yet largely overlapping categories (e.g., Bocken et al., 2016).

Globally, CE has been estimated to present a USD 4.5 trillion business opportunity by 2030 (Lacy & Rutqvist, 2016) countries, regardless of their respective stage of economic development, are projecting significant gains from pursuing a CE path. In India, for example, CE could help to achieve an annual value of 218–624 billion USD and a reduction of carbon intensity by 23–43%, by 2030 and 2050 respectively (Ellen MacArthur Foundation, 2016). This would equate to the equivalent of 22% of the total Sustainable Development Goals (SDGs) opportunity for India by 2030. In China, CE could create an annual value of USD 1.5–11.2 trillion by 2030 and 2050 respectively, reduction of greenhouse gas (GHG) emissions (by 11–23%) and of particulate emissions (by 10–50%) by 2030 and 2050, significant fall in traffic congestion (by 36–47% by 2030 and 2040) and bring middle-class lifestyle for more urban dwellers (Ellen Macarthur Foundation, 2018).

Resource efficiency actions have already successfully been practiced by forward-looking companies in manufacturing and service sectors with well-documented economic, social and environmental benefits, in industrialized and developing countries (Van Berkel, 2007). These practices have also been referred to as cleaner production, waste minimization, pollution prevention and eco-efficiency. Selection of renewable resources (as material or energy sources) and production of useful byproducts have been traditionally part of the scope of cleaner production, and, in hindsight, can be interpreted as early references to the need for circularity.

The following section explores the application of these three operational strategies to fish and seafood value chains.

4 Application of Circular Economy Strategies

4.1 Strategy 1—Maximizing the Use of Renewables and Non-harmful Input

CE starts with the selection of inputs with a view to maximizing the sustainable return of natural materials into the environment and maximizing the containment of man-made materials in closed technological cycles. A diversity of inputs is required across all stages of fish and seafood value chains. The analysis of inputs is here limited to produce (caught or harvested), feed use (for cultivation), plastics and energy.

4.1.1 Sourcing from Sustainable Fisheries and Aquaculture

CE stresses on not exceeding the productive and regenerative capacities of the biological and environmental systems from which economic inputs are taken. In the context of fish and seafood, the paramount concern is the avoidance of the depletion and conservation of ecological and biological health and integrity of the ecosystems in which fish and seafood are grown either in a natural environment (fisheries) or controlled environment (aquaculture). Significant progress has been made in understanding and assessing the sustainable yield of specific fisheries and aquacultures. To this end, elaborate regulations and fishing quota systems have been progressively set up over the past decades, with different degrees of effectiveness. One step ahead, there are the Voluntary Sustainability Standards, particularly through respectively the Marine Stewardship Council (MSC) and the Aquaculture Stewardship Council (ASC). Both have been developed through extensive multistakeholder processes using the best available scientific methods and require periodic assessment and (re-)certification of fisheries and farms and tracing of their respective produce all the way to the consumer. MSC fisheries standards are based on three principles, respectively: sustainable fish stock (indefinitely maintaining healthy and sustainable fish stock); minimizing environmental impact (maintaining species and habitats);

and effective fisheries management (legislative compliance and environmental standards). In a similar fashion, ASC addresses both environmental and social aspects of fish and seafood farms.

Sustainably-sourced produce is hence a key for CE implementation in fish and seafood value chains. International markets are indeed increasingly insisting on certification. The need for tracing certified produce incentivizes processors and other value chain partners to improve their operations, which generally contributes to reducing losses and waste, and preserving food quality and nutritional value. Not only large but also smaller fisheries in developing and in-transition countries turn to certification, often in collaboration with international NGOs and development partners. The Vietnamese aquaculture farmers—members of the EU-co-funded and WWF-lead project—aim at aligning themselves to the ASC standards paying close attention to the density of fish stock, feed, use of medication and banning child labor (WWF, 2020). Promising steps towards certification of fish and seafood are observed in India where WWF supported MSC certification of companies in Kerala, Tamil Nadu and Lakshadweep and works now with assisting shrimp farms in Nellore to become ASC-certified (WWF, 2021).

One of the largest surveys of seafood shoppers undertaken by GlobeScan has analyzed responses of nearly 26 thousand people from 22 countries concerning their relationships with the products and the sector in general (Macfadyen, 2009). The study revealed growing interest of consumers—both final consumers and processors—into independent verification of sustainability claims and independent labeling of fish and derivatives as well as in sustainability of production practices. Already a decade ago, an analysis conducted under the auspices of Macfadyen (2009) indicated that constantly growing demand for certified products, though different for different regions and varying for species, outstrips their supply.

Beyond certification, well-informed and responsible buyers can further influence the sustainability of their fish and seafood consumption, by selecting local varieties during the appropriate season, for which information and awareness campaigns, product information and (online) tools are being developed and promoted in different main consumption markets. The World Wide Fund (WWF), in collaboration with the North Sea Foundation and the Good Fish Foundation has developed guidelines directing consumers toward more sustainable seafood choices. So far, country guides are available for 25 countries including information relevant to aquaculture, e.g.,the impact of production system and management on the consumption of resources, impact on ecosystem and communities, and for wild-captured fish, e.g., state of stocks of specific species and the impacts of specific fishing methods. Assessment, following these methodologies, is done by experts based on available data resulting in recommendations. The use of another guidance—the Good Fish Guide of The Marine Conservation Society (GFG, 2020) also helps to understand which fish is more sustainable through sustainability rating that considers the origin of the product (farmed or caught), state of population, region, etc. The online search function (www.fishonline.org) provides information on over 150 species.

Other initiatives focus on blacklisting either by species, by season and/or by region. Greenpeace Canada, for example, issued a list of fish to avoid due to their endangered status, habitats or host ecosystems (Green Peace, 2020). India provides information on the seasonality of seafood products. Australian consumers are informed about the fish to avoid by the Australian Marine Conservation Society. Australia, as well as other countries are also providing consumers with lists of sustainable seafood restaurants (Good Fish, 2020).

4.1.2 Towards More Sustainable Fish Meal

The fish meal that is used to feed farmed fish is the most significant input for aquaculture, both money wise as well as in terms of environmental impact. Traditionally, it is prepared from other aquatic species. Over 69% of fish meal and over 75% of fish oil production for fish farming come from wild catch of fish with low economic value. The global fishmeal market is projected to grow from USD 6 billion in 2017 to USD 10 billion in 2027 (CIWF, 2020). At the same time, there is mounting societal pressure out of concern with overfishing and ecosystem damage. Opportunities are opened by research and practices that demonstrate the potential of utilizing products and byproducts from other non-aquatic species as feed for aquaculture. Attention to alternative sources of fish food is important as the demands of expanding aquaculture sector will exceed the availability of fish-based inputs with prices for fishmeal already on a steep rise (by nearly 250% for the last twenty years) (Index Mundi, 2020).

Plant-based proteins can satisfy the nutrition of selected species of farmed fish and crustaceans. Soy, rice and barley protein concentrates can provide feed alternatives for various commercial species, however composition of the feed is to be carefully managed to reach the desired digestibility coefficient. Research and industrial-scale trials show promising results. For example, soy-based concentrates and now developed by both established industry players as well as start-ups globally. Jiangsu Fuhai Biotech (China), Menon Renewable Feed (USA) and CJ Selecta (Brazil) are just some of the company examples that offer products and technologies leading to the production of plant-based fish-food with higher characteristics of digestibility, better intestinal integrity and better growth and reduced allergenic risks and, as a result, requiring lower use of antibiotics and other medicines, greater growth and reduced amount of wastes. Elimination of fish- and animal-based proteins also limits the potential for bio-accumulation of heavy metals and other toxins, particularly Persistent Organic Pollutants (POPS) and contamination with salmonella. Several companies avoid genetically modified plant products, e.g., soybeans.

Research and early industry practices furthermore show that *algae inclusion into the diet of fish* improves growth performance and feed utilization (Fish Site, 2013). Spirulina and seaweeds provide a rich source of amino acids and omega-3 and omega-6 fatty acids (Hoddar et al., 2020). There is also scope for use of woody *biomass for fish feed production.* Wood waste and sugarcane bagasse can, after hydrolyzation and fermentation, constitute products matching requirements of fish meal (WAS, 2020).

Insect-based protein can be another partial or complete replacement for fishmeal protein (PROteINSECT, 2016). Overall insect-based protein is considered to be more fitting for substituting fish-based meals for aquaculture in comparison with plant-based proteins, provided fatty acid profile and low levels of calcium and phosphorus are optimized. Overall insect-based feed is highly comparable to fish-based fish meal in terms of high digestibility, immunity and health of targeted species enabling high growth potential. Research on some insect species, e. g. the black soldier fly, common house fly, silkworm moth, and yellow mealworm, has highlighted the potential of this protein source and the importance of factory designs to maximize insect growth and yield (Riddick, 2014). Other optimization options could be through a symbiosis between sectors as insect cultivation could feed on waste biomass from other industrial sectors.

Qualities of insect-based feed have been proven scientifically and demonstrated by several established companies and start-ups at different stages of commercialization. Examples include Guangzhou Fishtech Biotechnology (China) producing functional feed, Nutrition Technologies (Malaysia) building industrial-scale facilities with the intent to bring their factories to Thailand, Vietnam and Indonesia, Protix (Netherlands) operating fully automated vertical factory with a normalized yield of 7,500 -ton protein/ha/year, InnovaFish (France) which product is commercialized with insect-fed fish sold in supermarkets around the country, Ynsect (France) that aims at building the world largest insect feed producing plant by 2022. AgriProtein (https://www.agriprotein.com/our-technology/) is a South African company that upscales organic waste into protein for animals including aquaculture feed, using black soldier fly technology. The company has achieved commercial success in South Africa and works with international partners on establishing factories in different parts of the world. Nutrition Technology (Malaysia) has spent three years developing technologies for the production of protein and oil from back soldier fly larvae as material for fishmeal and, by doing so, set a course to establish the largest production facility for insect meal in Southeast Asia (Fish Site, 2019).

Concerns about the sustainability of inputs into aquaculture inspired Asia–Pacific Regional Consultation on Responsible Production and Use of Feed and Feed Ingredients for Sustainable Growth of Aquaculture held in 2017. The discussions focused on the traceability of fish products and their impact on the consumers' health and aspects of alternatives to fish-meals, chemical and antibiotics use, quality and application of fish feed, purchase of aquatic animals, etc. Representatives of Bangladesh, Cambodia, China, India, Vietnam, Malaysia, Maldives, Indonesia, Myanmar, Nepal, Pakistan, Philippines, and Thailand discussed policies, financial mechanisms and skills development necessary to support the expansion of sustainable feed production.

4.1.3 Addressing Challenges of Plastic Materials in Fisheries and Aquaculture

Plastic is widely used in many parts of fishing and aquaculture—as a material for nets, tanks, pipes, packaging, and bags for input materials and feed as well as disposable products used by fishermen or aquaculture workers, with some of it either discarded or lost into the oceans and waterways. The sector is looking into alternative materials and techniques as its contribution to minimizing (marine) plastic littering. From the perspective of circular economy, strategies for dealing with plastic materials would be expanding, to the maximum extent feasible, the useful life span of plastics, substituting plastics with other materials, including e.g., plant-based plastic, retrieving lost and orphan marine plastics. Extension of plastic life span and waste minimization contribute to resource efficiency and will be dealt with in the following section.

Substitution is a priority for single-use applications or where otherwise leakage into the environment is likely to occur, e.g., in open water aquaculture systems, during open water fishing or at the stage of consumption. Plastic pollution is highly visible and of increasing global concern, and hence a key focus area for improving the sustainability of fishery and aquaculture operations. Proactive management and minimization of plastic waste are reportedly a motivation for staff and other stakeholders for more comprehensive environmental and sustainability initiatives.

Of particular concern are 'ghost fishing' nets, lines and ropes that impact marine life and cause habitat destruction for many years after being abandoned at sea. The switch to biodegradable material is promising, provided biodegradability is achieved in typical marine conditions (which are markedly different to standard testing for biodegradation in sanitary landfills). Examples of such nets were developed by the National Institute of Fisheries Science in Korea in partnership with FAO. The net which is close by its qualities to nylon and is recyclable, shows two years of degradation time reducing damage to the aquatic life (Kim et al., 2016).

Another motivation for the search for alternative plastic material input into fisheries and aquaculture is the reduction of petroleum use and the elimination of harmful chemical plastic additives. The BIOGEARS project builds knowledge of bio-based textile materials in marine environments and started the production of bio-based fishing gear (https://biogears.eu/). For example, Itsaskorda rope factory produces daily up to four tons of alternative ropes and has demonstrated suitability for fisheries and aquaculture, yet further scaling up depends on an adequate and uninterrupted supply of bio-based materials (Euro News, 2021).

The perishable nature of fish products makes it difficult to eliminate plastic, as packaging and insulation material, along the supply chain, particularly polystyrene foam boxes (which easily damage and blow away). Some alternatives have come up, such as the solid board packaging of Solidus Solutions which is suitable as ice-boxes to preserve fresh fish and seafood. The board material is both recyclable and renewable and has moisture-resistant properties and is more compact than polystyrene boxes. Kalaneuvos and Nordic Trout in Sweden and Finland are using EcoFishBox and thereby to reduced the volume of their packaged product by 1/7.

4.1.4 Use of Renewable Energy

Renewable energy has significant potential for aquaculture and fisheries and along their supply chains, yet technology solutions are context-specific and depend on the amount of harvestable energy (solar radiation, wind or waves) and energy demand. Cabling and maintenance are a challenge and costly particularly on open water, etc.

(Fish Site, 2019). Where water heating is needed in aquaculture for fish survival and growth solar heating can replace electric or diesel boilers, depending on heating regimes, make-up water sources and designs of solar collectors. Industry and regulators prefer solar energy and natural gas systems in US aquaculture (Kim, 2018). Gas systems can be combined with biogas production from the anaerobic digestion of aquaculture waste and wastewater.

More applications of renewable energy in aquaculture, fishing and fish processing are becoming available as a result of research and demonstration projects. Renewables become more viable in combination with energy efficiency, for e.g., pumps, lights and other devices. Wind and micro hydro power (in rivers or irrigation channels) generate electricity to run refrigerators, heat pumps, etc. (Fish Center, 2020). Wind power is used in many regions for traditional fishing and solar energy for operating fishing vessels has begun to attract interest. Research and prototypes of solar boats emerge in different regions with some designed specifically for fishermen, for example in Indonesia (Utama et al., 2013). Grieg Seafood (Norway) tests the pplication of a renewable-powered feed barge for farming salmon. Researchers from the University of Toronto are exploring the application of renewables to run aerators in small pond-based aquaculture farms (Fish Site, 2019). The Technical University of Delft investigates alternative energy solutions for powering fishing boats (Nieuwe energie voor de visserij, 2009). In Indonesia, under auspices of SWITCH-Asia project of the EU more than 50,000 small-scale fish farmers improved the energy efficiency of their aeration system (Switch Asia, 2016). Nine of them had also invested in production of biogas from shrimp farming waste and residue to produce electricity and more than one hundred had installed solar lightning.

For some of the developing countries use of renewables represents not only switch to more sustainable input but employment of more affordable resources. In spite of significant grid developments, electricity tariffs of Cambodia remain some of the highest in the region, which draws attention of the MSMEs to solar energy solutions. Switch to Solar project of EU-funded project supports MSMEs in the agri-fishery sector to switch from unsustainable to solar energy input.

4.2 Strategy 2—Improving the Efficiency of the Use of Materials, Energy and Water Along All Stages of Production and Consumption Systems

The second CE strategy concerns improving the efficiency of use of materials, and associated therewith energy and water, as this reduces net input requirements as well as waste generation, which in turn facilitates the circularity challenges of closing material cycles. It is also referred to as ‘slowing’ or ‘thinning’ resource flows in production and consumption systems. Materials and resource efficiency are well-known for industrial operations, albeit not yet commonly practiced, through concepts of waste minimization, cleaner production and eco-efficiency. Since 2008, the United

Nations Industrial Development Organization (UNIDO) and the United Nations Environment Programme (UNEP) have these and other complementary practices together under the umbrella of Resource Efficient and Cleaner Production (RECP) (Unido, 2015). As illustrated in Fig. 1, at its core RECP is best understood as a virtuous cycle, wherein firstly materials, energy and water are used more efficiently, leading to, secondly, the reduction of the generation of waste, effluents and emissions, contributing to, thirdly, improved occupational and community health and wellbeing, which in turns contributes to productivity and profitability. Operationally, RECP can be addressed through managerial, technical and operational measures by enterprise (See Fig. 1). These are often grouped into eight practices, respectively: good housekeeping; input substitution; better process control; equipment modification; technology change; on-site recovery; production of useful byproducts; and product modification (Van Berkel & Fadeeva, 2020). These can also be seen as complementary lenses to develop specific solutions for resource use and waste generation in specific sectors. RECP has proven to be a cost-effective method in sectors as diverse as processing and manufacturing, hospitality and services, as well as primary production in agriculture and aquaculture (Table 1).

Circular economy puts immediate emphasis on the design, operation, management and maintenance of the production system to optimize the use of input materials and minimize waste. Recovery of unutilized nutrients and feed dispersed and dissolved in water in aquaculture systems is not technically or economically feasible. Hence, it is necessary to practice resource efficiency particularly as feed can represent fifty or more percent of production costs and feed losses can increase to sixty to eighty percent depending on the system. Considerations of the design of cages, net-pens, ponds, feed formulation and optimization of feeding regime as well as the design of systems for recovery of solid waste become significant. Research by the United Nations

Fig. 1 RECP techniques (adapted from Van Berkel, 2018)

Table 1 Eight RECP practices illustrated in fish and seafood value chains

RECP practice	Description	Illustrative examples	
		Aquaculture and fisheries	Fish and seafood processing
Good housekeeping	Maintain a clean, organized and productive (‘*neat*’) workplace to eliminate avoidable ‘*wastage*’	First in, first out inventory management Proper maintenance of the equipment and prevention of spills and leaks Applying measures preventing loss of the gear and, in case of loss, its identification	Regular cleaning and maintenance of the processing equipment, e.g. sharpening of the cutters, etc Prevention of waste mixing, timely separation and safe storage of secondary materials (particularly when intended for further processing) Switch off equipment not in use, including lights, motors, etc
Input substitution (*)	Choose inputs that are efficient, effective and/or pose minimum harm to the environment and health	Use of alternative feed materials, e.g., plant or insect-based Substitution of (single use) plastics Use of renewable energy	Use of renewable energy Use of biodegradable and less toxic disinfectants, cleaning agents, etc.
Better process control	Monitor and control processes and equipment so that they always run at highest efficiency and with lowest wastage	Establish and follow Standard Operating Procedures (SOP) Use sensors for switching on aerators, pumps etc.	Monitor water and energy use Establish and follow Standard Operating Procedures (SOP)
Equipment modification	Make existing equipment more efficient and less wasteful	Optimize water and air supply networks to reduce leakage	Adjust fish cleaning stations to drain to middle Use vacuum to remove offal Dry transport belts for offal instead of water flushing

(continued)

Table 1 (continued)

RECP practice	Description	Illustrative examples	
		Aquaculture and fisheries	Fish and seafood processing
Technology change	Change over to new technology that is more efficient or produces less waste	Use of energy efficient equipment, e.g. pumps, motors, barges, vessels	Change to efficient equipment, e.g. water efficient nozzles and spray guns, energy efficient cooling and refrigeration, etc Use of phase change materials for energy storage to avoid freezer unit during cold transport
On-site reuse and recycling	Use previous *'waste'* for similar or alternative purpose in company	Recycling of water in the closed system aquaculture ponds	Recycling of water and energy (for selected processes) for production processes Reuse and recycling of packaging materials
Production of useful byproduct (**)	Convert a previous'*waste*' for a useful use elsewhere	Collect by-catch and fish waste for processing into fish meal or oil	Convert fish skin into alternative leather product Convert fish off cuts into fish flake products (e.g. tuna) Anaerobic digestion of waste water to product biogas

(continued)

Table 1 (continued)

RECP practice	Description	Illustrative examples	
		Aquaculture and fisheries	Fish and seafood processing
Product change	Redesign product to reduce its environmental impact during production, use and/or disposal	Change to more sustainable species (crosses over to input substititon)	Alternative fish conservation, e.g. dried fish, canned fish Diversification of product range with the goal to add value and to utilize own byproducts

(*) From an extended Circular Economy perspective, input substitution crosses over to the resource switching approach
(**) From an extended Circular Economy perspective, production of useful byproducts crosses over to the resource circularity approach

University of 32 fish farms in Cote d'Ivoire revealed higher feel utilization efficiency in farms that use industrial feed. Efficiency is widely measured by feed conversion ratio (FCO) which relates weight gained by a target animal to feed used during its lifetime. This measure is a good indicator for finding optimal feeding process leading to minimizing feed losses, species health and maximizing biomass gains. There are also measures, such as 'nutrient retention', that allow to relating content of feed and edible portions of animals (yield) (Fry et al., 2018). Science and technology advancements make it possible to reach maximum nutrient retention for a variety of species as indicated in the discussion on feed substitutes. Using a combination of these or similar measures supports the efficiency of food in aquaculture.

Some approaches such as aquaponics, aqua mimicry and integrated multi-trophic aquaculture, allow utilization of byproducts from some species as inputs to others allowing optimization of cost, improving quality of products and minimizing risks to ecosystems, yet many of them await conditions that would facilitate their broader uptake.

The reference point for efficient energy consumption in aquaculture is difficult to define universally as it depends on local conditions, the system used and target species. Yet, it is known that energy is used excessively, especially in developing countries, where the use of inefficient and outdated technology and suboptimal management practices add to the production cost and waste of resources. The GIZ project for intensive shrimp farming in Thailand showed that energy cost constituted 1/4th–1/3rd of the total production cost. However, also from an energy perspective, primary concern is feed utilization as according to the research of the World Fish Centre up to 90% of total energy requirements for aquaculture –can be attributed to the production of fish food.

With several energy use reduction measures identified, the use of efficient aerators on an as needed bases with use of oxygen sensors, as opposed to continuous running, could significantly cut down energy consumption (aerators are amounted up to 80% of energy cost). The efficiency of energy use can also be increased through aligning aeration with production load and with output.

Resource efficiency and cleaner production are well established in all stages of fish and seafood processing, and have demonstrated productivity, quality and cost benefits. International best practices and techniques have been well documented (COWI, 2018).

PT. Wahyu Pradana Binamulia (Makassar, Indonesia) is a company producing processed octopus, fish fillet and frozen whole fish. The companies work with the SmartFish Programme of UNIDO lead, without significant financial investments, and by focusing on better operational practices and housekeeping to a significant reduction in water consumption and wastewater generation. These improvements, together with energy savings (by 58%), resulted in annual reduction of CO2 by 636 tons (UNIDO, 2017). Agrex Seafood, a Vietnamese producer of frozen seafood and seafood meals, saved annually some USD 5000, for an upfront investment of less than USD 2,000 in: good housekeeping; high pressure spray guns; improvement of power factor; modification of framing operation; and optimization of lightning system (Dan et al., 2003). Fish processors in Veraval (India) invested approximately USD44,000 (with a payback of less than 14 months), in cleaner production and energy efficiency measures, including: belt conveyor for transferring baskets with fish (rather than water flow); use of spray guns instead of running hoses for cleaning and rinsing of fish; reuse of chlorinated wash water after filtration on a mesh screen in non-critical applications such as preliminary washing of incoming produce; insulation of cooling systems and pipe work: use of stainless steel trays instead of plastic trays to improve efficiency in cooling; installation of reverse osmosis system for water recovery and reuse; and installation of level controllers on overhead water tanks to avoid overflowing.

4.2.1 Minimization of Losses Along the Supply Chain—Focus on Cold Storage and Cold Chains

As fish and seafood are highly perishable products, logistics of the fish and seafood supply chains are of critical importance for the time of distribution (in the absence of a cold chain) or uninterrupted functioning of the cold chain. Losses start with delays between catch or harvest and entry into the secured cold chain at landing sites. Breakages in the cold chain or in delays of delivery lead to diminishing quality and spoilage of products. The US-based company InfraTab provides a RFID tag with a temperature sensor for controlling the temperature along the cold chain for perishable goods.

Several studies have clearly shown that temperature control and a well-designed cold chain is by far the most important strategy to keep quality and prevent losses of perishable fish and seafood. Cooling and in particular freezing consume high amounts of energy, and hence contribute significantly to the carbon-footprint of fish and seafood. This energy use, however, should be put into perspective by the fact that without the application of refrigeration the product losses would be enormous. Since cooling and freezing cannot be avoided, the challenge in this area is to develop and implement energy-saving refrigeration systems for both storage and transportation.

Today, ice is the most widely used cold storage technique for fishermen yet it often remains inaccessible or a scarce resource for small-scale and artisan fishers that account for up to 90% of global total with half of the world's catch. Quick access to consolidated and controlled cold chains is of key importance, and unfortunately a means for middlemen to keep prices low at landing sites for small fishers that cannot afford their own cold storage. As a result, fishermen's income is kept low and product wastage high. Work towards finding alternative solutions that is sustainable and affordable is ongoing. One initiative aiming at addressing the cold storage needs for small fishers in Mozambique is undertaken by a consortium of Rare, National Institute for the Development of Small-Scale Fisheries (IDEPA) and Ocean Excellence—a supplier of fish processing technology from Iceland. The prototype—designed for operating on solar and/or wind energy—will generate energy to achieve super chilling and will be tested aboard fishing boats, during shipping and in markets. This will allow fishers to retain quality of their product, reduce spoilage and, potentially, overfishing (RARE, 2021). National Institute of Solar Energy in India developed a container size solar powered refrigeration unit that could provide solution to remote fishing communities. A number of initiatives, e.g. Green Cooling Initiative, provide information, capacity development events and policy advice towards cooling technology solutions and standards (IKI, 2021).

Extension of shelf-life of fish and fish products beyond cold storage and cold chain consideration has been in the focus of attention of small-scale fisheries in West and Central Africa with new approaches and technologies emerging in different regions with limited access to electricity. FAO has introduced 50 percent more efficiency, in terms of wood consumption, smoking and drying kilns (Climate Initiative Platform, 2021). The FAO-Thiaroye fish processing technology came up with efficient smoking technology for small-scale fishing communities by encapsulating heat and smoke and functioning—in addition to mangrove wood—on coconut husks, sugar-cane bagasse waste and manure. The technology is piloted in thirteen countries in Africa and Asia (Climate Initiative Platform, 2021).

Extending the lifespan of plastic in operation—through introduction of procedures preventing braking and loss of, for example, fishing gear, crates, etc., leading to leakages of plastic waste into the (maritime) environment. Losses are particularly high during storm and other extreme weather events. Work is ongoing on development and promotion of best practices through checklists of pre- and post-storm management of cages and ropes at the commercial fishing boats or by open water farmers, along with identification in case of loss. Marking of fishing gear is key to achieve accountability in the sector for lost, abandoned, or discarded gear enticing operators to prevent losses and facilitate recovery. Keeping gear in operation through prevention of its loss has already begun in the industry by, for example, use of grappling hooks (fisherman in Florida) or acoustic retrieval mechanisms.

4.3 Strategy 3—Maximizing the Perpetual Cycling of End-of-Life/Secondary Materials

The third, and perhaps most defining, circular economy strategy is circularity, i.e., finding ways to put end of life materials into perpetual recovery and repeat use cycles. In case of renewable (and therefore in principle biodegradable materials), cycling can be achieved by safely returning materials into natural cycles whereas for technical materials it can only be achieved through technical cycles in economic production and consumption systems. The following focuses on opportunities, benefits and challenges for circularity in controlled growing systems, aquaculture, (industrial) symbiosis and for post catch processing.

4.3.1 Towards Closed Systems in Aquaculture

Solid waste that consists of the remains of the feed and undigested substances, is considered as one of the most harmful wastes in aquaculture (Global Seafood Alliance, 2020). Self-regulation of the pond system depends on the amount of waste recycled by pond with excessive nutrient input leading to eutrophication and death of the fish. Flow-through systems operating within the natural environment do not have such challenge but have a burden of capturing solid wastes and nutrients before these make way into the host environment. Closed ponds with Recirculating Aquaculture Systems (RAS) remove larger fractions of solid wastes but generally smaller suspended particles are not removed and hence accumulate in the system. RAS is practiced in multiple regions of the world, including in developing countries, e.g., Iraq. To facilitate water quality management Biofloc technology can be employed, which utilizes ammonia to grow microbial proteins that, in turn can be utilized as fish food. While such technologies are rather new and require significant technical expertise, entrepreneurs in developing countries, e.g., in Bangladesh, are working to make it into sustained commercial success by experimenting with seasonality, types of species, etc.

4.3.2 Interconnecting Sectors Towards Zero Waste

One of the important considerations in securing circular solutions is 'proximity' of the resource and energy loops to the stages of the value chain where such returns into consumption and production systems are possible. The Butterly Model for the circular economy, promoted by the MacArthur Foundation, provides an important illustration to this point. Among many triggered observations, confirmed by research and practices, is the one reaffirming the value of industrial symbiosis model where basically the waste from one (industrial) activity is used as alternative input for another (industrial activity). A well-known example is the use of industrial low-grade heat (e.g. from cooling water) to warm up aquaculture ponds to improve productivity, initially demonstrated in Kalundborg, Denmark. Happy Shrimps farms shrimps in cold climate of Rotterdam (The Netherlands) by using waste heat from a nearby power station. Other examples related to industrial scale manufacturing of insect-based feed proteins using waste starch from food processing to feed insect larva and waste heat from power generation to process the protein into feed. According to some calculations, up to 80% energy can thus be saved compared to a no-symbiotic model (Fadeeva abd Berkel, 2021).

Overall, integrated crop-livestock-fish systems can be found in diverse small-scale operations in Asia, including in Indonesia, India, Philippines, Vietnam, and Nepal (FAO, 1985). Even though small in scale, such systems, based on traditional knowledge of farming communities, provide solid knowledge for building future-proof integrated sustainable systems. The Food and Agriculture Organization (FAO) has listed rice-fish system in Zhejiang Province, China, as one of the Globally Important Agricultural Heritage Systems (GIAHS) in 2005. In such system, rice plants give fish shelter while fish protects the rice plants from larvae and weeds and generate waste that fertilizes the rice fields.

4.3.3 Wealth from Fish Processing Waste

Aquaculture, fisheries and processing produce large volumes of solid and liquid wastes ranging from organic (aquaculture waste produce, unutilized feed, accumulated sediments, discarded by-catch, rejects from on-boat and on-shore processing, etc.) to inorganic (wasted chemical inputs, broken cages and pens, broken or lost fishing gear., etc.). On shore processing can cause loss of 50–80% of the catch[1] as bones, skin, shells, guts, etc. that could potentially be used in other sectors for marketable byproducts. Fish waste can become a source of enzymes and bioactive peptides used for fish feed, fish sauce or fish silage production.

While use of fish waste for direct human consumption is difficult with some exceptions such as production of fish oil, and ample possibilities for utilization of byproduct exists, much of it is utilized for less value added products such as fish and animal feed or fish flower. Growing volume of waste and technology for its utilization offer additional solutions. Braking fish wastes into peptides and amino acids, i.e., Fish Protein Hydrolysates (FPH), gives a product with enhanced bioactive properties, including antioxidant qualities for food or pharmaceutical applications where they can replace synthetic products (Mohanty et al., 2018). Skin, bones and fins constitute up to 30% of byproducts and can become a source of collagen and gelatin production for diverse applications including pharmaceutical materials for wound dressing, carriers for drug delivery; food industry as a stabilizer of emulsions and possible substitute for bovine gelatin, or cosmetics (Mohanty et al., 2018). Other commodities that can be derived from fish processing waste include antifreeze proteins, pigments for medical and biomedical applications, bio-oil for application in diesel engines, bioactive compounds with antibacterial or antifungal qualities, and more.

Some companies seek to source fish byproducts from producers as alternatives for their traditional inputs. For example, Atlantic Leather company that takes its roots in lambskin leather production found fish skin as a substitute raw material in a view of scarcity of supply of traditional raw materials. There are expectations that exotic fish leather will soon become more widespread in use. Fermer, a company in France, uses natural tannin to tan fish skins for production of accessories such as shoes and wallets. Accessories are also produced by a tilapia producer Regal Springs as part of their zero-waste policy.

According to FAO, production of biofuel from fish waste can be done cost-effectively in many regions of the world as technology for such production is being adapted from the animal husbandry sector. If locally adapted and applied, fish farmers can receive significant amount of biodiesel (1 L from 1 kg of fish waste) at limited

[1] https://www.researchgate.net/publication/327249757_FUTURE_PROSPECTS_AND_TRENDS_FOR_EFFECTIVE_UTILIZATION_OF_FISH_PROCESSING_WASTES_IN_INDIA

cost. Researchers and fish producers in various countries are working on developing efficient processes of fish waste conversation into biodiesel. An EU project "Enerfish Wedge" is one of the example. Further research efforts are underway for co-processing of fish waste together with agricultural residues.

Finding alternative use for seafood and fish waste can have good economic benefits. While majority of offal and other processing waste is today used for fish meal or fish oil, some products can bring significantly more value. For example, Multi Bloom and Mega Green company working with Gurry Investment uses grinding and hydrolysis to make organic fertilizer. This value added product gets processors more than the double price for their fish waste.

4.3.4 Closing Plastics Loops

Marine plastic littering puts productivity and sustainability of fisheries at risk, yet at the same time, fishing and aquaculture are also a source of plastic. From circularity perspective, plastics as a man-made material or technical ingredient is to be collected, source segregated and recycled. The quality of recycling is still a challenge, with much plastic waste ending up in low value applications, which in turn is also a reflection of state of waste collection systems, resulting in contaminated and mixed plastics waste. Of particular concern is lost or abandoned fishing gear, for which good recovery and recycling practices are gaining ground. Net-Works is a programme that works with coastal communities in Philippines and Cameroon that incentivizes them to recover abandoned nets, which are then used as input materials for designer carpets. Goodwood Plastic Products in Fort Ellis (Canada) produces plastic timber for use in outdoor furniture and decks from plastic fishing ropes recovered by a diving company mixed with some other plastic waste. Sustain Technology, also from Canada plans to turn fishing ropes into diesel fuel.

5 Concluding Remarks

Fish and seafood are to be part of achieving the global nutrition and sustainable development goals. Business as usual operation and expansion of the sector though are not sustainable and are putting ecosystems and biodiversity increasingly at risk, both below water as well as on land. Today, developing and in-transition countries have become the largest suppliers of fish globally. To be sustained in their development of fishing and aquaculture they gradually turn their attention to a host of issues related to environment, resource efficiency, ecosystem integrity, and health. Such complex agenda requires rapid progress to secure access to the local and global markets demanding stringent quality, environmental and social performance and, ultimately, livelihood of people. Circular economy holds promise for focusing on key actions and innovations to achieve resource efficiency in fish and seafood value chains and put fisheries and aquaculture on a sustainable footing.

Circular Economy as a guiding concept comes into action where firms and value chains move individually and collectively towards resource circularity, resource efficiency and resource switching. Circularity without efficiency and concern for sustainable input has limited impact as it can—subject to intensity of operations—continue putting excessing pressure on resources and ecosystems. Efficiency without circularity and less harmful input can lessen material and energy circulation but will risk losing significant portion of potentially useful materials from the production-consumption system and compromising health and the environment. Considerations of more sustainable inputs and goals of restoration of ecosystems make circular economy more ambitious and comprehensive. The exploration of challenges and opportunities in the fish and seafood value chains presented here reaffirmed the applicability of Circular Economy to food systems. Practical examples of innovations and industry practices from developing countries provide testimony for emerging global consensus, commitment and action on sustainability of seafood and fish. Sustainability of the fishery or aquaculture farm within its host ecosystems is imperative as the uncontested starting point. However, multiple further actions and strategies are both needed and possible, particularly on feed alternatives (including plant and insect-based substitutes), minimization of processing waste and byproducts and their effective utilization (for nutrient or energy recovery and or as other useful byproducts), sustained efforts on efficiency of use of energy, water and materials in all stages of the value chains and concerted efforts towards maximizing the use of renewable energy and zeroing out plastics waste and littering.

From a systems perspective, circular economy also stresses upon the interconnectedness of aquaculture and fishing and their processing industries and the potential for industrial symbiosis with the other industrial sectors. Such symbiosis is possible in both the directions, with fish and seafood operations taking previously wasted resources from other sectors (e.g., waste heat to operate fish farms or organic byproducts as feed input) or other sectors taking previously discarded resources from fish and seafood operations (e.g., recycling of retrieved or dysfunctional fishing gear, fish skin leather etc.).

Notwithstanding the relative abundance of promising examples and innovations, it is equally evident that the scale and speed of their deployment does not yet meet the scale and urgency of the sustainability and nutrition challenges. Further efforts are needed to accelerate and scale up circular economy applications, while ensuring a just transition for the millions depending on fisheries and aquaculture for their livelihoods. First and foremost, this requires firm policy direction and regulatory security at global, regional and national levels for the primary production (wild catch and farmed) and their processing value chains, along with strong institutional, knowledge and operational capabilities to ensure data-driven, transparent and predictable implementation. Secondly, further efforts are necessary to create strong market pull for transformative change in the value chains, starting from consumer demand for sustainable fish and seafood an ultimately market rejection of unsustainable products. Such market pull can also leverage finance, R&D and other resources into a sustainable and circular transformation of fish and seafood value chains. Thirdly, efforts need to be focused on creating a vibrant ecosystem to support fish farmers, fishing communities and processors, to adopt best circularity practices, through training and capacity building, quality and assurance systems, development and promotion of replicable solutions appropriate in local context and business mentoring.

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Resource Efficiency for Sustainable Agriculture and Food Value Chains in India: The Case of Food Loss and Waste

Rijit Sengupta and Devyani Hari

1 Food Systems Transformation: Imperatives for Sustainable Development

Food system as defined by the Food and Agriculture Organisation (FAO) of the UN, encompasses all stages of demand and supply viz. growing, harvesting, packing, processing, transforming, marketing, consuming and disposing of food (Nguyen, 2018). The existing food systems have to cater to the needs of 7.8 billion people, globally. Currently, half of the habitable land (approx. 5 billion hectares) is dedicated to agriculture and related activities (of this, roughly one billion hectares is dedicated to crop cultivation) (Ritchie, 2019). Agriculture accounts for nearly 85% of the water usage meant for human consumption (D'Odorico et al., 2020). Irrigated agriculture represents 20% of the total cultivated land and accounts for 40% of the global food production (World Bank, 2020). World population is estimated to grow by 25% by 2050, which would entail a significant increase in agricultural production to meet food and nutritional requirements (FAO, 2009). Furthermore, increasing income levels are likely to continue pushing demand or toward meat, fruits and vegetables—requiring a change in production patterns as well (FAO, 2017). Such expansion of agriculture will however have to be designed while taking into consideration resource constraints and uncertainties like low availability of land, deteriorating soil quality, decreasing water resources and the vagaries of climate.

Unrestrained efforts to increase production have not only increased the stress on the environment (soil, water, forests) from expanding acreage but also increased the use of fertilizers and pesticides. As per OECD, agriculture is a significant contributor

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to water pollution owing to its fertilizer runoff, use of pesticides and livestock effluents (OECD, 2018). Negative impacts include deforestation, soil and water contamination and destruction of biological resources and diversity, thus contributing to a looming climate crisis. Food systems today account for nearly 37% of total global emissions (Schulte et al., 2020). Food systems for the future cannot just be about enhanced production but must also embrace systems that reduce environmental stress, contain emissions and mitigate the impacts of climate change, while enhancing benefits for the farming community. There is a fast-growing consensus that the food and land systems need to undergo major transformations to deliver on a number of the Sustainable Development Goals (SDGs).

No wonder, the topic of food systems transformation has received attention at the highest level, with the UN Secretary-General all set to convene a global Sustainable Food-Systems- summit in 2021 to raise global awareness and initiate collective actions to radically change the way we produce, process, and consume food (UN, 2021).

Despite rising trends in food production globally, hunger and malnutrition continue to remain serious concerns. Over 2 billion people worldwide suffer either from moderate or severe levels of food insecurity, as per the 'State of Food Security and Nutrition in the World' report of 2020. Further, nearly 700 million people were estimated to be undernourished globally by end 2019, and the COVID-19 pandemic is likely to add a further 80–130 million to this list (WHO, 2020). This statistic becomes confounding, especially when one considers the global food stock-to-use ratio (carryover stock as a percentage of total use), which is at a 20-year high of 33% (FAO, 2020).

India mirrors this dichotomy—in spite of being self-sufficient in food production, 39% of its population is undernourished and it ranks poorly on the Global Hunger Index (Pharo et al., 2019). The magnitude of the current challenges has been further highlighted in the recently released National Family Health Survey 2019–20 (NFHS-5) findings, presenting data on health, population resources and nutritional levels of women and children in the country. The Covid-19 pandemic will compound this problem further, given it is estimated that over 400 million Indians will be pushed into poverty. Clearly, food production isn't quite the only problem that we need to resolve at the moment. Efforts to strengthen public institutions, regulation, distribution systems and business/private sector engagement to ensure nutritious food reaches those in dire need, should be the priority.

As per the Food and Land Use Coalition (FOLU) initiative's assessment, there are ten critical factors (Pharo et al., 2019) that can support the transition towards sustainable food systems. One such transition relates to the management of food loss and waste. The high incidence of food loss and waste (FAO, 2017) estimated at 1.3 billion tonnes globally (Depta, 2018) exacerbates the untenable nature of our current food systems, both for producers and consumers. Food loss and waste have high implications not only on environmental sustainability (stress on local environmental resources), but also on economic sustainability (loss/reduction in income for producers) and social sustainability (impact on community food and nutritional requirements). Despite high volumes of food loss and waste and its implications on sustainability, this area hasn't quite received due attention in discussions related to sustainable food value chains, at least in India.

2 Sustainability Challenges in Indian Agriculture and Food Value Chains

Achieving self-sufficiency in food grain production to ease reliance on imports post-independence and to address the problem of recurring famine were the main motivations behind design and implementation of the 'green revolution' by the Government of India in the 1950s. The focus on food grain production and expansion of cultivated area was largely pivoted on staple crops—mostly rice and wheat. The Government of India created enabling policies and designed the institutional set-up to meet this goal. Resultantly, food grain production (rice, wheat, maize and other cereals) has grown remarkably from 51 mn tonnes (1950–51) to 276 mn tonnes (2016–17) since the advent of the Green Revolution. There has also been an incremental increase in the production of pulses and oilseeds over this period. From a paltry 23 mn hectares of irrigated land in 1951, irrigation has spread to over 72 mn hectares in 2015–16 (GoI, 2018), comprising around 40% of the total land available for agriculture in the country. Population has grown from 361 million in 1951 to 1.3 billion today. India not only boasts itself as a food self-sufficient country (with a large buffer stock) but also has come to the aid of other countries by supplying food in times of need. In order to bring permanency and provide the necessary policy backing, a legislative instrument was created through the National Food Security Act, 2013 to operationalise the constitutional provision of right to food and nutrition for all the citizens (right quality and quantity of food at affordable prices). This legislation brought within its fore two thirds of the population, who would receive highly subsidised food grains (NFSA, 2013). However, a large section of the Indian population still remains vulnerable to food (and nutrition) related shocks. COVID-19 has further augmented this challenge.

A review of the agriculture scenario in India today—60 years later clearly highlights that the legacy of the green revolution continues to dominate the sector. The emphasis continues to be on boosting production, rather than ensuring that the produce is well stored or processed and finds the right price in the market. While production has reached record levels, the focus on input-driven agriculture using high-yielding varieties coupled with the indiscriminate use of fertiliser, pesticides and water to support the rice–wheat system has had considerable negative impacts on soil, land, water and people. One of the frontrunner states of the green revolution in India—Punjab still remains the breadbasket of the country. However, the dominance on rice–wheat cultivation which covers over 80% of the cropping area in the state has affected the local environment and health of the farming communities (Pandey et al, 2020).

Agriculture and its associated sub-sectors contribute 19.6% to India's total GHG emissions (WRI, 2017). Major sources of emissions from agriculture include methane produced from livestock (largely cows and buffalo), rice cultivation and fertiliser application (Timperley, 2019). Further, the expansion of agriculture and allied activities in certain areas of the country have significantly contributed to loss of forests, wetlands and resulted in biodiversity loss (Almond et al., 2020). Focus on the rice–wheat system and to effectively utilise the short window between harvest and sowing force farmers to resort to burning of post-harvest stubble, resulting in poor air quality in many North Indian states year after year (Punjab, Haryana, Uttar Pradesh, Rajasthan) (Pandey et al., 2020; Sarkar, 2021).

Fundamental changes are required, as suggested by many academics and practitioners, to help the sector transition to sustainable and widely distributed agricultural growth that will boost India's GDP, increase export revenues, aid in conserving increasingly scarce resources like land and water, and enable a more orderly transition away from agriculture and into other productive sectors (Gulati, et al., 2020).

According to Gulati et al. (2020), following areas need to be prioritised if India is to develop sustainable food and agricultural value chains:

- Agricultural reforms are required to help farmers deal with the rising risks of weather and price volatility.
- Agricultural markets must be opened to more competition and provided with the proper infrastructure, for better returns to farmers and nutritional security.
- Policies to improve the allocation and efficiency of land and water are essential for natural resource conservation.

3 Towards Sustainable Agriculture and Food Value Chains in India: Opportunities & Challenges Post COVID-19

An overhaul of agricultural markets should be accompanied with some consideration of the choice of agricultural practices and products by the farming community—in order to promote a holistic model of sustainable agriculture and food value chain in India. Sustainable agricultural practices can provide the much-needed boost to strengthen the rural economy, restore local ecology and provide agro-entrepreneurs with an added advantage in the market, thereby contributing to the Government of India's aspiration of improving farmers' welfare.

According to Rao (2002), the following factors make up the framework for sustainable agriculture:

- Balancing the supply constraints imposed by the over carrying ecosystems capabilities with the food demand limits imposed by the world's expanding population and economy (system capacities)
- Understanding trade-offs between agricultural productivity and the standard of the natural resource base in various locations and agro-ecosystems as measured by appropriate sustainability indicators

- Taking into account the cutting-edge technologies and enhanced management techniques that might reorient the trade-offs in favour of enhancing both sustainability and productivity (Hegde & Sudhakara Babu, 2016)

Amalgamating experiences from the ground with the above determinants leads to a set of *principles* and *priority actions* on sustainable agriculture and the food value chains in India (as enumerated below). It also highlights linkages with specific Sustainable Development Goal targets.

- ***Principles:*** (i) Reviving and strengthening traditional agricultural practices along the lines of *regenerative agriculture* (SDG 2.4); (ii) Aligning principles of landscape and biodiversity conservation with agricultural practices (SDG 15.2, 15.5 & 15.9); (iii) Meeting the food and nutritional needs of farming families, especially the vulnerable (SDG 2.1 & 2.2).
- ***Priority Actions:*** (i) Placing farmers' welfare at the heart of agriculture market reforms (SDG 2.c); (ii) Encouraging and attracting youth in agriculture by investing in skills, vocation and entrepreneurship (SDG 4.4); (iii) Reducing food loss and waste reduction in improving margins for farmers (SDG 2.3 & 12.3).

3.1 Principles

- Reviving and strengthening traditional agricultural practices along the lines of *regenerative agriculture (SDG 2.4)*- India has had a rich history of traditional agricultural practices including zero tillage, zero budget natural farming, regenerative agriculture, and community farming which are now being considered 'cutting edge' and should be propagated by agricultural experts, technicians and extension workers especially in remote areas.
- Aligning landscape and biodiversity conservation principles with agricultural practices (SDGs 15.2, 15.5 & 15.9)—The IUCN encourages the use of Nature-based Solutions (NbS), which entails addressing major societal issues through the preservation, sustainable management, and restoration of both natural and artificial ecosystems, thereby enhancing biodiversity and improving human well-being. NbS should be taken into consideration for all the projects, especially those involving biodiversity hotspots etc. in India. NbS have a significant, but currently underutilised potential to help address global challenges like climate change, human health, food and water security, natural disasters, and biodiversity loss (Cohen-Shacham et al., 2016).
- Meeting the food and nutritional needs of farming families, especially the vulnerable (SDG 2.1 & 2.2). Combating malnutrition and hunger remains a priority especially for the most vulnerable and marginalised farming families and landless farm workers. While hunger-related deaths have not been reported even during the COVID-19 crisis, nutritional security remains a challenge in India, especially for children up to the age of 5 years. Agriculture and allied livelihoods can help improve the socio-economic conditions where it is most needed. Innovative public

and private sector collaboration models and approaches can help meet the nutritional security of children, adolescent girls and pregnant women on one hand and create sustainable livelihoods on the other.

Priority Actions:

- Placing farmers' welfare at the heart of agriculture market reforms (SDG 2.c)—Government of India has driven through legislation that provides the *option for farmers to sell their crops directly to the buyers of their choice* including the private sector. This is expected to provide better returns for farmers who were otherwise tied to the erstwhile 'mandis' established under the Agricultural Produce Market Committee (APMC) Act—which had been crying out for reforms. Effectively implemented, it also has the potential to provide benefits to consumers (access, quality, choice and price of food products). Such reforms cannot achieve benefits for the farming community automatically and needs to be closely monitored and assessed by the state governments, Panchayati Raj Institutions, community-based organisations and other actors. Rising inequality in the farming community is a concern (especially the dominance of large traders and agro-entrepreneurs and reducing margins and other livelihood impacts on smallholders and landless farmers), especially as these reforms get implemented.
- Encouraging and attracting youth in agriculture by investing in skills, vocation and entrepreneurship (SDG 4.4)—The farming community is ageing in India, as fewer youngsters get attracted to conventional farming. Local value-addition through financial support, investment and technological applications in storage, food processing (especially primary processing), logistics, and supporting Farmer Producer Organisations holds considerable promise in promoting sustainable food value chains, and ensuring the youth get integrated into the agriculture and food sector. Good practices from across the country could be documented and utilised for inspiration and capacity building aimed at building a battery of young *sustainable agro-entrepreneurs*. This would be crucial especially as a lot of young workers have returned to their villages from cities post COVID-19 and are looking for jobs/livelihood opportunities closer to home.
- Reducing food loss and waste reduction in improving margins for farmers (SDG 2.3 & 12.3)—A shift in policy and practice level interventions can address the problem of post-harvest food loss and contribute to improving farmers' income and resultant welfare. Currently, a significant portion of the food is lost within and around the farmgate. Such losses at the farm gate stifles productivity improvements and suppresses farmer's margins, and contributes significantly to greenhouse gas emissions and climate risks. Application of resource efficiency can help reduce food loss and waste and contribute towards decarbonising agriculture (Legg, 2017). The next section focuses on application of resource efficiency (circular economy principles and practices) in reducing food loss and waste in India.

4 Case of (Reducing) Food Loss and Waste in India (CRB 2019)

Understanding Food Loss & Waste and its Impacts

Food loss happens in the food supply chain from harvest up to, but excluding, retail, according to the Food and Agriculture Organisation (FAO) (FAO, 2019). Food waste is defined as the wastage occurring at the retail and consumption levels. In high-income nations, food waste volumes are higher in the downstream (during consumption phase) stages of the food chain. This is according to a 2013 FAO report. Food loss is greater at upstream stages (production, handling, storage, and processing) in low-income countries (FAO, 2013).

According to Ishangulyyev et al. (2019), infrastructure issues, excess production, harvesting timing, and harvesting techniques are some of the precise causes of food loss throughout the handling and storage stage. The main reasons for food loss in low-income nations are related to technical, managerial, and financial constraints on harvesting methods, infrastructure, storage and cooling facilities, packaging, and marketing systems. Food waste in middle- and high-income nations is mostly related to consumer behaviour and a lack of coordination among the various supply chain participants (Girotto et al., 2015).

Regarding food loss and waste in India, there is a substantial amount of data inconsistency. It's interesting to note that India is one of the few nations that have conducted two thorough studies on food loss during the past fifteen years, and a third research is currently being planned. The Indian Agricultural Statistics Research Institute (IASRI) covered 46 crops in the first one, which was undertaken in 2005 as part of an all-India coordinated research initiative on post-harvest technology. The Central Institute of Post-Harvest Engineering and Technology (CIPHET) and IASRI conducted a second study in 2013–14 that included 45 different crops. The table below provides quantifications of the amount of food lost for various crops and other agricultural products (Hussain, 2021) (Table 1).

A number of more recent studies have been conducted with limited geographical and crop coverage. However, there is a fair amount of discrepancy across these studies vis-à-vis food loss data, most likely due to differences in defining food loss and the metrics/methodology used in assessing food loss.

Given the considerable post-harvest losses, India has a poor availability of fruits and vegetables per capita (Felder, 2019). Despite a significant increase in the production of rice, wheat, and other cereals, their per capita net availability has not increased at the same level due to population growth, food loss and wastage, and exports, according to a report titled Food and Nutrition Security Analysis, India, 2019 by the Ministry of Statistics and Programme Implementation (MoSPI), the Government of India, and the World Food Programme (WFP). Food security and nutrition in India are affected by food loss (at or near the farm level), which is especially important for farming families and communities.

Finally, a recent UNEP Report estimates 8–10% global GHG emissions to be associated with food waste (food that is not consumed) (Zhongming & Wei, 2021).

Table 1 Magnitude of food loss (commodity-wise), CIPHET studies. *Source* (Hussain, 2021)

Serial number	Commodity	2012–13			2005–07
		Loss in farm operations	Loss in storage channel	Total loss	Total loss
1	Wheat	4.07	0.86	4.93	5.93
2	Paddy	4.67	0.86	5.53	5.19
3	Potato	6.54	0.78	7.32	8.99
4	Soybean	8.95	1	0.96	6.26
4	Tomato	9.41	3.03	12.44	12.47
5	Mango	6.92	2.24	9.16	12.74
6	Apple	9.08	1.31	10.39	12.26
7	Eggs	4.88	2.31	7.19	6.55
8	Inland fish	4.18	1.05	5.23	6.92
9	Poultry meat	2.74	4	6.74	3.65

Addressing food waste at retail, distribution and household level should also be included in national level discourses and actions/initiatives to combat climate change in India.

A number of initiatives have been designed and are being implemented by public agencies and the private sector to address the problem of food loss and waste in India. An overview of some of these initiatives have been presented in the table below. Further, the table also presents some international (country specific) initiatives, which could provide useful lessons for us (Table 2).

While a number of initiatives have been designed by the Government of India (various Ministries and agencies), the magnitude of food loss and wastage and its multiple impacts (social, environmental/climate and economic) pose daunting challenges for a sustainable food value chains in India. Given the complexity of the agricultural value chains, policy and practice level innovations are critical to address these challenges.

Collaboration between public and private sector actors will be the key to ensure that food loss and wastage are contained within set targets. Government needs to play a critical role as an important procurer of agricultural products in reducing food loss and waste. Private sector actors ranging from large multinationals to startups are also taking keen interest on the subject (HUL, 2021; Nainar, 2021).

A number of MNCs operating in India have made global commitments and set target for reducing food loss and waste, which needs to be implemented in India. This would help these businesses demonstrate their contribution to the Sustainable Development Goals, specifically SDG12 (sustainable production and consumption) and target 12.3. Private sector contribution to SDGs, is being strongly encouraged by the Government of India—as captured in India's Voluntary National Review of the SDGs (VNR2020) (NITI, 2020). Experiences suggest that public and private sector

Table 2 Overview of initiatives for addressing food loss and waste in India. *Source* CRB Analysis

Types of Initiatives	Initiatives	Details
Public	Model food processing policy, ministry of food processing industries (MoFPI, Government of India, 2017)	Emphasises the importance of reducing waste by: --Realizing the sector's enormous potential to boost the economy through improved use of agricultural products; --Increasing value-addition; --Ensuring better prices for farmers while ensuring availability of affordable and quality produce to consumers; Minimizing post-harvest losses and creating employment opportunities
	Creation/Expansion of food processing & preservation capacities (CEFPPC) scheme, MoFPI	The major goal of this programme is to build processing and preservation capacity and modernise or expand existing food processing facilities in order to increase processing levels and add value, which will reduce waste (MoFPI)
	Various initiatives of the food standards safety association of india (FSSAI)	--*The obligation of food donors and organisations involved in distributing surplus food is outlined in the Food Safety and Standards (Recovery and Distribution of Surplus Foods) Regulations (2019) (MoHFW, 2019)* --The Food Safety and Standards Authority of India (FSSAI) has launched a social initiative called the Indian Food Sharing Alliance (IFSA) to address India's food waste and hunger problems by bringing together a number of partner organisations, food recovery agencies, and non-governmental organisations (NGOs). Through the "Eat Right India" initiative, the FSSAI has started a massive transformation of the nation's food system to provide all Indians with food that is secure, wholesome, and sustainable. To ensure that our food is healthy for both people and the environment, Eat Right India uses a thoughtful combination of regulatory, capacity building, collaborative, and empowering techniques. (FSSAI, 2017)

(continued)

Table 2 (continued)

Types of Initiatives	Initiatives	Details
	Under the *Make in India* initiative (Department for Promotion of Industry and Internal Trade, 2014), six schemes have been adopted to reduce wastage and benefit farmers	--Mega Food Parks --Infrastructure for the Cold Chain, Value Chain, and Preservation --Capacity-building for food processing and preservation --Backward and Forward Linkages --Quality Control and Food Safety --Cluster for Agro-processing
Private	Sustainability initiatives by Agri-food MNCs	--Businesses have made commitments on various sustainability/SDGs targets for example—food security, nutrition, reduction of food waste, etc. Their implementation on the ground involves collaboration with producers and other value chain actors --Collaborative approaches/models like *food banks* which involves businesses, recovery agencies, local communities, CBOs, etc. are being explored
	Social enterprises	--Converting post-consumer waste into manure is being done by several social enterprises across India --Collecting surplus food from restaurants and other sources and distributing to less fortunate sections of society in cities has proven to be extremely effective in some cases --Contract farming—where farmers are supported with technology, capacity building initiatives and good agricultural practices to meet certain set quality and safety standards, has helped reduce food loss

(continued)

Table 2 (continued)

Types of Initiatives	Initiatives	Details
	Agri-tech driven initiatives[1]	--*Waycool* has achieved continuous reduction in wastage of agricultural produce procured by the company by adopting innovative technologies throughout the supply chain --*Farmpal* has designed an artificial intelligence solution to predict demand at 95% accuracy and keeping the wastage below 5% --*FarmERP* a fresh produce start-up company focuses on sourcing fresh produce directly from farmers with no intermediaries ensuring traceability, quality and safety --Food services and facilities management companies have been using tracking tools to measure wastage at any given point of time, thereby help in managing food loss and wastage

(continued)

[1] Names of these firms have been provided for better illustration of the point purely from an academic perspective, and not for promotional purposes.

Table 2 (continued)

Types of Initiatives	Initiatives	Details
International (country specific) initiatives	A number of countries have adopted national strategy/policy/actions to reduce food loss and waste, which could provide lessons for India	--**European Union:** EU Sustainable Food Initiative (*Farm to Fork*): underlines the need for food systems to be resilient especially to withstand shocks like COVID-19, focusing on (i) sustainable food production; (ii) food loss and waste reduction; (iii) Sustainable Food processing and distribution; and (iv) sustainable food consumption --**Germany**: National Strategy for Food Waste Reduction sets the framework for avoiding/reducing food waste and achieving mindset change in society. It enables better appreciation of the *true value* of food and resources needed for their production --France has passed legislation prohibiting supermarket food waste, requiring businesses to minimize, repurpose, or recycle their excess food (Mourad, 2015) --Australia: The National Food Waste Strategy (2017) offers a framework to enable group efforts to reduce Australia's food waste by halving it by 2030. (Australia. National Food Waste Strategy, 2017). Quantifying the $20 billion per year projected cost of food waste could be a motivating factor in finding a solution --Thailand: In 2015, the FAO and the Royal Thai Government launched a significant awareness-raising campaign to reduce food loss and wastage (Pacific, 2015)

actors in India could consider to ***target, measure and act*** towards reducing food loss and waste (Hanson & Mitchell, 2017). This would entail:

- TARGET: Ambition is sparked by targets, and action is prompted by action. Target 12.3 of the Sustainable Development Goals, which calls for a 50 percent decrease by 2030, should be adopted by governments and businesses.
- MEASURE: Management is based on what is measured. Governments and businesses participating in the food supply chain should begin measuring their food loss and waste, if they haven't already, and track their progress over time toward achieving the aim. Entities can move forward with measurement with the use of a food loss and waste accounting and reporting system.
- ACT: The most important thing is to take action. To reduce food loss and waste at every point in the food supply chain, both governments and businesses must take strong action, both individually and collectively. Everyone can find something to do.

A few specific areas where leadership by the Government (Centre and State) is critical, are:

- Development of a National Food Loss and Waste Reduction Policy
- Institutional framework to enable and support effective horizontal (inter-ministerial) and vertical (centre-state-local) coordination among public agencies
- Target-setting to reduce food loss and waste at all stages of the agricultural value chain (there is a need for setting better indicators under SDG12.3 in the National Indicators Framework for India) (MOSPI, (2018))
- Public sector engaged in procurement of agricultural products to play a leadership role in reducing losses and wastage of commodities along the entire value chain

5 Conclusion

The food we eat, the methods by which it is produced, and the quantities lost or wasted have significant effects on human health and environmental sustainability, as stated in the EAT-Lancet report (EAT-Lancet Commission on Food, Planet, Health)(Eat Forum, 2022). Getting the food system right will be crucial for nations to meet the Paris Climate Agreement's goals as well as the UN Sustainable Development Goals. The necessity for thoughtful, comprehensive, and creative measures to promote sustainable agriculture and the food value chain in India is generally acknowledged.

Not only is it an imperative now, post COVID-19 but also possible given the rich repository of traditional knowledge and skills of the Indian farming community combined with the advancements in science and technology—supported by the right enabling environment.

The earlier section in this chapter makes the case for reducing food loss and waste across crops as a ***key impact area*** for ***sustainable agriculture and food value chain*** for India—not only to augment food availability among the most vulnerable but also

Table 3 Proposed considerations for circular economy to address FLW. *Source* Authors' analysis

Principles of circular economy	Actions for reducing food loss and waste	Measurable indicator(s)[3]
Principle 1: Design out waste and pollution	Application of good agriculture practices and low-cost storage to reduce the volume of farm-level losses	– Volume of food loss reduced (per unit land area cropped)
Principle 2: Keep products and materials in use	Use of post-consumer food (surplus food) to feed marginalised and impoverished populations	– Households covered per day/year
	Use of post-consumer food waste for composting, manure	– Volume of compost generation (kg/annum) – Energy produced per year
Principle 3: Regenerate natural systems	Reduce/minimize adverse environmental impacts	– Pesticide and fertilizer residue (built-up in soil and ground water) – GHG emissions

to improve margins for farmers and contribute towards reduced GHG emission and climate change.[2]

Private sector in the food and agriculture business have to set food loss and wastage targets and develop action plans. Government will need to work closely together with the private sector to achieve this by creating the right enabling environment at the national, state and local levels.

In order to meet these aspirations, this chapter concludes by presenting a *framework for application of resource efficiency* (specifically the principles of circular economy) (EMF, 2012) in designing actions to reduce food loss and waste, and measure their efficacy. This can be used by both public and private actors. However, engagement of multiple stakeholders would be critical for its effective implementation (Table 3).

[2] The additional four ***key impact areas*** for sustainable agriculture and food value chain in India are:

- Meeting food and nutritional needs of the most vulnerable in the food value chain.
- Reviving and strengthening traditional and regenerative agriculture especially for soil and water conservation and preserving biological resources/diversity.
- Attracting youth by investing in value-added agriculture, focused on building skills, vocation and entrepreneurship.
- Improving working conditions and welfare of farming families.

[3] Indicators will need to be refined based on the local context and conditions.

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Technology and Innovation for Food Value Chain Development

Agricultural Value Chains in Developing Economies: A Theoretical Framework

Robert N. Truelove, Stephen C. Lellyett, Abukari Ibrahim Issaka, and Samsul Huda

1 Introduction

The aim of this chapter is to provide a conceptual framework for understanding value chains and to inform our understanding of complex systems, such as the food supply system, which is critically important to human life on this planet.

Essentially, a value chain represents the flow of goods, services and processes leading to final consumption. A given value chain may span the full range of processes involved from supply of raw inputs, production and manufacturing, distribution, marketing, to the sales and final disposal of associated waste, or any subset thereof. Agricultural value chains start with inputs to the production of food or other natural products, which may be consumed 'whole', or in a transformed state; and may be marketed and consumed 'locally' or transported and then marketed to the final consumer. Along this path, the goods may be bought and sold by one or more intermediary businesses. Each and every function carried out by participants along that chain may add value to the 'raw' farm product—value which in the eye of the final consumer is worth paying for, in order to satisfy their particular 'need' or 'want'.

In a world with finite resources it goes without saying, that the food supply system needs to be sustainable, that is it must continue to support human life without exhausting the planet's resources. But further than that, the impact of that system needs also to cause as little damage to the broader ecosystem as possible. So, sustainability in it its widest interpretation means satisfying human needs on an ongoing

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basis without exhausting natural resources and with as little detrimental impact on the inherited environment, as possible.

A more expansive definition of a sustainable food value chain which captures most of the points raised above is:

> the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials, and transform them into particular food products that are transported, marketed and sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources.[1]

Both value chain actors who directly own the product and the various business service providers such as banks, transporters, extension agents, input dealers and processors who charge a fee are encompassed within the 'full range of farms and firms'. The particular business environment in which these actors and service providers operate acts as a strong influence on the way they behave and perform.

A notional activity which expresses a purposeful human activity is referred to as a human activity system. These systems are referred to as notional because they are intellectual constructs and a simplified description of real-world activity. To improve a farming system as depicted in Fig. 1, inputs to animal and plant sub-systems, alongside the processing of their waste products via the decomposing sub-system, are all guided by human activity utilising innovations, allocations and operations which can impact the environment. This produces outputs that in turn impact on and are influenced by broader systems and forces beyond the farm. Managing this impact in a way that is sustainable beyond the farm should be a key objective of policy alongside fostering increased productivity of the farm itself. Capturing these objectives and sub-system interactions within the design of food value chain models is therefore important.

2 Value Chain Modelling of Agricultural Products and Its Interrelationship with the Three Fundamental Systems

The agricultural value chain encompasses all three of the fundamental systems that make up our complex world—the environmental or natural system (ecosystem); the economic system and human social system. All three interact across agricultural value chains at multiple points. Inputs to one system may draw on the stock of resources of another system, for example, gains in the productivity of crops requires an optimal supply of environmental inputs that includes adequate water from rivers, bores or rainfall, daily temperature exposure, solar radiation and evapotranspiration (ET), plus nutrients from soil with further dependency upon texture, chemistry, erosion hazard and hydraulic properties—sometimes built up over millennia in the natural environment. Whilst these may be initially free inputs, their usage may lead

[1] This definition is mainly a variation on and expansion of the definition by Kaplinski and Morris (2000).

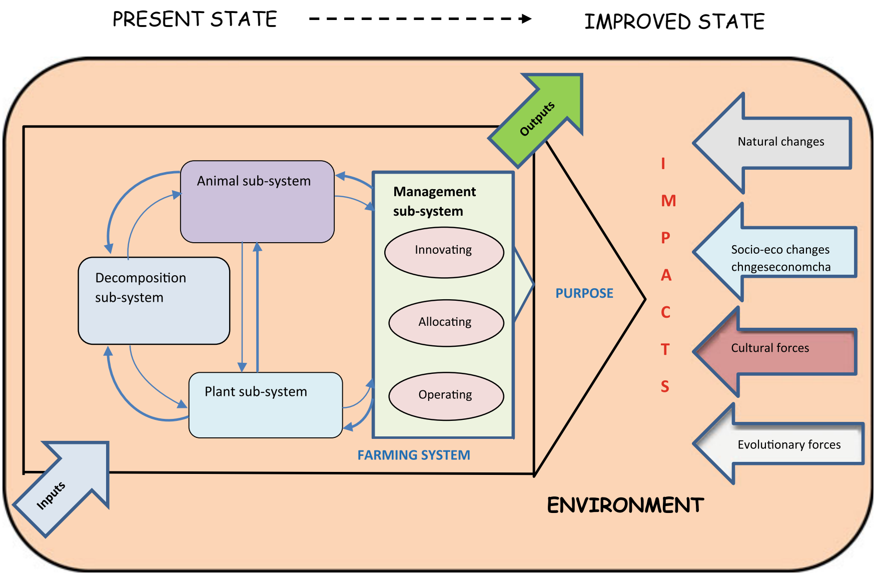

Fig. 1 A model of farming as a human activity system. Modified adaptation from Bawden (1992)

to environmental depletion that is not sustainable in the long run. For instance, unless properly managed (for example, by applying appropriate fertilisers), losses of soil fertility from overuse can eventually impact agricultural productivity, farmers' incomes and the ability to sustain livelihoods.[2]

In time, if practised across the farm sector and not rectified, such natural resource depleting activities may ultimately threaten a country's supply of arable land, food and thus food security giving rise to inter-generational unsustainability. With only narrow opportunities for non-agricultural off-farm income in the rural areas of many developing economies, such impacts can lead to increases in rural poverty. Furthermore, in developing economies the means to avoid natural resource depletion is often limited. E.g. limits in farmer access to capital for high-tech machinery, genetically engineered seeds, or the education required to adopt more sophisticated practices. Hence government investments in infrastructure, appropriate education, plus the delivery of research and development outcomes into practice, to name but a few, are important.

Whilst some of these inter-system dependencies can lead to inter-generational unsustainability of food security, others can lead to undesirable or unacceptable

[2] To illustrate the complexity of these issues—the manufacture of artificial fertiliser involves the use of fossil fuels and hence adds to carbon pollution, but the use of fertiliser increases the per hectare productivity of agricultural crops leading to less demand for land, hence less clearing of forest, thus preserving important carbon sinks. As well increased plant production results in more carbon absorption through photosynthesis and potentially, with the right farming technology, can lead to increased soil carbon, another important carbon sink. So, artificial fertilisers can be both a contributor to carbon pollution and a carbon sink promoter.

social or environmental outcomes. For instance, some farm production techniques, while dramatically increasing productivity and maximising economic efficiency, can have detrimental impacts on human social systems and the environment. Such is the case with adverse human health and biodiversity impacts due to the use of certain chemical pesticides. The cost of these impacts is not calculated in the farmers cost of production because it is not an immediate cash cost and is, as we discussed above, what economists call an 'externality'[3]. One of the earlier examples of a widely adopted agricultural technology causing major 'external' costs, not recognised before adoption of the technology, was the use of D.D.T (*dichlorodiphenyltrichloroethane*) by American farmers in the 1950s to control insect pests.

D.D.T is a chemical that does not breakdown readily, so washed into water ways it accumulates in fish and other species. Through its usage within agriculture, D.D.T worked its way up the food chain to eventually reach toxic levels in the prey of species such as the American Bald Eagle that led to its near extinction—the symbol on the seal of the United States of America was nearly lost to posterity.[4] Moreover, the accumulation of D.D.T in foods also posed significant long-term risks to human health. As a result of these negative externalities, the use of D.D.T was eventually banned in many countries, despite its benefits in increasing the productivity and economic efficiency of farming.

Likewise, in the assessment and optimisation of value chains, positive externalities should also not be overlooked. For example, the construction of dams to support irrigation may also have positive externalities in providing a safe source of water for drinking and sanitation.

Understanding the complex interrelationships of the three fundamental systems, the natural, the economic and the social systems, is critical to managing the sustainability of the food value chain. In order to do this, the component systems must be understood first. In this chapter, we look at the natural (which encompasses agriculture) and economic systems in some depth to build a theoretical framework that facilitates understanding how they interact and behave, and how they impact, and are impacted by the social system. Ultimately, this will enable the construction of

[3] In economics, the term 'externality' refers to a cost which falls outside the system under study. "*An externality exists whenever the welfare of …. a firm or household, depends not only on his or her activities, but also on the activities under the control of some other agent*" (Tietenberg, 2000). An externality is therefore a form of market failure. An example of a cost 'externality' is the pollution from mining activities of the Ok Tedi and Fly rivers in Papua-New Guinea, which caused large scale fish kills and threatened the food supply and health of villages living down-stream from the mine. While no doubt the compensation did not fully account for the cost of the disaster, $28.6 was paid in an out of court settlement and gives some idea of the cost of the 'externality'. https://en.wikipedia.org/wiki/Ok_Tedi_environmental_disaster.

[4] Exposed by Rachel Carson, in her famous book titled *Silent Spring*. In the book Carson said; "*chemicals sprayed on croplands or forests or gardens lie long in soil, entering living organisms, passing from one to another in a chain of poisoning and death.* Since the ban on the use of D.D.T and other organo-chloride pesticides, the American Bald Eagle population has recovered to the point where it was taken off the endangered species extinction list in 1995." Chapter 2 "*The Obligation to Endure*" *Silent Spring* Penguin Book 2268 1962 p. 23.

models to represent and aide in the optimisation of the food and other agricultural value chains.

Lellyett (2021) developed Fig. 2 schematically depicting a conceptual framework within which the agricultural value chain for a particular agricultural enterprise, industry or sub-sector can be analysed and optimised within its unique broader national or international context. This differs from the generic value chain model of Porter (1985) in that whilst Porter's model is targeted at the firm level, Lellyett's formulation reveals a view within a system-wide context that can be tailored to either an industry, sub-sector or firm level, depending upon the analysis required. Porter identifies 5 primary activities for a firm (Inbound Logistics, Operations, Outbound Logistics, Marketing and Sales, and Service), which together with supporting activities (Firm Infrastructure, Human Resource Management, Technology Development and Procurement), serve to produce a profit margin or competitive advantage at the firm level. Each of Porter's elements is either implicitly or explicitly contained within Lellyett's model, but Lellyett's model also depicts the external economic, environmental and social pressures acting upon and within the value chain. Inclusion of these pressures provides further context and constraints, within which the industry, sub-sector or firm must operate. Furthermore, Lellyett considers the downstream consequences and outcomes beyond the generation of firm margins, such as the consumption of outputs and waste disposal. Neither Porter's or Lellyett's model displaces the other in validity. They are complementary and harmonious, but geared toward different purposes in terms of analysis. The overall focus here is on the development of sustainable agricultural value chains at a macro level, inclusive of not only food inputs and production but also waste disposal, circular economy and external factors such as climate change.

Figure 2 is a high level and generalised outline of the model where the entire value chain exists within a unique national or international context arising from a mix of pressures, influences and constraints imposed by forces from the underlying economic, environmental and social systems. These will vary by country, industry, sub-sector and enterprise. Within that overarching environment, the agricultural value chain generically consists of initial Inputs, flowing into the agricultural production system (represented earlier from a systems perspective in Fig. 1 by Bawden). This in turn produces outputs that are transformed and supplied to consumers for use. The subsequent processes generate waste, which must then be dealt with. Within each of these successive processes along the core value chain, additional value is added in response to consumer demand or the demand of market participants that derives from final consumer demand. These impacts then disperse throughout the given national economy, and may also have international effects. In reality there may be instances where value is not added, not maximised, or where negative externalities are created. Such cases present an opportunity for reform or optimisation.

Depicted parallel to the core value chain in Fig. 2 are the intermediating influences of agriculture-relevant policy, infrastructure and social enablers (above the core), and supporting services (below). These factors are often key in constraining, optimising and sustaining the core value chain. For example, investment in major infrastructure enablers such as dams can provide a basis for irrigation inputs to the

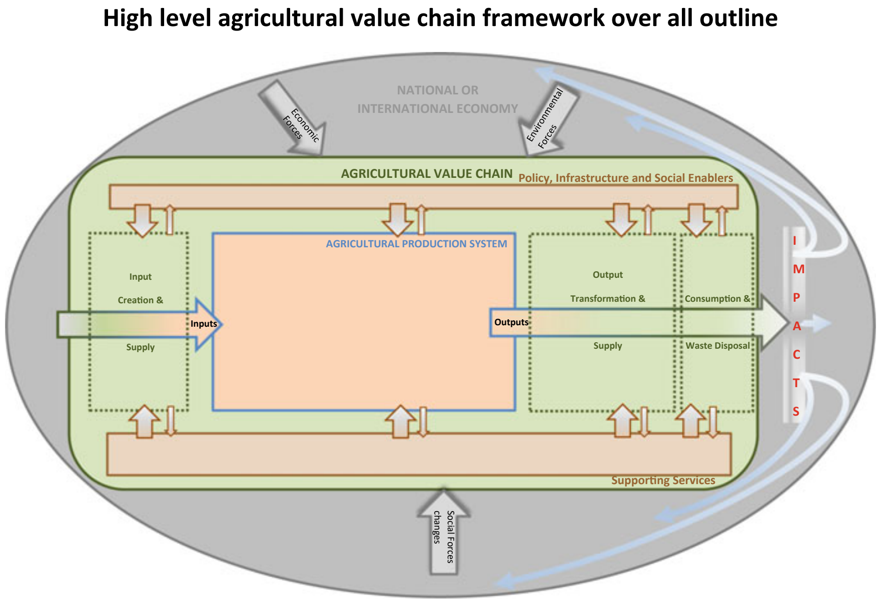

Fig. 2 Working along the length of the core agricultural value chain at various points is the influence of policy, infrastructure and social enablers directly relevant to agriculture on one hand, and various support services on the other. Each in turn may also be influenced by actors within the core value chain itself. The framework is intended for application at the enterprise, industry, subsector or global value chain level, within a given set of national and/or international level economic, environmental and social constraints (Developed by Lellyett, 2021)

agricultural production system, which if applied prudently can significantly boost yield quantity and quality. The influence of enablers and supporting services may manifest at any point along the core value chain. For instance, climate analyses and forecasts, available as supporting services, may indicate that in order to maintain product quality, maximise shelf-life, minimise waste and achieve premium pricing there should be an investment in refrigerated transport and storage services within the Output Transformation and Supply segment of the core value chain.

The application of Lellyett's model will be demonstrated in a later section by populating the framework with relevant details to depict some key differences and similarities in agricultural value chains between Developing, Emerging and Developed economies.

3 Global Agriculture and Sustainable Development in Developing Economies

The United Nations 2030 Agenda for Sustainable Development[5] provides an informative framework within which to contextualise the existential importance of agriculture into the future. The 17 Sustainable Development Goals (SDGs) and their associated targets provide a valuable yardstick against which to measure progress toward the long-term sustainability of human activity, and existence on earth. Agriculture either features explicitly, or indirectly impacts upon or is impacted by each of the 17 SDGs and a large number of the169 SDG targets. With a rapidly rising human population, limited arable land, diminishing natural resources, and significant economic reliance on the agriculture sector globally—particularly in developing countries—it is not surprising that agricultural development is central to the SDGs and their attainment. A comprehensive review of all aspects is beyond the scope of this chapter and book, however, in this section, we shall provide some highlights on progress and challenges, in order to convey the importance of agriculture to sustainable development, particularly in developing countries.

Global agricultural output more than tripled between 1961 and 2011. Although an increase in agricultural productivity has generally kept the overall aggregate and growing demand for food, fibre and other agricultural products within reach, the expansion of agricultural land has remained relatively limited. Total cultivated land increased by only 12% between 1961 and 2009, but productivity more than doubled. Where land clearing for agriculture has taken place, it is in developing countries like Brazil and Indonesia with a significant proportion of their population living in relative rural poverty. Worldwide, the amount of land needed to produce food for one person has decreased from 0.45 hectares in 1961 to 0.22 hectares in 2009. During the same period, the extent of irrigated land more than doubled, increasing from 139 to 301 million hectares (Earthscan, 2011). By providing farmers with access to water, irrigation has been a key factor in intensifying agricultural production—yet some 2.2 and 4.2 billion people globally lacked safely managed drinking water and sanitation respectively, in 2017 while post-covid the need for clean water has escalated—highlighting the delicate balance required between allocation of scarce water resources for agriculture to support food security, versus allocations for drinking water. At the same time, despite the observed improvements in agricultural productivity, the proportion of the human population on the earth suffering from moderate to severe food insecurity has been estimated by the United Nations (UNDP, 2020) to have increased from 22.4 to 25.9% between 2014 and 2019.

This brings into focus an example of tensions between achievement of some SDGs, in this case SDG 6 (Water Availability, Management and Sanitation) and SDG 2 (Zero Hunger). It raises concerns not only about the achievement of individual SDG targets, but also whether such tensions can be resolved without having to forego the achievement of either SDG.

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[5] United Nations (2015).

In this case, on the one hand, there is concern regarding the regression in food security against SDG target 2.1 which embodies the elimination of hunger and attainment of food security for all by 2030. With the quantity of food produced having increased significantly, it may be that inadequacy in food access and supply chains are amongst the primary drivers of this regression, highlighting the utility of bringing value chain analysis to bear in identifying specific problems and formulating solutions.

On the other hand, there is competing concern that SDG targets 6.1 and 6.2 that growing water allocations to agriculture may lead to under-allocations to drinking water and sanitation respectively that render these targets unattainable. Again, value chain analysis of water supply, demand and usage provides a useful tool for identifying solutions.

On the question of the adequacy of food production to support SDG2, although developing countries have contributed to the observed rises in agricultural productivity the opportunity exists to lift productivity further.[6] Small-holder farmers, which dominate agricultural output in many developing economies are often unable to afford the costs, lack the necessary access to capital, don't have the education necessary and lack a supporting national extension, research and development infrastructure to engender and sustain the adoption of better technological farming systems. This is a major risk and challenge to the achievement of SDG 2 generally and target 2.1 (By 2030, end hunger and ensure access by all people to safe, nutritious and sufficient food all year round) in particular.

FAO (2021) reported the first global assessment of progress with respect to food insecurity and malnutrition for 2020 against the 2030 Sustainable Development Agenda. It was found that hunger, as measured by the prevalence of undernourishment, had increased by 60 million people since 2014 to reach 690 million people in 2019. An acceleration in numbers during the later years of that period is attributed to higher numbers of conflicts, climate-related shocks and economic slowdowns. Should the trends continue, with currently estimated population and total available food projections taken into account, it could see numbers increase to over 840 million people by 2030. Developing countries would bear the brunt with Asia accounting for 330 million people, and Africa overtaking Asia to account for 433 million people. Moreover, preliminary findings also suggest that the COVID-19 pandemic may have added between 83 and 132 million people to the global number of undernourished in 2020. Although these estimates must be approached with caution—for example, because we do not know with precision how strong the COVID recovery or economic growth might be—SDG target 2.1 is clearly not on track to be successfully achieved by 2030.

Key to addressing these challenges is the achievement of SDG target 2.a which entails 'increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive

[6] The FAO estimates farmers in the poorest parts of the world could see crop yields improved 40% by the adoption of technological improvements such as improved varieties, application of fertilizers and mechanisation (FAO, 2018).

capacity in developing countries, in particular least developed countries'. In developed economies intensive agriculture has evolved with industry consolidation and the rise of very large-scale corporate farming, supporting national research and development programmes and ready access to finance and markets all of which, render capital intensive high-tech mechanisation, high cost fertilisers and pesticides, large-scale irrigation infrastructure and genetically engineered grains and animals, plus engagement of private extension agents, more affordable.

For developing countries dominated by small and marginal farmers, opportunities are now opening for transition from subsistence to micro-commercialism via intensification and diversification of production. This supports a virtuous cycle of gradually rising incomes, but also requires government commitment to the ongoing global democratisation of knowledge and research, provision of extension services, the opening of national and international markets and an increased government inclination and capacity to invest in large-scale underpinning infrastructure.

For those developing countries which have already established an agriculture sector dominated by micro-commercialism, the opportunity is to move further up the development scale toward large-scale commercial farming using high-tech intensive farming.

In both the subsistence and micro-commercialism cases, sector-wide structural adjustment is necessary to move further up the development scale. This takes time to achieve in a fashion that does not leave the small-holders and their communities behind, and result in increased poverty. Such outcomes risk placing at risk the achievement of SDG1 (Poverty Eradication) via regression against SDG target 1.5 which includes building the resilience and reducing the exposure and vulnerability of the poor to economic and social shocks. That is to say, a high degree of caution is required to avoid negative externalities in facilitating the transition up the development scale. For example, poorly managed corporatisation of farming may see small farmers unable to survive with rising food prices and without alternate sources of off-farm income, leading to an exacerbation of rural poverty.

With agriculture often still amongst the largest GDP sectors in developing countries, such structural adjustment is also central to achieving overall sustainable national economic growth, and full productive employment for all, which are foci of SDG 8. Agriculture stands to play a significant role, considering that global economic growth had slowed from 2.0% over 2010–2018 to just 1.5% in 2019, with further drops expected as a result of the COVID pandemic. Value chain analysis and modelling can provide a solid foundation upon which to develop and implement robust plans for guiding the necessary structural adjustments.

An important element in achieving the desired structural adjustment and full productive employment is the often very low labour market participation rate of women in developing country agriculture. In many such countries long-held social norms, especially for small farmers, have entailed rural women primarily rearing children and maintaining households, whilst men undertake business and agriculturally related activities. In most cases, the adjustments required involve management of improved infrastructure, diversification of outputs, adoption of new farming and business models and so forth, which arguably cannot all be achieved within the existing workforce profile. This goes directly to SDG targets 5.1 to end all forms of discrimination against women, and 5.5 includes ensuring women's full and effective participation and equal opportunities for leadership at all levels of decision-making in economic life. Given the entrenchment of social views, in many cases it is likely that without action on reforms to give women equal rights under national law in developing countries as embodied in SDG target 5a, the achievement of targets under SDGs 1 and 2 may not be fully realised.

So far we have discussed some aspects of the human, social and economic forces influencing the future course of agricultural development, however, agriculture is also inextricably dependent on the climate in a complex and non-linear manner. In fact, the global threats posed by anthropogenically forced climate change to human existence as we know it are so significant that SDG 13 is devoted to taking urgent action to combat climate change and its impacts. The 5th IPCC[7] Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) prepared in 2014 indicates that there is a high degree of consensus amongst leading global models and across a range of feasible planning scenarios out to 2100 that anthropogenic climate change will result in globally higher concentrations of atmospheric carbon dioxide (CO_2) and overall rises in average surface temperatures. For many crops, yield increases with increasing average temperature and carbon dioxide CO_2 through higher levels of photosynthesis. Thus, new cropping areas at higher latitudes that were previously too cold may become feasible. On the other hand, the nutritional quality of food and fodder may decline with the rising CO_2, and at low tropical latitudes rising average temperatures may exceed the survival or growth tolerance for some crops.

Crop and livestock dependence upon climate and the environment extends well beyond average temperature and CO_2 concentrations. Conditions such as soil nutrient levels, soil moisture, water availability, evaporation and many other naturally occurring variables influenced by climate must all fall within the survival and growth parameters and the timing necessary within the growth cycle, for each individual plant or animal species farmed.

Droughts, which have had devastating impacts on interannual agricultural productivity and contribute significantly to long-term desertification are associated with ocean to planetary scale interannual interactions between the oceans and atmosphere. In line with IPCC projections, the frequency, severity and geographic extent of droughts is likely to increase with the anthropogenic climate change. Likewise, floods can decimate crops and livestock. Kim (2016) has found that food security may be threatened, when there are changes in the frequency and severity of droughts and floods. Similarly, ocean temperatures and acidity are also projected to rise, affecting the geographic distribution of fisheries and posing significant threats to aquaculture and the survival of some marine species. Notably the geographic distribution of weeds and pests will also evolve under anthropogenic climate change.

Cognisant of the abovementioned and other threats, SDG Target 13.2 focuses on integration of climate change measures into national policies, strategies and planning.

[7] Porter et al. (2014).

There have been a range of assessments undertaken for various species in various locations, and the IPCC (See Footnote 7) has found that for the staple cereals of wheat, rice and maize the overall impacts on yield of a 2-degree Celsius rise in temperature above late twentieth century levels is expected to be negative in the absence of adaptive measures. Overall, the IPCC estimates that with agronomic adaptation crop yields could see rises of 15–18%, but with enormous variability in the effectiveness of adaptation measures from dis-benefits to very positive. Notably, for developing countries to achieve the productivity increases mentioned earlier, the adaptation and mitigation measures called for under SDG13 further compound the extent and complexity of structural adjustments that will be necessary.

Furthermore, it should be noted that the variance amongst the emissions scenarios and resultant projections from various underlying models is high, especially for important agricultural inputs such as rainfall which display a degree of spatial variability. Owing to the complex changes in climate variability across the globe under anthropogenic climate change, the complex and non-linear interactions of climate with agriculture, the large number of other non-environmental factors influencing agricultural productivity for each plant and animal species, and the uncertainty in current projections, a detailed coverage of all the permutations and combinations is not possible here. The next assessment report of the IPCC, due in 2021/2022, will no doubt provide more refined projections with reduced uncertainty, and more precise conclusions about the impacts on agricultural production.

The safety, quality and access to food could be significantly impacted by any climate-related disturbance to international or domestic food distribution and transport. For instance, in the United States, large volumes of grains are frequently moved within the food transportation system by water, through the large freshwater lakes and rivers with few, if any, alternate transport routes. In 2012 drought and high summer temperatures interrupted the supply of grains out of the mid-west, by barge, along the Mississippi River and its tributaries.

It is notable that there is also significant sensitivity in the transport, storage and processing portion of the agricultural value chain to loss and wastage of product. The United Nations estimated, in its 2020 report on the Sustainable Development Goals[8] under Goal 12 (Responsible Consumption and Production), that product losses in 2016 averaged around 13.8% globally equating to in excess of $400 billion.

There are further close connections between climate action and the 2030 Agenda for Sustainable Development. It will almost be impossible to eradicate poverty and end hunger without building resilience to climate change in small-holder agricultural production systems (FAO, 2016). And if the living standards of small-holder farms aren't raised the task of reducing detrimental farming practices such as 'slash and burn' land clearing that contribute to the problem of global warming will be much harder. This highlights the complexity of the issues and why modelling the systems to better understand this complexity will assist in designing the policies that achieve the desired outcomes and not adverse or even contrary outcomes.

[8] United Nations (2020).

Poorly designed interventions in the name of climate change can be counterproductive. For example, the Brazilian government under pressure from environmentalists introduced laws mandating that farmers set aside 35–80% of new farm land to be preserved as native vegetation.[9] The result was increased fragmentation of the Amazonian rainforest, leading to more loss of biodiversity than if a similar more concentrated land area had been allowed to be cleared for farming (Shellenberger, 2020). Probably, the only sustainable way of stopping further land clearing in the Amazon is to raise the living standards of the rural poor so there is less demand for uncleared land. One way of achieving this is by raising the productivity of the existing farmed land area.[10]

Notably, individual firms need not await large-scale reforms to demonstrate tangible SDG-based in-roads to improving agricultural development within their value chains. For example, CP All Plc.,[11] the sole operator of 7-Eleven convenience stores in Thailand plus several other business lines including logistics and marketing, has helped improve the operation of its considerable upstream supply chain of over 4500 suppliers by adopting a comprehensive set of performance indicators that directly support SDGs 2 (End Hunger), 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production) and 16 (Peace, Justice and Strong Institutions). Achievement of these indicators is underpinned by a Suppliers Code of Conduct and Suppliers Sustainability Management Process that in part seeks to assess suppliers against those SDGs.

In this section selected interdependencies have been discussed between agricultural development, particularly in developing countries, and the United Nations 2030 Agenda for Sustainable Development globally. Whilst some of the key issues connecting agricultural development with Sustainable Development Goals 1, 2, 5, 6, 8, 10, 12, 13 and 16 have been highlighted, this is by no means exhaustive. In fact, there are multiple interdependencies between agricultural development and all of the 17 Sustainable Development Goals, for which a fuller analysis alone could occupy several books. Nevertheless, the coverage of the topic and references elsewhere in this chapter is compelling evidence of the pivotal role that agricultural development, both generally and in developing countries, has to play in ensuring a sustainable future globally.

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[9] In 1965, *Brazil* enacted the first *Forest Code*. It required landowners in the Amazon to maintain native vegetation on 35–80% of their property. While rural farmers can buy land in the Amazon, they can only farm a portion of it. Of course, while that might be the law, demand for land from poor, landless 'ruralista's' and corrupt politicians means it is often circumvented.

[10] According to the USDA beef production in Brazil increased by 3.2% in 2020, mainly due to increases in average carcass weight. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Livestock%20and%20Products%20Semi-annual_Brasilia_Brazil_02-15-2020. Improved productivity, such as increased carcass weight, from the existing grazed land area, will help to take pressure off the demand for more land as productivity from newly cleared land is often very poor in comparison with existing pasture land.

[11] CP All Plc website "https://www.cpall.co.th/en/sustain/economic-dimension/supply-chain-management", viewed August 2021.

4 Micro-economic Theory Provides the Initial Framework for Understanding Value Chains

If there is a distinct breakthrough moment in our understanding of how the economy works and a 'foundation stone' upon which all the succeeding development of knowledge within the economic discipline, is built, it was the publication in March 1776, of Scottish parson Adam Smiths (1723–1790) massive tome titled '*An Inquiry into the Nature and Causes of the Wealth of Nations*'.[12] Rather than the established view of commodity markets as chaotic and undisciplined, Smith's hypothesis was that underlying all of what we would now call 'noise', is an orderly system where prices are struck in such a way as to ensure the supply of goods necessary to meet the needs of the human population. Smith analysed why trades people specialised in the production of certain goods and traded these goods for money, which was then used to buy their other needs, rather than each individual producing all the goods needed for their own requirements,

> it is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard for their own self-interest. (Smith[7] p. 27)

In other words, the combined efforts of each of these tradespeople specialising in the production of a particular type of good and acting in their own self-interest serves to maximise the economic output of the society, making everyone in the society better off.

Smith was fascinated with how supply and demand were balanced, and prices determined, in the marketplace. In the Appendix to Book 1 he included a database of wheat prices in England going back to the year 1202 up to 1740 and discussed at length what he thought the causes of variation were. One would marvel at what Smith may have been able to accomplish with the help of 'number crunching' computer technology!

Perhaps Smith's most lasting legacy is the metaphor attributed to him, of a '*hidden hand*' guiding and directing economic activity—a metaphor repeated in almost all introductory economic texts and known to all students of economics—but, which, ironically was not used by Smith in this context in the Wealth of Nations.[13] Smith's book *The Wealth of Nations* is to economics what Darwin's *The Origin of Species* is evolutionary biology, a foundation upon which continuing inquiry has built a formidable edifice of knowledge.

Following Smith there were numerous developments in what was then called the discipline of '*political economy*'. Notable amongst them is David Ricardo's discovery of comparative advantage to explain why nations trade; essentially, for what we now know from game theory, as a *Win–Win* situation, that is both parties gain from trade. Jeremy Bentham and his student John Stuart Mill developed the ideas

[12] Smith (1776). This was a "Massive tome" because while originally published in five volumes, the 2012 Wordsworth Classic edition runs to some 957 pages!

[13] The reference to an "*invisible hand*" in the *Wealth of Nations* is in Book 4 Chap. 2, where Smith discusses issues of foreign trade.

of utilitarianism, that is, the aim of the political economy should be to bring about 'the greatest amount of good for the greatest number'.[14] Later Karl Marx studied the formation of capital in great detail and the relationship between capital and labour to write a meticulous study of capitalism.[15]

But throughout this period many political economists grappled unsuccessfully with how supply and demand were balanced, and precisely how prices were determined. Untangling the causal relationships was difficult, a classic '*chicken and egg*' dilemma, which came first, supply or demand? The techniques of the enlightenment used so successfully in advancing our understanding of the physical world—reducing the problem to its component parts to study how they worked—were now applied to economic thought. The breakthrough in developing our understanding of the behaviour of markets and the way demand and supply interact to determine price, came from Cambridge Professor, Alfred Marshall.

In his book called *Principles of Economics*, (Marshal, 1890), he was able to explain, through a system of abstractions, specifically how the price mechanism worked, overcoming a fuzzy area that had thwarted the earlier political economists with their grander and broader ambitions. Marshall said it was both supply and demand that determined price, and that it was foolish to consider just one effect and not the other. His analogy was to liken it to '*the role of the blades of scissors*' in cutting paper, both blades are important to the process. Marshall was able to use mathematical equations to precisely calculate the equilibria between demand and supply. Not only that; but applying differential calculus the underlying tendencies towards equilibria of the individual component functions could be ascertained. Marshall provided the first building blocks of our modern-day economic models. The hidden forces that lay behind the determination of prices had been exposed, like gravity we knew they were there because of their effect, but now like the Newtonian laws of physics, the underlying mathematical relationship was exposed with certainty and precision.

The field of study, which developed from Marshall's work and which looks at the behaviour of individuals and single firms in the marketplace, has become known as *micro-economics*. Micro-economics is the theory of how individual businesses or consumers make decisions and act on those decisions. The next step was looking at what lay beyond the supply curve, and a theory of production was developed, which weighed costs and revenue to calculate the optimum level of output for a farm or business operating in an environment of perfect competition. It was found that firms would rationally expand production to a point where their marginal cost (that is the increase in cost that results from the last unit of input) equals their marginal revenue (the increase in revenue that results from the last unit of output); again,

[14] The key notion of Benthan's Principle of Utility is "*to approve or disapprove every action whatsoever, according to the tendency which appears to have to augment or diminish the happiness of the party whose interest is in question*" (Garvey & Stangman, 2012).

[15] Das Capital, another enormous tome, eighteen years in the making. In fact, it was incomplete when Marx died in 1883 and Frederick Engels and others completed the final volumes.

a mathematically precise optimum, which, by employing differential calculus, was easy to determine.[16] This was another equilibrium.

Next was the development of ideas as to what lay behind the demand curve, led by Arthur Cecil Pigou, who succeeded Marshall as professor of economics at Cambridge University. Building on Bentham's concept of utility, Pigou suggested rational consumers would purchase goods in such a way that maximised their '*utility*' or '*economic welfare*', and gave precise equations to the idea of a '*hedonistic calculus*'.[17] This led to a new field of study in micro-economics, new equations and new equilibria.[18] Numerous economists followed in the footsteps of Marshall and Pigou widening our knowledge of consumer behaviour, production economics and the theory of firm, using marginal theory and mathematical functions to calculate optimum solutions that minimised cost and maximised output, profit and consumer utility—the underlying relationships in all economic models.

Of particular importance was work by Geoffrey Shepherd, from Iowa State University, who analysed the way agricultural commodity markets operate using marginal theory, which enhanced our understanding of the basic forces at play in agricultural commodity markets.[19] Pathbreaking work by Earl O. Heady and his students, also from Iowa State University led to a better understanding of the economics of agricultural production. His book titled *Agricultural Production Functions*[20] applied marginal economic theory to a wide range of agricultural production applications.

While the reductionist approach to developing micro-economic theory gave us great insight as to what the hidden underlying forces at play in the economy were, they so abstracted what was occurring in the '*real*' world, the world of complexity, that their usefulness was limited. Key assumptions such as a large number of sellers and buyers each not able to individually influence the market price, that is, without what we now term '*market power*'; homogeneous products, that is, the output of each producer is indistinguishable from the output of other producers; no barriers to entry, so that anyone could become a participant in the market; did not reflect the 'real' world. Only later as computational power increased could this complexity be imputed into models of the 'real' world.

Also, the reductionist models looked only at one, two or at the most a few variables in relationship to each other. For example, the demand function which measures *the*

[16] For an explanation of the use of calculus and other quantitative methods in micro-economic analysis see James and Throsby (1973) Chap. 7 "The Economic Significance of Derivatives" Part 7.1 Elasticity pp. 81–85.

[17] The notion of maximising happiness had echoes of Epicurean hedonism so was sometimes referred to a "*hedonistic calculus*". Rather interestingly this notion has returned to modern economic thinking with a focus on not just measuring GDP or other purely monetary statistics to measure progress, but measuring "well-being". See Stiglitz et al. (2019).

[18] While '*utility*' and '*welfare*' are the terms used in economics, the term '*consumer satisfaction*' as used in marketing might more aptly describe what Pigou and later economists in this field were striving to understand.

[19] Shepherd (1941).

[20] Earl O. Heady and John L. Dillon *Agricultura; Production Functions* Iowa State U.P. Ames, Iowa (1961).

quantity demanded in relationship to the *price* of a good is a negatively sloped function reflecting the fact that consumers demand less of a commodity as the price rises. When overlayed on a positively sloped supply curve (the relationship between the *quantity supplied* the market and *price*), the intersection of the two curves gives an equilibria; the price at which the quantity supplied matches the quantity demanded (sometimes called the market clearing price). All other factors which affect the two relationships under study were assumed to be held constant—what is known in economics as the *ceterus paribus* conditions.[21] Of course, that is not what occurs in the 'real' world. In fact, because these conditions are in constant flux any equilibria as result of the isolated relationships under study is constantly changing—what we could term as a '*dynamic equilibria*'. Again, the parallels with ecological stasis in nature are apparent. And again, with the benefit of enhanced computational power we are better able to capture a representation of the '*real*' world in our models, by relaxing some of the *ceterus paribus* conditions. This is often done by running the model multiple times under different scenarios (that is varying one of other of the *ceterus paribus* conditions), to measure the sensitivity of model outputs and implied outcomes to a range of inputs.

5 The Emergence of Agricultural Supply Chains

Agricultural supply chains emerged out of village marketplaces. The first step was specialisation in production, which, as Adam Smith observed, in conjunction with exchange, created wealth—in this case it made the villagers as a whole, better off.[22] In a classic study on how economic relationships develop within a technologically primitive society, anthropologist and economist, Trudy Scarlett Epstein, examined the economy of the Tolai people from the Gazelle Peninsular of Papua New Guinea, between 1959 and 1961. In her book she described how traditional Melanesian village 'barter trade' markets using shell currency evolved into sophisticated trading centres such as the market in the capital city, Rabaul, when the village people started to engage in the cash economy. The copra trade was the main driving force of this change. Quite quickly, after colonisation, an agricultural supply chain for copra developed, creating new opportunities for villages and new economic relationships.

Agricultural supply chains emerge from primitive, subsistence, economies when the development process commences and surplus labour in the rural areas moves to the city. Since the city population can no longer source their food and other requirements locally, traders emerge, buying produce from farmers, aggregating and storing it, and transporting it to the city. In the city more traders emerge to wholesale and

[21] *Ceteris paribus*—Latin for "*other thigs being equal*".

[22] The first Chapter in Book 1 of *The Wealth of Nations* is titled "*Of the Division of Labour*" where Smith propounds his key thesis that "*The greatest improvements in the productive powers of labour, and the greater part of the skill, dexterity and judgement, with which it is anywhere directed, or applied, seem to have been the effects of the division of labour.*" That is, what is now termed the '*specialisation of labour*'.

retail the product. Thus, an agricultural supply chain is created—a pathway along which produce moves from farm to final consumer. In its earliest manifestation the supply chain conforms quite closely to the framework provided by micro-economic theory, because many of the underlying assumptions of micro-economic theory are met. There are generally many producers (farmers) in competition with each other to supply traders with product, the produce of each farm is similar (that is homogeneous), there are often many traders in the market also competing fiercely to procure stock. Distribution tends to be through small retailers or wet markets, again conducive to competition, so the result is a supply of cheap produce to consumers, maximising their '*welfare*' as in Piguo's models. A supply chain then, as distinct from a value chain, delivers to consumers goods at the cheapest possible price given the costs associated with growing, transporting, marketing and the other functions that are carried out along the chain. Because of competition between the businesses that carry out these functions, prices are continually under pressure all along the supply chain and forced down to provide consumers with the cheapest possible food or other goods. The small firms in the supply chain have limited market power and so tend to make a '*normal profit*'.[23] Commodity markets are typically highly competitive, so to survive businesses must keep costs down and meet the competitive market price to gain sales—that is they are '*price takers*' rather than '*price makers*'. Competition is the force that drives efficiency. Even today, with far more sophisticated value chains, the underlying efficiency created by competitive markets is all-important in generating economic growth and consequently raising living standards.

According to Porters generic strategy model, which we will discuss in more detail later in this Chapter, a key strategy employed by large firms in any industry sector is a '*least cost leadership strategy*', which is generally based on achieving economies of scale to keep cost down (Porter, 1980). So, as agricultural supply chains develop, what tends to happen is that a few very large firms begin to dominate the market, breaking down the perfectly competitive market model of many small firms in competition with each other; they secure a large market share, often over 50% of market sales -but not total dominance—by driving down costs so they can price their output highly competitively. This is pertinent in the context of developing economies, because many developing economies find themselves at a stage where their agriculture sector is dominated by small-holders plus fewer but very large multi-national firms with economies of scale from other markets. In order to survive small holders must use alternative marketing strategies, not based on least cost. Sometimes the over-regulated situation by Government disadvantages local small holders making them unable to compete with larger multinationals. Often, there is an outcry from the 'squeezed' local producers and a call for regulation to 'protect' their livelihoods

[23] Because competition will trade away higher than market prices, economists refer to the profit that a small firm makes, when in competition with many other similar firms, as a '*normal profit*'. Because of competition a '*normal profit*' in the long term will be equal to the cost of the capital employed in the business. This will be enough to encourage that business to stay operating and not deploy its capital elsewhere, but not enough to generate above market returns (or monopoly profits), because the business has little or no market power to charge higher prices. The result is maximum output of goods or services for the minimum capital required to produce that output.

but the answer as we will explain below is generally less regulation, not more. This will force the small holders to diversify and compete using alternative strategies, and although they will have much smaller market shares, the end result is a more dynamic and prosperous economy. To understand how these firms survive we need a new theoretical framework which has been discussed later in this chapter.

One of the distinctive features of agricultural commodity the supply chains is the variability of the supply. While demand tends to be relatively stable, growing with population, supply can be severely disrupted by the uncontrollable forces of nature. Since man first started farming, droughts, floods, pests' and diseases have been known to disrupt the supply of food, sometimes leading to famine, social unrest and war. As a consequence, food security is the foremost important policy goal of governments around the world. Understanding and managing the food supply chain is therefore critical to achieving this goal.

Supply variability inevitably leads to price variability, where equilibria are struck at different points along a positively sloped supply curve and when the quantity supplied in the market varies, while demand does not. Such price variability can cause social unrest particularly when consumers face higher prices because of supply shortages, so can be a threat to political stability.

Market disruptions also cause perturbations on the supply side with farmers reacting to changing prices by switching to other crops or livestock. Because of the time it takes to produce a crop or grow livestock, lags in the supply response can exacerbate these market moves. Much of Shepherd's book mentioned above is devoted to analysing these supply variations, detecting annual cycles in crop prices, sometimes with a tendency to become dynamically unstable as in the divergent cobweb model.[24] Shepherd also identifies cycles in hog and cattle prices related to the time it takes to breed up numbers in each particular species in response to price rises and when the increased supply eventuates, the market is often over-supplied and prices crash.[25]

Because of this inherent price instability, the farm sector has often sought to protect itself from the competition, which it perceives as a disruptive force because of the impact of price variability on farm incomes. Proponents of intervention in agricultural markets often claim agriculture should be treated as a special case. Frequently, the matter of production uncertainty is raised as the reason why agricultural markets should be 'stabilised'. As Williams points out the quest for price stability is often confused with seeking arrangements for 'price support' and the market interventions

[24] Shepherd op cit pp. 35–38. Another good illustration of an unstable divergent supply chain is the MITT, Sloan School of Management "beer game" simulation where after a few hot days and increased demand retailers order in more beer supplies than normal. Wholesalers stocks are then depleted and they place increased orders back to the brewery. By the time the beer is brewed and delivered, the hot weather has passed and the excess supply is no longer required. For a detailed description refer to Senge (1992) Chap. 3 "*Prisoners of the System, or Prisoners of our own Thinking*", pp. 28–54.

[25] A relatively recent study of the US cattle cycle and its impact on international commodity beef prices and consequently supply in the Australian cattle industry was done by Griffith and Alford (2002).

in the name of price support generally lead to greater instability, so are self-defeating (Williams, 2012).

6 Interventions in the Agricultural Supply Chain

After the depression of the 1930s, Australia implemented wide-ranging government interventions across the agricultural sector. Price regulation and production quota schemes were introduced for wheat, fresh milk, sugar and eggs. Marketing boards with monopoly control over the purchase and sale of commodities at the State level were also introduced with various levels of market intervention adopted for potatoes, barley, tobacco, apple and pears, wine, dried fruits, rice and other commodities. The wool industry, the country's largest agricultural export industry at the time, introduced a buffer price scheme in 1970, whereby it purchased back its own commodity in competition with buyers, mainly the representatives of overseas woollen mills, in an attempt to raise prices. The result was an accumulation of a massive stockpile of wool, partly underwritten by the Federal government, which eventually became financially unsustainable, prompting the Hawke government to intervene and wind up the scheme in 1991.[26]

Contrast this with the close 50-year relationship the Australian wool industry has had with the luxury brand Ermenegildo Zegna, whose chairman Count Paolo Zegna was recently appointed as an Honorary Member of the Order of Australia for significant service to the Australian Wool Industry.[27] Many Australian woolgrowers have benefitted financially from this relationship and the value that has been created by the Zegna company. Some of this created value has flowed back to fine merino woolgrowers in a sustained and ongoing way, whereas the short-term gains of the Reserve Price Scheme were totally dissipated on the winding up of the unsustainable intervention and went on to depress wool prices for many years after, as the accumulated wool stock pile was liquidated.

At around the same time the Hawke government initiated a major review into the competitiveness of the Australian economy, chaired by Fredric Hilmer, which resulted in the handing down of a report to the Heads of all Australian Governments in 1993 called the National Competition Policy Review (or more generally as the Hilmer report) (Hillmer, 1993). In the report Hilmer devoted a section to Agricultural Marketing Schemes and made the following comment;

> Arrangements of this kind are often grossly inefficient, and effectively tax users and consumers. According to the Industry Commission, such arrangements effectively taxed users and consumers by $550 million. Benefits to these groups from reform of the milk,

[26] The collapse of the Australian Wool Reserve Price Scheme is an example of a market intervention that went horribly wrong causing years of low income for growers as the huge stockpile of wool acquired under the scheme was slowly sold off, depressing market prices for many years. Refer to Bardsley (1994).

[27] Paolo Zegna receives top Australia Award (2020).

sugar and egg industries alone are estimated to total some $346 million per annum. (Hillmer, 1993)

The report went on to recommend the legislative and regulatory controls that enabled these schemes to operate be withdrawn in a wide-ranging programme of deregulation and *micro-economic reform*. This was carried out over the next decade and contributed significantly to reducing inflation, increasing productivity, and consequently raising living standards significantly faster in the years following the reform than had occurred in the decades prior.[28]

The lesson from the Australian experience is that supply and price management interventions in agricultural markets often lock in production inefficiencies, uncompetitive trade practices and hidden consumer taxes—which all act as a drag on economic growth and consumer welfare. So for developing economies with agriculture sectors dominated by small-holders or with the initial entry of larger scale corporate farms, instead of direct market interventions, governments are far better to focus on encouraging direct investment into the value chain by creating the right environment for capital flows into the system; enhancing the adoption of new production technology at both farm level and at other points along the value chain through education and research; setting the rules of the game through legislation that insures competition and discourages ‘rent seeking’; investment in public infrastructure such as transport networks, communications networks and even perhaps cold storage facilities and negotiating trade access to new markets; all factors that will help facilitate economic growth, but generally lie outside of the remit or capacity of individual players in the value chain.

7 Marketing Theory and How Value Chains Develop

Marketing as a specific discipline of study emerged in the decade following the end of WW2. Led by the US most economies in the western world were experiencing a strong, consumer led, economic recovery. Rising incomes substantially increased the purchasing power of consumers and with more purchasing power consumers started to demand more variety, better quality and more expensive goods. No longer spending most of their income on the basic necessities of life, consumers had more discretion as to how they spent their new-found wealth. A new understanding of consumer demand, beyond the price-driven assumption of micro-economic theory was needed. Businesses needed to change their products, no longer were the basic features of the commodity sufficient to attract buyers. New features such as packaging to prevent spoilage, convenience, portion size, and frozen products began to be demanded.

[28] See Sheng et al. (2019) for a detailed appraisal of the deregulation of the Australian dairy industry. The deregulation involved removing quotas on the production of fresh milk and controls over the price of fresh milk. Deregulation resulted in market share moving from less productive farms to more productive farms, thus increasing the efficiency of the system, as well as significant price reductions for consumers and increased product choice.

Businesses also needed to communicate these features to their customers, so advertising through the new media of radio, T.V., colour magazines became important. To be successful business needed to understand their customers—who they were, how they lived, what they thought of their product. A new body of theory was needed to provide these answers.

As with the other industries, the focus of the supply chain for agricultural products was shifting away from producers to consumers. No longer was it a matter of producing more to keep pace with the demand, now there was plentiful supply of most commodities, the issue was what to produce. What did consumers want? A prominent business management writer of the time, Peter Drucker, said; '*there is only one valid purpose of a business, to create a customer…*'. (Drucker, 1973). The shift to a consumer focussed supply chain marks the beginning of the emergence of what we now refer to as value chains. Profitable value chains don't simply push commodities down the chain; they focus on targeted marketing to understand what consumers want and are willing to pay for, then pull that product along the chain, transforming it where necessary to accurately meet a consumer's *wants* and *needs.* The *features* that consumers want in a product are those which provide them with a *benefit.* A product that *delivers added benefits* to the consumer is more *valuable* in the consumers' eyes, so they will pay more for it. This is how value is created and how value chains emerge.

A proper understanding of consumer *wants* and *needs* was a vital starting point for this new discipline of marketing. Important to this was the work of psychologist, Abraham Maslow. He said that humans have needs far beyond the simple biological requirements to maintain life. Human needs can be thought of as a hierarchy from the physiological needs which enable our survival to higher level needs that satisfy our self-worth and goals in life. Maslow identified five levels in the hierarchy of needs.[29]—see Fig. 3

Maslow's hierarchy of needs aligns with economic development, particularly as living standards rise. That is, as consumers become wealthier their needs shift up the hierarchy so the value they place on a particular product's features, change. The process of development starts with the bulk of consumers focused on meeting their everyday physiological needs—food, water and shelter. As the economy transitions consumers' needs change and move up Maslow's hierarchy. In developed economies many consumers are sufficiently wealthy to direct their purchasing according to what Maslow called self-actualization, that is according to deeply held values—so they demand products with features such as; 'fresh and natural', 'low food miles', 'animal welfare', 'fair trade', 'vegan', 'organic', 'non-GM'—often features poorer people cannot afford to be concerned about. As consumers move up the hierarchy the product features they demand change and therefore the value chain must adapt to better meet their needs.

[29] Maslow first put forward the idea in an article "*A Theory of Human Motivation*" published in the *Psychological Review* in 1943. While Maslow himself acknowledged that there was little scientific proof to support his contention it has proved to be a very useful tool in marketing, with a number other authors elaborating on Maslow's initial work. Clayton Alderfer's ERG (existence, relatedness and growth) model for example.

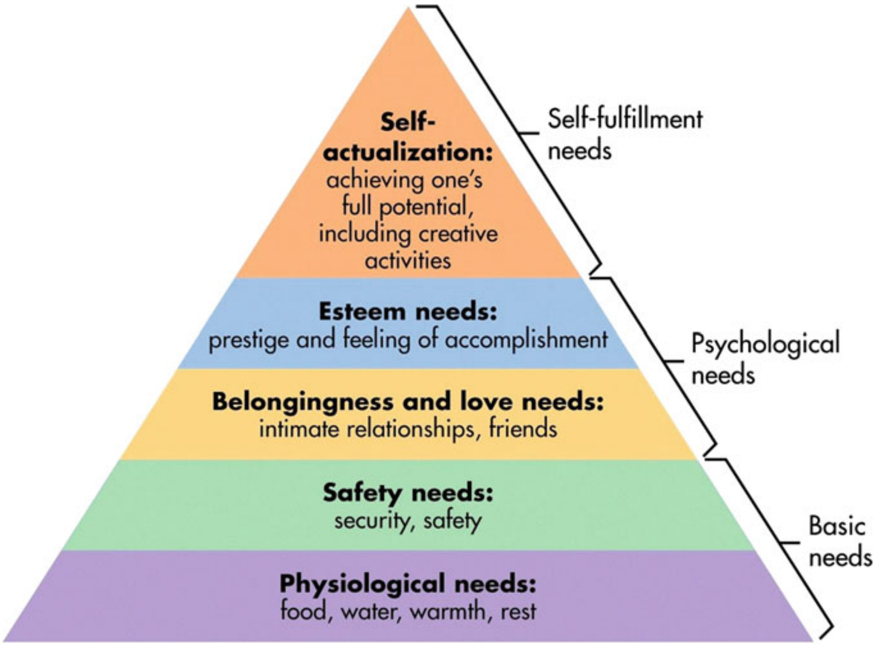

Fig. 3 Maslow's hierarchy of needs

So-called 'Green Marketing' is a good example of Maslow's higher level human needs. Many consumers are now highly conscious of the need to look after the environment and seek re-assurance from the brands they buy, that the product has been produced sustainably without damaging the environment. Narula and Desore (2016) investigated 140 existing green marketing research papers with special reference to consumer behaviour. Their conclusion was that research needs to be advanced in relation to addressing gaps between consumer perceptions and designing green products, identification of green segments, positioning green products and also inclusion of stakeholders in green markets. Within developing economies, this poses additional challenges and opportunities for helping address SDG12 (Ensure Sustainable Consumption and Production Patterns) whilst moving up the development scale.

We introduced above one of the three generic business strategies. Porter suggested businesses follow—overall cost leadership—in order to compete in highly competitive contemporary markets. It is now time to examine this further and discuss the two other strategies—product differentiation and consumer focus. The model Porter used to illustrate the concept is presented in Fig. 4.

Overall, cost leadership arises from the organic growth of the most successful firms in a highly competitive commodity supply chain, as the supply chain evolves over time toward a value chain. These firms use economies of scale to increase output at ever lower unit cost, and over time generally arrive at a dominant market share of a particular product, or category. But the equipoise of demand and supply in a still

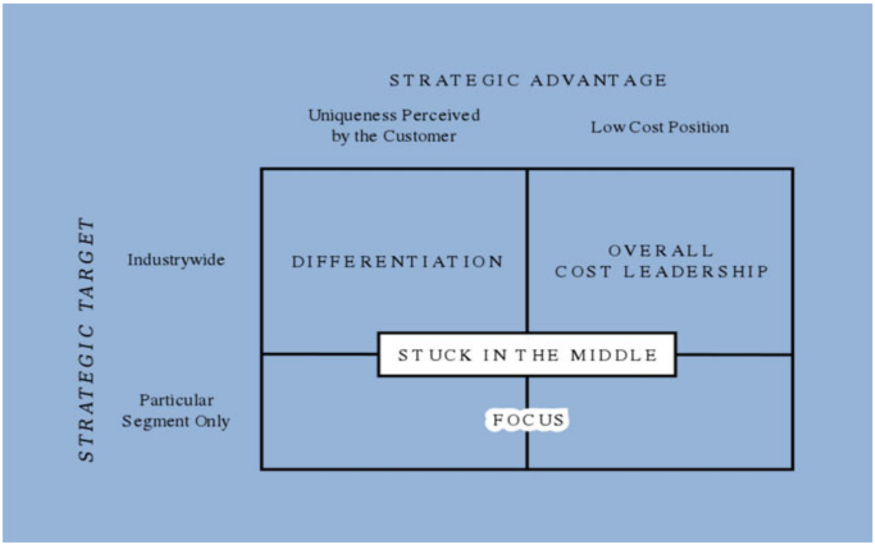

Fig. 4 Porters three generic strategies. *Source* Porter (1980) ISBN 0-02-925360-8, Fig. 2.1, p. 39

highly competitive market means these firms in the long run make little more than the market rate of return on the capital employed and while large, are unable to make significant monopoly profits, even though they may have a dominate market share. This is because any attempt to raise prices generally results in lower market share, hence lower growth and in turn lower volumes of output which reverses their key competitive strategy of continually offering lower unit costs. These firms tend to then become what in marketing terms is called *market leaders* and adopt an aggressive strategy of highly competitive pricing, mass advertising and working closely with their retail outlets to ward off competition.

In this situation, reflecting the situation in many developing economies, small holders will need to adapt in order to survive. Some may adopt differentiation or customer focus oriented strategies (see following sections), others may transition to become contract suppliers to the larger cost leadership firms or shift focus to complementary parts of the value chain, whilst some choose to group together in cooperatives to compete, whilst yet others may exit the sector completely to seek employment in other sectors. Governments should seek to support these transitions through investments in areas such as, to name but a few—research development and extension services, establishing and promoting enhanced access to capital, enhanced infrastructure development, facilitating opening of new markets, and establishing policies that support enhanced rural employment opportunities.

8 Product Differentiation

How do other firms compete against a market dominent least cost producer? One strategy is *product differentiation.* A key assumption of perfect competition is *homogeneity*; that is the output of all the firms in the marketplace are identical, so that a consumer would be indifferent as to which item they purchase. Markets with these characteristics are referred to as *commodity markets.* Contemporary marketplaces although they evolved out of commodity markets, no longer meet this key assumption of perfect competition. Instead they offer a wide array of similar products, but with different features, generally branded to distinguish each business's offering, and provide consumers with a choice as to what they might buy. Products in these markets are differentiated from each other by differences in their features, their branding, their packaging, their image and their pricing.

Basic differentiation by product feature is common in most consumer markets, but especially food, where a unique recipe (or formulation) for example will lead to a loyal base of consumers continually purchasing the product. The iconic Australian product Vegemite for example often introduced to children in school lunch sandwiches can capture a customer for life, once they have acquired a taste for the savoury product. Other nationalities not brought up with the spread, generally fail to understand its appeal. Many of the leading food products in contemporary value chains differentiate themselves from competitors using a unique flavour or recipe strategy—Coca Cola,[30] Tabsco sauce, Arnott's Iced VoVo biscuits, etc.

The most obvious point of differentiation used to distinguish products these days is their *brand*. Brands are unique product differentiators because they also create an identity for the product. Supermarkets may display a range of similar items, often side by side in the aisle, but differentiated by brand. Consumers think they are different products even though the basic ingredients may be much the same.

The aim of branding is to identify a product to consumers, highlight the unique features of the product and emphasise its benefits. Successful marketing of a product depends on how well the supplying company differentiates its products from its competitors; how clearly it identifies and communicates the product features to prospective consumers; and finally, how readily the consumer accepts the claimed benefit of buying the product.

An emerging area of differentiation is "provenance" – where the product is grown. This relates to the rise of concerns by consumers about "food safety", "healthy eating" and a new trend for "authenicity". These are examples of Maslow's self actualization attributes and may provide differentiation opportunities for products from developing economies to penetrate highly developed western markets. The

[30] As an illustration of the power of recipe's and formulations, in 1985 Coca Cola, in an attempt to take market share from its rival Pepsi, introduced a new recipe, and marketed it as New Coke. Blind taste tests had revealed consumers preferred the sweeter taste of Pepsi to Coca Cola, so after 99 years on the market Coca Cola reformulated its recipe to make it sweeter. However, the New Coke was angrily rejected by Coca Cola's existing consumers as "*not being Coke*". With sales plummeting it was taken off the market a few months later.

Sri Lankan tea brand Dilmah is just such an example and has been able to build a very successful international brand and a valuable export business.[31] Similarly, the marketing of developing economy outputs as 'fair trade' may also provide footholds in developed markets.

As consumers become aware of a brand, they develop a certain level of loyalty to the brand. Identifying who the most loyal customers are is very important, so communications such as advertising can be directed toward consumers most likely to buy the product.[32] Customers can be classified according to loyalty into various groups—*switchers* who are price sensitive and show no brand loyalty, *passively loyal* who see little reason to buy other brands, *habitual buyers* who buy a specific brand and see no reason to change, and *committed*. Some customers become so loyal to a brand that they act as *advocates* for the brand. Cultivating advocates has become a powerful means of promoting a business, or brand, especially in social media marketing.

9 Customer Focus

Another important aspect of modern marketing theory, unlike the presumptions underlying the micro-economic models, is the recognition that not all consumers want the same thing. Consumers differ in their demand for products, so choice of a variety of products is important—as any supermarket isles these days makes clear. Focussing on what customers *want* is the other generic strategy in Porter's model. This often requires in depth market research to find out exactly what *product features* customers want and then how to communicate the *benefits* of these features to the customer.

Consumers are not all the same. As discussed above, they have different needs, and hence different wants. Because of this, it is useful for marketers to group consumers with similar wants together in what are called *market segments*. The classification of a market segment can be by a single or a number of criteria. Multiple criteria will give rise to many market segments, each segment more tightly defined by the classification criteria. There are four broad market segment classifications widely used in marketing: *Geographic, Psychographic, Demographic and Behavioural.*

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[31] Sri Lankan tea producer Dilmah has successfully established itself in a number of developed economy markets in competition with well-established multi-national brands some dating back to colonial times, for example Lipton's.

[32] Garth Hallberg, who worked for the advertising agency J. Walter Thompson, published a book in 1995 called *All Consumers are Not Created Equal*, where he observed that companies derived around 80% of their revenue from roughly 20% of their customers. This uncannily conformed to a long-recognised distribution first discovered by Italian economist Vilfredo Pareto and has become known as the Pareto principle. Pareto observed that 80% of the land in Italy was owned by 20% of the population. Hallberg discovered that the Pareto principle applied to customer spending on a particular product.

Table 1 Dangar Research market segmentation of the Australian beef consumers in 1995. *Source* Dangar Research (1995)

Segment	Definition	Males (%)	Females (%)
Appreciator	'*I enjoy red meat, it's an important part of my diet*'	31	20
Acceptor	'*I like red meat well enough, it's an important part of my diet*'	39	36
Resistor	'*I do eat some red meat although, truthfully, it wouldn't worry me if I didn't*'	22	30
Rejector	'*I rarely/never eat red meat*'	8	14

Because people tend to live in localities that reflect their income and social class *geographic segmentation* can be a useful proxy for spending power. Some important basis for segmentation includes age, sex, family size and status and education. These are *demographic* factors. Marketers have long used *geographic* and *demographic* criteria to group consumers. Using these criteria consumers can be segmented into social grades or classes. People with similar interests can also be grouped into what are called *psychographic* market segments. Psychographic analysis uses qualitative measures to determine social class, lifestyle and the activities and interests of consumers. Finally, consumers can be segmented on the basis of their *behavioural* characteristics.

Consumer research carried out by Dangar Research [and funded by the Australian Meat and Livestock Corporation (AMLC)] segmented the Australian beef market into four categories according to attitude towards beef: *Appreciators*, *Acceptors*, *Resistors* and *Rejecters*. Table 1 presents the AMLC (1995) which shows the results of this survey.

The higher level of females in the resistor and rejector categories was of concern to the industry, so a campaign pointing out a key feature of beef—as an important source of iron in the diet (commonly more deficient in women than men, due to menstrual bleeding)—was initiated. By highlighting an important benefit of beef to women the campaign was able to reverse an adverse trend and win back some market share.

Having a customer focus means firms not only need to understand their customers, but also need to understand how their customer *perceives* them and their products. This led to a very important concept in marketing called *positioning*. In the marketing world the word positioning is used in a comparative sense.[33] It describes how one product compares to another, *in the eyes of consumers***.** Therefore, it is not just the product features that are compared, but the whole marketing mix associated with the product. It is how the product, in its totality, is perceived by the consumer.

> …. positioning is not what you do to a product. Positioning is what you do to the mind of a prospect. That is, you position the product in the mind of the prospect. (Ries & Trout, 2000)

[33] The concept of positioning was first introduced to the marketing field by Ries and Trout (1981).

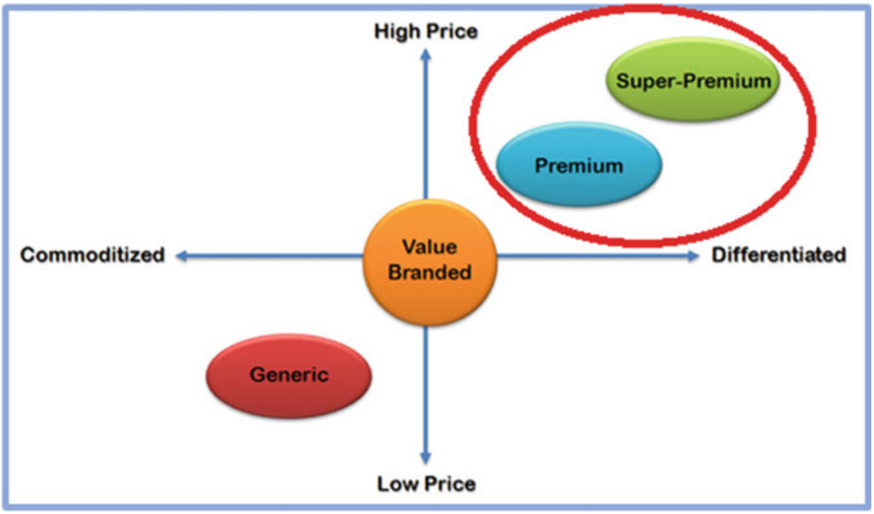

Fig. 5 A classic positioning grid

In marketing the word *position* is used in a holistic sense; it is the total of all aspects of the product that are compared, not just individual aspects. Product *position* is therefore multi-dimensional, even though certain characteristics may be emphasised in one product more than another, and this helps to differentiate the product from its competitors, it is the whole character of the product and its image in the minds of potential consumers that truly defines the market position. *Position* and *differentiation* are like the partners in a tango; both need to move together for the dance to succeed even though in reality both are moving in opposite directions—one forward and one backwards! Figure 5 shows the classical position grid derived from Reis and Trout's ideas which are now widely used in marketing.

Targeting a particular market segment, understanding the wants and needs of that market segment and tailoring a product to meet those needs are the basis of having a customer focus. But to be successful in the market place the product also needs to be positioned correctly to attract customer interest and sales.[34] All the nuances of modern marketing strategy are vital for success. Perhaps the most obvious candidates for failure are what Porter calls businesses that are '*stuck in the middle*'. That is, businesses that follow neither one of the other of the three generic strategies. The corporate graveyard is full of such firms.[35] The decline of Department Stores in

[34] In 1982, Colgate, the world famous toothpaste brand, tried to introduce a range of frozen ready to cook meals. It was a complete flop. As you would expect given a moment's thought—Colgate was positioned in the mind of consumers as toothpaste—not a food brand. It goes to show even big international companies can make serious marketing mistakes (Rosenbaum, 2017).

[35] The bailout of Chrysler Motors in 2009 by the US Federal Government and the failure of American Airlines which filed for bankruptcy in 2011, are often cited as examples of business failures attributable to a 'stuck in the middle' business strategy (Symonds, 2014).

recent years in the face of competition from '*category killer*' speciality stores is an example of being '*stuck in the middle*'.

10 The Impact of Innovation and Technological Change

One of the *ceterus paribus* conditions that impacts the supply of all commodities, but has particular importance in agricultural commodity markets, is the technical change. New technologies enable increased production efficiency; either by reducing the level of inputs required for a certain level of output (hence reducing the costs of production) or increasing the level of output for a given level of inputs, (or fixed resource base such as land). Technological change will shift the supply curve to the right, that is, enable more products to be supplied to the market at any given price. Technical innovation in agriculture over time has greatly reduced the number of people employed in agriculture as capital is substituted for labour.

In developed economies, technical change in agricultural production continues to be a major driving force of productivity growth and wealth creation. From the 1970s through to the early 1990s a mini-revolution in broadacre farming occurred with the widespread adoption of chemical weed control, improved varietal genetics and larger mechanical equipment such as air-seeders and combine harvesters. This led to productivity gains for broadacre cropping in Australia of over 2.0% per annum. Recent gains have been more modest, but overall broadacre cropping productivity over the period 1977–1978 to 2018–2019 has been 1.5% per annum (Boult & Chancellor, 2020). What this means is, that in Australia grain production has increased by between 1.5 and 2.0% each year since 1977–1978 from essentially the same production resource base. With an unchanged demand curve, the inevitable consequence of this increase in the quantity supplied the market, must be lower prices. However, demand does not stay constant and one of the main demand shifters is population growth. Australia's population growth over the 10 years to 2017 averaged 1.7%, not including net migration it was around 0.68%, so the increased productivity would have gone close to meeting the increased demand from population growth and certainly, if net migration were excluded, the increased supply would have been more than enough to cover the increased demand as a result of population growth from the balance of births and deaths (Australian Bureau of Statistics (ABS), 2018).

In the modern-day food value chain, technical innovation occurs at all steps in the value chain and competition forces firms to adopt new technologies or perish. Great steps have been made in food processing, the development of new consumer products and packaging of food that prevents spoilage and contamination, more efficient cold storage chains and logistics for transporting and storing food. Wholesaling and retailing are also under going dramatic change as a result of the digital revolution. The food value chain has probably never been more challenged than it is at present from the dynamic impact of technological change.

This impact means businesses are constantly searching for new and better ways of doing business. It means developing new products in order to compete. It also means '*revitalising*' existing products to keep them relevant to contemporary consumer *wants* and *needs*.

All products go through a life cycle. Some claim this cycle is shortening because of the technological change. The product lifecycle has four stages:

- Introduction
- Growth
- Maturity
- Decline

Some products are shooting stars—flashing brilliantly for a few seconds and then fading out; other seem to last for eons and never change, but these are rare and eventually old age catches up with them too. Some products have fast lifecycles—women's fashion for example which changes every season—others, long cycles that can last decades, even centuries, without change and some of the leading food product brands are good examples—Kellogg's Corn Flakes or Vegemite.

The profitability of a product tends to lag the sales cycle, as shown in Fig. 6 so that mature products often generating the highest profit. This creates the danger that the company will 'rest on its laurels' and may fail to revitalise the product before sales start to decline. Wise revitalization of a mature or even declining product can often lead to dramatic sales turn around and excellent profit results.

Technological change is also the driving force behind economic development. In the early phase, it may involve importing the technology and applying it to the local situation, but later on locally developed technologies will emerge. Adopting

Fig. 6 The product lifecycle; sales versus profits

new, labour saving techniques of production is one of the main features of economic development[36] (Thirwell, 1972, p. 30). This leads to a migration of the surplus rural labour from farms to city-based employment, hence creating a demand for food and other farm products in new urban centres. This process kicks off the development of an integrated agricultural/food supply chain.

In the so-called 'East Asian model of development', the surplus labour resources that exit the farm sector are used to develop an urban-based light manufacturing sector, primarily export focussed (Kuznets, 1988). Using the comparative advantage of low labour costs, the manufacturing export sector imports foreign capital in exchange for the exported manufactures, creating a virtuous cycle that eventually leads to higher levels of savings and domestic capital formation, which in turn can then be applied both to improving the efficiency and enlarging the manufacturing sector and to supporting investment into the agri-business supply chain. While the 'East Asian Model' relies substantially on market-driven private sector capitalism, direct government investment in providing seed capital, infrastructure, education and training and providing a strongly pro-business legal framework is also a feature of the model, with the emphasis on these differing between countries.

Thailand has largely followed the East Asian model of development and one of its leading companies, Charoen Pokphand Foods Public Company Limited (CP Foods) illustrates many of the concepts we have discussed above. It is an example of how simple supply chains evolve into sophisticated value chains in parallel with economic development. CP Foods is part of the Charoen Pokphand Group (CP Group), an agro-industrial and food conglomerate headquartered in Bangkok. It is the world's largest producer of animal feeds and shrimp (prawns), as well as being one of the top three global producers of poultry and pork.[37] CP group was started in 1921 by Chinese immigrant Cha Ek Chor, with a single store selling seed grains in Bangkok's Chinatown. In 1964, Dhanin Chearavanont, Cha's fourth son, took over the family business and is credited with building it into the multi-national business it is today. In 2020 CP Foods reported sales of 589,713 million baht (US 17,891 million) and net profits of 26,022 million baht (US 789 million)[38,39]. Total assets under management were estimated to be 761,719 million baht (US 23,110).[40]

The company's core businesses are livestock and aquaculture. Approximately, 64% of CP Foods revenue now come from overseas operations, with 30% from its home market in Thailand and 6% from exports. The company's main livestock business's include; vertically integrated chicken broilers, chicken layers, ducks, and swine. Its aquaculture business is mainly vertically integrated shrimp (prawn) and

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[36] Thirlwell largely subscribed to Rostow's theory of the five stages of development; traditional (as the Tolai economy before the copra trade); transitional (as countries like Papua -New Guinea are today; take-off (Vietnam today); maturity (as much of China and many other east Asian countries are approaching today) and high mass consumption. Rostow (1960) for a figurative model of Rostow's stages of growth see Drakakis-Smith (1990).

[37] https://en.wikipedia.org/wiki/Charoen_Pokphand_Foods#cite_note-1.

[38] Exchange Rate 2nd August 2021 32.96 baht to 1 USD.

[39] File:// https://www.cpfworldwide.com/en/investors/annual.

[40] File:// https://www.cpfworldwide.com/en/investors/annual.

fish farming. In its annual report CP Foods breaks down its vertically integrated businesses into three levels of operations; its feed supply business represents 37% or revenue, its farm production and processing 47% and its food distribution business 16%.

Following concerns raised in the press about employment conditions in some of its supplier firms, the company embarked on a major operational review of its supply chain and developed a sustainability programme[41]. In its latest sustainability report CP Foods confirms it has 1,332 suppliers—87.22% of which it classes as critical Tier 1 suppliers. The report goes onto state that 94.64% of Tier 1 suppliers have been supplied with a code of conduct.[42] It further states;

> Charoen Pokphand Group (C.P. Group) is fully committed to the responsible management of our suppliers, across our entire supply chain. However, due to the diversity of our business operations, with businesses, products, and services located in all regions of the world, this management might not cover all suppliers, particularly those located very far away. Another key challenge is that suppliers could still be lacking a full understanding of sustainability principles. Nevertheless, supply chain management is not merely one of the Group's key strategies for achieving sustainable growth, but also a way to create shared value among the group, suppliers, and producers, in line with the Group's 'Three-Benefit' Principle[43].

The '*Three-Benefit Principles*' are based on the following UN Sustainable Development Goals;

- SDG 4 Quality Education

  Increase the number of youth and adults who have relevant skills, and promote Entrepreneurship

- SDG 8 Decent Work and Economic Growth

  Promote development-oriented policies that support decent job creation, entrepreneurship

- SDG 9 Industry, Innovation and Infrastructure

  Upgrade infrastructure to make them sustainable, with increased resource-use efficiency and greater adoption of technologies

As the company has grown and the supply chain developed into a more sophisticated value chain, it has focused on Maslow's higher level, 'self-actualization' needs of its customers (as discussed above). These include developing a comprehensive 'responsible supply chain management' programme which includes the three SDG's listed above.

On its supply chain management website it states;

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[41] "Revealed; "Asian slave labour producing prawns for supermarkets in U.S. and U.K." The Guardian, 11th June 2014.

[42] https://www.cpgroupglobal.com/homes/SD_Responsible-Supply-Chain.

[43] op. cit.

> Supply chain management is the heart of the Company's business operation which propels competitive advantage, fulfillment of consumers' needs and mitigates the business risks. Therefore, the Company's goal is to support and reinforce all supplier groups' capacity in operating business for sustainable growth. This was achieved through integrating aspects of sustainability comprising governance, society and environment throughout the supply chain. The efforts aim to drive the organization and supplier's growth sustainably, in unison.[44]

CP Foods exemplifies how the business sector can often take the lead in pursuing SDG's, because the internal drivers of business success, that is meeting customers 'self-actualization needs', align closely with many of the aims of the SDGs. It is a good example of policy in action and the role governments and international bodies can play in setting business agendas.

11 Value Creation

It can be seen from the analysis above that value, in the eye of a consumer, takes many forms. It may be that the cheapest priced product will be perceived by some consumers as '*value for money*', but increasingly as consumers become wealthier, this is less and less so. Value might be having the knowledge that a food product is prepared in a hygienic way and safe to consume. It may be enhanced by having a government certificate that states just that—such as the health certificates issued by AQIS for meat killed in Australia abattoirs for export.[45] Value might be a quality attribute such as knowing a CAAB steak will not be tough when ordering it in a restaurant, or buying it for home cooking.[46]. Value might be being able to afford to buy and drink a bottle Penfolds Grange wine.[47] Consumers buy goods on basis of the ***perceived value*** to them. The notion of the ***value*** of a product is quite different to its ***price*** as Treasury Wine Estates the company that owns the Penfolds brand can attest, because not so long ago the company had to dispose of millions of litres of cheaper end wines because they couldn't sell them, yet they sell all they release of the Grange hermitage every year without any difficulty.

To analyse value we need to dissect it. Value can be divided into two components:

- Use Value
- Esteem Value

Use Value is given by the properties that accompany the product, i.e. in marketing terms its *features* which we discussed above. *Esteem Values* are the properties that

[44] https://www.cpall.co.th/en/sustain/economic-dimension/supply-chain-management.

[45] AQIS—Australian Quarantine Inspection Service.

[46] CAAB (Certified Australian Angus Beef) is a trade mark owned by the Angus Society of Australia and licensed to participants in the beef value chain that comply with a quality assurance program that has among one of its aims guaranteeing the eating quality of CAAB steaks.

[47] Penfolds Grange Hermitage is a South Australian premium wine brand owned by Treasury Wines Estates Ltd. A bottle of the current vintage sells for around $AUD750 in Australia. https://www.penfolds.com/en-au/wines/the-penfolds-collection-2020.

make a consumer want to buy and own it. Most luxury goods e.g. Cartier Watches, Chanel Perfume, Ermenegildo Zegna suits, have high *Esteem value*. There are often similar products, in terms of function, available at much lower prices in the market, but some people buy these high priced luxury goods simply because they can afford to—and this is an important component of esteem value—the capacity to pay the high asking price.

Value is multi-dimensional and as such creating value in the food marketing chain is open to any business or individual with an entrepreneurial flair who sees an opportunity to make money by selling someone a product.

Value can be created at any point in the chain and because of the integrated nature of the chain, value creation often involves multi-participant changes. The quality assurance programme for CAAB, discussed above, involved farmers, abattoirs, meat processors, wholesalers and retailers. All were required to adopt a QA system specific to their operations and subject to audit, so that the quality of the steak the final consumer bought could be assured because it had passed a QA test at all stages of the chain. As it developed the CAAB value chain acquired 'esteem value' s the brand became known for quality and was able to penetrate leading fine dining restaurants, not only in Australia, but also in developing countries such as Malaysia.[48]

To maintain this dynamism the environment in which businesses operate needs to be conducive to entrepreneurial endeavour, so regulation and the role government plays important.

12 Regulation and the Business Environment

On our journey so far, we have seen how sophisticated modern-day value chains emerged from highly competitive commodity supply chains. Competition in value chains still exists; they are still highly competitive, but in a different way. Rather than a focus on selling price, the competition is focussed on winning sales. This means offering consumer value and choice. Regulation needs to recognise this fact and create an environment that fosters competition within all the steps of the value chain. As discussed above, blunt instruments like price controls, compulsory acquisitions, government monopoly trading boards are not conducive to developing a competitive value chain. Regulation that focusses on eliminating anti-competitive behaviour should be the goal. Set the rules of the game so as to foster competition. Competition is still the best policeman for controlling price and all the other aspects of creating value. Regulation that prevents monopolistic or oligopolistic behaviour, breaks up cartels, breaks down barriers to entry and consumer protection laws that help prevent fraud and misrepresentation are what is required. What economists call '*rent seeking*', where businesses foster favours and preferment from government,

[48] The lead author was consultant to the Angus Society of Australia to develop a marketing plan for CAAB. He was also involved in developing export opportunities for the brand, specifically in Malaysia.

is a major anti-competitive problem in both the developed world and in developing countries and needs imaginative regulation to bring under control.

From a systems perspective regulation needs to work with the market to achieve better outcomes for consumers, not work against the market. This also applies when looking at how best to manage '*externalities*', such as climate change—where market-based solutions are generally a superior option to heavy handed interventions.

Having good models of the system under examination are therefore valuable tools for designing and testing policy options.

13 Characterising Agricultural Value Chains for Developing, Emerging and Developed Economies

With micro-economic aspects of agricultural value chains covered above, we now turn to the macro-scale to consider what factors differentiate and characterise agricultural value chains in Developing, Emerging and Developed economies.

In line with the previous discussions, the process of development begins with the local supply and demand relationships at village level evolving into longer supply chains that are primarily focused on the efficient use of inputs. At this stage, the emphasis is on price, competitive supply and the creation of value will emerge later with the rise of incomes. So, as economic development progresses, supply chains evolve into value chains encompassing the full breadth of inputs, outputs, consumption and waste disposal, with the creation of value-addition along the chain in response to changing consumer preferences. Initially, it is often the unmet demand for food in fast growing rural populations that provides the impetus for increased agricultural production beyond subsistence. Usually, this is first achieved through expanding resource use, particularly land. As a result of finite land availability, together with increased productivity, land becomes more scarce and expensive. At this very early stage, the supply chain is relatively unsophisticated and the demand is characterised by the populations' physiological need for food, corresponding to Maslow's[49] bottom tier. As development occurs the supply chain evolves into a value chain where the focus is no longer just on increasing supply, because the physiological needs of the population are already being met. At this point businesses in the chain now focus on meeting Maslow's higher level needs for their customers. Producers become proactive in identifying what customers want and produce accordingly.

To disaggregate this in greater detail, but at a broad scale, to reveal some key features that characterise agricultural value Chains in developing, emerging and developed economies, we first consider Rostow's model (1960). This model forms the basis for Modernisation Theory within the field of development economics and is outlined in Table 2, below. A full discussion of development theory is beyond the scope of this chapter. Suffice to say that whilst a number of assumptions may

[49] Maslow (1943)—a more in-depth discussion of Maslow's relevance to the development of marketing within value chains is covered later in the chapter.

or may not apply for individual economies, the model remains a useful indicator of development markers.

In addition to Rostow's insights, a key difference between developed and developing economies is often the extent to which supporting services are provided as public versus private services. There is a strong tendency in developed economies to provide nearly all agricultural extension services privately, whereas in many developing economies, because of a market failure by the private sector to provide these services, they are often publicly provided or supported. Furthermore, there is usually more public investment in supporting the agricultural research and development services (R&D) in developing countries to help drive productivity, although considerable public investment in these activities often continues in more developed countries as well. This is because public investment in R&D, has been shown to accelerate the development process in particular by making available by making available new technologies that enhance productivity and hence the economy.

By reframing the salient characteristics of each stage of Rostow's model (Table 2) in terms of their implications for agricultural value chains, along with the likely available policy, infrastructure and social enablers on the one hand, and

Table 2 Summary of key characteristics describing Rostow's (1960) model of economic growth as they correspond to Developing, Emerging and Developed economies

Rostow's stage of growth	Description of key characteristics	Correspondence to developing, emerging or developed economy status
Traditional society	Hunter-gatherer survival or subsistence agriculture. Extremely Limited technology. Lack of individual economic mobility. No centralised political system. Stability is the main societal imperative	No national economies remain at this stage of overall development
Pre-conditions for take-off	Centralised political system forms. Entrepreneurs emerge. Population growth accelerates. External demands for raw materials and/or unmet demand for food provide an impetus for economic growth. Trade commences. Agriculture led to growth. Investment into resource enhancement, such as ports and irrigation. Ohno (2009) stresses heavy reliance remains on extractive resources, monoculture exports, subsistence agriculture and foreign aid	Developing economies

(continued)

Table 2 (continued)

Rostow's stage of growth	Description of key characteristics	Correspondence to developing, emerging or developed economy status
Take-off	Urbanisation escalates. Industrialisation develops. Trade escalates. Strong investment in technological development. Shift from primary sector to secondary sector dominated economy. Supply chains develop. Ohno (2009) highlights the use of Foreign Direct Investment and foreign management to direct unskilled labour, in order to help progress industrialisation and expand exports including food	
Drive to maturity	Diversification of the industrial base. Heavy focus on export trade. Rapid development of transport infrastructure and social infrastructure (e.g. hospitals). Large investments in education. Shift toward domestic consumption as Maslow's lower-level needs is satisfied. Value chains supplant supply chains. Ohno (2009) stresses the need for locals to replace foreigners, and expansion to higher value activities is required for further progression	Emerging Economies
Age of high mass consumption	Disposable incomes are high. Consumption of high value and luxury goods becomes normative. Demand shifts to Maslow's highest tiers. The industrial base dominates with the services sector rapidly growing and the primary sector shrinking to a minor component of GDP. Technology, management and production of high quality goods are mastered. Equity, welfare and security issues are of primary importance. Heightened attention to sustainability and the circular economy	Developed economies

supporting services on the other, Lellyett's (2021) model (Fig. 2) can be customised. This provides an indicative view of how agricultural value chains can manifest in developing, emerging and developed economies.

These are displayed in Figs. 7, 8 and 9. Of course, this is idealised and carries the inherent challenges of Rostow's model in the real world. Nevertheless, these figures provide a broad but useful qualitative benchmark against which the individual progress of any given economy could be compared. This may help identify areas of need in facilitating a movement to the next stage of development.

Recent research has pointed to the significant contribution of Global Value Chains (GVCs) to trade-led economic development. GVCs are instances of value chains where two or more of the main production activities along the core of a value chain are undertaken in different countries, usually under the umbrella of a transnational company. For example, raw foods might be produced in a country endowed with high levels of natural resources (arable land, suitable climate, adequate water), then refined and transformed into other finished or semi-finished goods in a country possessing

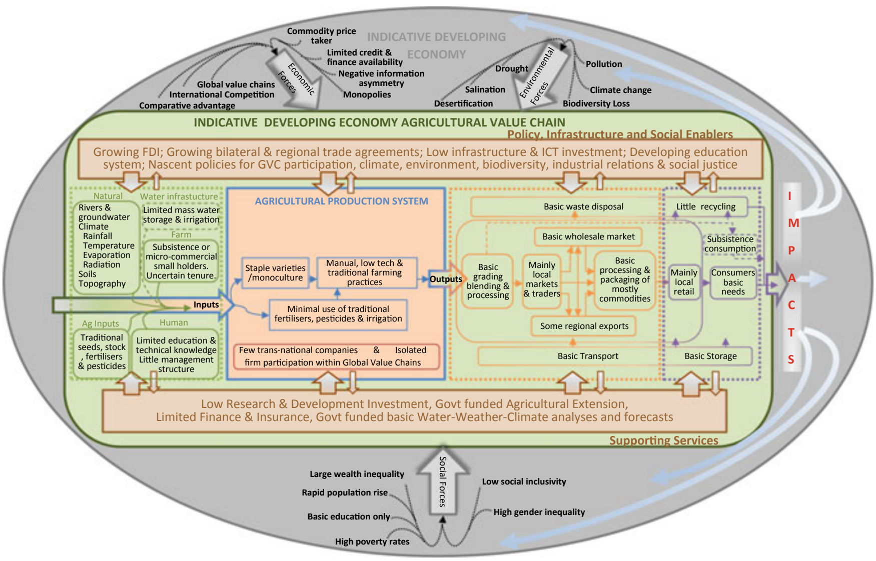

Fig. 7 Shown is an indicative developing economy agricultural value chain within the context of broader economic, environmental and social forces typically acting within and upon developing economies. Salient features such as subsistence or micro-commercial farms with limited technology and infrastructure supports, limited cropping varieties, low farmer education levels and limited access to capital selling into unsophisticated local markets with limited exports align to Rostow's Pre-conditions for Take-off and Take-off stages. At this stage of development the value chain downstream of agricultural production is usually not developed enough for participation in Global Value Chains (GVCs), however where natural resources are ample with farms beyond subsistence there is the possibility of farms contributing their raw outputs to GVCs. This representation is indicative only therefore drawing conclusions about any particular developing country requires a detailed analysis of its unique circumstances (Developed by Lellyett, 2021)

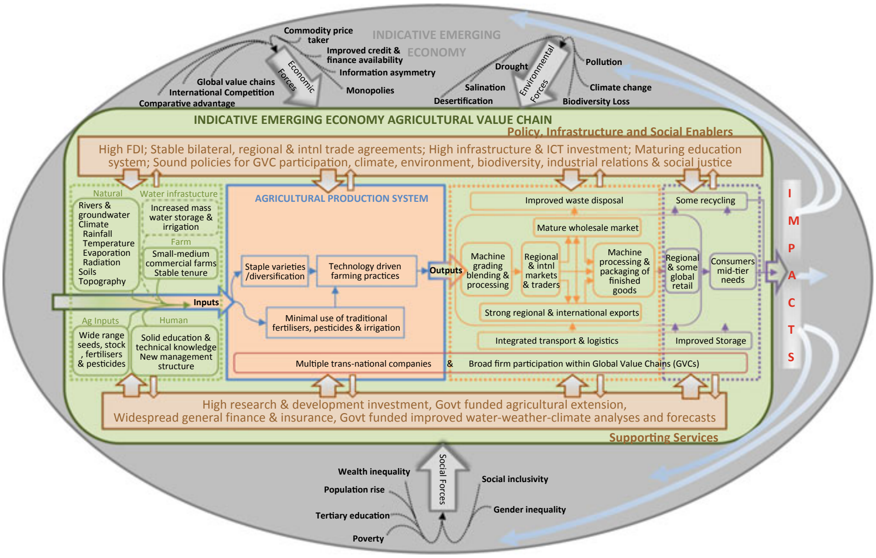

Fig. 8 Shown is an indicative emerging economy agricultural value chain within the context of broader economic, environmental and social forces typically acting within and upon emerging economies. Salient features such as proliferation of small to medium sized commercial farms with technology driven farm practices and enhanced infrastructural support, diversified crop and livestock operations, good farmer education levels, adoption of management structures, more readily available basic finance and insurance with selling into more sophisticated regional markets and increasingly global markets align to Rostow's Drive to Maturity stage. At this stage of development specific activities along the full length of the value chain may be sufficiently mature for participation in Global Value Chains (GVCs), particularly where natural endowments align strongly to GVC needs. This representation is indicative only therefore drawing conclusions about any particular emerging economy requires a detailed analysis of its unique circumstances (Developed by Lellyett, 2021)

the advanced technology and know-how required, in fact there could be several links in the chain from raw to finished goods.

Such GVC development leverages lower cost production of raw goods in the firms of one set of economies, and the efficient high-tech processing into semi-finished and finished goods of firms in other economies. With international transportation costs having reduced significantly and major advances in international communications and IT systems integration, this fracturing along the length of the value chain often renders GVCs a more efficient and productive structure. Key to their functioning is the very deep trade agreements required, usually at the firm level. Such deep agreements involve not only monetary exchange for purchases of inputs to successive steps along the value chain, but also agreements to provide access to intellectual property such as advanced research and development or production methods, management expertise and advanced technology.

The World Bank (2020) reports that GVCs account for around half of world trade today, but that trade growth rates have stalled since the global financial crisis of 2008. Whilst reforms to address the stalled growth is beyond the scope of this

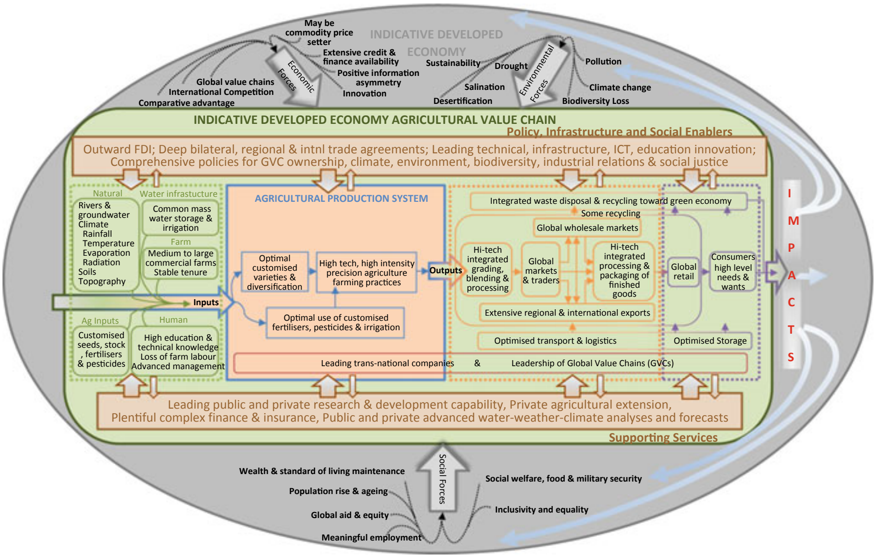

Fig. 9 Shown is an indicative developed economy agricultural value chain within the context of broader economic, environmental and social forces typically acting within and upon developed economies. Salient features such as dominance of medium to large sized commercial farms with high-tech high intensity precision agricultural practices and strong technologically advanced infrastructure supports, tertiary educated farmers and advanced management structures, technologically advanced inputs such as genetically modified seeds and breeding stock, ready access to customised finance and insurance with selling into sophisticated global markets align to meet consumers' higher level needs and wants align to Rostow's Age of High Mass Consumption stage. At this stage of development company scale, specific activities at all points along the value chain, plus ICT integration are collectively sufficiently mature to develop and lead Global Value Chains (GVCs). This representation is indicative only, therefore drawing conclusions about any particular developed economy requires a detailed analysis of its unique circumstances (Developed by Lellyett, 2021)

chapter, there is solid evidence that GVC participation by developing and emerging economy firms can lead to increased productivity and economic growth. Progressing along the value chain from inputs toward consumption, the value added is cumulative. Hence, precisely where on that trajectory an economy is able to participate matters. Upgrading to later stages is more beneficial, but usually accords higher technically difficulty, demanding successively more advanced infrastructure, knowledge and expertise.

How developing and emerging economies engage with GVCs is important in determining their ability to upgrade along the value chain, and not get trapped at the less profitable earlier stages. The engagement must be such that it enables the capture and leverage of technology and knowledge transfers. These transfers must be sufficiently dispersed throughout the economy, and accompanied by matching education and available capital to support their adoption. Ohno (2009) asserts that this needs to extend to local human capital at all levels in all areas replacing foreigners in order to successfully transition from Emerging to Developed economic status.

Because individual developing and emerging economy firms may lack the expertise required to successfully negotiate such engagements there is an important role for government to help facilitate.

Thus given the right circumstances, participation in GVCs provides a potential pathway for developing and emerging economies to accelerate development. Reverting to Lellyett's (2021) model, Fig. 10 shows an indicative GVC with an embedded developing economy farm enterprise. Notably, developing economies generally lack sufficient maturity in most functions along the value chain to effectively participate in GVCs, except perhaps for the production of raw outputs which may be possible if farms are already commercial, of adequate scale, and endowed with favourable natural inputs. Emerging economies by contrast may well have individual firms with sufficiently developed capabilities at other points along the value chain to effectively participate in GVCs.

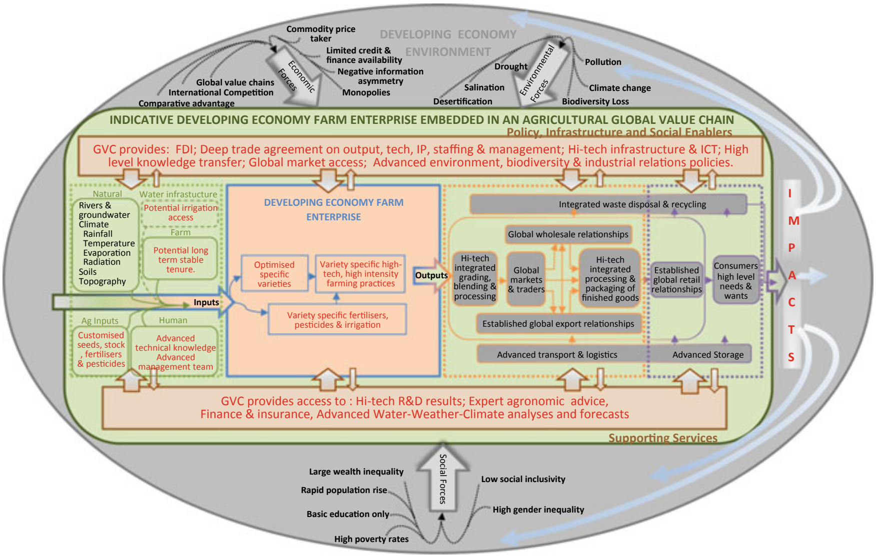

Fig. 10 Shown is an indicative Global Value Chain with an embedded developing economy farm enterprise. Highlighted in red text are the capabilities inherent in the GVC that may be made accessible and available to the developing economy farm enterprise. Typically developing economies lack sufficient maturity in the greyed-out functions within the GVC, however specific functions may be accessible to emerging economy firms sufficiently developed. Notably, the GVC capabilities are beyond what is generally available within overall developing or emerging economies themselves—hence participation in GVCs provide a pathway for the accelerated development of developing and emerging economies through technology and knowledge transfer. Realising accelerated development is however contingent upon dispersion of knowledge more broadly throughout the economy and sufficient available capital to support adoption of high-tech infrastructure and practices. (Developed by Lellyett, 2021)

14 Sustainability

Ensuring a sustainable agricultural/food value chain is a vital imperative for all governments. Feeding their populations, guaranteeing food safety, ensuring future needs will be met, having reserves in case of emergencies, are all part of this remit. Nobel prize winner Amartya Sen in his careful analysis of twentieth century famines concluded they were often caused by government policy, political interference, wars and social disturbances causing disruption in the supply chains and not from a lack of agricultural productive capacity (Sen, 1982). Famines in recent years in Somalia, Yemen and the Dafur region of South Sudan reflect the same with ongoing civil war disrupting agricultural production and supply chains in regions that would otherwise be food self-sufficient.

The object of this disquisition has been to show the complexity of modern food value chains, but also how they can be better understood by analysis and how by using the knowledge gained from a thorough understanding of how they work, better management and regulation of the systems can be achieved. This management needs to be focused on creating and maintaining sustainable food value chains. That is, despite our focus in the paper on economic efficiency, also on the maintaining a sustainable environment and human social well-being—what is commonly referred to as the triple bottom line.

Sustainability also means designing systems that are robust and able to withstand changes in the external environment including unforeseen 'shocks'. Nassim Nicholas Taleb in his book AntiFragile makes the point that most natural systems and man-made systems that have evolved over a long periods of time tend to be 'robust', whereas newly created man-made systems, even though they may be brilliantly engineered to survive most foreseeable shocks, can in fact be quite 'fragile' (Taleb, 2012). This is because causation variables that are distributed according to a normal distribution (or 'bell curve'), tend to revert to the mean over time. So, over a large number of events, as occurs in nature, or through 'trial and error' experimentation by humans over many generations working out what practices are the best, 'robust' (and by default the less fragile) systems evolve. Many traditional farming methods fall into this latter category and that is why it can sometimes be very hard to get subsistence agriculturists in developing economies to change their practices. When your existence depends on getting a crop every year to feed your family, certainty of the result is more important than achieving a higher yield.

Taleb also makes the point that extremely rare events (low probability of occurrence), but with high costs in terms of outcomes, perhaps even catastrophic, can make what appear to perfectly sustainable systems that go on for years, fragile. He called these 'black swan' events, a term that has now become part of the modern lexicon. 'Black swan' events are rare, unforeseen, events, events nobody thought possible, so-called because of the shock Europeans had, when used only to swans being white, they first saw Australian Black Swans. Planning for 'black swan' events is difficult, because, by definition they are unforeseen. But with thought, systems can be designed to be more robust and therefore more able to withstand 'black swan' shocks.

The emergence of the SARS Covid 2 virus in late 2019 in Wuhan, China, which quickly became a world-wide pandemic, is just such a 'black swan' event. Extremely difficult to foresee, although some argue a pandemic was inevitable at some time or another; the consequences have been extremely costly, both in terms of human health and lives, as well as economic. The impact of lockdowns to try and curb the spread of the virus has disrupted many global supply chains including vitally important food supply chains. It has led to calls in many countries of greater self-sufficiency, especially for medical and vital food supplies. It has exposed the weaknesses ('fragility') of some global and even local supply chains.

Some general principles apply in reducing 'fragility'; a wider distribution of players rather than concentrated participants in a market; small rather than large, because a few small businesses going bust do not have a significant impact on the overall economy, whereas one large business such as the failure of American Bank Bear Stearns, triggered a global financial crises; short rather than long supply chains, because the possibility of disruption is far greater in long supply chains, as the recent Covid 19 'black swan' experience has shown.

Many man-made systems are actually specifically designed (by default) to fail in 'black swan' events. A widely accepted design precept is to design to a 95% tolerance level for a particular variable. Black swan events, being extremely rare, generally have less than a 5% chance of occurrence, so fall outside this tolerance level. Failure to understand the true causation and probability of occurrence can lead to the conflation of causations and effects and miss diagnosis of a problem.

The drive for greater efficiency can also be a cause of increased 'fragility'. The running aground in March 2021 of the MV Ever Given in the Suez Canal is a good example. Originally built in 1869 to take the vessels of its day, the canal is less than 200 m wide in many parts and just 24 m deep. But since its construction the drive for greater transport efficiency has led to significantly bigger vessels. The Ever Given, carrying 18,300 containers, is around 400 m stern to bow and 60 m across with little draft beneath the vessel in the canal. When strong winds swept out of the desert the huge bulk of the cargo deck acted like a giant sail, causing the vessel to veer uncontrollably from side to side. The vessel displaced hundreds of thousands of tonnes of water which had to squeeze through the narrow passages between the hull and the shore on either side, making the steering dynamically unstable. The result was it ran aground blocking the canal for 6 days, holding up billions of dollars of seas freight and disrupting Asia—Europe supply chains.[50] At least 20 bulk carriers of livestock were reported as delayed in the event,[51] raising concerns over animal welfare, the potential for disease and loss of profits due to the impact on the deteriorarting conditions of animals. Asia-bound grain cargoes alone of 768,000 tonnes were also reported as delayed.[52] It is almost certain, that supplies

[50] Chellel et al. (2021).

[51] The Guardian (2021).

[52] Grain Brokers Australia (2021).

of lumber, vegetable oils, fertilisers and cereals were also delayed considering the very high annual tonnages transiting the canal—with respective 2019 totals[53] coming in at 2.8MT, 124.8MT, 138MT and 363.8MT.

15 Conclusion

Agricultural value chains develop in tandem with economic growth. In developing countries rising agricultural productivity drives a transition from small-holder subsistence through to small-scale commercial farming to an eventually much larger scale, intensive, agricultural production. This leads to a capital intensive, consolidation of production resources. Progressively surplus labour moves out of the countryside to new industrial cities. City workers need for food and clothing creates a supply chain, which in time evolves into a value chain as the wants of city-based consumers become more sophisticated. Value is created by meeting the wants and needs of consumers. Over time consumers become less sensitive to price as their incomes rise and although it is always part of the value equation, other product features such as convenience, safety and eating quality become more important to consumers. As consumers place value on these features, opportunities arise for new production methods, transformations, services etc., which creates jobs and economic activity.

Moreover, throughout this transition there are growing global economic, social and environmental pressures that may threaten global food security including population growth, inequality, poverty and anthropogenic climate change. Not only must developing country agriculture face these challenges to meet and sustain increasingly higher levels of productivity, but often those involved in the value chain itself also face intense challenges within their own communities and businesses. The 2030 Sustainable Development Goals and Targets provide broad yet useful guide lines to progress for incumbents within agricultural value chains and governments which help illuminate pathways forward in undertaking structural transitions, including those facilitated by the provision of appropriate infrastructure, policy and education plus research, development and extension services.

Moving forward, the businesses will have to adopt one or more of three generic strategies; cost leadership, differentiation or customer focus. If competition is allowed to do its task, then the efficient value chains will deliver to consumers all the variety and choice they demand at prices consumers are willing to pay. In other words, a competitive market is the best way of assuring a sustainable supply. The role of government then is to set the rules within which the businesses must compete, in particular ensuring businesses are always subject to competitive pressure as this will create the most efficient value chain. As economist Milton Friedman observed, businesses fundamentally don't like competition and so will do everything they can to reduce or avoid it (Friedman, 2009). It is therefore up to the government to set

[53] Suez Canal Authority (2021).

the rules to make sure businesses do face competition and don't mislead consumers. Businesses need to be 'rule takers', not 'rule makers'.

The biggest threat to efficient markets in many developed economies is 'rent seeking', that is where businesses seek government protection (licensing, tariffs, quota's, etc.), in order to avoid competition. 'Rent seeking' is one of the greatest threats to the development of efficient value chains and is especially a problem in developing countries where corruption is rife and legal and regulatory institutions are weak. The object then of government policy in order to do the 'most good' for its population, following Bentham's precept, should be the creation of competitive, sustainable, value chains.

By modelling complex systems, we get a better understanding of the cause and effect relationships and from that a better understanding of the threats that are likely to disturb the system, that is an understanding of the 'fragility' of the system. Nothing can be more important than the food supply system to human well-being. Identifying threats to the food supply system in particular potential 'black swan' events, is vitally important. And although 'black swan' events cannot be foreseen, by definition; these can be countered to some degree by building 'robustness' into the system, so the system is less 'fragile' and better able to withstand shocks. Modelling is a powerful tool for experimenting with 'fragility'. By tweaking different variables, weaknesses or 'fragility' can be identified. So, rather than trying to forecast future outcomes, which are almost inevitably wrong, the true value of modelling is to understand how systems behave and their potential 'fragility'; so this knowledge can be used to make them more 'robust' and thus make them more resilient.

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Tunnel Farming as an Adaptation Tool Against Climate Change Effect Among Smallholder Farmers in Nepal

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1 Introduction

Climate change adversely affects the smallholder farmers and threatens global progress toward poverty alleviation, food security, and sustainable development as prioritized by the global Sustainable Development Goals (SDG) (Fuso Nerini et al., 2019; Harvey et al., 2018; United Nations, 2016). Globally, 767 million are smallholder farmers who cultivate less than 2 hectares (ha) of land and are extremely poor, living under the poverty line of $1.90 a day (Lowder et al., 2016). These smallholder farmers are extremely susceptible to climate change since most depend on rain-fed agriculture, cultivate marginal areas, and lack the financial resources to practice climate-resilient agriculture (Donatti et al., 2019; Holland et al., 2017). Thus, enhancing these farmers' agricultural adaptive capacity is crucial to improving their livelihoods reducing global poverty, addressing the climate change effect, and achieving the SDGs.

Different adaptation strategies such as the usage of diverse crop varieties, soil and water conservation, early and late planting, improved irrigation, agroforestry and seed banks have been used to mitigate the impact of climate change (Below et al.,

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2012; Deressa et al., 2011; Harmer & Rahman, 2014; Othniel Yila & Resurreccion, 2013). However, there is a lack of studies that examine the real linkage between these adaptation strategies, crop productivity, and farmers' livelihoods. Only a few of the studies Di Falco et al. (2011) in Ethiopia, Huang et al. (2015) in China, and Roco et al. (2017) have studied the impact of these strategies on crop productivity and livelihood of farmers. Hence there is a necessity to conduct additional research to identify appropriate adaptation strategies that significantly improve livelihoods of small holder farmers.

Studies concentrating on identifying adaptation strategies and assessing their effectiveness are paramount for an agricultural country like Nepal, highly vulnerable to climate change. As per the report issued by (germanwatch.org), Nepal is ranked 9th in Global Climate Risk Index 2020. This is because majority of population (66%) is engaged in agriculture (FAO, 2021) who is directly or indirectly affected by climate change. Furthermore, among these farmers, 90% are smallholder farmers living with limited livelihood options and low living standards. Identification of appropriate adaptation strategies helps farmers tackle climate change and contribute to enhancing their livelihood. Tunnel house technology could be one such adaptation strategy that could be useful for smallholder farmers. Also, there is rapid increase in the number of farmers adopting tunnel technology since last few years. This chapter examines the effectiveness of tunnel technology as an adaptation practice and explores whether tunnel technology has improved the farmers' resilience by reducing the vulnerability of climate risks on crop productivity and income.

2 Agriculture and Smallholder Farmers in Nepal

Nepal is 147,181 km^2 in area and is divided into three ecological regions, the Terai, the Hill, and the Mountain. The mountain region covers 35% of the total land area and ranges from 2500 to 8848 m above the sea level (masl). Most of the area is comprised of steeply sloped lands, snow-covered mountains with comparatively few valleys. Only 4% of the land is cultivated as the rest is not suitable for agriculture. The primary staple crops are barley, buckwheat, and potato with livestock also playing an important role. By contrast, the Hill region covers 42% of Nepal's total area, out of which 15% is cultivated (MoALD, 2019). This region is also primarily composed of steeply sloped lands with several small valleys ranging from 500 to 2500 masl. The Terai, also known as flatlands, constitutes 23% of the total land area with relatively high agricultural potential of which about 38% is cultivated. This region extends from 60 to 500 masl. Rice, maize, wheat, and oilseeds are the predominant crops. It is relatively better off than the mountain and hill regions regarding social and economic infrastructure development.

A dominant sector in Nepal, agriculture contributes about 27.6% of the Gross Domestic Product and employs 66% of the population. Farmers are further classified as small commercial farmers, subsistence farmers, and landless/near landless farmers (Gc & Hall, 2020; MoAD, 2014; Roka, 2017). Most are landless/near landless farmers

(53%), owning less than 0.50 ha of land. Together, they cultivate 19% of the total available land. Nearly 27% are ‘subsistence farmers’ holding land of 0.5–1 ha and cultivating nearly 30% of the total land. The remaining one-fifth are considered as small commercial farmers with landholdings from 1 to 5 ha or above.

3 Impact of Climate Change on Agriculture and Smallholder Farmers

Although Nepal contributes only about 0.025% of the global annual greenhouse gas emissions, it is highly vulnerable to climate change (Central Bureau of Statistics, 2019). Mainly, farm households are more vulnerable because the livelihood of farmers is directly linked to the climate. Limited livelihood options predispose smallholder farmers to the harsh climate change effects, making them the most vulnerable (Mertz et al., 2009). Numerous studies have shown that rainfall and temperature have severely affected smallholder farmers and the agriculture sector.

Nepal’s agricultural sector is highly climate-sensitive due to heavy reliance on natural rainfall, as only 40% of the agricultural land is irrigated (Gentle & Maraseni, 2012; MOALD, 2019). The unpredictable rainfall patterns can adversely affect agriculture production and smallholder farmers (Urothody & Larsen, 2010). A late or erratic monsoon can cause significant changes in crop-growing seasons and cropping patterns that quickly damage crop damages and turn into subsequent food insecurity. For example, in 2006, some parts of eastern Nepal faced an extreme drought caused by low rainfall that declined the rice production by 30% and overall crop production by 12.5% at the national level (Malla, 2008). During the event, smallholder households were the most affected as they didn’t have any livelihood option other than agriculture production.

Temperature change also affects agriculture and smallholder farmers in several ways. Temperature rise may affect the physiology of plants and may affect productivity significantly. Barrueto et al. (2017) found that an increase in temperature has reduced banana productivity and increased production cost due to increased post-harvest losses in the western part of Nepal. Temperature rise has dried the leaves making the tree fruitless, which significantly reduced the productivity. The same research also observed some altitudinal shifts for oranges in the central region of Nepal. While oranges that grew an altitude of 900 masl were of low quality and shriveled up, the orange trees thrived and bore fruits at higher altitudes of 1400 masl.

Besides temperature and rainfall, few studies have also indicated that other hazards such as fog, wind storms, and biological disasters have also impacted agriculture and smallholder farmers. Research by ActionAid (2007) based in the Kapilvastu district of Nepal revealed that prolonged fog periods led to slower drying of the charcoal’s biomass resulting in less production for charcoal producers. Similarly, the temporal shift of wind storms from April/May to July/August had also affected the primary fruiting period of bananas, reducing their production for smallholder farmers in the western region of Nepal (Barrueto et al., 2017). In addition, Helvetas Swiss Intercooperation (2017) showed that drought and dry conditions facilitated white stem borer and fruit flies that adversely affected coffee and orange production in southern Nepal.

4 Adaptation Efforts Against the Effect of Climate Change on Agriculture

Concerns and experiences of a changing climate have showcased a vital need to bolster farmers' adaptive capacity. This is achieved by harnessing better knowledge of adaptation strategies and the implications of such adaptations in farm productivity (Di Falco & Veronesi, 2014). The adjustment in agronomic practices that are either natural or human systems in response to climate change impacts is adaptation (Easterling et al., 2007). Many adaptation strategies have been introduced in Nepal in response to numerous adverse climate effects (Patra & Terton, 2017). These adaptation strategies could be broadly categorized into macro and micro levels based on geographical coverage and scope.

Macro-level strategies generally cover large geographical areas and are administered by national-level government institutions or development organizations. One such strategy intervention is the "Adaptation to Climate-Induced Threats to Food production and Security" implemented in 2018 in the Karnali region of Nepal (WFP, 2018). Executed jointly by the Ministry of Science, Technology, and Environment and the World Food Program, this intervention helped smallholder farmers adapt to climate change through improved livelihood assets and natural resources management. Likewise, the Government of Nepal has commenced various policy initiatives such as the National Adaptation Plan of Action (NAPA) 2010, the Climate Change Policy (2011), the National Framework for Local Adaptation Plans for Action (LAPA) 2011, and the National Adaptation Plan (NAPA). Besides, several other strategies such as capacity building and greater policy integration programs have been implemented at the national level.

Micro-level strategies usually consist of community-based adaptation strategies implemented in a small area at the local level. Consultative Group for International Agricultural Research's (CGIAR) program on "Climate Change, Agriculture and Food Security" is a micro-level program that attempts to develop climate-smart villages in the community (Patra & Terton, 2017). Another includes the International Development Enterprise's (iDE) project that supports smallholder farmers' investments in Climate-Smart Technologies. Interestingly, farming households are also found making numerous changes to prevailing agricultural management methods to combat the climate change effects at a local level (FAO, 2013; Khanal et al., 2018; Maharjan et al., 2017). For instance, soil and water management, adjustments to the timing of farm operations and crop and varietal adjustment are the common strategies that farmers have been applying to tackle climate change.

Besides farm management strategies, there are technology-based adaptation strategies also in place at the local level. The tunnel house technology is one such strategy that has gained popularity amongst many vegetable farmers in Nepal. Especially in the hilly region, the adoption rate is higher (Lamichhane et al., 2017) mainly because it can be customized, built, and installed locally in various land shape and sizes, ensure year-round production and earn regular income (Merrey et al., 2018). Additionally, substantial technical and financial assistance from the government and development organizations have also helped farmers adopt technology extensively. For instance, government projects like Prime Minister Agriculture Modernisation Project (PMAMP), Project for Agriculture Commercialization and Trade (PACT), High-Value Agriculture Project (HVAP), High Mountain Agribusiness, and Livelihood Improvement (HIMALI) have promoted tunnel-based cultivation in many hectares of land (Atreya et al., 2019). Likewise, various national and international development organizations have implemented several projects where tunnel technology has remained one of the essential components. As a result, there has been a significant increase in farmers adopting tunnel farming over the last decade.

5 Tunnel House Technology

The tunnel house technology is centered on the infrastructure that makes crop production possible for an extended period (FAO, 2013). While tunnel technology was adopted by developed countries a long time ago, it is relatively new to Nepal and was introduced in 1996 only. As opposed to sophisticated tunnel in other countries, here, the technology comes in the simpler form. There are two types of tunnels currently in practice in Nepal: Low and High Tunnels. Low tunnels are small in height and are used to cultivate cucurbit crops like gourds. These tunnels are mostly used in raising nursery stage crops of different vegetable crops to maintain temperature levels.

On the other hand, high tunnels are much taller and provide better ventilation and air circulation. It consists typically of bamboo or GI pipe structure, covered with clear plastic Silpaulin, usually 45–90 GSM. The plastic is only covered at the top of the gabled roof in the hilly region but may be entirely covered in a colder region. The prescribed size is 12–25 m in length, 5–6 m in width, and 2–4 m in height. A walking path of 75 cm is usually suggested inside the tunnel, as shown in Fig. 1 (MOALD, 2019). Nepalese farmers, however, are found to resize the tunnel area depending upon the size and layout of their farmland. Usually, farmers also equip their tunnels with drip irrigation, which helps water management during the dry season and inadequate rainfall. As the high tunnels are the dominant forms in the hills region, hill region, for our study, we considered tunnels that are semi-open, covered at the top and equipped with drip irrigation Fig. 1.

It is believed that tunnel technology is an effective adaptation strategy that helps to alleviate the effects of climate change by protecting crops from extreme heat during summer, heavy rainfall during monsoon, and cold during the winter season. Therefore, it enables farmers to grow crops throughout the year, producing a higher

Fig. 1 Tunnel technology based agricultural adaptation strategies

quantity of crops and earning more income. However, there is no evidence of whether the technology has been efficient in reducing the climate change risk experienced by smallholder farmers. Although past few studies have measured the monetary benefits, none of them viewed tunnel technology as a viable adaptation method. This chapter aims to examine whether the tunnel helps in addressing the climate change risks. We use the Kathmandu valley as a case study and study if tunnel technology has helped smallholder farmers tackle climate change risks.

6 Case Study

6.1 Study Area

Kathmandu valley is one of the most developed parts of the country that occupies 569.80 km^2. It is situated between 27° 36′ N and 27° 50′ N latitude and 85° 7′ E and 85° 37′ E longitude. The valley constitutes three districts, namely Kathmandu, Lalitpur, and Bhaktapur, as shown in Fig. 2. The valley is surrounded by the hills of elevation more than 2000 masl, whereas the central part consists of flat land and small hills with an elevation of 1300–1400 masl. Big cities and settlements are located in the central flat area, whereas in the surrounding hilly region, most of the land is used for agriculture by smallholder farmers. In recent times, tunnel farming has been growing popularity in these hilly regions. As reported by Atreya et al. (2019), Kathmandu alone covered 250 ha of land area under the tunnel house technology in 2015/16. For these reasons, Kathmandu valley was chosen as a case study to explore whether tunnel technologies are effective adaptive strategies for reducing the climate change effect. However, before studying such strategies' effectiveness, a comprehensive assessment of location-specific climate change risks is vital (Gamble et al., 2010). This is particularly true for smallholder and subsistence farmers who use their understanding of the local climate when making decisions (Wilken, 1990). In the next section, we assess the climate change risk in our study site.

Fig. 2 Study area

6.2 Climate Change in the Study Area

The Kathmandu valley is characterized by a sub-tropical and temperate climate with four seasons, namely, pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November), and winter (December–February). These can be broadly categorized into summer (March–October) and winter (November–February) seasons as well. We studied time series data of temperatures and the rainfall of 30 years from 1990 to 2019 to examine how the local climate of Kathmandu valley has been affected by climate change in each season.

6.2.1 Temperature

The trend analysis was performed using Mann Kendall's (MK) test for 30 years' time-series data (Figs. 3 and 4). The trend was observed for the winter and summer seasons. The time-series analysis reveals a gradual rise in minimum (T_{min}) and maximum (T_{max}) temperatures. Both the summer and winter minimum temperature (T_{min}) has increased significantly at 95% confidence level (Table 1). Notably, during the winter season (November–February), the T_{mi} increased significantly since 1990. There is also a marked seasonal variation in T_{max} and T_{min}; for T_{max} the fluctuation is between 28–30 °C during summer and 18–25 °C during winter (Fig. 4). The highest and lowest mean minimum and mean maximum were significantly different for both seasons in 2010. The highest mean maximum temperature was 30.08 °C observed during the summer of 2010, while in the same year, it was the highest of the winter of 30 years reached at 24.75 °C. Further, in the same year, the mean minimum temperature was the highest hitting 18.45 °C in the summer whereas the highest mean minimum temperature of 8.42 °C was observed in 2016. Rise in the minimum temperature affects crop yield significantly.

Time-series climate data are generally heterogeneous due to the influence of various natural and anthropogenic forcings on the climatic variables, often leading to breakpoints within the long-term data. These breakpoints are likely to influence climate trends and variability. The advantage of MK tests over simple trend analysis is that they can overcome these breakpoints' effects. Pettitt's test was done to detect the most probable breakpoints in the winter and summer-time T_{min} and T_{max}. Using these breakpoints, Mann–Whitney test for climate variability was then conducted (Fig. 4). Winter time T_{min} shows significant variability in the mean values, and so does the summer time T_{max}. MK trend also shows a significant increase in the summer time T_{max} (Table 1). Both summer T_{min} and T_{max} an average increase of 0.4 °C per year during the 30 years. An increase in maximum temperature has the potential to enhance the spread of invasive weeds (Adhikari et al., 2019) and increases air pollution (Patz et al., 2000); increase in temperature and air pollution could have synergistic negative impacts on the crop yield (Gupta et al., 2017).

Table 1 Trend analysis for winter and summer season temperature in the study area during the last 30 years

Season	Mann Kendalls		Thiel-Sen's slope		Pettitt's test		Mann–Whitney test		
	2-sided *p*-value	Kendall's tau	Sen's slope	z	*p*-value	Probable change point	*p*-value	A	B
Summer									
T_{min}	<0.0001	0.568	0.036	4.389	0.0007	16	0.874	17.5	17.5
T_{max}	0.00015	0.49	0.047	3.782	0.0005	15	<0.0001	28.50	29.32
Winter									
T_{min}	<0.0001	0.595	0.056	4.603	0.0009	13	<0.0001	4.91	6.00
T_{max}	0.721	0.048	0.005	0.357	0.233	8	0.711	18.63	18.77

A = average for sub-series 1; B = average for sub-series 2

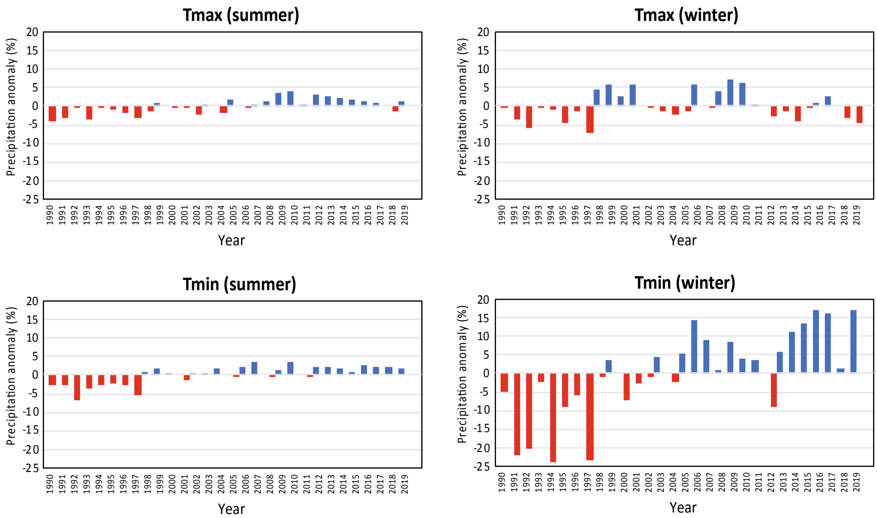

Fig. 3 Temperature anomaly in summer and winter season during the last 30 years. *Source* Department of Hydrology and Meteorology, Government of Nepal (2020)

6.2.2 Erratic and Low Rainfall

There has been a noticeable variation in rainfall patterns over the past thirty years (Fig. 5). A general pattern of declining rainfall has been observed for all the seasons, with monsoon rainfall showing a more marked decline in rainfall. Although the MK trend analysis shows a declining trend in all seasons except pre-monsoon, the trends are not statistically significant. In the case of monsoon rainfall, the low rainfall from 1991 to 1993 and higher rainfall in 2019 may have affected the trend analysis. Decreased winter rainfall patterns have been observed strikingly in December, a month when winter crops need field moisture. The maximum mean monsoon rainfall recorded was 11.97 cm in 1999, with a low of 5.85 cm in 1991. When we evaluate pre-and post-monsoon or in the winter season, the peak was 4.65 cm in pre-monsoon in 1998, and there was no rainfall in 2019.

Even though the MK trend may not show a statistically significant increasing/decreasing trend, the year-to-year variability is very high. For example, the winter rainfall in the year 2003 was 150 times that of the long-term average, while in the following year 2004, it was 39% less than the long-term average (Fig. 5). Huge year-to-year variability is observed for winter and post-monsoon seasons. Such variability is critical for the yield of crops grown in the winter season.

Analysis for heterogeneity of the time-series data suggests the presence of probable breakpoints in the data (Table 2). Mann–Whitney test suggests variability in the data, especially for monsoon and winter rainfall, where the data shows the decline in the mean rainfall values (Fig. 6). Bohlingera and Sorteberga (2018) also reported a decline in the monsoon rainfall around Kathmandu.

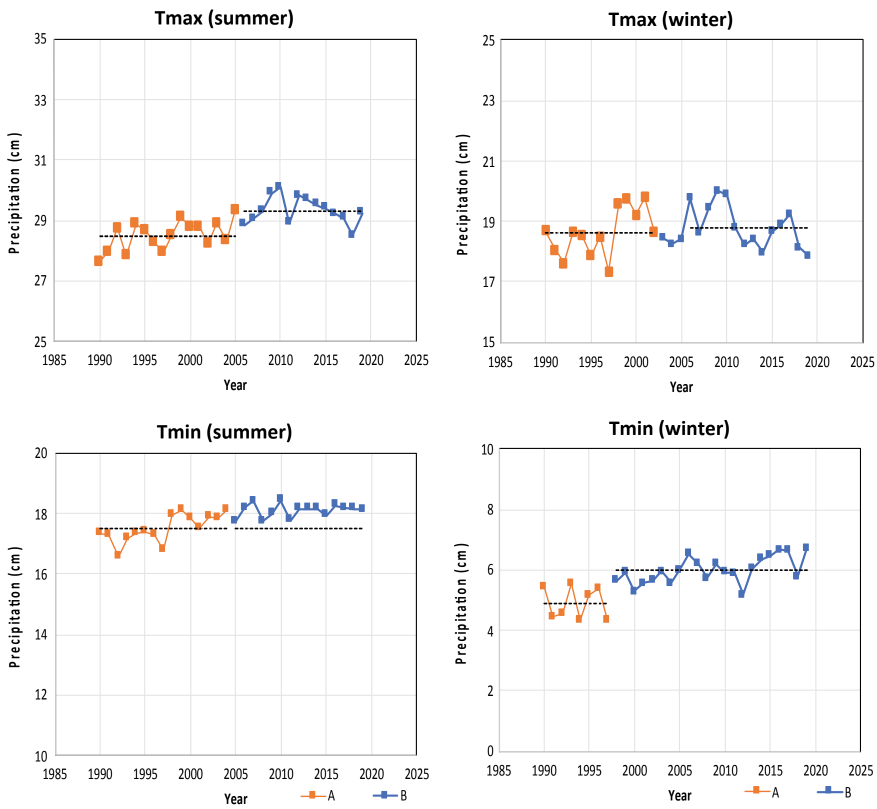

Fig. 4 Mann–Whitney test for variability in timeseries maximum temperature (T_{max}) and minimum temperature (T_{min}) data. The timeseries data is divided into two sub-series at the breakpoints identified by Pettit's test. A = Sub-series 1; B = sub-series. *Source* Department of Hydrology and Meteorology, Government of Nepal (2020)

6.3 Data Collection and Analysis

The increasing trend of climatic variables such as temperature and erratic rainfall patterns indicated a climate change scenario and confirms that smallholder farmers are affected by climate variation in the study area. It also consolidated the necessity of further study to investigate the feasibility of adopting the tunnel technology as an appropriate adaptation strategy for farmers to tackle the climate change effect.

6.3.1 Data Collection

Both quantitative and qualitative means were adopted to collect the data. First, a focus group discussion was conducted with a few farmers to explore how tunnel technology

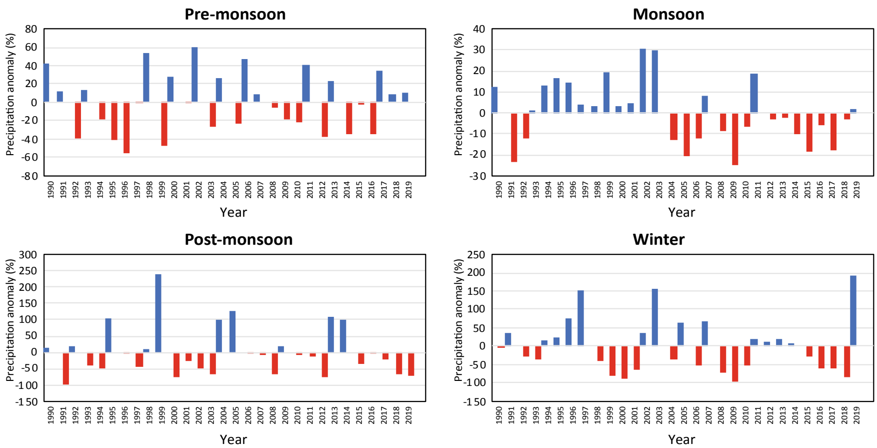

Fig. 5 Rainfall anomaly in the four seasons during the last 30 years. *Source* Department of Hydrology and Meteorology, Government of Nepal (2020)

has helped them tackle the climate change effects. The focus group participants indicated that tunnel technology has protected crops from temperature and rainfall and has improved crop production and income. Therefore, for the household survey, a semi-structured questionnaire was prepared that consisted of questions about climate change's effects on production and farm income. As the cost determines income, farmers were also asked about the different costs incurred on inputs (seeds, fertilizers, pesticides, irrigation, tools, utilities), labor, land, and tunnel technology (drip irrigation installation, plastic mulching, and bamboo/metal pipes structures). Since farmers reported that the tunnel is often used for three years once installed, one-third of the total initial investment was only included as the annual cost for further statistical analysis. Additional questions were also included in the questionnaire to reflect the economic and socio-demographic background of farmers' age, ethnicity, family size and educational status. For the survey, sample households were selected from the record provided by the local government institution-Agriculture Knowledge Centre, Lalitpur. 60 tunnel adopting households were purposefully selected who were cultivating at least 80–90% of land under the tunnel house. This was to ensure that tunnel adoption's real effect is captured accurately, which was impossible if tunnel house was established in a small land portion. Similarly, non-adopters were randomly chosen from the same region who were similar in socio-economic characteristics to the adopters but did not have a tunnel in their farm. Altogether data were collected from 82 non-adopters.

Table 2 Trend analysis for annual and seasonal rainfall over the last 30 years

Season	Mann Kendalls		Thiel-Sen's slope		Pettitt's test		Mann–Whitney test		
	2-sided *p*-value	Kendall's tau	Sen's slope	Z	*p*-value	Probable change point	*p*-value	A	B
Monsoon	0.175	−0.177	−0.052	−1.356	0.026	14	0.131	10.228	9.515
Post-Monsoon	0.52	−0.085	−0.006	−0.642	1	27	0.117	0.908	0.397
Pre-Monsoon	0.943	0.011	0.003	0.071	1	7	0.311	2.189	2.588
Winter	0.335	−0.126	−0.006	−0.963	0.577	8	0.078	0.673	0.462
Annual	0.093	−0.218	−0.029	−1.677	0.122	14	0.017	4.450	3.931

*Note*A = average for sub-series 1; B = average for sub-series 2

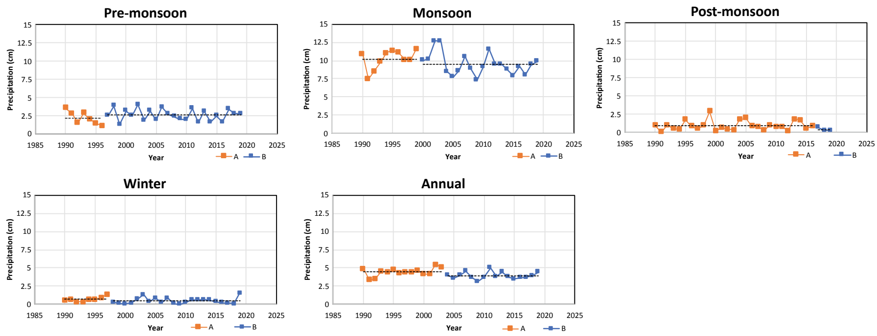

Fig. 6 Mann–Whitney test for variability in time-series rainfall data. The time-series data is divided into two sub-series at the breakpoints identified by Pettit's test. A = Sub-series 1; V = sub-series 2

6.3.2 Data Analysis

We analyzed the quantitative data using descriptive statistics. Ratio, percentage, and means were calculated to quantify the effect of tunnel technology. Furthermore, independent two-sample t-tests were carried out to test the significance. We used Stata software to analyze the data to derive the expected results.

6.4 Results

This section begins with the description of tunnel adopters and non-adopters using the household survey data to identify what socio-demographic factors influence farmers toward adaptation strategies such as tunnel technology. We then compare the crop production and income of adopters and non-adopters to study whether tunnel technology has helped farmers adapt to climate change. We use the descriptive measures of mean difference and two independent sample t-tests for the analysis.

6.4.1 Socio-economic Characteristics of Farmers Adopting Tunnel Technologies

The result of descriptive analysis based on mean difference and t-statistics is shown in Table 3. It shows that there are substantial variations between adopters' and non-adopters' socio-economic characteristics. The findings illustrated that adopters' average age is 37 years, which is five years younger than non-adopters ($p < 0.001$). This may be because younger farmers are better educated, risk-taker, and open to new ideas. They are also excellent at networking and contacting individuals, allowing access to relevant knowledge and support from supply chain players, governments, and donors. This result is consistent with the results from Nigeria (Awotide et al.,

2016) and Moldova (Pilarova et al., 2018), where young farmers have embraced new technology than older farmers.

Regarding education, the years of schooling significantly affect tunnel technology adoption (Table 3). Remarkably, all farmers adopting tunnel technology have attained at least a few years of formal education. On the contrary, some non-adopters were uneducated (11%) and did not attend any school. Educated farmers have a high degree of awareness and are likely to adopt new strategies to tackle climate change effects.

The ethnicity of the farmers significantly affects the adoption of tunnel technology. Farmers from Dalit and Indigenous ethnic groups who are designated as low caste are less likely to adopt tunnel technology as they are usually poor and lack sufficient financial resources to adopt tunnel technology (Table 3). Kumar et al. (2020), in their recent studies in Nepal, highlighted a similar concern that Dalit has comparatively minimum adoption percentage of improved crop practices and mini tiller technology than other ethnic groups because of weak economic conditions. This concern is also reflected by a strong association between farm size and adoption. The average farm size of a household adopting tunnel was 0.37 ha significantly greater than non-adopters by 0.15 ha ($p < 0.000$). Farmers with large land areas are affluent and can make additional investments for adaptation strategies such as tunnel technology.

Interestingly, around 32% of farmers are influenced by their neighbor farming practices, indicating that social networks are also critical for the diffusion of adaptation strategies. Observing neighbor's farming techniques and practices helps to minimize the risk of loss by gaining insights into technical and financial requirements and know whether investing in the technology would be profitable. Studies conducted in India (Munshi, 2004) have stated the importance of neighbors in the diffusion and adoption of technology and adaptation strategy.

6.4.2 Tunnel Technology and Climate Change Effects

The descriptive analysis results showing the impact of tunnel adoption on crop production and income are shown in Table 4. The results suggest that farmers who had adopted the tunnel technology can produce more crops and are better adapted to climate change effects. For instance, the average crop production of tunnel adopting households is 50.11 ton in one ha of land, significantly greater than non-adopting households by 30.38 ton. During the household survey and preliminary focus group discussions, many farmers also confirmed that tunnel technology protects crops from extreme temperature and rainfall and has increased productivity. A study by Gentle and Maraseni (2012) stressed that the adoption of adaptive methods had an important and beneficial influence on productivity. Similarly, Abid et al. (2016), Jacobsen et al. (2012) and Sloat et al. (2020) found that the implementation of climate adaptation techniques have substantially improved food production while facing various climate-related adversaries that hinder normal crop growth.

Crops are subjected to several adversaries due to erratic rainfall and temperature change. Erratic rainfall patterns such as heavy rainfall can damage the crops and induce other complicated effects such as waterlogging, whereas low rainfall

Table 3 Socio-economic characteristics of tunnel adopters and non-adopters

Description of variable	Full sample	Nonadopters (NA)	Tunnel adopters (A)	Difference (A-NA)
Number of respondents	142	82	60	
Age of respondent (years)	39.62	41.48	36.68	−4.80 ***
Gender				
Female (%)	0.17	0.2	0.14	−0.06
Male (%)	0.33	0.4	0.27	−0.13
Numbers of members in the household	5.63	5.51	5.81	0.30
Number of members of the working-age group (15–59 years)	3.88	3.87	3.89	0.02
Number of members of age groups below 15 and above 59 years	1.78	1.64	1.92	0.28
Ethnic background of the respondent				
Dalit ethnic community	0.06	0.09	0.03	−0.06*
Indigenous community	0.19	0.19	0.19	−0.01*
Higher caste	0.25	0.31	0.19	-0.12
Education level measured in years of schooling				
Respondent with no formal schooling (%)	0.06	0.11	0	−0.11***
Respondent with 12 or less years of schooling (%)	0.32	0.34	0.31	-0.03**
Responded with more than 12 years of formal education (%)	0.12	0.15	0.10	−0.05
Area of land under vegetable cultivation measured in hectare (ha)		0.226	0.373	0.15***

(continued)

Table 3 (continued)

Description of variable	Full sample	Nonadopters (NA)	Tunnel adopters (A)	Difference (A-NA)
Influence of neighbor's farming practices on adoption of tunnel technology (1 = yes; 0 = otherwise)	0.33	0.35	0.32	−0.03 **

***, **, * are significant at 1%, 5%, and 10% level, respectively

Table 4 Impact of Tunnel Technology on Agricultural Production and Income

Description of variable	Full sample	Non-adopters (NA)	Tunnel adopters (A)	Difference (A-NA)
Cost of production of vegetables in 1 ha of land (USD/ha)	11,441.86	5606.31	17,277.41	11,671.10***
Total quantity of vegetables produced in 1 ha of land (Ton/ha)	34.92	19.73	50.11	30.38***
Total income from vegetable in 1 ha of land (USD/ha)	15,355.82	8233.60	22,478.05	14,244.44***
Profit from vegetables in 1 ha of land (USD/ha)	3913.96	2627.29	5200.63	2573.34**

***, **, * are significant at 1%, 5%, and 10% level, respectively

may induce water scarcity. Farmers reported that tunnel technologies had directly protected crops from being damaged by heavy rainfall including occasional hailstorms. Additionally, farmers are well adapted to water scarcity problems as drip irrigation is usually installed with tunnel houses which helps to irrigate crops and retain soil moisture with a minimum water volume.

Likewise, high temperatures during the summer season can increase evaporation and reduce the soil's moisture inducing drought. Excessive heat can also affect plant physiology and make them moisture deficit and cause heat stress and injuries. Farmers pointed out that the tunnels provide proper shade and protect crops from such effects. On the contrary, during the winter season, crops can be easily affected by cold temperatures and fog. The frost during winter may even induce fungal diseases resulting in the yield reduction. With the tunnel technology, farmers reported that their crops are better protected from cold temperature and other fungal diseases and have better production. They further confirmed that they could continuously grow crops in the summer and winter seasons, thus significantly increasing their productivity, which is impossible through open field cultivation.

The increased productivity has offered a higher-income earning possibility to smallholders. The findings suggest that the tunnel adopters have higher income and profit than the non-adopters (Table 4). Adopters earn $22,500 annually in one ha of land, significantly greater than the non-adopter by 14,244 ($p < 000$). Furthermore, the annual profit is almost doubled and greater than the non-adopter by $2,500 per ha land. Interestingly, tunnel adoption has also helped farmers to be economically empowered and independent. Farmers can earn regular income as they can harvest and sell crops throughout the year. It is easier to manage daily household expenditure, which is difficult in open field farming as income is earned only once or twice a year during a crop harvest.

Furthermore, farmers can take advantage of the market condition and fetch remunerative prices for their crops. For instance, during household surveys, farmers revealed that they cultivate tomatoes to supply maximum quantity to the market during the rainy season. This is because the supply of tomatoes declines due to recurring floods in the neighboring country India, which eventually increases domestic vegetables' prices providing additional income opportunities for the smallholder farmers.

7 Conclusion

Climate change induces significant threats and risks to these farming populations, which depend entirely on agriculture and agricultural products for survival. Changes in temperature and erratic rainfall patterns may reduce productivity, induce diseases, and cause physical damage. This has led small holder farmers to opt for numerous adaptation strategies. One such strategy is the adoption of tunnel technology which is mainly due to extensive promotion from government institutions and development organizations. This chapter attempts to illustrate the importance of tunnel technology as an effective adaptation strategy to climate change effects among smallholders in Nepal.

We took Kathmandu valley as a case study to explore the effectiveness of tunnel technology. First, we undertook a trend analysis of the last 30 years' time-series data of temperature and rainfall to understand the climate variability in the study site. The result indicated significant variation in the temperature and rainfall, which might have affected the smallholder farmers in numerous ways. Then we explored whether the adoption of tunnel technology has helped farmers to tackle such climate change impacts. Cross-sectional data on crop productivity and crop income was collected from tunnel adopters and non- adopters to study who are better resilient to climate change effects.

The descriptive analysis revealed that tunnel technology significantly increases the crop productivity and income of smallholder farmers tackling climate change hazards. The tunnel protects crops from severe climatic conditions such as extreme rainfall and high temperature enabling farmers to grow continuously throughout the year, contributing to better crop productivity and higher income. Interestingly, farmers can also earn a regular income for the whole year-round, which further contributes to ensuring sustainable livelihoods. Thus, tunnel technology could be considered as an effective adaptation strategy contributing to three SDGs of poverty elimination (#1), zero hunger (#2), and climate action (#13).

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Chickpea Nutritional Status and Value Chain for Sustainable Development

J. S. Sandhu, Shailesh Tripathi, and S. K. Chaturvedi

1 Introduction

Chickpea (*Cicer arietinum* L.) is an important nutrient-rich pulse crop which is indispensable for ensuring global food and nutritional security. World over it is grown across more than 55 countries in an area of about 14.5 million ha (m ha) with a production of 14.8 million tonnes (m t) as per statistics available (FAOSTAT, 2017). During the last decade (2005–07 to 2015–17), the chickpea production increased by 39% mainly due to 24% increase in area. India is the largest producer of chickpea with a share of about 69% in area and 68% in production in the world. In India, during the triennium (2014–17), the chickpea covered 8.74 m ha area producing about 8.0 m tones (Agricultural Statistics at a Glance, DAC&FW, GOI, 2017). Until recently, India remains to be a major importer of chickpea (especially desi type) because of increasing demand during the past decade. During last three consecutive year's chickpea production crosses 10.0 million tonnes (m t) mark that has also helped in achieving self-sufficiency in pulses production in India. During 2020–21, the chickpea production is set to cross 11.62 mt https://eands.dacnet.nic.in/Advance_Estimates.htm. There are two distinct types of chickpea (desi and kabuli) cultivated in different parts of the world with the domination desi types in Asia. Desi types have pink flowers, presence of anthocyanin pigmentation on at least collar region, stem, and petiole. Seeds are mostly brown and with varying intensity right from light yellow to black. The kabuli types are white flowered, lack anthocyanin pigmentation and have white or beige coloured ram's head shaped seeds with smooth seed surface.

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Desi chickpea accounts for 80–85% of the total chickpea area and are mostly confined to Asia, Australia, and Africa while kabuli chickpea are largely grown in West Asia and North Africa (WANA region), North America, and Europe.

The demand for high quality edible legumes for human consumption is rising in both developed and developing nations as more people are becoming aware of the nutritional and health benefits of consuming legumes. Chickpeas are a substantial low-fat source of protein in the diets of millions of people who live in underdeveloped countries in Asia, Africa, and the Middle East despite the fact that they consume a lot of cereals. Chickpea seeds are rich in minerals and fibre, and they also include 20–22% protein (P, Ca, Mg, Fe, and Zn). The lipid component of chickpea seeds contains a lot of unsaturated fatty acids. It possesses more carotenoids (-carotene, cryptoxanthin, lutein, and zeaxanthin) than the genetically altered "Golden Rice" (Abbo et al., 2005).

Traditional processing techniques such as soaking, sprouting, fermentation, boiling, roasting, parching, frying, and steaming are primarily used to prepare chickpea for human consumption (See Figure: Laurette Dubé-personal communication, McGill University, Canada). Unlike vicin in faba beans and trypsin inhibitors in soybean, chickpea does not possess any particular significant anti-nutritional element. The sole drawback associated with chickpeas is flatulence brought on by a higher content of oligosaccharides from the raffinose family (RFOs). Research has revealed that people who eat chickpeas get more dietary fibre, polyunsaturated fatty acids, vitamin A, vitamin E, vitamin C, folate, magnesium, potassium, and iron than people who do not (Wallace et al., 2016). The human beings do not have the enzyme for the digestion of RFOs, which pass undigested through the stomach and upper intestine. Till date, very little or no efforts have been directed toward breeding of varieties with reduced concentration of RFOs. So far little work has been done to develop varieties of chickpea having high protein content only. There is need to develop biofortified varieties having high Fe and Zn content to alleviate nutrients deficiency besides addressing issue of protein malnutrition particularly in Indian sub-continent and sub-Saharan Africa. The development of value -chains alongside different stakeholders would certainly help in addressing issues related to nutritional security through chickpea.

2 A. Nutritional Value of Chickpea

(I) Chickpea seed proteins

Due to the inclusion of protein, minerals, vitamins and fibre among other nutrients, chickpea grains and seeds are traditionally regarded as a great source of energy. Salt-soluble globulins or storage proteins, which are created during seed development and kept in protein bodies, make up the majority of the protein in seeds. These are needed during germination to give the seedling's growing skeletons of nitrogen and carbon. Albumins, which contain several "housekeeping" proteins, lectins, and lipoxygenases, make up the remaining sections of seed proteins. Due to their low quantities of amino acids containing sulphur, globulins are of poor nutritional value for humans and monogastric animals. Crude protein content in chickpea seeds ranges from 12.3 to 31.5%. (El Hardallon and Salih, 1981; Jukanti et al., 2012). Eight annual wild species of the genus Cicer had an average seed protein content of 207 g/kg, ranging from 168 g/kg in C. cuneatum to 268 g/kg in C. pinnatifidum (Ocampo et al., 1998). Antioxidant system responses in wild and cultivated chickpeas were compared (Kaur, et al., 2009). Raw chickpea seeds have a 34 to 76 percent in vitro protein digestibility (Khattak et al., 2008). Due to their lack of sulphur-containing amino acids, the proteins found in legumes like chickpeas are not regarded as "complete" in comparison to the majority of animal-derived proteins (methionine and cystine).

By combining it with cereal proteins, which have a complimentary composition, one can attain a balanced intake of necessary amino acids. The use of gene transfer technology to increase the level of sulphur-containing amino acids has been made necessary by the lack of variety for the content of sulphur-containing amino acids in the primary gene pool of chickpea. Sunflower seed albumin (SSA), a seed-specific chimeric gene, increased methionine production by 24–94% while decreasing cystine by 10–15% compared to normal chickpeas (Chiaiese, 2004). Additionally, efforts have been made to change the globulins' amino acid content or generate exogenous proteins rich in sulphur (Krishnan, 2000). Protein quality of legumes, such as chickpea, can also be significantly improved by heat treatment, since it destroys and/or inactivates many heat-labile anti-nutritional factors.

(ii) Chickpea seed carbohydrates

The range of chickpea's total seed carbohydrates is 52.4 to 70.9 percent (Agrawal & Bhattacharya, 1980). The primary carbohydrate found in chickpea seeds is starch, which typically ranges from 41.0 to 50.8 percent with the mean value of 47.3 percent in most cultivars (Jambunathan & Singh, 1978). Among all crops, pulse seeds have the highest quantities of oligosaccharides. Galactosides make up roughly 62 percent of the total amount of sugar (mono-, di-, and oligosaccharides) in chickpeas, making them the second most prevalent carbohydrates in the plant kingdom after sucrose (Han & Baik, 2006). (Sa´nchez et al., 1998).The oligosaccharide raffinose family, which includes verbascose, stachyose, and raffinose, is a subclass of -Galactosides. Since humans lack the enzyme -galactosidase, which breaks down these oligosaccharides, these compounds build up in the large intestine of the human digestive system. Galactosides go through microbial fermentation in the colon producing hydrogen, methane, and CO2, which are what cause tummy pain (flatulence). Compared to desi types, kabuli types have more soluble carbohydrates (sucrose, glucose, and fructose) (Jambunathan & Singh, 1980).

(iii) Fat and crude fiber

Between 3.8 and 10.2 percent of chickpeas are fat (Jambunathan and Singh, 1978). Kabuli and desi chickpea seeds were found to have fat contents of 3.4–8.83 percent and 2.9–7.42 percent, respectively, according to Wood and Grusak (2007). Roughly 66 percent of PUFA, 19 percent MUFA, and about 15 percent SFA are found in chickpea seeds (Wang & Daun, 2004; USDA, 2010). In chickpea flour, linoleic acid predominates over oleic acid and palmitic acid (Ling and Robinson, 1976). Due to the high quantity of essential fatty acids, particularly linoleic acid and linolenic acid, chickpea has a hypocholesterolemic impact (Ghiradi et al., 1974).

Compared to other pulses, chickpeas have a comparatively larger level of nutritional fibre. It is roughly 18–22 g per 100 g of uncooked chickpea seeds. Soluble and insoluble fibres make up the majority of dietary fibre. While insoluble fibre is metabolically inactive yet aids in bowel movement, soluble fibre is slowly digested in the colon region of the large intestine. After passing through fermentation, the insoluble fibre helps the proliferation of colonic bacteria (Tosh & Yada, 2010). The amount of seed coat is directly correlated with the crude fibre concentration.

(iv) Minerals and vitamins

Minerals (Ca, Mg, P, and K) and vitamins (riboflavin, niacin, thiamin, folate, and beta-carotene, which is a precursor to vitamin A) are abundant in chickpeas. Low-income individuals' diets are lacking in calcium and iron, especially for newborns, young children, pregnant women, and nursing mothers. On average, raw chickpea seeds contain 5.0 mg of Fe, 4.1 mg of Zn, 138 mg of Mg, and 160 mg of Ca per 100 g. (Wang and Daun, 2004; USDA, 2010). The daily dietary requirements for Fe (1.05 mg/d for men and 1.46 mg/d for women) and Zn (4.2 mg/d for men and 3.0 mg/d for women) can be satisfied by consuming roughly 100 g of chickpea seeds each day (Jukanti et al., 2012).

When eaten with other foods, chickpea can supplement a person's nutrient needs. It is a somewhat good source of tocopherols (both and) and folic acid (Ciftci et al., 2010). According to reports, chickpeas have more -carotene per dry weight than the endosperm of "Golden rice" or red-colored wheat (Abbo et al., 2005; USDA 2010).

3 B. Health Benefits Associated with Consumption of Chickpea

It has been demonstrated that eating pulses, such as chickpeas, can potentially improve human health by lowering the risk of chronic illnesses. Due to the presence of physiologically active components that have positive health effects, it is becoming more and more popular as a "functional food." Chickpea seeds have historically been used as stimulants, tonics, and aphrodisiacs (Pandey and Enumeratio, 1993). They have also been used as appetisers, to relieve thirst, to lessen stomach burning, and to eliminate parasitic worms from the body (antihelminthic property). In Ayurvedic medicine, preparations from chickpeas are used to treat a variety of ailments, including difficulties with the liver, spleen, or gall bladder, bronchitis, skin diseases, bronchitis, and blood abnormalities (Sastry and Kavathekar, 1990). In China, Uygur people have been using chickpea for over 2500 years as a herbal medicine to cure hypertension and diabetes (Zhang et al., 2007).

Chickpeas may be helpful in reducing the risk of cardiovascular illnesses since they have a low glycemic index, are an inexpensive source of dietary fibre, and contain bioactive substances (phytosterols, saponins, and oligosaccharides) (Duranti, 2006). 50–60% of chickpea fat is made up of the two polyunsaturated fatty acids (PUFAs) linoleic acid and oleic acid. It has been demonstrated that PUFA consumption, particularly linoleic acid, has a positive impact on insulin sensitivity, haemostatic variables, and serum lipids, reducing the risk of heart disease (Hu et al., 2001). An Australian-style wheat-based diet supplemented with isoenergetic chickpeas significantly lowered blood total cholesterol and low-density lipoprotein cholesterol, according to a controlled dietary intervention research (Pittway et al., 2007). Yang et al (2007) showed that chickpeas significantly improved insulin resistance and prevent postprandial hyperglycemia and hyperinsulinemia induced by chronic high fat diet in rats.

When healthy adults consume 200 grammes of chickpeas per day, butyrate is the most prevalent short-chain fatty acid produced (Fernando et al., 2010). By inhibiting cell growth and causing apoptosis, butyrate has been demonstrated to reduce the risk of colorectal cancer. Other bioactive components of chickpeas, including lycopene, biochanin A, and saponins, have been shown to lower the prevalence of various cancers (Mathers, 2002).

Human studies have discovered that eating chickpeas enhances bowel health overall, as evidenced by increased frequency, ease, and softness of stools when compared to a typical diet (Murty et al., 2010). Increased satiety and fullness were the results of adding chickpeas to the diet.

4 Value Chain Development

Chickpea grains are rich source of protein, minerals, vitamins, fibre, and potentially health beneficial phytochemicals (Jukanti et al., 2012) and are major constituent of vegetarian diet in Indian sub-continent. Most of the time kabuli chickpea are consumed as whole grains whereas desi ones are used as splits (*dal*) or after grinding as flour in form of sweet and salty dishes. Sprouted grains are eaten as a vegetable or salad in many countries. In India, people also eat young leaves and tender stems after making curries. Immature green seeds have special consumers' preference as vegetable, therefore fetches higher price in market. Grain husks, stems and leaves are used in livestock feed. In the United States and European countries, chickpea is marketed dried or canned or in various vegetable mixtures. Mashed (roasted) chickpea mixed with oils and spices (hummus) which is a popular hors d'oeuvre i.e. served in small quantity before the main part of a meal in the Mediterranean Middle East. Nutritional aspects of immature green grains have been assessed by several researchers, however a few published work are available (Sandhu et al., 2007&b and Sharma et al., 2009). As the immature green grains of chickpea are easily digested and are low in anti-nutritional factors like phenols and flatulence inducing oligosaccharides, the development of suitable varieties and value chain will help consumers to get access to the nutritious food easily and farmers will also get premium price for produce.

In India, a large number of high yielding chickpea varieties (desi as well as kabuli) having consumers' preferred traits have been developed (Chaturvedi et al., 2014). So far this area remains untapped and varieties developed so far are not suitable for immature green grain's harvesting purpose at appropriate time of demand by the consumers. Desi types usually have varying colour ranging from light brown to black and usually of small to medium seed size occupying more than 85% of the chickpea area. These are consumed as whole grain (roasted), parched grains or after splitting as *Dal* (about 10–12%) or in preparation of varying types of sweet or salty snacks using flour (88–90%). The green colour chickpea grains turn to black when steam cooked or roasted as whole grains, hence less preferred by consumers.

There is increasing demand for immature green grains of desi chickpea for vegetable purpose. The kabuli types are beige white to white in colour with large or extra large seeds and usually consumed as whole grain only after cooking in our country. Ample scope exists for promotion of immature green chickpea grain (IGCG) as vegetable. To exploit the vast potential of immature green grains for cultivation and consumption future varieties need to have some of the important traits. It is fact that most of the present day varieties recommended for cultivation are providing green grains as these varieties take very long time to initiate podding and develop seeds. Further, in northern India, temperature drops during December/January to less than 10 °C leading flower or pod drop (Chaturvedi et al. 2009 and Bhardwaj and Sandhu, 2009), making these varieties unfit for immature green grain harvest. The other most important trait that requires retention of green colour of immature grain as immature grains should remain green (greenness) till grain size reaches to 90% of its size at physiological maturity. The immature grain should not turn to pale-green when fully developed or ready for harvest when these are to be used as vegetable purpose as an alternate to vegetable pea to cook with rice (*Pulao*). The harvesting through combine machines help simultaneous threshing as well. The storage of chickpea grains at ambient temperature helps in ensuring availability of raw material (grains) for processing during entire year. The processed grains in forms of splits (*dal*) or after dehusking can be stored for a longer period. The value addition in terms of development of snacks (salty or sweet) and smart foods are going to change the market and consumption patterns.

5 Challenges for Improving Nutritional Quality of Chickpea

Chickpea being nutri-rich food, not much efforts were done scientifically to further improve nutritional values and traits responsible for minimizing or curing diseases. In recent years, researchers have initiated work to develop nutri-dense chickpea varieties by improving grain protein content, Fe and Zn contents. Large variability for protein content (12.4–31.5%) exists in the cultivated and wild species which could be exploited in breeding cultivars with increased protein content. Lack of methionine and cystine is still regarded as a target for chickpea improvement. Singh and Jambunathan (1982) studied the amino acid composition of different protein fractions and their distribution in different chickpea seed components. The glutelin fraction contained more sulphur amino acids and hence identification of chickpea accessions with higher ratio of glutelin to globulin would help to improve protein quality. Efforts have been made to capitalize on these large genetic variations to enhance grain protein content in chickpea involving already identified donors (T39-1, A1-1) having > 28% total protein content at several research institutions including ICRISAT, JNKVV, ICAR-IARI and ICAR-IIPR in India. Utilizing T 39–1, one chickpea variety (IPC2005-62: DCP92-3 × T39-1) possessing more than 26% grain protein content has been identified and released for further notification for cultivation and bringing in seed chain. This has opened doors for improving total seed protein content and improving nutritional value by way of increasing Fe and Zn content in future varieties. The identification of QTLs controlling traits those are nutritionally important is also in progress. Further, efforts are needed for assessing the genetic variability for various nutritional quality traits and anti-nutritional factors in the gene pool of the cultivated and wild chickpea. The genetics of the quality traits and G x E interactions must be studied in order to make the desired improvement in these traits. Identification of diverse lines with respect to the nutritional traits and anti-nutritional factors would help in development of mapping populations for identifying markers linked to the genes controlling these traits.

6 Summary

Chickpea plays an important role in the nutritional security of Indian population. There is a need for research and action that helps in advancing modern technologies with addition of traditional knowledge that fast-tracks the convergence of both individual and collective ventures on the production and consumption of whole and value-added chick-pea products. Pasta, breakfast cereals, snacks, breads, and other food categories could benefit from future food with current appeal. There is a need for research that identifies the precise change in physico-chemical properties, as well as nutritional and other quality profiles, associated with various foods.

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Towards Responsible Food Consumption

Changing Food Consumption Pattern and Its Implications on Achieving Zero Hunger in India (SDG-2)

S. K. Srivastava, Deepthi Kolady, and Sudipta Paul

1 Introduction

India has emerged as one of the fastest-growing economies of the world and is witnessing steady progress in the key indicators of economic growth and development. The economic development is evident from the substantial increase in real per capita monthly income from Rs. 1388 to Rs. 3554, and the reduction in poverty levels from 45 to 22% between 1993–94 and 2011–12 (Srivastava et al., 2016). Further, growth in food production at the aggregate level has remained higher than the population growth (Srivastava & Pal, 2020) and the present level of food production in the country is adequate to sustain food security (GoI, 2018a). Besides, rising income and improving food availability, rapid demographic changes (e.g. urbanization) are taking place in the country. The immediate effect of these changes falls on the level and composition of food demand which in turn influences the nutritional status of the households. The pieces of evidence reveal a shifting food consumption pattern from cereals to high-value foods such as milk, fruits, vegetables, non-vegetarian items, processed food, etc. (Meenakshi, 1996; Radhakrishna, 2005; Rao, 2000; Srivastava et al., 2013). It is pertinent to explore the extent to which changing food consumption pattern is getting translated into nutritional improvement.

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Despite significant economic growth, the present status of nutrition of Indian households is below the desired level (Basu & Basole, 2012; Deaton & Dreze, 2009; Meenkashi & Vishwanathan, 2003; Patnaik, 2010). Improving nutritional status is, therefore, accorded a high priority in the developmental planning and present policy discourse has been reoriented from food security to nutritional security. Further, India has fully adopted the sustainable development goals (SDG) framework of the United Nations and aligned its developmental priorities with the global goals (GoI, 2020). Out of the 17 universally agreed SDGs to be achieved by the year 2030, SDG-2 aims to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. Target-2.1 of the SDG-2 is to end hunger and ensure access by all people, in particular, the poor and people in vulnerable situations, including infants, to safe, nutritious, and sufficient food all year round by 2030.[1] Target 2.2 of the SDG-2 aims to end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating woman and older persons. Achieving these targets depends on a complex set of linkages among various inter-related factors. As the intake of an adequate amount of nutritious food is a pre-requisite to the nutritional outcomes, it is essential to unravel and analyze the changing consumption pattern and draw its implications on nutrition.

The present paper provides an account of the nutritional status of Indian households in terms of both the nutrient intake and the nutritional outcome indicators. Subsequently, we have examined the temporal changes in food consumption patterns and compared it across expenditure classes and rural and urban areas using the nationally representative surveys of the National Sample Survey Office (NSSO), Ministry of Statistics, and Programme Implementation (MoSPI). Further, the implications of changing consumption patterns on the nutrient intake have been analyzed. The findings are expected to enrich the ongoing discussion on achieving the target of zero hunger in the country.

2 Nutritional Status of Indian Households

The nutritional status of a person can be understood from the adequacy of nutrients derived from the food intake and the level of anthropometric indicators. NSSO conducts quinquennial Consumption Expenditure Surveys (CES) of Indian households and records the level and pattern of consumption of various food and non-food commodities. By applying nutrient conversion factors (GoI, 2014) to the amount of food consumed, the average level of intake of major nutrients (calories, protein, and fat) can be derived. Table 1 presents trends in average calories, protein, and fat intake based on 50th (1993–94) and the latest available 68th (2011–12) rounds of CES. Further, the National Nutrition Monitoring Bureau (NNMB) of the Indian Council of Medical Research conducts surveys on the diet and the nutritional status of the

[1] https://sdgs.un.org/goals/goal2.

Table 1 Trends in nutrients intake in India (Unit/capita/day)

Indicator	1988–90/1993–94	2011–12	Recommended dietary allowance**
Calories (kcl)*	2146	2088	2100 (U)-2400 (R)
Protein (g)*	60	57	46 (W)-54 (M)
Fat (g)*	35	45	25 (W)-30 (M)
Calcium (mg)#	565	433	1000
Iron (mg)#	27.2	13.4	19 (M)-29 (W)
Vit-A (μg)#	282	296	840 (W)-1000 (M)
Vit-C (mg)#	37	46	65 (W)-80 (M)
Riboflavin (mg)#	0.9	0.8	2.4 (W)-2.5 (M)
Niacin (mg)#	14.2	13.7	14 (W)-18 (M)

Data source * NSSO, MoSPI; # NNMB, ICMR; ** ICMR (2020); M: Male; W: Woman; R: Rural; U: urban

rural population. From the NNMB surveys conducted during 1988–90 and 2011–12, the average intake of micro-nutrients in rural areas is presented in Table 1.

Long-run trends show a decline in the per capita intake of most of the nutrients supplied from the food consumed. The average per capita daily intake of calories, which provides the energy needed to sustain life, has declined from 2146 kcl in 1993–94 to 2088 kcl in 2011–12 among Indian households. Similarly, protein intake, which builds tissues and provides a structural framework to the body, has declined over time. On the other hand, intake of fat, which if over-consumed is considered harmful for the health, has increased from 35 to 45 g per capita per day during the period under consideration. The intake of micro-nutrients except for Vit-A and Vit-C among rural households has also witnessed a declining trend.

A comparison of actual intake with the recommended allowances reveals the inadequacy of nutrients needed for a healthy life (Table 1). On the other hand, average fat intake among Indian households is higher than the recommended level and rising over time. Inadequacy of calories and protein is termed as under-nutrition/under-nourishment (hunger) and malnutrition, respectively. A comparison of actual calories intake with conventional ICMR norms (2400 kcal in rural and 2100 kcl in urban) reveals that 72.14% (77.24% in rural and 59.41% in urban) of the Indian households suffered from under-nourishment in 2011–12 and its incidence increased between 1993–94 and 2011–12 (Srivastava & Chand, 2017). But, when actual calories intake was compared with the Food and Agriculture Organization's (FAO) norm of 1800 kcl, the incidence of under-nourishment reduced to 29.55% (28.39% in rural and 32.87% in urban) in 2011–12 with a declining trend between 1993–94 and 2011–12. Varying level and contrasting trend in the incidence of under-nourishment implies that the choice of alternative norms completely alters the conclusions about the nutritional status. This warrants developing a consensus on the norms and possibly an official estimate on under-nourishment (like poverty rate) in the country.

Incidence of under-nourishment varies widely across the households with significantly higher levels among poor households (Fig. 1). The estimates show that up to

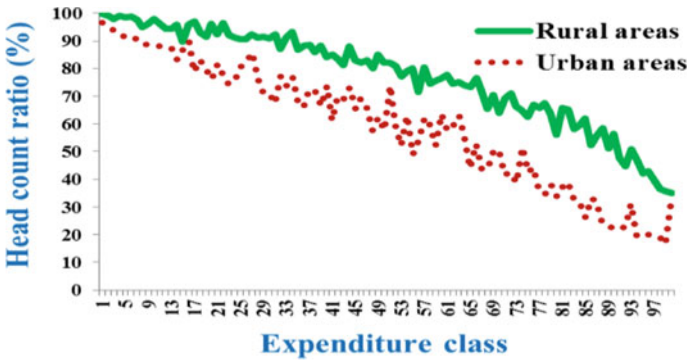

Fig. 1 Expenditure class wise incidence of undernourishment, 2011–12

90% of the bottom 10% (based on consumption expenditure) of the Indian households suffer from undernourished. Even in the top expenditure class, up to 35% of rural households and 33% of urban households remain undernourishment. As these households do not have income constraints, such type of undernourished can be termed as 'voluntary hunger'.

The extent of under-nourishment is another important indicator of nutritional status and is estimated as an absolute deviation of actual calories intake from the norm expressed as a percentage of the norm. The extent of under-nourishment during the year 2011–12 was up to 41% among poor rural households and 30% among poor urban households. On the other hand, the average level of calories intake among rich households was higher than the recommended threshold. The presence of both positive average deviations from the norm (Fig. 2) and incidence of under-nourishment among rich households (Fig. 1) imply both under as well as over-nutrition among these households in the country. In other words, it can be termed as 'double burden' of nutrition, necessitating a differentiated strategy of improving calories intake among poor persons and reducing calories intake among rich persons consuming excess calories. Such desirable trends are taking place and calories intake between poor and rich households are converging over time (Fig. 2).

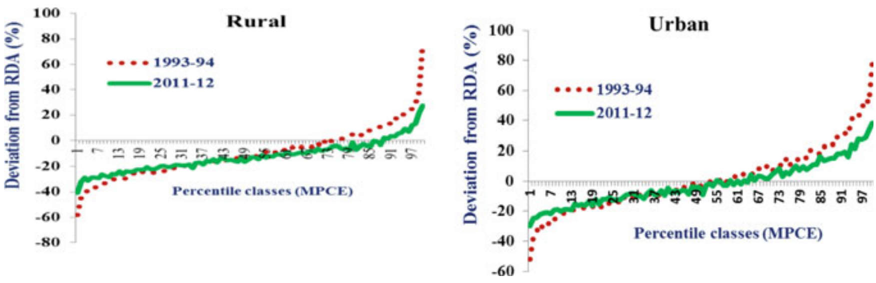

Fig. 2 Expenditure class wise extent of undernourishment

Further, improving equality in calories intake accompanied by a reversal of the long-run declining trend in calories intake since the year 2009–10 (Kolady et al., 2020). Although the level of calories intake in 2011–12 was still less than in 1993–94, there was a 2.7% increase in per capita calories intake, from 2034 kcal in 2004–05 to 2088 in 2011–12. Srivastava and Chand (2017) have identified that among several factors, a sufficiently large increase in income along with improved PDS after 2004–05 triggered the upward trend in calories intake during the recent years. Another study by Kolady et al. (2020) found that the declining trend in calories intake in India has been partly due to measurement issues and that correcting for these issues through refinements in data collection for *food away from home* in 2011–12 had a positive effect on the reversal of the calorie intake decline. The study provides insights for further improvement in data collection regarding household-level consumption expenditures.

Although calories intake is improving, there existed a large-scale calories deprivation across the states in 2011–12 (Fig. 3). Based on ICAR norms, the mean calories intake exceeded the norms only in rural areas of Lakshdweep, Himachal Pradesh, and Uttarakhand and in urban areas of Himachal Pradesh, Uttarakhand, Lakshadweep, Jammu & Kashmir, Puducherry, Andaman & Nicobar, Tripura, Punjab, Mizoram, Haryana, Rajasthan, and Andhra Pradesh. Even in the states with relatively higher calories intake, a substantial portion of the population in both rural and urban areas was under-nourished.

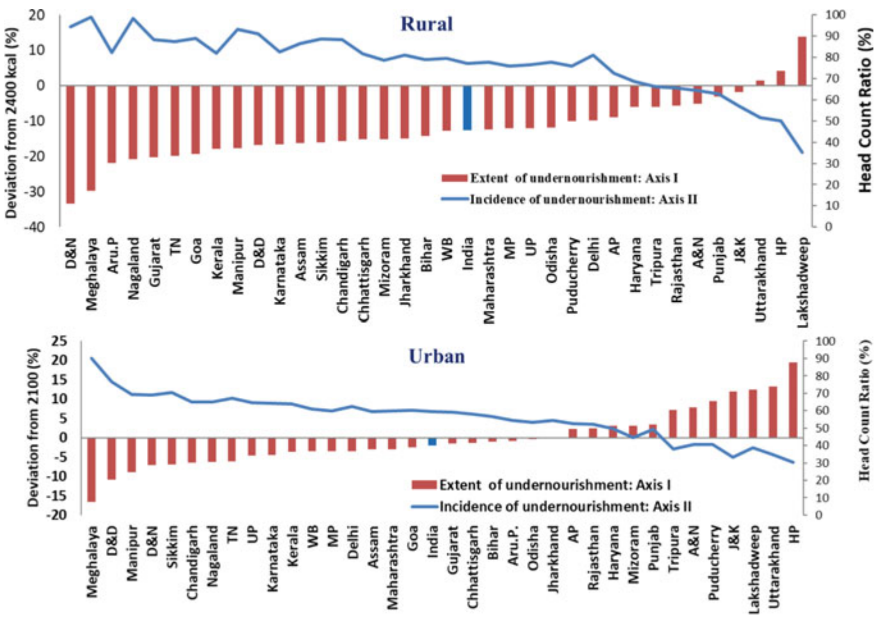

Fig. 3 State-wise incidence and extent of undernourishment in India in 2011–12

In addition to the large-scale prevalence of under-nourishment, there exists malnourishment (protein deficiency) in the country. Although the average intake of protein during the year 2011–12 was higher than the recommended norms (Table 1), 36.7% of rural households and 43.8% of urban households did not consume the minimum recommended level of protein (Chand & Jumrani, 2013). Similarly, the intake of micro-nutrients among Indian households is grossly inadequate.

The outcome of the inadequate intake of nutrients is reflected through the anthropometric indicators which are estimated by conducting a large-scale multi-round National Family Health Survey (NFHS) in a representative sample of households throughout India. According to the latest available 2015–16 survey, every 3rd child in the country is either stunted or underweighted, every 2nd child and woman is anemic and every 4th woman suffers from low BMI (Table 2). The child and woman, who constitute about 70% of India's population, represents not only the present but also the future human resource base and suffers from the poor status of nutrition. Temporal comparison, however, shows an improving trend in the nutritional status in terms of most of the indicators. Serious efforts are being extended in the country to strengthen ongoing nutrition-specific and nutrition-sensitive programs of the government and accelerate the improving trend in nutritional outcomes. One such initiative is the launch of the National Nutrition Mission (POSHAN Abhiyan) in 2018 to achieve the set targets by adopting a new nutrition strategy with the key features like governance reforms, strong convergence mechanism among schemes and related ministries, prioritized action to reach critical groups, ICT based real-time monitoring, incentivizing states and stakeholders, and community mobilization. This strategy is expected to contribute immensely to achieving the sustainable development goal of zero hunger.

The nutritional outcomes are the result of a complex set of socio, economic, demographic, genetic, cultural, policy, infrastructure-related factors affecting availability, affordability, and utilization of food inside the body. The scope of this paper is limited to the changes in the food consumption pattern of Indian households and its implication on nutrition. This is discussed in the following sections.

Table 2 Anthropometric indicators of nutrition outcomes in India

Indicator	1992–93	2015–16
Stunted child of <5 years age (%)	52	38
Wasted child of <5 years age (%)	18	21
Underweight child of <5 years age (%)	53	36
Anemia in children (6–59 months)(%)	74.3#	59
Mortality of child of <5 years age (%)	11	5
Anemia in women and girls (15–49 years)	51.8	53.0
Women with low BMI (%)	35.8*	23

for the age group (6–35 months), * For 1998–99
Source NFHS Surveys

3 Food Consumption Pattern and its Implications on Nutrition

The nutritional status of a person directly depends on the level and composition of the food consumed. This section discusses temporal changes in overall consumption expenditure pattern, food expenditure pattern, and level of food consumption in rural and urban areas and across expenditure classes. Implications of food consumption patterns on nutrition are analyzed by examining corresponding trends in nutrients derived from the food consumed.

3.1 Changing Expenditure Pattern of Indian Households and Nutrients Intake

Allocation of consumption expenditure among food and non-food expenses is one of the important determinants of nutrition at the household level. This can be understood by examining trends in real food expenditure, non-food expenditure, and calories intake. In 1993–94, 64.6 and 57.6% of the total household consumption expenditure in rural and urban areas were allocated to food, respectively (Table 3). Between 1993–94 and 2004–05, almost all incremental consumption expenditure was allocated to non-food expenses such as education, health, etc. and real food expenditure (expenditure at current prices deflated with consumer price index) declined at an annual growth rate of (–) 0.72% in rural areas and (–) 1.60% in urban areas. On the other hand, non-food expenses registered an annual growth of 3.17 and 4.58% in rural and urban areas during the same period, respectively. A decline in real food expenses was also accompanied by a decline in calories intake. In the subsequent period between 2004–05 and 2011–12, an increase in total consumption expenditure was sufficiently large leading to an increase in both food and non-food expenses. Consequent to the positive growth in food consumption, calories intake also registered positive growth, though at a relatively lower rate. This evidence implies from a nutritional point of view, an increase in income of the household should be sufficiently large to cover both food and non-food expenses. Due to relatively higher growth in non-food expenses, the household budget allocated towards food has declined steadily and reached 48% in rural areas and 37% in urban areas by the year 2011–12.

3.2 Expenditure Class Wise Consumption Pattern and Nutrients Intake

There exists a significant variation in the level and composition of consumption expenditure across the income classes. During the year 2011–12, households

Table 3 Changes in expenditure pattern and calories intake among Indian households

Year	Real* food expenditure (Rs./capita/month)		Real* non-food expenditure (Rs./capita/month)		Calories intake (kcal/capita/day)	
	Rural	Urban	Rural	Urban	Rural	Urban
1993–94	599	914	329	672	2153	2071
2004–05	553	766	463	1099	2047	2020
2011–12	622	923	665	1554	2098	2056
Compound growth rate (%)						
1993–94 to 2004–05	−0.72	−1.60	3.17	4.58	−0.46	−0.23
2004–05 to 2011–12	1.69	2.70	5.31	5.07	0.35	0.26

Source Authors' estimates based on Consumption Expenditure Surveys of NSSO
* Values deflated with consumer price index (CPI) for agricultural labor for rural and CPI for urban non-manual employees for the urban sector at 2011–12 prices

belonging to the top decile class (Based on MPCE) spent 9.44 times higher expenditure on food and non-food items as compared to the households belonging to the bottom decile class (Table 4). The low level of expenditure (on food) by the poor household is reflected in the significantly lower calories intake as compared to the rich counterparts (Fig. 4). MPCE-calories intake curve presented in Fig. 4 shows a positive association between income and calories intake and supports income supplementing measures of the government for improving food and nutritional security. Further, up to 61.3% of the total expenditure was allocated to food by the bottom decile class households as compared to 28.7% by the top decile class households in the year 2011–12. This shows a significantly higher propensity to consume food among poor households as compared to the rich counterparts. Consequently, with the increase in the income of the poor households, calories intake increases at a higher rate (Fig. 4). Thus, the nutritional impact of the increase in income is much higher for poor households. The marginal effect of income on calories intake, however, is weakening over time, particularly among the rich households, which is indicated by a downward movement of the MPCE-calories intake curve between 1993–94 and 2011–12 (Fig. 4). This implies that other non-income factors are becoming important for nutrition.

3.3 Food Consumption Pattern and Nutrients Intake

Apart from the level of expenditure, nutritional status depends on the composition of food consumed by the households. The evidence from a nationally representative consumption expenditure survey (2011–12) of NSSO reveals that the food basket is dominated by cereals constituting a 23% share in total food expenditure, followed

Table 4 Decile class wise consumption pattern in India in 2011–12 (Percent)

Items	Decile classes*										
	1	2	3	4	5	6	7	8	9	10	All
Total expenditure (Rs./capita/month)	533	711	839	959	1098	1260	1470	1774	2311	5033	1599
Non-food	38.7	40.4	42.0	43.3	45.4	46.9	49.3	52.6	56.9	71.3	55.7
Food	61.3	59.6	58.0	56.7	54.6	53.1	50.7	47.4	43.1	28.7	44.3
Cereals	34.6	31.7	29.1	27.4	25.7	24.2	22.9	20.9	19.1	14.8	22.7
Pulses	8.0	7.5	7.5	7.3	6.9	6.8	6.7	6.4	6.0	4.9	6.4
Edible oils	9.3	9.1	8.7	8.4	8.1	8.0	7.8	7.3	6.8	5.5	7.4
Milk	8.1	11.5	14.0	15.9	18.1	19.5	20.2	22.3	23.4	22.2	19.2
Fruits	1.0	1.4	1.6	2.0	2.1	2.5	2.8	3.2	3.8	4.8	3.0
Vegetables	12.9	11.7	11.2	10.7	10.1	9.8	9.7	9.2	8.8	7.4	9.5
Non-veg	5.2	6.5	6.7	7.0	7.3	7.5	7.6	7.8	7.9	7.4	7.3
Other foods#	21.0	20.6	21.1	21.4	21.7	21.6	22.3	22.8	24.2	33.0	24.4

* Based on monthly per capita consumption expenditure (MPCE); # Other foods include dry fruits, beverages, snacks and processed items, cooked meals taken outside home, spices, sugar, and salt
Source Srivastava and Sivaramane (2020)

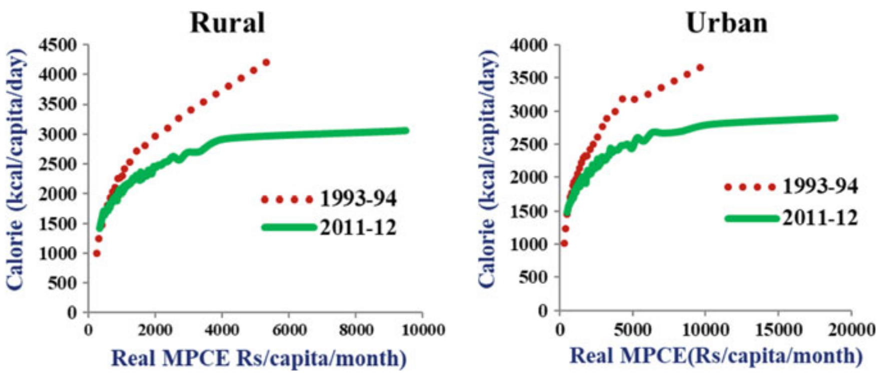

Fig. 4 Association between income and calories intake among Indian households

by milk and vegetables (Table 5). The average per capita household consumption of cereals was 357 g per day which supplied about 60% of total calories and protein in the year 2011–12. About half of the fat intake was supplied by edible oils followed by milk. Thus, cereals are the predominant sources of calories and protein, while edible oils primarily supply fat intake. Any change in the consumption of these food items will have an immediate effect on nutrients intake.

A comparison of the level of household consumption with the recommended dietary allowance reveals that the average consumption of cereals within the household boundaries is marginally higher than the recommended quantity. Actual cereals

Table 5 Composition of food consumption and sources of nutrients intake in 2011–12

Food groups	Composition of food consumed at household		RDA (grams/capita/day)	Sources of nutrition (% of total)		
	Value (% of total food expenditure)	Quantity (grams/capita/day)		Calories	Protein	Fat
Cereals	23	357	326	59	60	9
Pulses	6	27	71	5	11	1
Edible oil	7	22	30#	10	0	49
Milk	19	165	377	8	11	27
Vegetables	11	186	432	5	6	1
Fruits	3	23	100	1	0	0
Non-veg	7	16	118	5	6	1
Others*	23	–	–	7	6	12
Total	100 (708)	–	–	2088	57	45

* Includes spices, dry fruits, sugar, processed food, outside foods and snacks, etc.
# RDA for fat including all sources for moderate activity status
The figure within parenthesis is actual food expenditure in 2011–12
RDA: Recommended dietary allowance
Data sources Authors' estimates based on CES of NSSO

consumption will be even much higher if we add the consumption of food consumed outside the home. Similarly, the consumption of edible oils is higher than the requirement (~15 g/capita/day). On the other hand, consumption of other food items including outside home food consumption such as pulses, milk, fruits, vegetables, and non-vegetarian products is far less than the recommended allowance. These evidences reveal the imbalanced composition of the food basket which transmits to the nutrients supply as well. Efforts are therefore warranted to diversify the food consumption basket for improved nutritional security.

The composition of food baskets varied across expenditure classes (Table 4). The share of cereals, pulses, edible oils, and vegetables in total food expenditure was higher among the household belonging to the lower expenditure classes in 2011–12. On the other hand, the share of milk, fruits, non-vegetarian products, and other foods (including processed foods, dry fruits, beverages, etc.) in total food expenditure was higher among the households belonging to higher expenditure classes. This implies that with the increase in income, an Indian household diversifies food basket and allocates a relatively higher food budget to high-value food commodities such as milk, fruits, non-vegetarian products, etc.

Despite the dominance of calorie-rich staple foods like cereals, relatively poor households suffer from a high incidence of under-nutrition (Fig. 2). This is primarily due to the low-level food consumption among these households as compared to the recommended threshold. However, the gap between the actual consumption and recommended allowance is narrowing down over time.

3.4 *Dietary Diversity and Nutrients Intake*

Although cereals remain a predominant constituent of the Indian diet, their share in food consumption and nutrients intake is declining due to rising dietary diversification towards high-value food commodities. This is indicated by the 10.47 percentage points decline in the share of cereals in food expenditure, 15.78% decline in actual cereals consumption and consequently 23.56% (−233 kcl) decline in calories intake from cereals between 1993–94 and 2011–12 (Table 6). On the other hand, the consumption of non-cereals food is rising. In other words, the food consumption pattern is gradually shifting from relatively cheaper nutrients supplying food (cereals) to costlier nutrients supplying food. The nutritional effect of diet diversification would depend on net nutrient intake which would be positive when the real food expenditure increases sufficiently to cover the incremental cost of supplying nutrients. The empirical evidence shows that between 1993–94 and 2011–12, real food expenditure has increased only by Rs. 23 per month (3.84%) in rural areas and Rs. 9 per month (0.98%) in urban areas.

A perusal of Table 6 shows that the decline in calories intake due to a reduction in cereals consumption (which supplies about 60% of calories intake) could not be accompanied by a commensurate increase in calories intake due to an increase in consumption of high-value foods. The outcome is a net reduction in calories intake. Similar trends shall hold for protein which is predominantly supplied by cereals only. This evidence implies that the present rate of dietary diversification is insufficiently being translated to the improvement in calories and protein intake. Srivastava et al. (2016) found a negative association between the dietary diversification index and

Table 6 Food consumption pattern and calories intake among Indian households

Food group	Share in total food expenditure		Food consumption (grams/capita/day)		Calories intake (Kcal/capita/day)	
	2011–12	Percentage point change over 1993–94 (%)	2011–12	Percent change over 1993–94 (%)	2011–12	Absolute change over 1993–94
Cereals	22.67	−10.47	357	−15.78	1222	−233
Pulses	6.42	0.90	27	7.66	95	8
Edible oil	7.43	0.34	22	58.54	198	73
Milk	19.24	3.80	165	12.08	168	20
Vegetables	11.05	1.66	186	14.10	103	23
Fruits	3.02	0.95	23	18.72	18	1
Non-veg	7.3	1.94	16	24.01	19	3
Others	22.87	0.88	–	–	265	46
Total	100 (708)	–	–	–	2088	−58

Source Authors' estimates based on Consumption Expenditure Surveys of NSSO growth in calories intake, meaning that diet diversification has resulted in lesser calories intake. On the other hand, Parapuurathu et al. (2015) have found evidence of a positive association between diet diversity and calories sufficiency in eastern India. Given that diet-diversification is expected to have positive effects on the intake of micro-nutrients, vitamins, and minerals, it is an aspect that needs to be investigated in future research.

The decline in the consumption of cereals is primarily accounted to coarse-grains (presently being promoted as nutri-cereals) due to reduced availability and changing consumer preferences towards fine cereals and non-cereals foods. During the pre-green revolution era (1965–66), nutri-cereals were cultivated in 36.90 million hectares (mha) area which declined to 14.72 million ha (60% reduction) in 2016–17. The reduction in area under nutri-cereals is primarily a negative externality associated with the rising commercialization of agriculture in a market-led economy which leads to increasing specialization in few market-friendly and relatively higher return generating crops (rice, wheat) to maximize the farm profits. The nutri-cereals, although superior to rice and wheat in terms of nutrients content and environmentally more sustainable, do not provide attractive returns to the farmers in the present market and policy environment. Odds against the nutri-cereals have been further aggravated by changing dietary habits. Consequently, the per capita monthly consumption of nutri-cereals declined by 80% from 4.12 kg in 1972–73 to 0.83 kg in 2011–12 in rural areas. In urban areas, consumption of nutri-cereals declined by 42% from 1.39 to 0.81 kg during the same period.

As per ICMR-National Institute of Nutrition, nutri-cereals are nutritionally superior to fine-cereals like rice and wheat as their amino acids are more balanced and have a higher content of crude fiber and minerals such as iron, calcium, zinc, phosphorus, etc. For instance, finger-millet (*ragi*) has 34 times more calcium, four times more iron, and 18 times more fiber than rice. Little millet has 1.7 times more calcium, 13 times more iron, and 38 times more fiber than rice. Foxtail millet has three times more calcium, four times more iron, and 40 times more fiber than rice. These grains shall be promoted as a substitute to fine-cereals for a nutritionally improved and balanced diet.

Several initiatives have been taken by the government to promote nutri-cereals in the country (PIB, 2018). For creating awareness about the nutritional properties of these grains, the government has changed its nomenclature from 'coarse-grains/millets' to 'nutri-cereals' (GoI, 2018b). India has celebrated 2018 as the national year of millets and based on India's proposal, FAO has declared 2023 as the international year of millets. Further, to accelerate its production, the government has created a dedicated "Sub-Mission on Nutri-Cereals" under the existing National Food Security Mission. The sub-mission is being implemented in 202 districts of 24 states which includes 8 North Eastern states and 2 Hilly states. Besides supporting farmers with technical inputs, including seeds, the mission focuses on post-farm-gate processing, aggregation, and provides linkages to the value addition industry and markets. Also, seed hubs are being planned in major millet growing states and a referral lab is being set up at the ICAR-Indian Institute of Millets Research, Hyderabad to give a fresh impetus to R&D activities.

On the demand side, the mission is focusing on creating consumer awareness. To promote the demand for nutri-cereals, the government has included these crops in the ongoing food and nutritional security schemes like Integrated Child Development Services (ICDS), Mid Day Meal and Public Distribution System (PDS) schemes and procurement is being carried out at minimum support prices (MSP). As the government cannot procure the entire production of nutri-cereals, efforts shall also be extended to promote value addition and processing of these crops which will improve domestic demand and help farmers to realize better prices. In the long-run, farmers shall be incentivized to grow nutri-cereals and declining trends in production and consumption of these crops shall be reverted.

3.5 Contribution of the Public Distribution System (PDS) in Supplementing Nutrition

The Public Distribution System (PDS) is India's most important food security program, through which the government provides staple food at subsidized prices (central issue price), particularly to poor households of the society. During the year 2011–12, 27.20% of rice and 17.14% of wheat consumption at household was supplied by PDS in rural areas. In urban areas, the share of PDS in total rice and wheat consumption was 18.69% and 9.42%, respectively (Table 7). The PDS is primarily targeted toward poor households. This is evident by the fact that 67 and 53% of rural and urban households belonging to the bottom decile class (based on MPCE) were dependent on PDS in the year 2011–12 (Fig. 5a) and PDS supplemented 24.60 and 16.31% of the total calories intake of these households residing in rural and urban areas, respectively (Fig. 5b).

Table 7 The share of PDS supplies in total rice and wheat consumption (Percent)

Food	1993–94	2004–05	2011–12
Rural			
Rice	9.15	12.82	27.20
Wheat	5.36	7.15	17.14
Calories intake from PDS supplies (kcl/capita/day)	134 (6)	140 (7)	294 (14)
Urban			
Rice	13.86	10.92	18.69
Wheat	8.89	3.59	9.42
Calories intake from PDS supplies (kcl/capita/day)	179 (9)	87 (4)	158 (8)

Figures within parentheses are the share of calories derived from PDS supplies in total calories intake
Source Authors' estimates based on Consumption Expenditure Surveys of NSSO

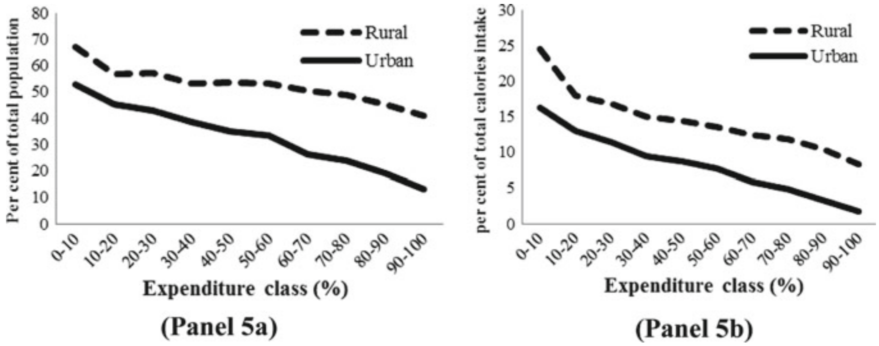

Fig. 5 Expenditure-class wise access to PDS (panel 5a) and the share of PDS in total calories intake (panel 5b) in 2011–12

The contribution of PDS in supplementing nutrition has seen significant changes after 1993–94. Between 1993–94 and 2004–05, there was a very small increase in calories derived from PDS supplies in rural areas and a very sharp decline in urban areas. Calories derived from PDS supplies declined to half in urban areas between 1993–94 and 2004–05. The decline in the contribution of PDS in urban areas might be due to the shift in policy from universal access to targeted PDS (TDPS) in the year 1997. However, after 2004, the PDS got improved considerably with the concerted efforts of many states to revive its functionality (Chatterjee, 2014; Himanshu & Sen, 2011, 2013; Khera, 2011a, 2011b, Rahman, 2014). Consequently, calories intake from PDS supplies more than doubled among both rural and urban households between 2004–05 and 2011–12 (Table 7). A study by Srivastava and Chand (2017) revealed that improvement in PDS after 2004–05 positively contributed to the reversal of the declining trend in calories intake.

Since the enactment of the National Food Security Act in 2013, the coverage of PDS has been expanded significantly covering 75% of rural households and 50% of urban households of the country. Given the shifting priorities of the government from food to nutritional security, existing coverage of the commodities shall be broadened by adopting a nutrition-sensitive approach.

4 Conclusions

India has witnessed significant progress in economic growth and food production, and the present policy discourse is shifting from food security to nutritional security. The government is committed to achieving sustainable development goals (SDGs) of the United Nations and has aligned national priorities with the SDGs. Among 17 SDGs, goal-2 (zero hunger) aims at ending hunger and malnutrition by the year 2030. Among several inter-related factors, the nutritional status of a person primarily depends on the level and composition of food intake. The present paper has provided an account of the nutritional status of Indian households in terms of nutrients intake and anthropometric outcome indicators, and analyzed the effect of changing food consumption patterns on nutrition.

Despite significant economic progress, the present nutritional status of Indian households is at a sub-optimal level. The intake of nutrients particularly calories, protein, and micro-nutrients has declined between 1993–94 and 2011–12 and the present level of intake is inadequate for a healthy life. On the other hand, fat intake is higher than the threshold and is rising over time. Given that all these estimations are sensitive to the selection of reference norms, for example, ICMR versus FAO, there is a strong need to develop a consensus on the selection of reference norm. Once a reference norm is agreed upon, an official estimate on under-nourishment (like poverty) in the country can be provided by the government.

The incidence and extent of under-nourishment vary across the expenditure classes, rural and urban areas, and states. Most of the households belonging to lower expenditure classes suffer from high levels of under-nourishment. At the same time, more than a quarter of the richest households also consume lesser calories than the recommended norms which can be termed 'voluntary hunger'. Further, the evidence reveals a 'double burden of nutrition in which both under-nutrition and over-nutrition coexists in society. This warrants a differentiated strategy of providing affordable access to nutritious food to poor households and creating awareness among rich households about a balanced and nutritious diet. Inadequacy of nutrients intake is also reflected in most of the anthropometric indicators.

Although there exists large-scale undernutrition in the country, nutritional status is improving in recent years. Long-run declining trends in calories intake have reversed since 2004–05. A sufficiently large increase in income, improved PDS, and improvement in data collection are the major factors triggering the upward trends in calories intake. Further, inequality in calories intake between poor and rich households is narrowing down over the years. Nutritional outcomes are also witnessing an improving trend over time. To accelerate these trends and achieve SDG-2 target, the government has implemented a New Nutritional Strategy and launched National Nutrition Mission (POSHAN Abhiyan) which focuses on governance reforms, convergence mechanisms, prioritized actions, real-time monitoring of program implementation, incentivization, and community mobilization.

Improving income of the households remains a necessary condition of improving nutrition, but it should be sufficiently large to cover both food and non-food expenses. Further, the association between income and calorie intake is weakening over time and other non-income factors (education, awareness, sanitation, etc.) are gaining importance. Apart from the level of income and its allocation between food and non-food expenses, nutrition status depends on food consumption patterns. Cereals are the predominant constituent of the Indian diet and supply about 60% of calories and protein. Thus, any change in the consumption of cereals has direct implications on the nutrients intake. About half of the fat intake is derived from edible oils. The evidence reveals that the imbalanced composition of the food basket transmits to the nutrients supply as well. Efforts are therefore warranted to diversify the food consumption basket for improved nutritional security.

The food consumption pattern is changing steadily away from cereals to high-value food commodities. However, dietary diversification is not translating to improvement in calories and protein intake. A decline in consumption of cereals is primarily accounted to the nutri-cereals whose consumption has declined by 80% in rural areas and 42% in urban areas between 1972–73 and 2011–12. As nutri-cereals are nutritionally superior to fine-cereals (rice and wheat), these grains shall be promoted. Several efforts are being extended by the government to promote nutri-cereals both from the demand and supply side.

PDS plays a critical role in supplementing food and nutritional requirement by supplying cheaper staple foods to poor households. After the enactment of the National Food Security Act, its coverage has extended to 75% of rural households and 50% of urban households. Given the shifting policy discourse from food to nutritional security, coverage of commodities and population under PDS shall be reviewed by adopting a nutrition-sensitive approach. This will contribute significantly to achieving the SDG target of zero hunger.

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The Impact of Strategic CSR on Small Holder Farmers: A Study of Agri-Input Firms in India

Ashima Mathur and Anushree Poddar

1 Introduction

The concept of the social responsibility of business has gained unprecedented momentum over some time (Yuan et al., 2011). Corporate social responsibility (CSR) has great potential to make socio-economic contributions that can ensure profitable sustainability (Hopkins, 2016) and gain sustainable mileage in the long run (Scheyvens et al., 2016). Today, CSR is no longer limited to philanthropic motivations and action but involves important management decisions in the area of economic, social and environmental aims (Carroll, 1979). CSR has direct relations with a companies' corporate reputation (Calabrese et al., 2015). Integrating CSR initiatives strategically with core business strategy is also a challenge that firms face today (Narula & Upadhyay, 2010).

The agriculture industry in India is the primary source of livelihood for about 58% of India's population and one of the largest contributors to the GDP in the Indian economy. Gross Value Added by agriculture, forestry, and fishing was estimated at Rs. 19.48 lakh crore (US$ 276.37 billion) in FY20. The industry is undergoing a number of transformations over the past few decades. These include—rising penetration of the organized sector, growth in contract farming, agriculture becoming more mechanized, easy loan facilities, rise of exports, use of agrochemicals and high yielding seeds, and an increasing role of the private sector in processing, branding and marketing IBEF, 2021).

Being an important sector for Indian economy, it is always under scrutiny for many negative reasons (Blowfield, 2012; Raj, 2014). The upstream side of the food value chain is criticized heavily for concerning the use of genetically modified organisms

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(GMOs), pesticide residues and fertilizers (Irz et al., 2001; Jansen & Vellema, 2004). In India, environmental degradation due to the use of excess fertilizers and pesticides, burning of agricultural waste and exploitation of farm labourers is gathering people's attention. Also, despite having the second-largest arable land the agricultural yields remain low as per international standards (Hopkins, 2016). The share of agriculture in the GDP has halved and it still employs around half of India's workforce (Pingali et al., 2019). The stakeholders have growing concerns and are becoming increasingly risk-conscious. In addition, the global market of agribusiness is highly competitive and is governed by many standards. All these issues have a direct impact on the agricultural products sold in domestic and foreign markets (Tallontire & Greenhalgh, 2005).

The smallholder farmer population constitutes nearly 80 percent of the total agriculture production in India and is an important stakeholder group for the agricultural input firms. Farmers are also a source of employment that contributes to rural development, and even to other sectors of the economy since an increase in their income can create a market for services and goods (Guidi, 2011). Farmers face unprecedented challenges and are vulnerable to risks due to the lack of funds, small fragmented lands, and dependency on natural resources. Despite their importance in food production, smallholder farmers are often neglected and encompass the world's undernourished population, most of them living in absolute poverty (Guidi, 2011). By connecting the farmers, building their capacities at various levels and providing quality resources the agribusiness firms can pave the pathway of opportunities for the farmers. In return, businesses can ensure the long-term supply of high-quality crops, improve the company's image, and gain the company's "license to operate". Thus, the development of farmers is a win–win proposition for the agribusiness firms to secure the supply of agricultural produce, and simultaneously improve the conditions of many farmers (Heyder & Theuvsen, 2008).

Bearing these facts in mind, the chapter aims to highlight the CSR practices of Indian Agri- Input firms and the alignment of their CSR practices with SDGs.

This chapter comprises six sections. Section 1 includes a brief introduction to the study. Section 2 covers the literature on CSR and Agribusiness firms. Section 3 highlights the objectives and methodology of the study. Section 4 presents the results and discussion. Section 5 provides conclusions drawn from the study.

2 Literature Review

CSR has evolved over a while from being a philanthropic concept to strategic CSR (Falkenberg & Brunsæl, 2011; Singh, 2010; Tilt, 2016). Researchers use corporate citizenship, business ethics, sustainability, triple bottom line, corporate responsibility, and corporate governance, interchangeably referring to CSR (Agrawal & Sahasranamam, 2016; Alhaddi, 2015; Arevalo & Aravind, 2011). With a tremendous amount of work on CSR, researchers have also defined and critically examined the definitions of CSR (Dahlsrud, 2008; Hemingway, 2002; Smith, 2011).

For this study, the authors have adopted the definition given by the World Business Council for Sustainable Development (WBCSD, 1999, p. 3). It defines CSR as "the continuing commitment by businesses to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as the local community and society at large."

Researchers have identified several incentives for businesses to engage in CSR activities (Biró & Szalmáné Csete, 2021; Heyder & Theuvsen, 2012; Hiss, 2006). The drivers of CSR have been identified as pressure from stakeholder groups, gain competitive advantage, reputation and brand image, increased financial performance, supply-side and demand-side drivers, demand from consumers for green products, ethical standards and policies (Guidi, 2011). All these factors have a positive impact on the firms' performance and help in gaining a competitive advantage. It is also considered as a tool through which companies obtain their "license to operate" (Heyder & Theuvsen, 2012; Hiss, 2006) and improve their reputation with positive effects on companies' financial performance (Assiouras et al., 2013; Marotta et al., 2017). Companies are sustainable when they achieve goals involving all three Ps in the bottom line: profit, people and the planet (Verhees et al., 2008). Based on these assumptions, several scholars consider CSR as a tool through which companies can implement sustainable development (Heyder & Theuvsen, 2012).

CSR has gained importance in the agribusiness sector. Agribusiness significantly depends on natural resources and considerably impacts the environment. Therefore, businesses in this sector are always under scrutiny (Biró & Szalmáné Csete, 2021; Heyder & Theuvsen, 2008; Narula & Upadhyay, 2010). Additionally, agribusiness input companies face several social problems and ethical issues, about the use of genetically modified organisms, land degradation and exploitation of farmers (Heyder & Theuvsen, 2012). These perceived pressures push companies to adopt socially responsible behaviours (Elford & Daub, 2019; Nazzaro et al., 2020). Existing literature indicates that CSR can be conceived as a tool through which agribusiness companies mitigate their risks and increase their competitiveness. Heyder and Theuvsen (2008) developed the "house of CSR" model which is to balance the economic, ecological and social performance of a company.

More recently, CSR has been interpreted as a strategy of competitive advantage for value creation in agribusiness companies (Biró & Szalmáné Csete, 2021). CSR became a strategic factor to enable companies aiming to become more socially aware to address challenges related to the environment and consumer protections.

CSR Landscape in India

The Ministry of Corporate Affairs has incorporated section-135 in the companies' law 2013, which entails the regulatory landscape of CSR in India. Where it has mandated that Indian companies have to spend at least two percent of their average net profit towards activities mentioned in the Schedule VII of the act if they have a net worth of more than 500 crores in INR or have a turnover of more than 1000 crores in INR or earns a net profit of more than 5 crores.

This law applies to all companies, may it be a holding or subsidiary or a branch of a foreign company in India. The Ministry of Corporate Affairs issued this notification on 27 February 2014 and it came into effect from 1 April 2014 (Chatterjee & Mitra, 2017).

The activities under which a company can allocate its CSR funds are specified under the Schedule VII of the Act are as follows (Ministry of Corporate Affairs, India).

No. of activity	Activities
1	Eradicating hunger, poverty and malnutrition; promoting health care including preventive health care and sanitation including contribution to the 'Swachh Bharat Kosh' set up by the Central Government for the promotion of sanitation and making available safe drinking water;
2	Promoting education, including special education and employment, enhancing vocational skills especially among children, women and elderly and differently abled and livelihood enhancement projects;
3	Promoting gender equality and empowering women, setting up homes and hostels for women and orphans; setting up old age homes, day care centres and other facilities for senior citizens and measures for reducing inequalities faced by socially and economically backward groups;
4	Ensuring environmental sustainability, ecological balance, protection of flora and fauna, animal welfare, agro forestry, conservation of natural resources and maintaining quality of soil, air and water including contribution to the 'Clean Ganga Fund' set up by the Central Government for rejuvenation of river Ganga;
5	Protection of national heritage, art and culture including restoration of buildings and sites of historical importance and works of art; setting up public libraries; promotion and development of traditional arts and handicrafts;
6	Measures for the benefit of armed forces veterans, war widows and their dependents;
7	Training to promote rural sports, nationally recognized sports, Paralympic sports and Olympic sports;
8	Contribution to the Prime Minister's National Relief Fund or any other fund set up by the Central Government for socio-economic development and relief and welfare of the Scheduled Castes, the Scheduled Tribes, other backward classes, minorities and women;
9	Contributions or funds provided to technology incubators located within academic institutions which are approved by the Central Government;
10	Rural development projects
11	Slum area development

SDGs and their alignment with the agribusiness sector in India

Millennium Development Goals (MDGs) concluded in 2016 and the shortfalls of that gave birth to the Sustainable Development Goals (SDGs), which is a set of 17 goals and 169 associated targets. SDGs have a proper inclusion of the business sector in its goals and are very significant for them especially the agribusiness sector in India. Agribusiness companies will be benefited directly and indirectly by indulging in the SDGs as it will facilitate in combating the regulations of carbon emissions, climate change, fiscal crisis and energy prices (Blowfield, 2012). Ways need to be found out in which global goals are being moulded to fit in the national agendas. It will help in bringing out a new global development paradigm shift (Gore, 2015). Agribusiness has been said to have an enormous impact on SDGs pertaining to social sustainability (SDG 1—no poverty, SDG 2—zero hunger, SDG 5—Gender equality, SDG 8—Decent work and economic growth), and SDG 10—reduced inequalities and SDG 12—Responsible consumption and production), as well as environmental sustainability (SDG 13—climate action and SDG 15—life on land) (Hinson et al., 2019; Ros-Tonen et al., 2019).

3 Objectives and Methodology

The objective of the research is to examine the trends in CSR in the agri-input sector of selected Indian Companies and to study the role of CSR in addressing the issues of farmers. The agri-input companies were selected from BSE 500. Six agri-input business companies fall under the list of BSE 500 companies. Out of the six shortlisted companies, CSR-related data for the following four companies were available i.e. United Phosphorus Limited, Bayer Crop Sciences, Rallies India and Godrej Agrovet.

Secondary data were collected from different databases like Capitaline, which is an Indian corporate database with an exhaustive list of financials from over 35,000 companies, GRI disclosures, company annual and sustainability reports (Table 1).

The CSR budget of the four companies was examined for the four financial years 2016–2020 (Table 2). The methodology adopted for mapping the CSR activities of

Table 1 Financial details of selected companies for the year 2019–2020

In Rs. Crore

Categories	Bayer	UPL	Godrej Agro	Rallis
Total turnover (Rs. Crore)	3,609	9,641	5159.69	2,251.82
Total profit after Taxes (Rs. Crore)	475	461	293.31	183.69
Total spending on CSR as per PAT (Rs. Crore)	1.80%	3.54%	5.85%	More than 2%
Key products/Services	Dekalb, Nativo WG and RoundUp	(a) Industrial chemicals (b) Agrochemicals (c) Hybrid Seeds	1. Animal feeds 2. Agriculture inputs/Crop protection 3. Vegetable oils	Agri inputs, comprising crop protection products, plant growth nutrients, organic compost and seeds

Source Compiled from data available on public domain on different sources

Table 2 CSR Expenditure of the selected companies from year 2016–2020

In Rs. Crore

	Bayer		UPL		Godrej Agro		Rallis	
Year	Prescribed	Spent	Prescribed	Spent	Prescribed	Spent	Prescribed	Spent
19–20	8.475	8.525	9	16.35	5.37	5.85	4.51	4.51
18–19	9.04	9.043	4.8	18.08	4.7	4.8	3.85	3.85
17–18	10.093	8.049	5.94	20.36	4.311	4.3897	3.88	3.88
16–17	10.023	10.023	4.89	23.79	4.056	4.056	3.91	3.91

Source Compiled from data available on public domain on different sources

the selected cases with the schedule 7 of companies act and the 17 SDG goals are drawn from Poddar et al., (2019) wherein the authors have mapped the segregated indicators as per the 17 SDGs under the 10 subheads of the schedule 7. On similar lines, the CSR activities of the selected firms were mapped with Schedule 7 of the CSR Act and the SDGs (Table 3).

4 Results and Discussion

For a detailed analysis, four input agribusiness companies were selected. The readers are being provided with the profiling of the selected cases to set the context. Table 1 provides the financial details for the year 2019–2020 regarding the companies' turnover, net profit, total spending on CSR, and the sectors in which they operate.

(I) CSR Practices of Selected Input Agribusiness Firms

The prescribed CSR expenditure was compared with spent CSR expenditure for the four companies for the years 2016–2020 (Table 2). It can be inferred that all four businesses are spending either the total prescribed amount or over and above the prescribed amount as seen particularly in the case of UPL. UPL in all four years has spent almost double the prescribed amount on its CSR activities.

CSR activities of the selected four firms were closely examined and mapped with Schedule 7 of Section 135 in the companies' law, 2013.

Bayer

In India, the Crop Science Division of Bayer has businesses in seeds & traits, crop protection and non-agricultural pest control. The prescribed CSR amount of Bayer has decreased from 10.023 to 8.475 (In Rs. Crore) from the year 2016–2017 to 2019–2020 (Table 2). In the year 2019–2020, the key beneficiaries of their CSR project are the farmers as more than 50% of the CSR expenditure is on projects focused on productivity enhancement support to smallholder farmers, drought alleviation projects, and rural development projects.

Table 3 Details of the CSR projects undertaken by the selected companies in the year 2019–20

In Rs. Crore

CSR projects	Amt spent (Rs. Crore)	Schedule	SDGs
Bayer			
Productivity enhancement support to smallholder farmers through the introduction of modern technology	5.77	10	12
Drought and alleviation of farmer distress	1.821	1	12
Rural development programme	0.582	2	8
Programme for primary prevention of sexual violence	0.229	3	5
Bayer fellowship project	0.127	2	4
Total amount spent	8.529		
UPL			
Institution of excellence	11.3	2	4
Sustainable livelihood (School sanitation, girl safety training, industrial safety training, and revival of old villages)	0.35	I, 2, 3, 4, 10	8
Natural conservation	0	4	15
Local area and national need	4.7	1, 2, 3, 10	8
Total amount spent	16.35		
Godrej Agro			
Integrated rural livelihoods program – Increasing household incomes – Strengthening agriculture, animal husbandry and allied activities – women empowerment	2.71	2, 3, 4, 10	8 (10, 12, 5)
Community development initiatives – Infrastructure development – Promotion of education, – Sanitation and – Clean drinking water – Health awareness – Waste management	0.4	1, 2, 4, 10	8 (9, 4, 6, 3)
Integrated watershed management	0.6	2, 4, 10	6
Promotion of agriculture and animal husbandry	1.22	2, 4, 10	12
Support for promotion of education and arts	0.44	2,5	4
Disaster relief	0.28	12	15
Expenditure on administrative overheads	0.2		
Total amount spent	5.85		

(continued)

Table 3 (continued)

In Rs. Crore			
CSR projects	Amt spent (Rs. Crore)	Schedule	SDGs
Rallis			
Jal Dhan (Watershed project, water harvesting and rooftop harvesting)	1.6261	4	6
RUBY project—Education (Career guidance, Soft skill, IT, Science and English intervention, Educational support to unprivileged students) and volunteering initiatives	0.92	2	4
TARA project skill development	0.1291	2	8
Greening project afforestation (Conserving soil and water, increasing groundwater level, green cover)	0.0127	4	15
Rural development, healthcare and sanitation (including marathon and St. Jude)	1.1062	1	8
Farmer safety	0.3032	2	12
C-SAFE	0.1759	4	15
Covid-19 relief work	0.014	1	3
Salary and admin cost	0.2314		
Total amount spent	4.5186		

Source Compiled from data available on public domain on different sources

United Phosphorus Ltd.

UPL is a provider of total crop solutions designed to secure innovative products and services that make agriculture sustainable. Out of the 4 companies under examination, the CSR spent of UPL for all four years is over and above the prescribed CSR budget (Table 2). UPL Limited built institutions of excellence to improve the quality of education and to raise responsible and skilled human capital in the region of their operations. The other activities undertaken by them are focused on sustainable livelihood, nature conservation, school sanitation, girl safety training, industrial safety training, and revival of old villages (Table 3).

Godrej Agrovet

Godrej Agrovet Limited is a diversified, research& development-focused agribusiness company, dedicated to improving the productivity of Indian farmers by innovating products and services that sustainably increase crop and livestock yields. The CSR budget of Godrej Agrovet has increased over the period of the last 4 financial years (Table 2). The main focus of their CSR projects is on training youth, thereby increasing their employability (Table 3). Their CSR programme focuses on women empowerment, economic growth, water management and mitigating farmers' vulnerability to climate change impact.

Rallis India Ltd.

Rallis, a TATA Enterprise is a subsidiary of Tata Chemicals, with its business presence in the Farm Essentials vertical. The company has spent its prescribed CSR budget in the last four financial years (Table 2). Some of their CSR projects are—Jal Dhan project which is on water management, RUBY project focused on education and volunteering initiatives, TARA project on skill development, the greening project on afforestation, rural Development, healthcare and sanitation. Rallis is the only company out of the firms under examination to dedicate a part of their CSR budget to Covid relief (Table 3).

(II) **SDG wise Analysis of the CSR Projects**

It can be seen that even though the number of CSR projects undertaken by the input agribusiness firms is very small, still it covers 7 SDGs in 2019–2020 (Table 3). The most targeted SDG by all the firms is SDG 8 on Decent Work and Economic Growth. The other SDGs mostly targeted by the firms are SDG 4 on Quality Education, SDG 12 on Responsible Consumption and Production and SDG 15 on Life on Land.

From the analysis, it is clear that the businesses are using the CSR budget strategically. Farmers being their primary stakeholders are majorly targeted through projects on rural development, sustainable livelihood, support for productivity enhancement, and drought alleviation projects.

(III) **CSR Practices supporting Farmers**

The CSR funds can help in addressing challenges faced by the agriculture sector in India in the following ways: (i) Providing market linkage- being an agrarian economy the size of operations is already huge but the linkage between the stakeholders in the value chain is very poor, be it forward or backward linkage. The corporate sector has the bandwidth to assist in providing the necessary medium of linkage. (ii) Agriculture comes under a very unorganized sector, and a major reason for the same is that the farmers are not equipped enough or educated enough to understand the rule, regulations, and procedures for the same. The corporate sector is extremely organized and can help farmers formalize things. Their CSR funds can be easily used for the same and their expertise and infrastructure can be utilized to provide a more formalized structure. (iii) The farmers operate in rural settings and lack marketing skills. Through CSR, the companies can provide that linkage to the farmers and help them get better prices for their products. The companies can utilize their CSR funds in providing direct marketing options to farmers directly to the consumers. (iv) CSR funds can be utilized to improve the infrastructure of the market yards which are ill-equipped at most places. (v) Through utilizing the CSR funds the company can educate the farmers regarding the cleaning, sorting, grading, and packaging of the produce. Due to the wrong means of doing so a substantial part of produce gets wasted. (vi) A buffer can be provided by the corporate through their CSR fund to the farmers dealing in high-value crops. (vii) The business can utilize their CSR funds to help reduce the environmental degradation due to agriculture in the ways like disposal of manure in the right manner, reduce the soil and water damage, deforestation is condemned, recyclable packaging is done. (ix) Educate farmers regarding the international standards for enhancing the export of farm produce from India. (xi)The CSR funds can be utilized in reducing the unfair means of doing business like involving child labour, poor safety standards, and working condition. (xii) Women play a significant role in agriculture and if they are included in agribusiness value chains with defined roles and remuneration, it will certainly reduce gender inequality. (xiii) The Covid 19 pandemic has threatened the small land holders in many ways. To cope with this shock, it is important that businesses work strategically with these farmers to develop sustainable resilient farming practices.

5 Conclusion

The study contributes to already existing work on CSR by agri- input businesses. It is clear from the data (Table 2) that the selected four businesses have been spending their prescribed CSR budget during the period of study (2016–2020). Table 3 provides a summary of key CSR initiatives of the companies mapped with the list of activities in schedule 7 of the Companies Act, 2013 and SDGs. The primary beneficiaries of these CSR activities are the farmers and their families. It is observed that the initiatives are focused on sustainable livelihood, rural development, technology support, education of children, clean water and sanitation, health programmes, water management, and environmental protection.

From the data above, it is observed that the selected firms have taken appropriate strategies to set up strategic partnerships with landholders. These partnerships create opportunities for both parties and give a competitive advantage to the firms by maintaining the supply side.

Although agribusiness is linked to all the 17 SDGs Zero hunger, responsible consumption and production, no poverty and decent economic growth are the SDGs where agriculture has the maximum impact. The businesses under study, address SDG 2 on Zero Hunger through sustainable agricultural practices, but no direct linkage with CSR projects related to it were found.

The challenges in the agriculture sector highlight the vulnerability of farmers. Recognizing these challenges, the agribusiness firms are at the right juncture to address these issues and create a positive impact on the farmers which will create value to their business as well. Training & skill development, information sharing, and building market linkages are the key areas reflected from the data (Table 3) which leads to relevant improvement of the small farmers' situations. In addition, firms are achieving positive environmental impacts by water management programmes. The study also shows that CSR initiatives are skewed towards the economic and social front and less focus is observed on the environment. Although, agricultural diversification is being practiced by firms as a CSR initiative but can be scaled up to higher-value commodities.

The success of CSR initiatives depends largely upon the implementation mechanism and specific standards for certifying the agricultural products and increasing the yield. Adopting sustainable agricultural practices may not be possible by farmers alone. To increase the production and upscale farming techniques partnerships between businesses and farmers can provide the needed fund and knowledge to the farmers and in return get loyalty and support.

The dependency of agriculture on natural resources is high and the impact of climate change poses a serious risk, therefore there is a need to increase the horizon of CSR initiatives and focus on environmental goals. A Climate-resilient water management system can be introduced through partnerships.

The study identifies the gaps in the CSR practices of four companies and can enable businesses and research to develop strategies for the future.

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Linking Small Farmers to Markets: Markets, Institutions and Trade

Marketing Constraints of Non-timber Forest Products: Evidence from Jharkhand, India

Muneer Ahmad Magry, David Cahill, James Rookes, and Sapna A. Narula

1 Introduction

The interests in NTFP development and management have amplified over the last few decades (the late 1980s onwards) alongside the developing universal apprehensions about rural poverty, conservation issues and the recent adaptation of concepts of sustainable development (Pain et al., 2021; Belcher et al., 2005), to this end NTFPs, are yet to get mainstreamed at par with other livelihoods initiatives, i.e., agriculture, horticulture among others.

Non-timber forest products (NTFPs) have gained global attention as they provide employment, food security, and economic contributions to the communities that are dependent on them (Chakravarty et al., 2016; Jhonson et al., 2013), thus contributing in a way towards achieving UN sustainable development goals, i.e., (gaol one on no poverty; goal 2, zero hunger; goal eight decent work and economic growth).

NTFPs can be an integral part of subsistence livelihoods (Emery et al., 2001, Pilz 2006), and commercial sales of NTFPs are valuable sources of income for people, seasonally or during times of economic distress (Pierce and Emery 2005, Frey et al., 2018b). Forest-dwelling communities rely on NTFPs for their sustainable livelihoods and socio-economic development (Alex et al., 2016). It has been proposed that NTFPs can bring an economic revolution and uplift the lives of forest dwellers and the forest

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fringe communities by providing tangible and intangible assistance (Pandey et al., 2016; Ojea et al., 2016; Suleiman et al., 2017).

The marketing of NTFPs has been one of the essential sources of household incomes (Timko et al., 2010). The NTFP markets are a mix of informal and formal markets. In NTFP market structures, informal markets refer to unregulated markets outside the regulatory system (Hembram & Hoover, 2008; Thomas, 2001). At the same time, formal markets refer to the regulated markets that are registered and operate in an organized manner (Greene et al., 2000; Greenfield & Davis, 2003). The communities who rely for their sustenance on NTFPs face difficulties in selling NTFPs at local markets as they face the monopoly of traders in price fixation as one of the major constraints (Ballabh, 2001; Saini, 2016., Sudhakar et al., 2013; Mary et al., 2017) and the unorganized pattern of NTFP markets have all been attributed as one of the major bottlenecks in NTFPs development.

The NTFP based local markets have been poorly recognized and often ignored, the comprehensive information on the extent, functioning and structure of the local NTFP trade is scanty, and few statistics are available (Vantomme., 2003; Molner et al., 2006). The NTFPs that are being sold in regulated markets (i.e., national and international markets) gain more attention from the development institutions and governments, and these NTFPs are value-added and fetch good returns (Marshall et al., 2006; Wynberg & van Niekerk, 2014), in contrary, the NTFPs that are being sold in local markets which often lack institutional and government support and these NTFPs remain undervalued (Shackleton et al., 2007, 2008). In this way, the NTFP market chains are characterized by local and broader contexts. The NTFP based studies have focused on economic and social contexts (Wynberg & van Niekerk, 2014). Various studies have been carried out to examine the NTFP market-related constraints considering the top-level actors and activities of the market chain (Kar et al., 2012), whereas at the same time, the role of NTFP collectors in the development of NTFP market chains have been missed out. Thus, there is a greater need to understand and examine the constraints faced by the NTFP collectors and provide possible solutions to overcome these constraints for the development of NTFPs into small-scale enterprises, empowering and mainstreaming the forest dwellers.

In developing countries like India, NTFPs have been providing multiple benefits to the tribal and rural communities (FAO, 2014 and 2016; Newton et al., 2016; De la O Campos et al., 2018), but the monetary benefits that NTFP collectors deserve have not been fully realized due to various constraints, among these limitations the NTFP market chain is one of the significant constraints that is being faced by the NTFP collectors (Magry et al., 2022a, 2022b; Kar et al., 2012). Keeping this background into consideration, this study was designed and carried out in the state of Jharkhand, India. The Jharkhand state is one of the important sources of NTFPs to the tribal community that lives in the periphery of the forest. Tribal communities are known as schedule tribes as per the constitution, they have been given the rights to collect forest products which include NTFPs, fodder for grazing animals and the right to safeguard and protect the community forest resources by the Forests Right Act, 2006 (GoI, 2006). Jharkhand has long been affected by a Naxalite-Maoist insurgency (Shah, 2010; Sunder, 2011), and due to the consequent security and inaccessibility issues, the tribal community face major hurdles in NTFPs commercialization and trade. Considering the preceding, this study aimed at analyzing the following objectives:

- The market awareness amongst the NTFP collectors.
- The constraints being faced by the NTFP collectors in the marketing and trade of NTFPs.
- The initiatives that can be adopted to avoid the constraints faced by the NTFP collectors.

2 Methodology

2.1 Data Collection

The data for this study were collected from the khunti district of Jharkhand state of India. Before data collection, ethical approvals were obtained from the respondents and the university ethics committee. Before the final primary data collection, a reconnaissance survey was utilized to meet various stakeholders and get first-hand information on the demographics and socio-economic conditions of the study region. During the reconnaissance survey, interaction with the NTFP collectors was made with the help of local NGOs and village heads to get familiarity and build goodwill with them; this helped in primary data collection. A pilot study was conducted for questionnaire testing before the extensive primary data collection. After testing the questionnaire and familiarity with the study region, the questionnaire was revised, and some of the questions that were found unsuitable were discarded, and some more helpful questions were included. A comprehensive and complete primary dataset was collected after the pilot study.

The structured questionnaire survey was the central approach for the collection of data. The primary data were collected from 387 respondents in 62 villages across the six administrative regions of the study region (Table 1). The selection of villages for the survey was based on a set of various parameters, and the household survey within villages was conducted randomly, keeping in mind that the majority of households in a village were engaged in NTFP collection. The criteria and parameters used for selecting a village to be included in the survey were: Dependence of local people on NTFPs, the village demographic structure, the distance of the village from a central town/district headquarter, and the distance of the village from the forest.

The information gathered using the questionnaire from the respondents is provided in (Table 1).

Table 1 Overview of the information gathered from the respondents in the study site

Marketing structure	Constraints	Importance of this information
• The existing marketing structures • Connectivity to the nearby markets • Distance to the nearby market • Awareness regarding the market information on prices, • Minimum support price (MSP) • Stakeholders in market chain • Market location information	• Marketing related constraints (information) • Transportation related constraints • Value addition and storage related constraints • Suggestion on eliminating all these constraints	• It will help in identify the major constraints and barriers in NTFP marketing chain • On the basis of the results generated the issues faced by marketing chain of NTFPs can be addressed

2.2 Data Analysis

Descriptive statistical analysis was employed on the data. For analysis of the market awareness among the respondents, cross tabulation was used for descriptive statistics and Chi-squared tests (χ^2) with a 1%, 5%, level of significance were also used for examining the uniform distribution of respondents' responses. Also, the Cramer's phi (χ_c) statistic was used to check the strength of association between the columns and rows in the contingency tables (Zar, 2015).

The logit model was employed to check the relationship between (Market awareness) and Independent variables (Gender, Education and Distance of forest from village).

P_n ($Y_i = 1$) = $f(X_{i1}, X_{i2}, X_{i3}, \ldots X_{iM})$ Where Y_i is the dependent variable (Governance awareness) where $Y_i = 1$ for awareness and $Y_i = 0$ for Not-aware and X_i are the explanatory variables. Logistic function which is central to the logit model can be represented as follows $P_n(y_i = 1) = P_n = \frac{1}{1+e^{-W_i}}$ i = 1, …, N. Where $W_i = b_0 + \sum_{j=0}^{M}$ bjxij is a linear combination of the independent variables.

The frequency of respondents was calculated using excel for exploring the constraints faced, existing source of market information, and initiatives required for eliminating the market constraints.

Table 2 The profile of the respondents in the study area

Study region	Total respondents		Education		Primary occupation level		
District (Khunti) Blocks (Khunti, Murhu, Rania, Karra, Erki and Torpa)	Male	Female	Illiterate	Primary education	Homemaker	Wage labor	Agricultural farmer
	106 (27.4)	281 (72.6)	194 (51)	193 (59)	270 (68.8)	12 (3.1)	105 (27.1)

n = 387 (figures in parenthesis are percentages).

3 Results

3.1 *Socio-Economic Profile of the Respondents in the Study Region*

This study was conducted in the Khunti district of Jharkhand; a total of 62 villages were surveyed across the six administrative regions/blocks within khunti district. The selection of villages for the survey was based on various parameters, and the household survey within villages was conducted randomly, keeping in view the fact that almost every household in the village is engaged in the NTFPs collection. Out of 387 respondents (Table 2), most of them were female (72.6%) as women are primarily involved in the NTFPs collection compared to men. The primary occupation of the respondents was varied. However, most of them were homemakers (68%), followed by farmers (27%).

3.2 *The Existing Market Channel of NTFPs in the Study Region*

The existing marketing channel in the study region for the NTFPs (lac, mahua, and tamarind) is provided in (Fig. 1). The market channel of the NTFPs (lac, mahua, and tamarind) were found to be similar. Therefore, each functioned similarly and with similar functions that included collection, transport, processing, direct sales, and sales through intermediaries or small traders. In the study region, the market chain of NTFPs lac, mahua and tamarind followed the arrangement where the first node started at the NTFP collectors level, they visit the nearby forest to collect the NTFPs, mostly women groups are involved in the collection, in some of the villages, the children were also engaged in NTFP collection. After collection, the

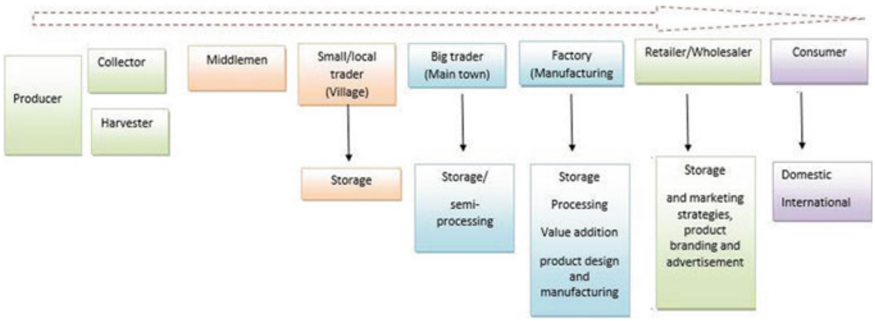

Fig. 1 The existing structure of market chain of NTFPs in the study region. The arrows represent the place of each stakeholder across the market chain of the studied NTFPs

NTFP collectors instantly sell their produce either to intermediaries or small traders in the villages or the nearby market (weekly haat). Further, in the market channel, the NTFPs move to the big traders located in the town, then it moves to the factories to product manufacturing and finally to the costumers through retailers and wholesalers.

It was seen that the NTFPs sold in the nearby market or within the village to the middlemen or small traders were unprocessed, the sale of NTFPs was instant, and the NTFP collectors sell their produce just within days after the collection for the need of urgent money. In the study region, it was recorded that local traders visit the villages, and the tribal community assembles at one common place and sells their produce.

The NTFPs are sold for monetary returns as well as for some daily essential commodities and utilities. The NTFPs are sold, and paddy, salt, and soap is purchased in return as a barter. These local traders then transport the NTFPs to the big traders (the trader located in the town, the prominent trader purchases NTFPs in bulk from other parts of the state). At the big trader's level, the NTFPs are stored, and some semi-processing (deseeding, cleaning, and sorting) of NTFPs is carried out. The big traders wait for the demand to increase and also the price rise. At the next level, the NTFPs go to the factory for product manufacturing. The NTFPs are then distributed to the retail stores and finally reach the consumers.

3.3 Market Awareness Level Regarding the NTFPs in the Study Region

In the study region, the market awareness level of respondents was analyzed; it has been argued that market awareness and knowledge (information on nearby market, transportation, NTFP price) is one of the prerequisites in NTFPs trade (Cunningham et al., 2017). The chi-square tests ($\chi 2$) analysis presented in (Table 3) shows the significant uniform distribution of the respondents at ($p > 0.01$) level of significance.

Table 3 The market awareness of the respondents in the study region

Indicators	Details	Market awareness	No market awareness	Pearson Chi-Square	Cramer's V
Gender	Male	85 (21.96)	20 (5.17)	207.9***	0.733***
	Female	21 (5.43)	261 (67.44)		
Age	30–40	38 (9.83)	21 (5.43)	78.3***	0.450***
	40–50	59 (15.25)	163 (42.11)		
	>50	9 (2.33)	97 (25.05)		
Education	Illiterate	39 (10.07)	155 (40.06)	13.6***	0.188***
	Literate	67 (17.32)	126 (32.55)		

****,** and * represents 1%, 5% and 10% significance level; n = 387 (figures in parenthesis are percentages)*

The Cramer's phi (φc) value shows that there is a strong association of variables analyzed. The survey results revealed that more than 70% of the respondents were unaware of the market structure of NTFPs (Table 2). Further, it was seen that the male respondents (21%) (Table 2) were having some awareness level of the NTFP markets as compared to their women counterparts; only (5%) of women respondents revealed that they know about the NTFP market structures. For the men group, their market awareness can be attributed to their engagement in the NTFP trade, whereas the women group are limited to the collection of NTFPs only; their role remains missing in downstream levels of NTFP value chains.

Further, the logit analysis results validated that women respondents (Table 3) lack market awareness as compared to men respondents; the results were significant at ($p > 0.01$) level of significance with ($\beta = -4.147$). The results further revealed that the respondents with primary level education had some market awareness as compared to those respondents who belonged to the illiterate group, the results were found to be significant at ($p > 0.01$) level of significance with ($\beta = 1.598$). It was also seen that the distance of the village from the market is also one of the reasons for having no market awareness; these results were also found to be significant at ($p > 0.05$) level of significance with ($\beta = -–0.037$). The distance of market to village plays a role in the market awareness level of NTFP collectors; the more distance of market from the village impacts market awareness level of the NTFP collectors.

3.4 *Existing Source of Market Information for NTFPs in the Study Region*

To understand the existing information sources, the NTFP collectors were asked to reveal various sources available in the study region to provide them with market information. The survey results (Fig. 2) show that local traders and the middlemen are the significant sources that provide information on markets and the NTFP prices

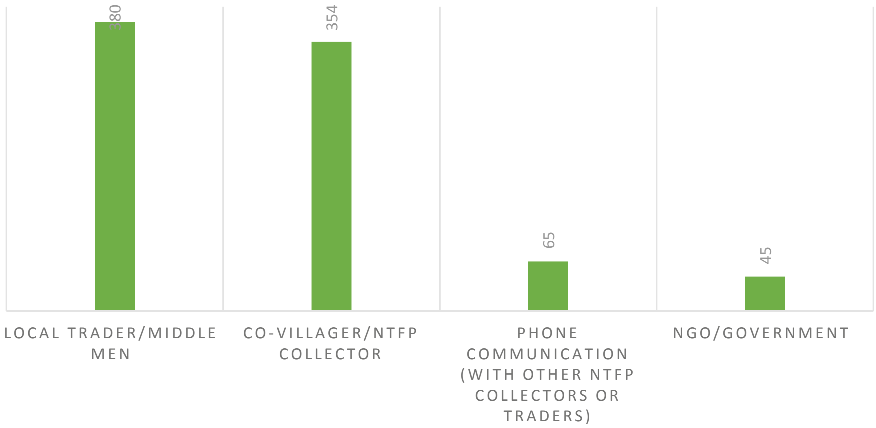

Fig. 2 The existing information source on the NTFP markets (nearby market, NTFP prices, transportation, alternative market) (n = 387)

to the NTFP collectors. However, the respondents highlighted that the intermediaries and the small traders being the source of market information hinder their opportunity to get good returns of their NTFP produce, as they limit the scope of NTFP collectors to visit other markets and reduce their bargaining power. Further, the NTFP collectors said that the co-villagers or co-NTFP collectors also remain an essential source. The NTFP collectors exchange the market information with each other to sell their NTFP produce.

The survey results (Table 4) revealed that the respondents were unaware of traders operating in the NTFP market chain as the traders usually come from the town and operate on behalf of big traders. Further, the respondents revealed that they were unaware of the actors, activities, and stakeholders involved in the market chain. The respondents had no information of the end-users of the NTFPs, and they were not having any information on the cost–benefit margins between the upscale market chain actors and stakeholders.

3.5 Constraints Faced by the Respondents in Marketing of NTFPs

The respondents were asked about the various constraints they face in the marketing of NTFPs in the study region. The results revealed that most of the respondents (Fig. 3, Table 5) highlighted that the transportation facility from the village to the market is one of the most significant constraints they face; the respondents further revealed that they could not due to insufficient transportation availability not visiting the nearby markets. In this case, the middlemen and small traders visit the villages and purchase the NTFPs from the collectors at low prices or in exchange for barter.

Table 4 Logit model showing the relationship of Market awareness (dependent variable) with gender, education and distance of village from the forest of the respondent

Indicator	Co-efficient (Standard error)
Gender of the respondent	−4.147*** (0.401)
Educational qualification	1.598*** (0.405)
Distance from village to town	−0.037** (0.018)
Intercept	1.418*** (0.423)
Log-likelihood	224.903
Nagelkerke R square	0.646
Number of observations	387

This subjects the NTFP collectors to exploitation. The respondents revealed that the middlemen and small traders decide the price according to their will and the bargaining power remains. In this case, the NTFPs collectors are being ignored, and the financial returns are limited. The Middlemen and small traders take complete advantage here in this case.

Further, the NTFPs collectors highlighted that the transportation cost is higher than what they can afford, and it limits them to travel to the markets to sell their produce. The respondents also highlighted that lack of financial support, poor roads and market awareness are also significant constraints faced by the NTFP collectors (Table 6).

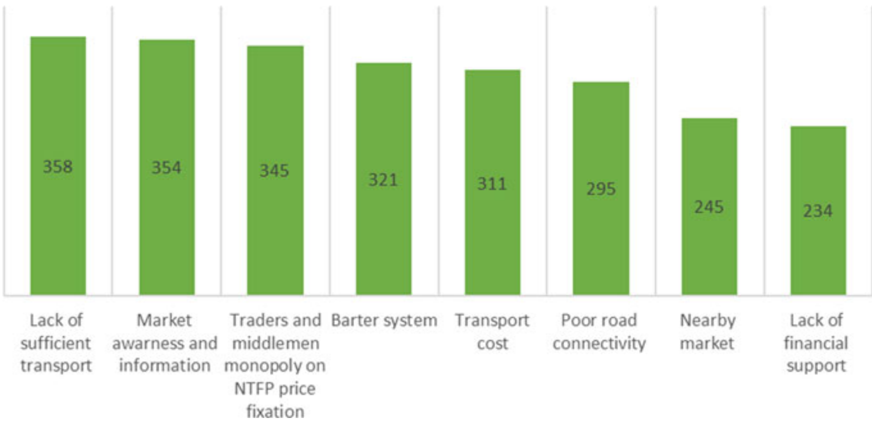

Fig. 3 The constraints faced by the NTFP collectors in marketing of NTFPs in the study region (n = 387)

Table 5 Information of the respondents on various market-related activities of the NTFPs in the study region

Are you aware of the following	Lac	Mahua	Tamarind
The nearby market to your village	Yes	Yes	Yes
Middlemen whom you sell your produce	Yes	Yes	Yes
Trader whom you sell your produce	No	No	No
Stakeholders in NTFP trade	Yes	Yes	Yes
End-user of NTFP	No	No	No
Cost benefit between you and trader	No	No	No
Cost at which trader sells to factory	No	No	No

Source Field survey

Table 6 Major constraints faced by the farmers in marketing of NTFPs in the study region

NTFP	Constraint faced
Lac	Lack of sufficient transport, Traders and middlemen monopoly, poor road connectivity, lack of information on markets
Mahua	Market awareness and information, barter system, traders and middlemen monopoly, nearby markets far from villages, transport cost
Tamarind	Barter system, Traders and middlemen monopoly, lack of transportation facility, transportation cost

Source Field survey n = 387

3.6 Respondents' Suggestions to Eliminate the NTFPs Faced Constraints

The NTFP collectors were asked for the possible solutions that can be used to eliminate or reduce the constraints faced by them (Fig. 4). The NTFP collectors have been living in the study area for decades, and they have been collecting the NTFPs for their subsistence. Their indigenous knowledge is critical for devising any welfare programmer or eliminating the constraints and barriers to developing NTFPs. This was considered, and NTFP collectors were asked about the best options that can eliminate some of the significant constraints they face in the sale of their NTFP produce. The respondents highlighted that the traders and intermediaries monopoly in price fixation of the NTFPs is one of the most significant constraints they face. The small traders and intermediaries fix the NTFP price as per their will and thereby exploit NTFP collectors. The respondents feel that if some stringent legal protocols in place can avoid the small traders and intermediaries monopoly over the price fixation of NTFPs, it can help them get good monetary returns. Further, the respondents highlighted that transportation availability and lower transportation cost would help them visit the nearby markets and sell their NTFPs produce; this can also help the NTFP collectors save some money. The respondents also highlighted that the market

Fig. 4 Initiatives required to eliminate NTFP market constraints

awareness regarding reasonable prices and demand and supply gaps could also help them gain more monetary benefits.

4 Discussion

The study revealed that the NTFPs collectors face various levels of constraints in the marketing of their NTFP produce, impacting the financial returns to the NTFP collectors. The respondents highlighted that the traders and intermediaries monopoly over the price fixation of the NTFPs is one of the significant constraints they face; the traders and intermediaries fix the prices of NTFPs according to their will, thus limiting the scope of higher returns to NTFP collectors. The monopoly of traders and intermediaries can be attributed to the related constraints that NTFPs collectors face in the marketing of their NTFPs, i.e., lack of transportation, higher transport cost and poor road connectivity; all of these play a significant role in traders monopoly as the NTFP collectors are unable to afford the higher transport costs. The NTFP collectors are unable to go to the markets, the small traders and intermediaries visit the villages to purchase the NTFPs as per the prices they fix for NTFPs and, also the barter system is often used where traders take advantage of the NTFP collectors. Keeping in view the above discussion, it can be seen that the existing market linkages are the poor market. Thus it impacts the NTFP collectors.

Previous studies have also highlighted the monopoly of traders and intermediaries as one of the significant constraints in NTFP marketing (Bhattacharya & Hayat, 2004; Marshall et al., 2006; Shaanker et al., 2009). A study conducted by Kar et al. (2012) in Bangladesh highlights that lack of transportation, poor road connectivity, and transportation cost are the significant constraints that the NTFP collectors are facing. Another study conducted by Kumar et al. (2018) in Gujrat, India, has highlighted that the traders' monopoly in NTFPs price fixation is one of the most significant constraints that the NTFP collectors face. Marshall et al. (2006) highlighted that safeguarding a reasonable market price for the NTFPs is not attainable at the NTFP collectors' level due to the obstacles faced by the NTFP collectors in terms of no processing at the village level and trader's monopoly. Other studies have also highlighted that poor road connectivity and higher transport cost are significant constraints by the NTFP Collectors (Awono et al., 2010; Nkem et al., 2010; Saha & Sundriyal, 2012). It has also been reported that the market types and structure are influencing the NTFP prices, such practices have been reported in various countries like South Africa, India, Mexico, and Bolivia (te Mahapatra & Shackleton, 2012; Saha & Sundriyal, 2012; Shackleton et al., 2011; Velde et al., 2006). One of the studies conducted by Malleson et al. (2014) in Ghana, Cameroon, and Nigeria has reported that external market forces influence the NTFP prices. The studies have been highlighting such issues for years as our study highlights, but no action has been taken as part of the redressal mechanism; there is an urgent need to put a framework or mechanism in place that can be utilized to avoid all such constraints when NTFPs are being looked as the major player in circular bio-economy transitions and achieving global goals.

This study further examined the market awareness and knowledge level of the NTFP collectors and the results revealed that the NTFP collectors lack the market awareness; they possess minimal or no information of the upscale stakeholders that are present in the NTFP market chain. They are unaware of the cost–benefit arrangements between the upscale stakeholders in the market chain. The results highlighted that the male NTFP collectors and those who have possessed primary educational level have some information on the market structure of NTFPs. The reasons for having no market awareness can be attributed to the fact that the women group mainly carries out NTFP collection and further up the market chain, their role remains missing. The traders are primarily men, and they often tend to visit the villages for the purchase of NTFPs; this leads to the market information gap to the NTFP collectors. It has been reported previously that apart from various socio-economic parameters, education level is the primary driver of market awareness of NTFP (Loaiza et al., 2015; Ghosal and Liu, 2017). Previous studies have highlighted that education plays a role in understanding the market structure of NTFPs. The studies have also highlighted that inadequate market information and awareness are among the major concerns faced by the NTFP collectors (Marshall et al., 2006a; Shackleton et al., 2007). A study conducted by (Jha, 2016) reported that due to a lack of information on market locations, prices on NTFPs and unavailability of transportation, the NTFP collectors receive low monetary benefits from their NTFP produce. (Belcher et al., 2004) has reported that market information is a vital constituent for better earning by the NTFP collectors.

This study also examined the respondents' views on the major initiatives and efforts that can be utilized to reduce the constraints faced by the NTFPs collectors. The results revealed that the NTFPs collectors are facing the major challenge posed by traders and intermediaries monopoly over the price fixation. The NTFP collectors were of the view that they can be part of the price fixation and the traders, this could help reduce the trader's monopoly over the price fixation and help in good monetary returns to the NTFP collectors. Further, the NTFP collectors highlighted the need for frequent and low-cost transportation facilities, market information, good road connectivity, processing, and value addition at the village level. These facilities can be some of the initiatives that can reduce the constraints faced by the NTFP collectors, and they can fetch better monetary returns. This will help their overall development, improve their living standards, good and quality education to the children, and health and hygiene improvement. In this way, the sustainable development goals on decent work, health and hygiene, sustainable livelihoods, and equality can be achieved.

5 Conclusion and Recommendations

This study highlights various constraints faced by the NTFP collectors in the marketing of NTFPs that included trader's monopoly, transportation unavailability and cost, lack of market information. This warrants the possible actions that can be undertaken to reduce the constraints faced by the NTFP collectors; this study highlights the possible actions based on the NTFP collectors views that can be adopted for successfully minimizing the constraints faced for NTFP development at the village level. The possible actions as per the NTFP collectors include frequent and low-cost transportation facilities, market information, good road connectivity, processing, and value addition at the village level, in addition to this minimizing the monopoly of traders on price fixation, NTFPs collectors skill development, market linkages and financial assistance.

To achieve the proposed possible actions highlighted by the NTFP collectors, an institutional mechanism can be developed that can inform the NTFP collectors with the pertinent information on related policies, market awareness camps for information dissemination, financial linkages for processing, and value addition at the village level; this will enable them to trade NTFPs with better returns. In this regard, the NGOs can play an important role with active support from the government and corporate sectors. There is also a greater need to make the NTFP market organized and regulated; the regional or national level government can provide a policy framework entirely dedicated to NTFPs development to keep a regular check on NTFPs related market activities, that can ensure NTFP collectors better returns and will ultimately help in empowering them. Taking actions and devising the frameworks that will help promote the NTFPs development by eliminating the highlighted constraints and barriers will help achieve sustainable development goals.

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Impact of Marketing Reforms on Farm-Market Linkages

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1 Introduction

Agricultural marketing is the key ingredient in getting the farmer an appropriate price for his produce. Agricultural marketing system in a broader way is defined as institutional and physical established to execute all activities engaged in the movement of products and services from the place of initial production to the ultimate consumers. This includes storage, assembling, packaging, transportation, wholesaling, retailing and export of agricultural produce besides other supporting services like establishment of grades and standards, market information, financing, trade, price risk management and formal institutions engaged in operationalizing the reported crucial functions. Marketing of agricultural products also reflects another area that is centric to deliver the produce from rural to rural and urban as well as rural to industrial customers. Therefore, market reforms are well recognized as a Center point of agricultural development policy.

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1.1 Need of Reforms and Their Genesis

A successful marketing system prioritizes providing remunerative prices for the producers at cost-effective terms of marketing, along with timely delivery of supplies to customers at reasonable prices. Various Governmental initiatives have been implemented from time to time which have led to the improvement of marketing system.

To stimulate economic growth, employment and overall well-being in remote regions, the agriculture industry requires well-functioning markets. A larger part of the required investment is likely to come from private sector, warranting a favourable policy and regulatory environment. Additionally, there is a strong need to devise and implement potential policies to promote the sourcing of the agricultural commodities directly from farmer producers and to strengthen effective linkages from the farm production to processing industries and well-organized retail chains. Subsequently, state administrations are recommended to amend their APMC Acts in order to liberalize India's agricultural marketing system. To shield the farmers' interest and to secure sufficient availability of food grains for official procurement, a host of prohibitions were enforced by the state and central government. However, unrestricted domestic marketing regulations have resulted in higher marketing costs, risks, and uncertainties undermining the agricultural sector's performance.

1.2 Impact of Reforms Over a Period of Time

Several changes were implemented in the 1990s to help the agriculture industry integrate more fully with the global economy. Quantitative limits on agricultural commodity imports were lifted in April 2001. In 1994, agricultural export policies were liberalized. Export quotas were relaxed, minimum export prices were abolished, and finance was made more readily available. The "Vishesh Krishi Upaj Yojana" (Special Agricultural Produce Scheme) was implemented in EXIM policy 2002–2007 with special incentives to enhance agricultural exports. However, the government frequently tinkers with export policies in order to ensure steady commodity supplies and keep domestic prices stable.

A number of reforms in the economy have been introduced since inception of new economic policies in 1991. Improving commodities market performance, reforming the APMC Act, reforming price policy, rationalizing input subsidies, boosting public investments, operating futures trading, and encouraging private sector participation were among them. Under the Essential Commodities Act, necessary changes were made to gradually reduce the degree of controls and regulations. The Indian government issued the Removal of (Licensing requirements, stock limits, and movement restrictions) on Specified Foodstuffs Order in February 2002. This decree lifted all restrictions on dealers' purchasing, stocking, and transportation of the designated commodities, including wheat, paddy/rice, coarse grains, sugar, edible oil seeds, and edible oils. Any order issued by the states/UTs under the ECA regulating licensing, storage, transportation, and distribution of any of the enumerated commodities requires prior approval from the Central Government. The Department of Agriculture and Cooperation drafted a model law on agricultural marketing for state governments to consider and approve. It calls for the creation of private markets/yards, direct purchase centers, consumer/farmers' markets for direct selling, and the promotion of PPP in the management and growth of agricultural markets in India.

The government prepared the Agricultural Produce Marketing (Regulation and Development) model Act, 2003 as a key initiative. And in line with this model act, all States/UTs committed to amending their individual State APMR Acts in accordance with the Model Act. Setting up markets in the private/cooperative sector, rationalization of market fees, promoting contract farming, direct marketing, grading and standardization, including the establishment of a Grading and Standardization Bureau in each State/UT are some of the key characteristics of the Model Act. The states have only revised their policies in three areas: direct marketing, contract farming and the establishment of private marketplaces.

1.3 Need of New Reforms: Suggestions from the Committee on Doubling Farmers' Income

The reforms in agriculture sector were primarily intended to increase output and enhancing food security. The strategies adopted by the government always were focused towards the welfare of farmers but never explicitly recognize the need to increase farmers' income. At the world level, agricultural environment is continuously changing in terms of trade practices, business opportunities and availability of technology. Low level of income earned by farmers has led to agrarian distress. Considering this, Government of India set up a committee to double the farmers' income by 2022. For enhancing farmers' income inter alia, marketing was considered vital.

The report released by the sub group on "agricultural marketing and value chain" suggested strategies to eliminate constraints faced by farmers and other value chain players. The country's agricultural marketing system was also developed through infrastructure, improved access to the necessary information, efficient produce flow, decreased transaction costs, and reduced food waste. The strategies suggested in the report have focused on following issues.

Strategies suggested in doubling farmers income report
• Creating a conducive environment for the development of agricultural marketing (Agricultural Marketing reforms) • Encourage investment in agricultural marketing infrastructure mainly infrastructure that supports perishables and integration of markets • Enhancing access to market information by farmers and other players of value chain • Negotiable warehousing receipt and other means to enhance credit availability • Strengthening institutions to facilitate the integration of farmers with market • Capacity building and skill development to bring a concept like management and entrepreneurship in agriculture and help farmers to plan their crops according to market need • Value chain approach for overcoming the constraints faced by farmers • Integrated market operating at national level (e-NAM)

2 New Reforms

Reforms in agriculture and market related policies are done to facilitate farmers to discover better prices and to protect different stakeholders from any sort of exploitation at the hands of middlemen. Regulation of agricultural market through APMC act was one such reform which was expected to do so but it failed to achieve many of its objectives. Its advantages to farmers have been well documented by many studies. However, it was not moving in the tandem with changing economic environment and thus other reforms came into picture. The system of APMC was characterized by

Monopoly of licensed traders: The necessity of compulsory license for any agent to operate in a regulated market resulted in the monopoly of the agents.

Lower price realization by farmers: Commission agents and traders associate together by forming a group and deliberately specify lower prices of produce thus defeating the very primary purpose of these regulated markets i.e. to act as a price discovery system.

Multiple points of levy market charges: Apart from market fee and commission agent charges there are other charges like weighment charges, hamal charges, purchase tax etc. For certain states it is even 15% of total charges (DFI, Vol 4).

Accessibility to market: At most of the places, the regulated markets are located at a greater distance which makes it expensive and time taking for the farmers to reach these markets.

Delay in payment: The payment of price of produce to the farmers is delayed which compels them to sell their produce outside the market yards.

Cartelization: Licensed traders form cartels and market was regulated on the basis of their decision.

Entry barrier: The entry of new entrants in regulated market is very difficult due to the presence of such cartels.

Inadequate market infrastructure: Improper storage, sorting, grading and post-harvest management facilities at market resulting in non-remunerative prices to the farmers.

2.1 e-NAM

On April 14, 2016, the Union Government announced a Central sponsored Scheme to promote the one nation-one Market through a unified electronic platform known as e-NAM. "Small Farmers Agribusiness Consortium" (SFAC) has been designated as the key promoter of e-NAM by the Department of Agriculture and Cooperation (DAC) Ministry of Agriculture, through an open procurement, SFAC picked Nagarjuna Fertilizer as a strategic partner (SP) to design, run, and manage the e-NAM platform. This initiative's vision is to enhance uniformity in agricultural marketing by streamlining procedures across integrated marketplaces, eliminating information gaps between buyers and sellers, and promoting real-time price discoveries based on real demand and supply situations.

For promoting trading on e-NAM platform, states must enact the following basic three measures in their APMC Acts: one trader license valid throughout all marketplaces in the state territory; levy of market fees at a single point, particularly on the very first wholesale purchase operation from the farmer; and 100% electronic trading of the agricultural produce identified for each mandi. Other significant needs for starting e-NAM at their APMC include harmonization of quality standards, assaying, and soil testing facilities near mandis (Nuthalapati et al., 2020).

2.1.1 Benefits of e-NAM

- It facilitates farmers with a number of alternatives for selling the produce at optimum prices at the nearest mandi.
- It facilitates traders to access a larger national market for the purpose of secondary trading.
- It allows bulk buyers, processors, and exporters to participate directly in local mandi trade, lowering intermediation costs.
- It facilitates traders and commission agents in reduction of book keeping through system generated reports for improved inspection and regulation.

A total of **1,76,13,992** stakeholders (Table 1) 1000 mandis have been registered under e-NAM portal. A total of 175 commodities are being traded (as per the details given in Tables 2 and 3).

Table 1 Stakeholders details of India (as on 28.02.2022)

States	21
Traders	219,639
Commission agents (CAs)	102,771
Service providers	0
FPO's	2083
Farmers	17,289,499
Sum total	17,613,992

(*Data source* e-NAM web portal)

Table 2 Number of unified licenses (As on 31st January, 2021)

S. No.	State/UT	Registered Mandis on e-NAM	Traders registered on e-NAM	Number of unified licenses distributed by state
1	Andhra Pradesh	33	3288	3288
2	Chhattisgarh	14	3076	33
3	Chandigarh	1	78	0
4	Gujarat	122	9302	15
5	Haryana	81	11,845	36
6	J&K	2	56	0
7	Himachal Pradesh	19	1962	0
8	Jharkhand	19	1993	39
9	Madhya Pradesh	80	21,320	396
10	Kerala	6	172	29
11	Karnataka	2	562	0
12	Odisha	41	4681	4681
13	Puducherry	2	152	0
14	Maharashtra	118	19,706	0
15	Rajasthan	144	23,211	23,211
16	Tamil Nadu	63	3442	315
17	Uttar Pradesh	125	34,689	110
18	Punjab	37	2260	1
19	Uttarakhand	16	4670	4670
20	West Bengal	18	2980	0
21	Telangana	57	5681	5681
Total		1000	1,55,126	42,505

(*Source* e-NAM web portal)

Table 3 Commodities traded on e-NAM

Commodity category	Number of commodities
Food grains/cereals	26
Fruits	31
Vegetables	50
Spices	16
Oilseeds	14
Miscellaneous	38
Total	175

Source e-Nam web portal

2.1.2 Challenges

Technically, e-NAM is expected to benefit all stakeholders involved in the agricultural commodities value chain by bringing much-needed efficiency in the agricultural marketing system. However, past researchers have also highlighted problems with e-NAM implementation around the country. Bisen and Kumar (2018) clubbed the main hurdles in e-NAM implementation under the three I's (i.e. Information, Infrastructure and Institutions). Infrastructural problems include weak back end infrastructure, inadequate scientific warehousing and storage facilities, restricted numbers of cold storages, inadequate refrigerated van facilities, deprived assaying and grading amenities in markets etc. In addition to that, farmers tend to have little awareness regarding the process and benefits of e-NAM leading to a lack of interest and discourages farmers to participate in trading through e-NAM. Farmers are also concerned about the poor price for the produce if it is identified to be of sub-optimal quality. This highlights the absence of assurance on the quality of the commodity as most of the agricultural commodities are perishable. Furthermore, there are obstacles in the form of states' lack of motivation to support and implement their APMC Act to include provisions like single point levy of market fees; sole trading licenses as well as e-trading, as well as delays in notification, are major legal stumbling blocks in the e-NAM implementation. Besides, human resource limitations include a lack of competent people in APMCs, a restricted number of skilled traders proficient in dealing with the e-platform, and farmers with limited literacy.

2.1.3 Impact of Electronic Platform on Agricultural Marketing

- e-NAM has a good impact on peasants in form of greater price realization, ease of online payment, improved capabilities for determining product quality, and a less cumbersome and transparent sale process (Sekhar & Bhatt, 2018).
- Average market prices in e-markets increased significantly during 2007–2015, while price variability decreased significantly. There was a rise in the average market arrivals, as well as more openness and fewer payment delay (Reddy, 2016).

- Nuthalapati et al. (2020) looked at pricing discrepancies in grains and pulses among sample states before and after the e-NAM. In 2017–2018, farmers in Haryana, Madhya Pradesh, Telangana, and Uttar Pradesh made money selling both paddy and wheat, while farmers in Gujarat and Maharashtra lost money. Farmers in Gujarat, Madhya Pradesh, and Telangana made a profit on Jowar but lost money on Bajra. They also discovered that farmers cultivating pulses in Gujarat, Madhya Pradesh, Telangana, and Uttar Pradesh had a negative price difference, meaning that they had not made profits from pulses, whereas Haryana and Maharashtra had profited. During the pandemic, some significant new elements were added to the trading platform, such as the ability for Farmer Producer Organizations (FPO) to buy and sell their produce directly from their own collection center without having to transport it to physical mandis, as well as a warehouse based trading and logistics module that provided users with trackable transport facilities.

2.2 *"Model Agricultural Produce and Livestock Marketing, (Promotion and Facilitation) Act, 2017"*

The act came in 2017 by a committee on Marketing Reforms constituted by central government under the chairmanship of Dr. Ashok Dalwai, Additional Secretary (MoAFW). Few salient features of this act are:

S. No.	Features
1	It facilitates the provision of direct marketing bringing farmers, processors/retailers/exporters/end consumers on a single platform
2	It gives freedom to agriculturists to sell their produce anytime anywhere
3	It provides provision for electronic and spot trading platforms thus facilitating transparency in market system
4	It clearly defined the roles and responsibilities of the Director of Agriculture Marketing and the Managing Director of Agricultural Marketing Board (MoAFW) of the respective State/UT
5	It encourages investment in development of markets and marketing infrastructure
6	It has the provision of single point collection of market fees across the entire state and unique trading license thereby eliminating multiple market charges
7	It creates a favourable environment for the establishment and operation of private wholesale and marketplace facilities (MoAFW)
8	It includes provisions for special agricultural commodity market yards (SCMM) and market yard of national significance
9	It allowed for the designation of silos/warehouses/space as market sub-yards/cold storage structures, allowing farmers to have improved market access

This act follows a holistic approach to solve the existing problems of regulated markets. Since agriculture is a state subject, the states are allowed to adopt entire or certain portions of Model Act (Yadav, 2018). It provides facilities for trading of agricultural produce including livestock and a barrier free environment for different stakeholders to perform freely. This will help farmers in better realization of prices as farmers can connect with different buyers directly. It is expected to increase the producer share in consumer rupee. It keeps contract farming outside of the ambit of APMC to avoid any sort of conflict of interest. Traders and commission agents consider contract farming as threat since it will have direct impact on their realized revenue. For this another act was floated i.e. "Model Agricultural Produce and Livestock Contract Farming and Services (Promotion and Facilitation) Act, 2018". It allows easy participation of private players through contract. This act encourages trading on pre-agreement basis between producer and buyer. The producer can reduce the risk due to fluctuation in demand and prices of produce and traders can procure quality material at pre-decided price. It can also help in the transfer of latest technology from lab to land, thereby making agriculture look more lucrative. The produce has to be covered under insurance and no permanent structure can be constructed on producer's land. Earlier contract farming was registered with APMC in some states. All the market charges including fees and taxes were paid to this committee however no facilities like market area and infrastructure were provided to them. This model contract farming act provides for establishment of independent state level authority to take care of its proper implementation. Farmer Producer Organizations have a very crucial role to play in this act. These organizations are responsible for bringing small and marginal farmers together and mobilize them for better trading options which otherwise is very difficult to achieve.

2.3 Farmer Producer Organizations

It's a producer organization where the members are farmers or primary producers. The basic aim of these FPO is to facilitate farmers in realizing better prices. These organizations bring farmers together so that they can have good bargaining power than individual farmers. Indian agriculture is characterized by the vast majority of small and marginal farms. Due to small fragmented land holdings, higher cost of cultivation, lack of access to credit, quality inputs, limited access to market, lower quantity for sale etc. has resulted in making agriculture an unviable option of earning money. These small and marginal farmers rely on an informal credit structure and get exploited at the hands of money lenders. Moreover, while moving produce from field to end consumer, number of intermediaries are involved which results in reducing producer share in consumer rupee. These inefficiencies and challenges call for the formation of a structure that can bring these small and marginal farmers together as a group. Farmer Producer Organization is one such initiative that collectivizes small farmers to provide them the benefit of forward and backward linkages (Bikkina et al., 2018). Collectivization of farmers, especially small and marginal farmers, can provide gains in productivity and better bargaining power (Agarwal, 2010).

FPO is established in the form of cooperatives, companies or as a society. The cooperative structures can be transformed into farmer producer companies at a later stage (Rao, 2019). SFAC and NABARD assist in the creation and promotion of FPO's.

In order to transform agriculture into a viable business venture, the federal government has proposed that 10,000 FPOs be formed and promoted over the following 5 years, beginning in 2019–2020. Government advocates establishment of FPC over cooperatives where cooperatives are not doing well. This will help in removing the limitations under Cooperative Act and will give the benefits of Company Act while broadly following the principles of Cooperatives. Over the last decade, around 7000 FPOs have been formed across the country. These were founded as a result of several government of India initiatives (namely SFAC), state governments, NABARD, and other organizations (NABARD Report 2020-2-21. **National Paper—PLP**).

2.3.1 Significance of FPOs

In the third tranche of Aatmanirbhar Bharat, the focus has been given to FPOs. It emphasizes on creation of farm-gate level agriculture infrastructure through FPOs and formalization of micro food enterprises. It will create favourable ecosystem for the development of efficient decentralized agriculture marketing system which will lead to better price realization of agricultural produce.

FPO provides accessibility of the potential markets located in metropolitan cities. This is very important particularly for those farmers who have adopted high value crops as well as organic farming. According to Manaswi et al. (2020), the producer share in consumer rupee for organic chilli was observed to be the highest (65%) in the case of marketing channel III (Farmer-FPO = 1-FPO = 2-Consumer). The number and transaction costs in marketing declined with the help of FPOs. Farmers from the group were able to sell organic products in speciality markets in major cities.

Small and marginal farms make up the majority of Indian agriculture, hence, FPO mitigates their risk of distress sale and it will help farmers to move from subsistence farming to market-oriented commercial farms.

Members of the FPO had higher net farm income than non-members, which was statistically significant. Sorting, packing, loading, and sealing tasks could provide additional man-days of employment for FPO members. Further, FPO members were using an extra income on education and health (Singh, 2019).

Farms rely primarily on their own previous experiences as well as information from other farmers. So, farmers could not get the proper market intelligence in time. FPOs can provide the marketing security of the agriculture produce with competitive prices.

During the imposition of strict lockdown at initial phase of covid-19 pandemic across India, various governments proposed alternative marketing channels which can focus on direct to home delivery of essential products. This proposal opened opportunities for supply chain innovations for the benefit of farmers. In such situations, governments have promoted FPCs to work as collection centers to directly sell to consumers. About 125 FPCs in Haryana were registered on e-NAM web portal for online trading of horticultural items. In Tamil Nadu, 100 FPCs (0.23 million farmers) have been registered on the National Commodity and Derivatives Exchange (NCDEX) trading platform. The state of Maharashtra, with many robust FPCs, is promoting the sale of customized packets of vegetables directly to consumers (Boss et al., 2020).

2.3.2 Few Successful Examples of FPO

(i) **Junnar Taluka Farmer's Organization and producer company**: There are numerous examples from across the nation which cites the potential benefits of establishing FPO for farmers. One such example is quoted by Sawairam (2015); Junnar Taluka Farmers' Organizations and producer companies, in Narayangaon, Maharashtra that was established to overcome the exploitation of farmers by middlemen in tomato farming. Farmers were not given appropriate price of their produce; their payments were delayed and there was no proper flow of information. Basically, they were at the mercy of the middlemen. When these farmers came together and formulated FPO, they were able to break the chains of traders and middlemen and witnessed an overall development in their area. With the help of FPO and PC, they gathered more knowledge about crop loans, financing options, updated technologies and better ways to link up with the market. The wholesale market of tomato was developed by them which attracted traders from Ahmedabad, Surat, Baroda, Agra, Lucknow, Delhi, Bengaluru and many more. The company has also entered in contract farming of potato with companies like ITC, Siddhivinayak, Thorat Traders.

(ii) **SEWA**: Another very popular example is of a village level producer organization in Gujarat, SEWA (Self Employed Women's Association) which empowered women farmers to avail inputs, information, financial services, training, awareness, risk mitigation techniques and market linkages (Desai & Joshi, 2014). It is a collaboration between a nonprofit company (NGO) and the commercial private sector.

(iii) **Shramajivi Nagpuri Santra Utpadak**: During the pandemic situation in 2020 when there was restricted movement of produce, most of the crops faced losses. Farmers at individual levels faced higher losses due to break in market linkages. Under such situation also, FPO orange growers namely Shramajivi Nagpuri Santra Utpadak in Amravati manage to curb its losses. During March 2020, there were unseasonal rains and sudden lockdown. The price of the oranges crashed by more than 60%. Seasonal fluctuation, labour shortage and price crash took a heavy toll on orange growers. With the help of district administration and Maharashtra State Agricultural Marketing Board, this producer company managed to get permission at different levels and was able to achieve tie up for processing of produce and eliminated most of the losses that occurred during that period.

More corporatization, privatisation, and engagement of organized parties are likely to result in increased investments and tech-based innovations, particularly in supply chain infrastructure, as a result of the widening of the agricultural trade. It will throttle the competition in the market thus facilitating farmers to get the best bargain for their produce. Through one nation-one market, corporate companies can bridge the existing demand and supply gap, benefiting both producers and consumers besides helping to reduce the price volatility in the market. Furthermore, the end consumers are also expected to be benefitted from the efficient supply chains and reduced prices as lesser hands are involved. End users will also be benefitted from improved infrastructures and climate-adjusted storage, which will result in higher-quality perishable items with a longer shelf life.

3 Global Experience of Establishing Farm-Market Linkages—Evidence from Other Developing Nations

All the developing nations broadly have similar macro issues. In order to overcome these issues, various reforms have taken place in these countries also. Looking at the Agri-Reforms in India and its impact, it becomes inevitable to understand the reforms undertaken by other developing nations so that we can have a clear picture of the future scenario of farm-market linkage.

a. **Myanmar**

Problems before reforms	Reforms	Impact	Future reforms
The major issues with Myanmar Agriculture policy are the lack of credit facility and Absence of property rights to secure title of the land	Improvement of rural infrastructure, access to affordable inputs and ease of credit availability with micro finance	Removal of market distortions like export restrictions. Myanmar has emerged as one of the largest exporters of beans and pulses in recent years. This shows that liberalized trade policy in other commodities may demonstrate its huge potential Along with this, public expenditure and investment on infrastructure and power generation as well as distribution is the need of the hour	• Granting complete production rights for farmers so that they can diversify into various crops as per the demand • Telecommunication reforms to promote market intelligence • Reforms to liberalize import licensing system to strengthen the currency • Remove restrictions on lending to farmers by private banks

(*Source* Haggblade et al., 2013)

b. **China**

Problems before reforms	Reforms	Impact	Future reforms
Prior to the reform, private ownership of land was forbidden, and the families worked together as a team. Due to the difficulty in performance monitoring, the returns were distributed equally among households regardless of the varied levels of work put in by individuals. As a result, farmers received poor incentives, resulting in an inefficient production system	Chinese reforms started from market orientation due to which the majority of the people were able to earn their livelihood The Chinese policymakers took a step-by-step approach by first creating incentives and facilitating the institutions for marketing and their next step was to open up the markets expanding the role of private trade	These reforms ensured widespread distribution of gains which built a unity in the political support for such reforms This resulted into better resource allocation and their domestic production became more competitive This boosted the rural non-farm sector indirectly and led to rapid reduction of poverty	Agriculture's national investment contribution must be proportional to its national income There has to be a tradeoff between growth in agriculture and modernization as the current investment thrust is on the latter one

(*Source* OECD Report, 2018)

3.1 Adhering to Global Quality Standards

Developing nations often criticize the quality standards of developed nations to act as non-tariff barriers (Henson & Caswell, 1999). As per the WTO norms, member countries can set their quality norms as per their own interest and requirement provided these standards do not necessarily hamper the trade benefits of other members. Although these standards are voluntary it becomes practically impossible to compete in this cut throat competition without adhering to these norms (Jaffee et al., 2005). This becomes a reason for distortion of the trade particularly with the countries of European Union where quality standards are relatively stringent. There is a need of developing countries coming together and through lobbying can address this practice.

One such standard is Global GAP (Good Agricultural Practices). This standard is primarily concerned with food safety, but it also addresses environmental concerns, health safety, welfare and traceability of the produce. Small farmers are unable to meet the standards as these certifications need technical expertise as well as high investment in compliance. These issues make high value markets inaccessible for small farmers.

On the other hand, adapting to such standards can turn this into opportunity. Farmers can create a unique selling proposition for their produce and reap the benefit of higher profit margins by supplying good quality produce to the consumers as well as strengthen the supply chain by minimizing the losses throughout the channel.

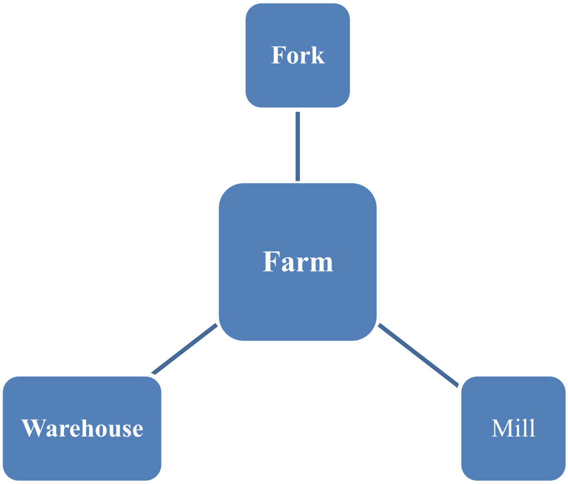
3.2 Adhering to SPS Standards

Sanitary and Phyto sanitary standards are established with the aim of protecting human, animal, and plant life from the dangers of pests and diseases, risk due to food and feed additives, poisons, and pollutants. It may result into the following benefits like reducing rejects in consignment, fetching higher prices, reduced risk of losses and higher share in trade. However, from the consumer point of view also it adds a safety value against food borne illness caused by pathogens. Failure to comply with these norms may result in permanent loss of market and trade opportunity. Higher quality product which follows the foreign standards not only opens the arena for exports but also increases the domestic value of the products. Many countries like Russia and Egypt have imposed temporary bans on the products due to SPS issues. Import of fruits from Moldova were banned due to oriental fruit moth issue. Also, Egypt has implemented a zero-tolerance measure for ambrosia and ergot in 2016 and no tolerance policy for poppy seeds which was found in the imported wheat.

4 Successful Cases: Innovations in Agri Marketing

(i) Agribolo

This venture was started by three Mumbai based entrepreneurs Balaji Balaraman, Ajeet Godara and Arvind Godara. The basic aim behind this establishment was to digitalize agriculture. They are currently spread across four states namely Rajasthan, Maharashtra, Punjab, and Haryana with over 2,50,000 farmers registered. They were aware about the challenges that farmers are facing in retrieving the correct information, sourcing the raw material and input of the required quality, market linkage and irrigation facilities. Moreover, the climatic conditions and the attack of pests on their crops made the farmers more vulnerable. This was the exact time when money lenders and middlemen started exploiting the farmers. With the mission to break this vicious cycle, the trio started “Agribolo”. The business model for their enterprise is as shown in the figure.



Source: Krishisutra, 2013

Agribolo has developed a model so as to connect farmers, warehouses and processors. They provide technical as well as financial assistance to farmers. They also create a linkage between farmers and the Agri-Input companies to ensure the quality of the input. They provide market information to the producers related to demand and supply of their produce to facilitate informed decision-making. The stakeholders can connect them through toll free number, SMS service and mobile application. They have designated various field experts who can connect with the farmers directly and guide them in relevant solutions. For input and output sourcing, the firm also links farmers with the industries and corporations.

Other tasks in which the company works with the farmers include milk collection, cow feed, nursery development, and water sheds. To enable extension services, they have established "Agribolo Kisan Seva Kendra" franchises that act as "one-stop shop" with the capacity to handle around 250 farmers within a 15–20-km range. They can seek professional guidance, service aggregation, and agri-related activities from experts. The team connects the farmers directly to APMC where they can sell the produce. The company's mission is to build a long-term value chain connection for farmers across the country.

(ii) **Agrowave**

This delhi based start-up is working as a farmer to business model. They are using mobile pickup stations to connect farmers with various businesses like hotels, catering, retailers, etc. Anu Meena who is the founder of this startup conceptualized the issues faced by farmers after harvesting and came up with this idea that they can buy the fresh produce from farmers using a connected network of farm-gate mobile pickup stations with smart route mapping. When the produce reaches the warehouse, it can be sorted, graded and packaged to reap the appropriate margins. This packaged good is then sold to business. The company has managed to achieve a revenue of 27 crore rupees in FY 2020 with the help of just 50 mobile picking stations.

(iii) **Bijak**

It is a Business to Business model that creates link among the farmers, middlemen and processors. The founders started this venture with a vision to digitalize the physical mandis and minimize the exploitation of farmers. The model works through an App that connects mandis, commission agents, brokers, mills, processors, traders and all the other stakeholders. By sharing this database, they also earn commission from rural banks and NBFCs. In addition, they are paid a commission on each loan made by farmhouse lenders.

For traders, credibility is a very important factor to establish business relations across the state. This app facilitates traders to sell and buy across states and provides updated market information on all the crops through a single click. Along with this, the transport fleet has a tracking facility and so the stakeholders get a fixed timeline to plan their commitments. Their current operation is spread across 22 states, over 550 regions and they deal in more than 80 commodities. The company has seen a growth of 278% in terms of transaction value since March 2020.

(iv) **Agricultural Market Intelligence**

Market information and intelligence are important aspects in the agriculture sector as efficient agriculture marketing is a need of the hour. Price forecasting is an important component of market intelligence that helps farmers and merchants make up-to-date decisions about what to raise, when to retail, and where to retail their crops. Price projections are prepared by utilizing complex tools such as ARIMA, ARCH, and GARCH models to analyse the prices of agricultural commodities across time series data. During the pre-sowing and pre-harvesting scheduled months, a final integrated price projection was arrived based on farmers' and traders' expectations as well as model price forecasts, and it was disseminated to farmers and traders via various ways. Pre-harvest price estimates are less out of step with actual prices than pre-sowing price forecasts, and the percentage divergence has decreased with time. The rabi pre-harvest 2015–2016 price estimate had the lowest variance (−1.18%), while the Rabi pre-sowing 2014–2015 price forecast had the highest (−12.17%). As a result, a total of 12 price projections with greater than 90% accuracy were generated and dispersed through various channels such as the university website, magazine, newsletters, SMS to farmers, booklets, farmer trainings and meetings, and so on. This aided various parties in making decisions concerning the sale of their products.

5 Conclusion and Research Implications

Agriculture is the mainstay occupation for indian population and a majority of them belongs to small and marginal farmers. For the improvement of these communities, an operative marketing system that ensures remunerative prices to producers through cost-effective marketing and supply of goods to consumers are required which need to be supported by strong agricultural marketing policies, To safeguard farmers' interests and accomplish higher growth in changing economic situation, the government has implemented a number of agricultural marketing reforms from time to time. As agriculture is a state subject hence the states must lead in the adoption and implementation of necessary changes in order to push the agricultural marketing system's frontiers to the next stage of growth.

The central government flagship scheme e-NAM has been able to provide a much-needed impetus to the ongoing agricultural reforms by successfully integrating 1000 markets across the country. The evidence has shown the e-NAM has an affirmative effect on the income of the farmers with a significant reduction in price variability across the markets. Having said that, the effective implementation of e-NAM coupled with easy accessibility of the market intelligence to the farmers need to be accorded with high priority in addressing the marketing problems of the farmers.

Farmer Producer Organizations are one of the most effective tools for increasing farmers' negotiating power and effectively driving Aatmanirbhar Bharat by forming an effective and well-balanced association concerning rural and urban economies. FPOs have also been identified as one of the most effective tools for combating the negative impact of COVID-19 on the agrarian community.

For the growth of agricltural markets, a huge invesment is also needed in the sector. A significant portion of this investment is likely to come from the private sector, necessitating a proper policy and regulatory environment. There is a necessity to increase private agricultural investments in the area of modern post-harvest infrastructure. More corporatization, privatisation, and participation by organized players will result in increased investments and technological innovations, particularly in supply chain infrastructure the same will render our agriculture more competitive and will also encourage the competition in the market thus facilitating farmers to get the best bargain for their produce. Corporate companies can bridge the existing demand and supply gap, benefiting both producers and consumers besides helping to reduce the price volatility in the market. Moreover, as fewer hands are involved, end consumers are expected to benefit from efficient supply chains and lower prices. End users will benefit from the better infrastructure and climate-controlled storage facilities, as well as higher-quality perishables with a longer shelf life.

The presence of country at global platform makes it an indicator of measuring the success of such reforms. Various cases of developing countries like China, Vietnam and Malaysia show that well planned agri-reforms help domestic production in becoming more competitive. In the case of China, small farmer's livelihood is greatly vulnerable to international trade policy especially in a model where foreign direct investment is allowed. This shows the interdependency of various policies on each other and its impact. These criteria should be considered well before finalization of trade policy as it provides safety net and assistance to shift to a new production system. Trade policy-making should fully consider the difference between small farm subsistence-oriented production and commercial production systems in competing with developed countries. There is always a tradeoff that has to be done while setting up priorities in investment. Along with this, it is very crucial for the farmers to understand the role of quality for sustaining in the existing markets and enter the new markets. Various forms of quality certifications act as an important tool to enhance the trust of the consumers in agricultural produce at the same time ensuring access to export markets. These quality certifications help farmers learn new techniques to deliver quality and build their capacities thereby contributing to the overall value chain development.

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Smallholder Agriculture in Developing and Emerging Economies: The Case of Sri Lanka

H. S. R. Rosairo

1 Background

Sri Lanka is regarded as a developing country, and is making efforts to improve its economy through the upliftment of all its sectors. Sri Lanka is an agricultural country with a population of 21.8 million. The agriculture sector contributed to 6.5 percent of the total economy 2019. While making efforts to maintain a vibrant agricultural industry to support the domestic economy, Sri Lanka attempts to maintain a healthy agricultural exports sector. Agricultural exports accounted to approximately 2.3 billion US$ in 2019 (CBSL, 2019). Sri Lanka attempts to make foreign exchange available to enhance its purchasing power in the regional and global trade.

Sustainable food value chains are important for emerging economies such as Sri Lanka to achieve economic and social sustainability. Sri Lanka has been making efforts to formulate and adopt policies that support agricultural development and sustainable food value chains. These in turn will be useful in achieving wider goals such as economic prosperity, improved nutrition and diets, zero hunger, eliminating poverty and climate change mitigation and adaptation which are in line with the United Nation's Sustainable Development Goals. Smallholder agriculture plays an important role in this context. This chapter on smallholder agriculture in Sri Lanka as an emerging economy, explains the link between Sri Lanka's small farmers and markets through institutions and agricultural trade.

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2 Agriculture in Sri Lanka and its Sectors

Sri Lanka is recognized as a low-middle income country with a population of 21.8 million people (World Bank, 2018). The total land area of Sri Lanka is 65,610 km^2 of which 62,705 km^2 are land and the remainder is inland water bodies (CBSL, 2019). Some of the basic climatic features of the country are given in the Table 1. These and many other features such as soil characteristics render Sri Lanka very suitable for agriculture. Agriculture is very contributory to the economy of the country having contributed to 6.5% of the gross domestic product (GDP) in the year 2018 (CBSL, 2019). Therefore, agricultural development and the GDP growth in agriculture can contribute powerfully towards reducing poverty and hunger, compared to GDP growth of other sectors. Further, over 25% of the employment is in the agriculture sector in Sri Lanka (World Bank, 2018). Therefore, agriculture is considered the backbone of the economy of the country.

Prominent sectors in the crop-based agriculture in Sri Lanka are classified as paddy; plantation crops including tea, rubber and coconut; export agricultural crops; vegetables; fruits; sugarcane and other field crops. Some of the fruit cultivations and plantations are sectors in which long-term or perennial crops are cultivated. A portion of these is classified as large-scale agricultural operations. Other crops are mostly cultivated in small land plots.

The contribution to the GDP by the animal husbandry-based agriculture in Sri Lanka has been 2.0% in 2018 (DOA, 2019). It is classified in to two sectors, namely livestock and fisheries. Sri Lanka's livestock sector is mainly comprised of cattle, buffaloes, goat, sheep, swine, and poultry (mainly chicken and duck). There are over 600,000 registered farms in Sri Lanka which are mainly organized with smallholder (popularly known as small-scale) farmers (Daniel et al., 2020). The fisheries sector consists of three sub-sectors namely, coastal; off-shore and deep sea; and inland and aquaculture. These sectors play an important role in food and nutritional security, health, and rural livelihoods in Sri Lanka.

A vast population in the developing world depends on agriculture for their livelihoods, and the economies of these developing nations depend heavily on agriculture. Sustainable development agenda captures this situation to highlight important aspects such as alleviation of poverty and hunger, and responsible consumption and production. The situation with Sri Lanka is no different.

Table 1 Basic climatic features of Sri Lanka

Feature		Reading
Temperature range (minimum–maximum °C)	Low country	24.6–32.3
	Up country	18.4–27.6
Average annual rainfall (mm)		2054
Average annual humidity (percentage)		74.0

Source CBSL (2019) and weather-and-climate.com[a]

[a]https://weather-and-climate.com/average-monthly-Humidity-perc,Colombo,Sri-Lanka

Rural areas are an important segment in Sri Lanka as around 82% of its population of 21.8 million people live in rural areas where poverty is a common issue. As we know, agriculture is predominantly practiced in rural areas whereas urban agriculture is still in a rudimentary state in Sri Lanka. Over 72% of the Sri Lankan population depend on agriculture for their livelihood (De Costa, 2010). Many people are employed, directly or indirectly, in the agricultural sector which is highly vulnerable to natural tragedies such as climate change.

3 Agricultural Trade and the Smallholder Farming Sector in Sri Lanka

Agricultural trade is a basic economic concept involving the buying and selling of agricultural products. Agricultural trade may take place between producers and buyers within an economy. Trade of food products between two economies takes place in international trade. Food trade is important in making food products available in destinations where the particular product cannot be produced (adjusting food production shortages), mainly due to physical and climatic reasons and also where vulnerable segments of people reside. It also can bring financial benefits and prosperity to players in the food value chains including the smallholder farmers. Therefore, trade plays a crucial role in making food products available to consumers worldwide. This has the ability in ensuring food security across the globe. Ancient traders from the Middle East and Europe were the pioneers of food trade of Sri Lanka, both in terms of exports and imports.

Factors that determine the usage of agricultural inputs by the smallholder farmers and their ability to supply the food products in right quantities on a regular basis, builds-up an important discussion. They are capable of producing to meet the standards and requirements of international markets because of their small scale. On the other hand, unlike large-scale farmers, smallholder farmers could produce niche products in smaller quantities. Therefore, smallholder farming is a unique sector with important benefits as far as agricultural trade is concerned. However, many of the Sri Lankan smallholder farmers continue to trade through scattered, conventional and traditional producer-driven markets that suffer post-harvest losses exceeding 44% for some vegetables (Dharmathilake et al., 2020).

The place of the smallholder farming sector in the context of food security and the trade of food products will be an extensive discussion. Though the smallholders receive a healthy production from their farms, they still face limitations in trade due to factors such as price fluctuations, presence of middlemen, unfavorable exchange rates and many more. Ever rising transport costs affect both output and input prices and trade of food (Baiphethi & Jacobs, 2009). However, the supply challenges continue to deny consumers the benefits of low crude oil prices as local oil marketers pass on the high transport and operational costs to consumers. The government does not seem to pass on any benefit available in the fluctuations of prices of oil in the world market, to the food producers, transporters and general consumers. On the other hand, high oil prices lead to high energy, transport and production costs which smallholder farmers are not able to fully pass on to buyers, resulting in reduced profits to farmers.

There is a need to significantly increase the productivity of smallholder agriculture sector and ensure long-term food security. This can be achieved by encouraging smallholder farmers to pursue a sustainable increase of production through higher production efficiencies, greater land use and better inputs. There should be methods to develop cost-effective ways to improve access to superior inputs through improved delivery. Smallholder farmers should be provided with better opportunities to trade their tradable surplus, and to reduce transaction costs of trade. Development of well-functioning input markets to help increased productivity is complementary. It is mandatory to establish superior trade platforms to market smallholders' output.

There should be policy support to assist smallholders by investing in infrastructure, to improve the quantities of products that their farms' produce, reaching the food supply chains. This would promote agricultural trade to a great extent to ensure food security status. Recent development initiatives such as the World Bank funded Agriculture Sector Modernization Project implemented by the Ministries of Agriculture and Primary Industries are also in an attempt to improve infrastructure to facilitate agricultural trade (Exhibit 1).

Vulnerabilities in the agricultural production have an impact on the trade of these commodities. Smallholder farmers in Sri Lanka are quite vulnerable in-terms of working capital. There is a need for policy support to facilitate working capital for smallholder farmers. An important initiative in securing working capital for smallholder farmers is the concept known as 'contract farming'.[1] The importance of contract farming in the output of specified quantities of products at specific times to the supply chains should be emphasized. Contract farming provides means to manage complex production processes with greater precision and to develop shorter supply chains. This can result in higher quality, safer food with lower production and marketing costs. Contracting can overcome imperfections in input and output markets by providing credit, seeds, machinery services, human capital and market access to farmers (Guo et al., 2007). Stronger formal linkages of smallholder institutions with supermarket chains are likely to improve marketability and profitability of their products (Exhibit 2).

Trade liberalization with various bases as well as trade limitations under policy environments shape the picture of demand and supply of food products. The new retail chains in Sri Lanka shows considerable progress. Key supermarket chains in Sri Lanka include Keells, Cargills, Arpico, Laugfs and Softlogic Glomark. The state has good policy in place to support the local retail chains to perform well. It also assists exporters of food and other agricultural products through institutions such as Sri Lanka Export Development Board and diplomatic missions to reach global markets. Small-scale farmers that produce food and other agricultural products for export receive assistance and monitoring by world famous certification agencies to meet the complex quality standards of the overseas markets (Minten et al., 2009).

[1] Contract farming is also known as out-grower farming in Sri Lanka.

The state services for plant and animal quarantine also provide valuable advisory and certification for the benefit of exporters. This includes various institutions of smallholder farmers who supply directly to exporters.

Exhibit 1: Agriculture Sector Modernization Project: A new future for smallholder farmers in vulnerable areas in Sri Lanka

Sri Lanka's agriculture consists of two sectors; the plantation sector and non-plantation sector. Eighty per cent of the agricultural land is under non-plantation food crops comprising mainly of cereals, pulses, vegetables and fruits. These are primarily grown as smallholdings. Around 80 per cent of the total food products are produced by about 1.65 million smallholders scattered throughout the country. The average extent of their lands is less than two hectares[1]. It has been observed that some areas in the Northern, Eastern and Uva Provinces in Sri Lanka need assistance despite various interventions in the past to reduce poverty. Poverty and living standards remained quite unfavourable in these areas.

The Government of Sri Lanka has recognized that a shift is needed within agriculture to serve smallholder farmers to elevate their life standards. The Agriculture Sector Modernization Project (ASMP) is being implemented by the Ministry of Agriculture and the Ministry of Primary Industries from 2016 to 2022 with a proposed credit amounting to US$ 125 million provided by the International Development Association of The World Bank. The ASMP has been implemented in seven districts of five provinces viz. Jaffna and Mullaitivu (Northern Province); Batticaloa (Eastern Province); Monaragala (Uva Province); Anuradhapura and Polonnaruwa (North-Central Province); and Matale (Central Province) to benefit smallholder farmers. These districts have been highlighted with their high poverty rates, hence the need for this development intervention. Approximately 15,000 smallholder farm households will directly benefit from this project.

The key project objectives are to support increasing agriculture productivity, improving market access, and enhancing value addition of smallholder farmers and agribusinesses in the project areas. The crops have been selected carefully to improve the local food security situation through increasing domestic food crop production and import substitution. The project will work in collaboration with the private sector agribusiness companies as business partners to establish improved value chains for the products produced by the shareholder farmers. ASMP will also facilitate mobilization of smallholder farmers as shareholders for the establishment of limited companies (LCs) by the end of 2022. The project will assist these companies to establish formal supply contracts between LCs and agribusiness partners. Therefore, the Agriculture Sector Modernization Project offers a great opportunity for the smallholder farmers of above seven districts in Sri Lanka.

[1]http://www.agrimin.gov.lk/web/index.php/home-1/12-project/841-agriculture-sector-modernization-project#:~:text=About%201.65%20million%20smallholder%20farmers,poverty%20over%20the%20past%20decade.

Exhibit 2: Contract farming in Sri Lanka: a solution for the working capital problem of smallholder farmers in Sri Lanka

Contract farming in Sri Lanka (also called 'out-grower farming') has been practiced in Sri Lanka for a long time. Both crops and livestock products or food and non-food agricultural products are produced under contract farming arrangements. Contract farming is a form of vertical coordination of agribusiness firms in food supply chains. Contract farming can be defined as a mutually beneficial contract arrangement between a contract farmer (smallholder farmer) and an agribusiness partner (trading firm) in which the agribusiness partner supplies starting materials and all or most of the inputs and ensures buying-back the entirety of the output at a specified time and at a pre-determined price.

Usually, the agribusiness partner maintains a business relationship with a group of contract farmers who supply a semi-finished or a finished commodity. The agribusiness partner supplies a range of inputs and facilities including extension services, quality checking and valuation of harvest, assured market for the produce with transport facilities for its contract farmers. Costs incurred by the agribusiness partner will be deducted from the proceedings of the contract farmer. These costs can be translated as the working capital of the contract farmer.

Working capital has been a long-term issue for the smallholder farmers in Sri Lanka. They obtain financial assistance from formal sources such as banks at standard rates of interest or informal sources such as local money lenders at high interest rates. These are settled at the end of the cultivation season, if harvests are favourable. Therefore, there has been a working capital deficit for many of the smallholder farmers. Contract farming can be viewed as a very valuable development intervention that can address this issue of working capital deficit. Food crops such as gherkins, French beans, maize and baby corn; and livestock products such as broiler chicken have been popular agricultural products produced under contract farming arrangements. In addition, a range of ornamental fish are popularly produced in Sri Lanka for export under contract farming.

Suitable crop insurance schemes can be introduced to safeguard both parties of contract farming; the smallholder farmers and the agribusiness firm, in yield loss situations due to diseases, pests and environmental problems such as climate change. Contract farming provides a sustainable income to the risk aversive yet capital lacking smallholder farmers. It also ensures a guaranteed market and a price for smallholder producers; secured supply of inputs; and provision of new technology, which are essential components in food security.

Smallholder farmers have integrated under various institutional frameworks such as farmer cooperatives, smallholder groups, smallholder societies, and other SFIs to join emerging retail trade networks. This has benefitted the smallholder farmers in Sri Lanka and consumers in high-end markets within the country and overseas as well. Local supermarket chains have developed their own semi-organized smallholder farmer groups in various parts of the country to obtain continuous supply of vegetables and fruits. This has created rather short supply chains for vegetables and fruits in Sri Lanka. While reducing post-harvest losses, this practice has the ability to increase the producer's share in the consumer's or rupee.[2] However, this is not happening in many of the other supply chains operating in the country.

[2] This is the price received by the farmer (farm-gate price) as a percentage of the price paid by the consumer (retail price).

3.1 *Challenges of Trading Food and Agricultural Products*

Food and agricultural products and the production processes have special characteristics rendering them different from the manufactured goods sector. These special characteristics have an effect on the food trade, and the demand and supply of these products. Some of the special characteristics which can be considered as challenges for the food sector are briefly explained below. Sri Lanka is a tropical country. The average temperature and humidity are considerably high (Table 1). These natural factors may worsen in the context of climate change and global warming. These have impacts on food security hence hunger; and health and well-being of vulnerable segments of people in Sri Lanka.

Perishability of food products: Food products are basically perishable. Perishability varies with the type of product but can be reduced by processing. Trading of food faces enormous challenges due to their short shelf-lives.

Seasonality of production: Many food products are either seasonal or have long and rigid production cycles. It is quite an expensive operation which require cooling facilities to make them available during off-season. Smallholder farmers always struggle with this but market intermediaries who have the right facilities for storage or processing, capture the benefit of higher price during off-season.

Bulky nature of products: Food products are always bulky compared to their price. This makes transportation, storage and other sales operations difficult and expensive. This is particularly a problem encountered during exporting. Sri Lanka has been a regular exporter of food products, yet this hasn't been able to bring expected monetary benefits to smallholder farmers in Sri Lanka.

Variation of quality of products: Agricultural and food products show variation in quality in terms of ripeness, color, weight etc. within the same batch of products. Modern high-end retail markets demand for a uniform product. It is quite expensive to produce uniform batches of products due to discarding of off-grades. This especially places the smallholder in Sri Lanka in a challenging position for which they must then trade through less beneficial conventional marketing channels which do not demand such high uniformity.

Need for processing: Most of the food products need to be processed to enhance their shelf-life and to add value. This raises the final price at the consumer retail market. Most of the smallholder farmers are not able to embark on processing which is performed by the trading intermediaries. Beverages such as tea provide an adept example (Perera, 2014). As a result, producer's share in the consumer's Rupee is quite low for the smallholder farmer in many instances.

Irregular supply of food products: Agricultural production is quite vulnerable and depends a lot upon natural or environmental conditions. Weather and climate change affect crop and livestock production significantly. Ordered quantities cannot be made available due to natural calamities. Cultivation, harvesting and trade of cereals, vegetables and fruits were affected during 2020–2021 due to the COVID-19 pandemic situation. The situation was same with livestock products such as poultry meat and eggs during this period. Therefore, the incidence of the disease had negative effects on the food security in Sri Lanka. The irregularity of supply from smallholders increases the difficulty for corporate buyers such as local supermarket chains in Sri Lanka to forecast sales.

Small size of holdings and scattered production: It is quite difficult for few smallholders to make an impact or make a pressure on stakeholders as and when needed due to their small scale of operation. Their land use efficiency (efficiency of land utilization) has room for improvement in many areas and sectors. The transaction costs borne by corporate buyers tend to be high due to the scattered nature of smallholders in rural areas in Sri Lanka. The situation could be further aggravated by higher input prices due to scarcity during pandemics and extreme weather conditions resulting in a higher cost of production within smallholder farming operations.

Long distance from the farm to marketplace: The demand for food in more populated urban areas is greater than that in the rural areas where the food is produced. It is even longer in the export trade. Local market hubs mainly for vegetables and fruits are situated in few central locations such as Dambulla, Keppetipola and Colombo in Sri Lanka. Export hubs are located mainly around Colombo. Rural road networks, condition of lorries (with very limited cold transport), and packing are in rather poor condition in Sri Lanka. Therefore, traders have to bear extra costs on inefficient transport. These could drive the retail prices up creating a pressure on food availability situation for vulnerable segments of people in Sri Lanka (SGDs 2 and 3).

4 The Smallholder Agriculture Sector in Sri Lanka

Smallholders engaged in agriculture around the world produce food items as well as non-food items. However, a greater proportion of them devote their operations to the production of food. Agricultural development is a prominent strategy of poverty reduction in most agriculture-based and developing economies. Smallholder farming systems spread all over the world produce a range of products of crop and livestock origin. They provide livelihoods and bring food to the tables of world's rich and the poor households alike. The development of smallholder farming can increase the household incomes of smallholders in rural communities and reduce food expenditure, thus contributing to rapid rates of rural poverty alleviation. It may also reduce income inequality (Magingxa & Kamara, 2003; Diao et al., 2010; Barham & Chitemi, 2008).

It is claimed that around 60–70% of world's food is produced by smallholder farmers. Small farmers, small-scale farmers and smallholder farmers are the terms that are commonly used to identify the types of farmers in the smallholdings sector. It is difficult to synthesize a simple definition for the term smallholder. The literature has used a mix of characteristics and methods for this purpose. The most popular criteria are on the basis of (i) the location or the agro-ecological zones in which they operate; (ii) the composition of the farm portfolio of crops and livestock and the landholding; or (iii) on the basis of annual revenue generated from the farming operation (Gollin, 2014). According to Food and Agriculture Organization (FAO, 2012), smallholders are the small-scale farmers who operate in farmlands varying from less than one hectare to 10 ha. The norm for the minimum is 100 m^2. A smallholding can be defined as a small-scale agricultural operation that produces products for sale and the farmer who is engaged in it is a smallholder. In this sense, a smallholding is an economic unit. The conventional rural smallholder agriculture and the new developments in the urban smallholder agriculture are both exciting sectors in Sri Lanka.

Agriculture is also popularly practiced as home gardens in rural as well as urban areas of Sri Lanka. These mostly produce vegetables and fruits, and rear few livestock animals for the consumption of the household but do not seem to produce a significant quantity of saleable surplus of products. Therefore, their motive is driven towards the food security of the particular household. They mainly use family labor for the production process and use minimum amounts of agrochemicals. Home gardens which are managed methodically could contribute immensely towards the food security, health and wellbeing of households.

Smallholder farmers in Sri Lanka are engaged in plantation crops, non-plantation crops or livestock sectors. Some smallholders are engaged in more than one of these sectors at the same time. Smallholdings of tea, rubber, coconut and sugarcane, which are popular plantation crops in Sri Lanka, are quite prominent sectors. For a developing country such as Sri Lanka, tea is an important crop in terms of export earnings and employment (Perera, 2014). Approximately 16% of Sri Lanka's arable land is occupied by tea. The tea smallholdings sector, which is more formal and organized than the other crop and livestock sectors and the most prominent of all smallholdings sectors, has nearly half a million smallholders occupying 60% of the total tea lands and produce 70% of the total production of tea in Sri Lanka. Small tea lands of around 10 acres, managed on personal basis is considered as a tea smallholding in Sri Lanka. On average, the land area of coconut smallholdings ranges between two and 20 acres. Kandyan forest gardens (De Jong et al., 1994) and the traditional *chena* cultivation are also well-known traditional smallholder farming systems in Sri Lanka.

Furthermore, smallholder farmers obtain services of a small labor force which mostly include a mix of family labor, shared labor and a very small hired labor force for their farming activities (Takane, 2008). The farm income is the main source of household income of most smallholders (Qiao et al., 2016) in Sri Lanka. Therefore, smallholdings in Sri Lanka contribute positively to alleviate poverty.

In tea sector, the small holding operations are regarded as more productive compared to the much more formal large plantations sector, that the average yield in the tea smallholdings sector was higher than that in the large plantations sector in the year 2019. This trend has been continuing for the last decade or so. Main reasons for this success have been the greater flexibility shown in the smallholdings sector in adopting good agricultural practices.

5 Features and Importance of the Smallholder Sector in Sri Lanka

The smallholders are important in many ways. Rural empowerment, rural development, and economic development of the developing economies such as Sri Lanka are ensured through the development of the rural smallholder agricultural sector.

Rural areas are rich with large extents of arable land; although each farmer owns a small plot of land, with natural resources and manpower that are necessary for agricultural operations. Rural farmers are capable of obtaining the resources such as land, water, plant materials and etc., from their surrounding environments and manpower from their families themselves to cultivate their small land extents (Rosairo & Potts, 2016). Therefore, small land plots are advantageous for the resource-limited smallholder. Smallholders who are resource limited farmers, can exercise close supervision and control because of small land extents. With the suitable external environment factors, they are capable of obtaining an optimum harvest per land unit. For these reasons, their cost of production is also low. Therefore, smallholders are able to make food products available to the community at low prices.

It is understood that the smallholders tend to live in hazard prone rural areas due to a lack of resources to live elsewhere (Chan, 1995). Smallholders have unique features with their capacity for small-scale farming and resource management. They depend heavily upon natural resources for their farming operations and are limited in their capacity to cope with climate change and extreme weather conditions (De Silva & Kawasaki, 2018). This renders them more vulnerable to natural disasters (Fankhauser & Burton, 2011).

Further, they can also diversify to satisfy the demand of high-end markets for specific products such as organic food and bee-honey (Ayuya et al., 2015). They also cultivate a range of traditional crop-based products (Jarvis et al., 2011) including traditional rice and yam varieties for health-conscious market segments. This provides the additional benefit of restoration and protection of the traditional germplasms. The diversification could lead to strengthening of rural household incomes and livelihoods of the smallholders.

Smallholder farmers in Sri Lanka adapt numerous strategies to enhance their incomes. These include inter-cropping to enhance the land efficiency; combining crop cultivation with livestock farming in some areas; commercial agricultural ventures with crops such as gherkins, baby corn, sweet corn etc.; bee-keeping; floricultural ventures; cultivation in small-scale poly-tunnels (greenhouses); and agri-tourism ventures. They also attempt to reduce operational expenditure by utilizing family labor; home-made compost using crop, animal, and kitchen waste; obtaining fodder from the surrounding for their livestock (De Jong et al., 1994), and obtaining energy from fire-wood and coconut shells for farming and household activities.

6 Constraints in the Smallholder Sector in Sri Lanka

The importance of the smallholder agriculture has been a highlight in many rural development initiatives. Despite being small in scale, smallholders exhibit a comparatively higher production than large-scale farmers (Chandio et al. 2020) in many sectors including tea. However, smallholder agriculture faces a range of challenges, emanating from natural environment and the business environment that can determine its performance. There are numerous constrains faced by the smallholder sector including institutional policy; financial; capacity and technology-related; and input and product markets. Figure 1 depicts the key constraints or challenges that can have impacts on the economies of smallholder farmers in Sri Lanka and sub-sections below briefly explain these constraints.

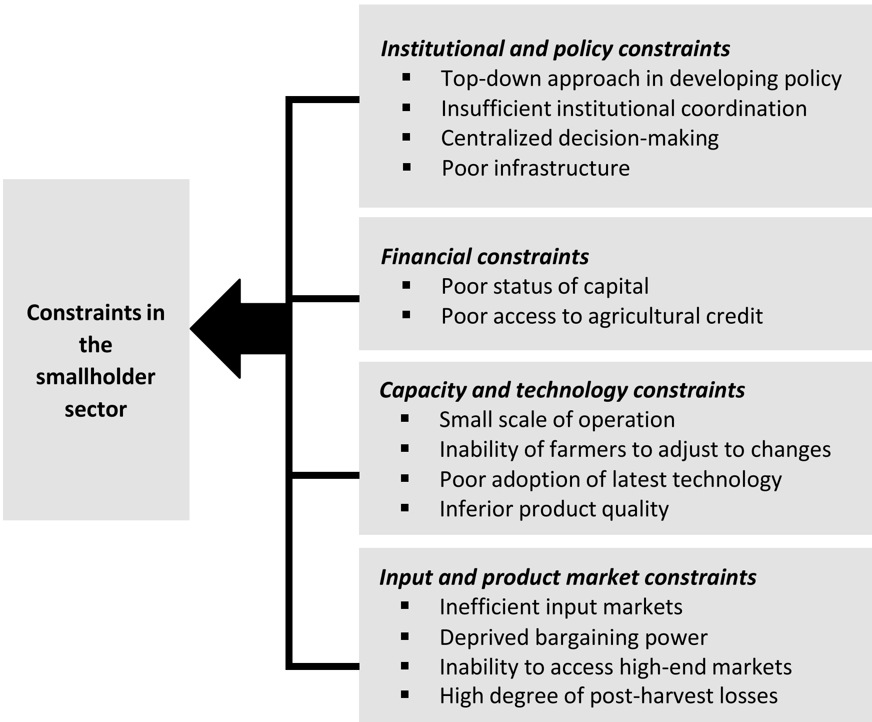

Fig. 1 Key constraints in the smallholder agricultural sector in Sri Lanka

6.1 Institutional and Policy Constraints

Top-down approach in developing policy: Research and development priorities in agriculture are generally identified and lined-up by top levels of relevant institutions. This is done with very little collaboration and dialogue with field levels who really understand and feel the real practical issues faced by smallholder farmers. Many policies are formulated without consultation and dialogue with smallholder farmers. There may be limitations in farmer participation, however, participation ensures the identification of real issues at the grassroots levels and a participatory approach is more appealing to smallholders who are the ultimate beneficiaries of policies. There is a lack of participation at the designing stages of many research and development activities, and policy.

Insufficient institutional coordination: There are number of different state ministries, departments, monitoring bodies, research institutions and other organizations related to agriculture and allied themes in Sri Lanka. State organizations that are engaged with smallholder farmers operate with little or no coordination among them. This has resulted in detrimental effects such as duplication of activities, expenses and funding; conflicting policies; and mismatch of policies. This situation has created inefficiencies in the system and has not served the smallholder farmers in intended paths.

Centralized decision-making: The decision-making process in many relevant institutions is quite centralized and bureaucratic. This has resulted in poor flexibility in the formulation and implementation of policy and planning. This has also resulted in a narrow focus regarding development activities. Many development interventions have focused on a single (or a narrow range of) crops or livestock species with little regard to broad issues that affect the smallholder communities.

Poor infrastructure: Poor agricultural infrastructure continues to hinder the activities of smallholders in Sri Lanka (Tudawe, 2001). Low public spending on rural infrastructure such as electricity, road networks, irrigation tanks and irrigation systems is a serious concern in rural Sri Lanka, as they need development. Three-phase electricity is often not available in rural areas; which has discouraged investment in cold storage facilities, mechanized irrigation, and processing plants for farm products. Post-harvest facilities such as cold storage and packing facilities are in a state of severe undersupply in many of the rural areas. Gravitational irrigation is commonly used in cultivation in Sri Lanka. Heavy investment has to be done by smallholders who plan to start specific agricultural ventures that need lift irrigation, fertigation etc.

The interior and rural road system and vehicles for transportation of agricultural products, which is important for market development in terms of distribution of farm inputs and products, is a serious infrastructural bottleneck facing agricultural development in Sri Lanka. As a result, middlemen have taken over the dominance in the agricultural value chains (Kiriveldeniya & Rosairo3., 2020). When development projects plan their development activities, a significant investment has to be set aside to develop the road systems in respective areas to bring the intended benefits of the projects to reach the smallholder farmers.

Poor conditions of the market infrastructure facilities in rural areas are common. *Pola*[3] has been a common retail market for agricultural products in Sri Lanka. Rural smallholders bring their products to this rural market for the local community to purchase. The local authorities in respective villages provide and maintain sales space, shelter, water supply for product cleaning etc. These market infrastructure and transportation systems need development to provide a satisfactory service to the rural smallholders and buyers. Therefore, the poor agricultural infrastructure has a negative effect on the productivity of smallholder farmers and the food security in Sri Lanka.

6.2 Financial Constraints

Poor status of capital: Smallholders in Sri Lanka are usually unable to separate their agribusiness activity from the rest of the household activities. They also do not keep records of farm expenditure, farm income or chronological record of farm operations. This results in them being unable to decide whether the agricultural operation is profitable or at a loss and to set aside profits to be used as working capital during the subsequent cultivating season. Many of the smallholders find the working capital by selling or mortgaging their jewellery and household effects or by borrowing at high interest rates. This will not make their farming a rewarding operation. Additionally, limited capital and assets can restrict smallholders' agricultural productivity, income, and agricultural modernization thereby affecting the food security.

Poor access to agricultural credit: Agricultural credit enables the industry to acquire latest technology for agricultural development. Therefore, credit has a high demand in the industry especially among smallholders. The repayment capacity hence credibility (i.e., credit history) of small farmers in Sri Lanka for formal credit is very poor. Their accessibility to institutional credit is poor also due to the poor collateral status (Hussain & Thapa, 2012), and the absence of business planning and direction. These make them vulnerable and force them to borrow from informal sources such as micro-credit from village lenders, input sellers, and market intermediaries at high rates of interest. Input sellers and intermediaries usually tie-up the repayment with household effects and selling of the harvest. This poor credit situation also renders the smallholder unable to use technology to practice value-addition to capture higher financial gains through new products and markets. Therefore, smallholders' poor borrowing capacity puts them under severe disadvantage.

[3] *Pola* is a traditional rural marketplace in Sri Lanka. There are a large number of smallholder farmers and village collectors bring mainly agricultural commodities as well as other groceries for sale at the *Pola*. The infrastructure is generally provided by local authorities in the respective areas. *Pola* is held on a specific day of the week in a particular location.

6.3 Capacity and Technological Constraints

Small scale of operation: Smallholders in Sri Lanka do not have the capacity, land and other resources to produce large quantities of their product in a given season. This renders them unable to capture economies of scale in the production operation. It also renders the post-harvest functions such as marketing, uneconomical. This lowers the farm-gate price due to poor profit margins for middlemen in the marketing channels for their products.

Inability of farmers to adjust to changes: Smallholder farmers lack an ability to change due to lack of drive to change and their desire to avoid risk involved in change. Smallholders in Sri Lanka, especially the smallholders in the upcountry vegetable sector, are quite entrepreneurial in their attitude but not necessarily in their behavior (Rosairo & Potts, 2016). This makes them weak in adjusting to and adapting new innovations and new technologies. Their reluctancy to introduce modern technologies which contain higher risk is quite prominent and renders them unable to reap the benefits of change.

Poor adoption of latest technology: Agriculture should progress from traditional methods to latest technology in order to bring about economic incentives for smallholders and achieve sustainable development goals. Improvements in agricultural production and productivity (Dercon et al., 2009) can be derived with the use of modern technology and quality inputs. As mentioned above, the limited access for finance and the scattered nature of small plots of farmlands had limited the smallholder farmers' adoption of modern technologies, especially the use of modern machinery. Also, the technological transformation in the smallholder sector in Sri Lanka is quite ineffective because agricultural research, development and extension are not meaningfully integrated. Relevant training programs on latest technologies are also not penetrating into rural areas to benefit smallholders.

Inferior product quality: Smallholder farmers generally attempt to maintain a low cost of production in an attempt to capture higher margins. They tend to use inferior inputs at inappropriate amounts than recommended. In addition, there appears to be a wide gap between their technical knowledge and the latest technological developments in agriculture. Important post-harvest operations such as standardization and grading, cold storage, cold transport, and scientific packing methods are not practiced by many smallholders in Sri Lanka (especially in the vegetable and fruit sectors). These lower the quality of the final product thereby making it unable to be acceptable to high-end markets and command poor prices.

6.4 Input and Product Market Constraints

Inefficient input markets: Inputs such as agrochemicals and inorganic fertilizers are sold freely in Sri Lanka. These products are promoted and distributed by large-scale importers through well-developed dealer networks scattered throughout the country.

Many of the dealers who are not part of the extension service provide agrochemicals to smallholder farmers on credit, along with incorrect advice. As a result, small-scale farmers often use higher dosages than prescribed, thereby raising the cost of production as well as causing environmental hazards.

In early 2021, based on an 'organic only' concept, the government of Sri Lanka imposed a total ban on the imports of agrochemicals and fertilizers of inorganic origin. However, organic inputs are in severe short-supply in Sri Lanka, hence are not available in the market in required quantities. High demand and short-supply for these inputs has resulted inferior and uncertified products reaching the market. The research, farmer training and extension in eco-agriculture requires a great degree of development in Sri Lanka. Therefore, smallholders have not been able to capture full benefits of latest developments in eco-agriculture.

Deprived bargaining power: The smallholder farmers in Sri Lanka do not enjoy a strong and competitive position in the supply chain of their products. A vast majority of them are not market-driven, hence considered as price-takers. In Sri Lanka where agricultural products are exposed to open and competitive market forces, the middlemen decide the farm-gate price. This is further aggravated by the fact that much of their products are non-value-added primary products. These conditions leave them in very poor bargaining positions.

Inability to access high-end markets for products: Supermarkets and large retail shops are rapidly spreading throughout Sri Lanka, and the relevant retailing culture is also emerging at a rapid pace. In addition, there are large number of exporters of agricultural products. Supermarket chains and exporters have their registered suppliers for vegetables, fruits, poultry products and many other farm products, hence have short supply chains. A key precondition for transformation of the agricultural sector from subsistence to commercial production is access of smallholder producers to these high-end markets. However, barriers for them accessing these markets are that they are unable to meet the high-quality standards, food safety requirements, as well as the delivery schedules demanded by international and local supply chains. Therefore, smallholder farmers do not seem to benefit from these efficient markets and local-level value-addition, but are more exposed to competition and vulnerabilities in the traditional supply chains in Sri Lanka.

High degree of post-harvest losses: Smallholders as a whole dedicate a greater proportion of their farming operation to the production of food, and account for greater crop diversity than the large-scale farmers. Smallholders supposedly have low degree of post-harvest losses within the farms mainly due to close supervision over small-scale operations. However, in reality, products of smallholders sustain very high rates of post-harvest losses due to inefficiencies in the supply chain. For example, vegetables such as leeks, cabbage and carrots produced in Nuwara-Eliya district in Sri Lanka tend to sustain post-harvest losses as high as 44, 43 and 30%, respectively, within the supply chains (Dharmathilake et al., 2020). Therefore, effective quantities that reach the retail customer would be extremely low. This situation leads to a lowered share held by the producers in the consumers' Rupee, which in turn results in poor livelihoods at smallholder level and poor food security at the national level.

7 The Role of Smallholder Agriculture in Achieving Food Security and Sustainable Development

7.1 Food and Food Security

Food provides the human body with carbohydrates, proteins, fat, vitamins, minerals and other nutrients that are needed for it to sustain growth and to ensure smooth function of vital processes of the body. These substances are necessary for the body to stay alive and active; move and perform day-to-day activities; stay strong; and to prevent it from being ill. Food is an essential factor for humans (and all living beings). Humans need food in the proper quantities and at the right times for proper nutrition.

Food can be categorized basically as plant or animal origin. The plant component of our food is provided by crops that the farmers cultivate and the animal component is provided by the livestock reared by livestock farmers. Farming deals with the cultivation of soil and rearing of animals. It stimulates plant and animal growth to produce crops and livestock products for the consumption of people. Farming needs natural and human resources, and inputs in order to be successful. It also deals with the rational decision-making regarding the optimum use of scarce farm resources to achieve farming objectives.

Sustainable agriculture can be defined as farming using sustainable practices to meet the society's present demand for food and fiber needs, without compromising the ability of future generations meeting their demands. Sustainable agricultural practices are intended to protect the environment, enrich the earth's natural resource base, and maintain and improve soil fertility. It dictates us to understand the ecosystem and demands us not to control nature. However, agriculture often conflicts with nature and places pressure on natural resources and the natural environment. Most of the smallholder farmers practice farming in rural areas. Therefore, smallholders' adapting sustainable practices has a great importance in terms of sustainable development.

The term food security describes whether a country had access to adequate food to meet the dietary energy requirement of its people. Food security at the national and global level tends to focus on the supply side of the food equation (Godfray et al., 2010). The dietary energy is usually represented by food. However, availability does not necessarily assure access, and sufficient calories do not assure a healthy and nutritional diet (Pinstrup-Andersen, 2009). National food security endorses self-sufficiency or in other words, whether the country produces the amount of food it needs or its population demands (Mbow et al., 2020). Self-sufficiency would entail that all citizens had access to enough food produced within the country or the domestic production of food products is adequate to meet the economic demand.

People in various parts of the country have their own food preferences and ways and means of having access to food in order to satisfy their dietary needs for their bodily growth and development, and to lead an active and healthy life. According to the United Nations Committee on World Food Security (CFS),[4] food security is achieved when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their food preferences. Food security is a worldwide concern (especially under worldwide pandemic situations such as COVID-19) and it will continue to be a long-term concern for developing countries such as Sri Lanka.

The availability, access and the utilization of food are important aspects of food security. Factors such as food loss and food waste may affect the quantity of food reaching the consumer.

Food loss refers to the quantity (or quality) of food lost within the food chain up to the retail traders, whereas food waste is the quantity decreased from the retail traders and thereafter, including the consumers (FAO, 2021). Food loss and waste can be collectively referred to as post-harvest losses. Food production and post-harvest loss are directly linked with the sustainable development goals[5] of reduction of poverty from the farmer's side and zero hunger from the consumer's side. These aspects are reported to be strongly linked with the concept of food security.

Unlike the corporate agribusiness sector, smallholder farmers who are engaged in crop and animal husbandry in Sri Lanka are quite flexible in their production systems (except for the land factor). The agricultural decisions of smallholders are mostly household decisions. They are able to make decisions and introduce changes easily and rapidly due to the absence of red tapes and bureaucracy. Their overheads are low and they are mostly sole operators. Smallholders in Sri Lanka are the main growers of most crops and livestock, and they are the main producers of food products for the country. Therefore, programs to assist them in their agricultural operations can enhance the agricultural production that can make higher quantities of agricultural products reaching the markets. This should theoretically lower the prices of most main food items, making them more accessible to people, meaning they can have access to better meals. Therefore, the place of the smallholders and the role that they play at all levels of the food market are crucial to achieve sustainable food security of the country.

7.2 Smallholder Farming and Food Security

Food security remains a challenge if agricultural productivity is not enhanced and not in par with the rising population. Enhancing access to markets and agricultural credit; adaption of new technology; and the use of improved varieties and high-quality inputs can boost the agricultural productivity. Smallholders in Sri Lanka depend significantly on the state of intervention to realize all these. Therefore, policies that

[4] Committee on Food Security is an international and inter-governmental platform established by the UN to ensure food security and nutrition for people. It works with its stakeholders and reports to the UN and FAO.

[5] Defined by the UN; Department of Economic and Social Affairs, Sustainable Development.

enhance access to both input and output markets, and improvements in the farming system (the production process) remain key. In particular, improving the access of smallholder farmers to efficient markets can help to achieve food security (Gollin, 2014), since the stability of the supply of quality food products is suggested to be dependent upon the links between the farm and the consumer.

When small-scale farmers adapt modern technologies; and diversify into improved crop varieties and rear improved breeds of livestock, they increase their agricultural productivity and incomes, thereby increasing local food security. Relevant policies and incentives that encourage modification in smallholder farms are necessary for Sri Lanka to escape poverty.

7.3 Smallholder Farming and the Food Security Status during covid 19 pandemic

Sri Lanka's economy was growing considerably well at an average of approximately six per cent during the last decade, prior to the COVID-19 pandemic in 2020. Sri Lanka has policies in place to prevent the rural economy led by smallholder farmers who play an important role, from being neglected. However, lockdowns and travel restrictions during the pandemic outbreak situation had a significant effect on smallholder farmers throughout the country. Food, mostly crop products such as vegetables and fruits; and livestock products such as poultry meat, eggs and milk; and green tea leaves, were wasted at high rates during the pandemic of COVID-19 since early 2020. This also increased the prices of food products.

New policies introduced to curb the spread of pandemic of COVID-19 such as travel restrictions brought about structural changes within the traditional and supermarket supply chains. Food products produced by many smallholders in rural areas could not be made available in other parts the country due to transport and travel restrictions. There was a reduction in the food availability in the market due to the malfunctioning of village collection system of vegetables, fruits, tea leaves and other food items. Cultivations of crops and rearing of livestock were affected due to the lack of availability of inputs. Heavy losses of agricultural products at the smallholders occurred at the beginning of the pandemic during early 2020. Measures were taken to protect smallholders from major economic losses due to their small scale. Transport permits were issued by the authorities to facilitate the distribution of agricultural products from farmers to consumers. Crop-based and livestock-based smallholder farmers ensured that their local communities were reasonably food secure during the pandemic in 2020. Although the rural households were somewhat protected from hunger during this pandemic (Boughton et al., 2020) the urban populations in the country were affected by temporary food insecurity during the first half of 2020.

As the pandemic situation continued, there were positive effects as well, particularly on the smallholder agriculture including; zero or reduced imports of agricultural products from overseas, promotion of organic agriculture by the state through

Fig. 2 Road-side shop selling fruits and vegetables on retail scale[6] (*Photo* By author)

national initiative, maximum use of arable lands, providing of planting materials and extension services to promote highly demanding crops such as turmeric and ginger; facilitation of formal credit at reduced interest rates (Ceballos et al., 2020), and the promotion of urban agriculture as a national need. Further, the requirement of linking the smallholders to the end market; importance of cold storage, cold-chain management and postharvest technologies to preserve the excess production; and the efficient transport of fresh products were also emphasized during the pandemic situation (Huss et al., 2021).

The traditional rural *pola* system in Sri Lanka was completely disrupted due to regulations preventing social gathering. The need for strong smallholder farmer institutions to organize the market activities during the pandemic was powerfully felt. Different mechanisms such as home delivery; door-to-door selling; local mobile selling; hawkers; and road-side selling (Fig. 2) were adopted by many smallholder producers as new and shorter supply chains of food products from smallholders to retail consumers.

Supermarket chains and exporters recommenced their contract farming arrangements (see Exhibit 2) when economy was recovering from the pandemic. Smallholders who used greenhouses, packing facilities, cold storage, and specialized inputs could once again dedicate to specialized outlets (Kiriveldeniya & Rosairo, 2020) through collective action. These efforts could ensure food security and reduced poverty even during and after the pandemics such as COVID-19.

[6] Road-side shops became a common retail marketplace during the COVID-19 pandemic. Many of these shops are not registered with authorities. They sell food items mainly vegetables, fruits, dry-fish etc. Some of the items are the harvest of local smallholders and home gardens. These shop-keepers also buy items from transport agents who transport food items from other areas of the country.

8 Smallholder Farmer Institutions and their Role in Sustainable Development

The productivity and profitability within the smallholder sector are in need of development. Therefore, there has been a need to shift the agricultural strategy to (a) modernize the resource use and (b) convert the low-value primary products producing sector into a system that will produce high-value, value-added and export-oriented products or import-substituting products. A significant plan so adopted was the formation of smallholder farmer institutions (SFI) to achieve higher agricultural productivity; improving market access for smallholders; and enhancing value-addition of smallholder farmers to achieve food security in Sri Lanka. Smallholder farming sector occupies a significant extent of arable land and known to contribute significantly towards the agricultural output of the country thereby contributing to its food security. The SFIs can link the smallholder farmers to high value institutional markets. Therefore, organized smallholder farmers are a promising vehicle for agricultural development and rural development for food security. Sustainable development agenda also promote strong farmer institutions.

After the late 1970s in Sri Lanka, smallholder agriculture intensified due to population pressure and the incentives for commercialization became prominent. The formation of more formal farmer groups or smallholder farmer institutions became more popular with this shift in Sri Lanka. Although they only gained popularity later, formal farmer institutions have a long history in Sri Lanka.

8.1 The Need for Collective Action and Benefits of Smallholder Farmer Institutions

Smallholder farmers cannot capture economies of scale due to their small land sizes and the small scale of operation. In Sri Lanka, smallholders are exploited by the middlemen who are much organized in supplying to traditional markets and economic centers established by state interventions. Therefore, smallholder farmers have become price-takers. The much more organized high-end markets such as local supermarket chains, exporting companies and export agents prefer to deal with SFIs instead of individual farmers to reduce transaction costs of economic exchange.

A farmer group is a collection of farmers who share a common sense of identity and who are contributing towards a common aim under the direction of a leadership. Farmer grouping is a social process to facilitate their agricultural operations. They help individuals achieve goals which are otherwise difficult or even impossible. Farmers can engage in useful interactions more rapidly with others in group contexts. Group farming; a type of an informal institution, has been a familiar thought in Sri Lanka for a long time in the history. This has been practiced by the earliest settlers who engaged in agricultural operations in Sri Lanka (Wanigasekara, 1979) with the *chena*[7] cultivation which is a very less intensive method of cultivation. Smallholders in Sri Lanka rely heavily on family labor due to its low cost and availability at times of necessity. However, family labor has become insufficient during labor-intensive stages of the agricultural operation such as land preparation, weed control and harvesting. Smallholder farmers who are unable to pay for the labor, seek for group activity in such situations. Group farming has been adapted very popularly in lowland cultivation, mostly with the staple food, paddy, as well as in the highland cultivation of short-term crops such as vegetables, fruits, pulses and other cereals.

The term horizontal coordination among farmers is used to identify a collective action achieved among a group of farmers who share a common purpose. Smallholder farmers are motivated for horizontal coordination to achieve objectives that are difficult to achieve as individuals. Horizontal coordination is a vehicle for smallholder farmers to access modern markets, which are moving targets, for their products. There are a large number of them established in various parts of the country, especially in the predominantly agricultural areas such as Anuradhapura and Polonnaruwa districts. Horizontal integration among smallholders is a more formal structural arrangement in the context of globalization and the emergent forces from the modern supply chains. Business models of smallholder farmer institutions should efficiently link them with agribusiness concepts rather than social needs of farmer communities.

Farmer institutions in Sri Lanka play a prominent role in coordinating smallholder farmers specially to manage shared resources such as irrigation water, and fisheries. Other objectives of these institutions include the procurement of inputs in wholesale for bulk discounts; obtaining formal credit; processing and marketing of products (Batuwitage, 1998). Farmer institutions can also invest in shared assets such as storage and processing facilities, as well as in intangible assets like product certifications, patents, and trademarks. Investments on such assets by smallholder farmers individually seem impracticable (Poulton & Lyne, 2009).

Institutional aspects are a key feature (Stockbridge et al., 2003) of SFIs while provision of services for members appears to be a core function. Majority of the smallholders become members of these SFIs mainly to gain access to these services. Smallholder farmer institutions help to maintain internal and social relations among its members (Rondot & Collion, 2001). A SFI is defined as a formal institution[8] which is farmer-owned and farmer-controlled with formal voluntary membership, set-up for the economic benefit of farmers. Many of the SFIs have few main features namely; membership of smallholder farmers, geographical membership base; rural institutions; producer-owned and controlled; and engaged in collective marketing activities (Penrose-Buckley, 2007). The services offered by SFI are; bargaining with customers; collecting market information; accessing inputs, services and credit; providing technical assistance; processing facilities, and marketing of farm products (Kassam et al., 2011) (Table 2) that support their farming activities.

[7] An ancient type of highland agriculture where slashing, burning and cultivation was practiced. Farmer groups deter pests and obtain mutual help in agronomic practices in the chena cultivation. Agrochemicals were not used in this method. This is very seldom practiced at present.

[8] An institution established with a social or an institutional influence for collective action.

Table 2 Key services provided by smallholder farmer institutions in Sri Lanka

Service	Details of provisions
• Marketing	Input supply, output marketing, bargaining, processing linkages, market information
• Production	Collective production activities, product consolidation
• Managing common property and resources	Irrigation water, pasture, fisheries
• Financial services	Savings, loans and other forms of farm credit
• Technical services	Extension, research, technical advice, education
• Training	Business and entrepreneurial skills, general training
• Social and welfare services	Health, safety networks, self-help, voluntary services
• Policy advocacy	Formalities, liaison with facilitating institutions

Source Stockbridge et al. (2003) (amended)

The criteria of formal membership usually include a payment of membership fee and/or a percentage of the farmers' proceedings. They primarily enhance agribusiness activities and livelihoods of their smallholder farmer members and secondarily ensure food security of the country. They serve both individual farmer and farming community needs. They primarily enhance agribusiness activities and livelihoods of their smallholder farmer members and secondarily ensure food security of the country.

Smallholder farmer institutions are required to be profitable with strong financial viability and engage in activities that bring benefits for members, in order to ensure the support of members in the long-run, in order to survive in today's competitive markets (Kassam et al., 2011) and business environments. They are required to increase revenues, become efficient and operate similarly to true companies in order to sustainably serve members with long-term economic incentives. However, SFIs have been mostly established in Sri Lanka for social objectives and to manage common property rather than to achieve business objectives. Therefore, higher productivity, better markets and marketing channels, and value-addition have to be in the objectives of establishment of SFIs in anticipation of achievement of food security and poverty alleviation.

8.2 Types of Smallholder Farmer Institutions in Sri Lanka

Smallholder farmer institutions in Sri Lanka differ in terms of conditions of registration, organizational structure, goals and objectives, scope of activities, institutional

Table 3 Details of some smallholder farmer institutions in Sri Lanka

Category of SFIs	Number of SFIs	Number of members
Tea smallholders' development societies	1460	347,425
Mahaweli farmer organizations (MASL, 2018)	1059	115,571
Farmer companies (Esham & Usami, 2007)	92	6364

arrangements, corporate governance and the management. According to a different typology, there are two broader categories of SFIs including traditional SFIs established as a response to address market failures and the other ones as vertically integrated or offensive organizations such as marketing cooperatives (Michalek et al., 2018). Farmer cooperatives, farmer companies, agrarian and Mahaweli farmer organizations, and tea smallholders' development societies are the most prominent types of SFIs available in Sri Lanka.

A well-known category of SFIs in Sri Lanka has been the farmer cooperatives. Approximately five percent of the cooperatives registered in Sri Lanka are agricultural and fishery cooperatives (Mahindapala et al., 2020). A majority of members of these farmer cooperatives is smallholders. These institutions follow fundamental cooperative principles such as the open and voluntary membership; democratic member control; members' economic participation; autonomy and independence; education, training and information; cooperation among cooperatives; and concern for community (Axworthy, 1977). A farmer cooperative is an organization in which those who transact with the organization (patrons) also own and formally control the organization, and derive significant benefits from those transactions over and above any financial returns they derive from their investment in the organization (Evans & Meade, 2005). Cooperative organizations in Sri Lanka are monitored by government officials (Winslow, 2002). There are a number of dairy, inland fishery, marine fishery; tea; coconut; and other agricultural cooperatives in operation in Sri Lanka.

Farmer companies[9] (FC), another form of SFIs, were established in Sri Lanka in the late nineties (Table 3). There were over 92 FCs registered in Sri Lanka (Esham et al., 2007). These were owned and patronized by the farmers and were theoretically intended to operate similar to public unlisted companies. However, in practice they were more similar to farmer cooperatives in terms of their internal dynamics hence classified as hybrid organizations that had a close resemblance to traditional cooperatives than they were to true companies (Rosairo et al., 2011). Farmer Companies were expected to improve smallholder income by coordinating them for higher productivity; creating competitive supply chains; and shifting smallholder farmers into shareholders. Therefore, FCs were expected to enhance the food security situation in the country. However, none of the FCs are surviving at present.

[9] Farmer Companies (FCs) in Sri Lanka were initially registered under Part VII of the Companies Act, No. 17 of 1982, which provided for the establishment of 'Peoples Companies'. This Act was later replaced in 2007 by a new Companies Act No. 07 of 2007 and all FCs were required to re-register under the new Act.

There are farmer organizations (FO) established under the Department of Agrarian Development and the Mahaweli Authority of Sri Lanka. Supporting sustainable agricultural development, strengthening community work, and managing common resources such as irrigation water are main objectives of FOs. State officers are usually appointed to the governing bodies of FOs for monitoring purposes. Farmer organizations which are established almost everywhere in the country assist their membership mainly to enhance the production of crops such as paddy, vegetables and fruits with the view to enhance food security. Products of smallholder members of FOs are normally sold through the conventional supply chains.

Tea is a prominent export commodity and a key economic crop in Sri Lanka. Over 55% of the total tea land area is cultivated by smallholders (approximately 122,604 ha) who produce over 75% of tea in the country. Tea smallholder development societies have been established under the auspices of the Tea Smallholdings Development Authority. They follow a tier system where the tea smallholders are members at the rural level and the highest tier is the national level tea smallholders' federation. A great advantage of the tier system of SFIs is that it facilitates taking the news about various issues and problems at the farmers' level that have to be addressed, up to the national federation where solutions can be drawn after consideration and dialogue at the national level. However, this particular SFI system has not been able to eliminate the exploitation of smallholder farmers by the intermediaries in the supply chain of green leaves. A vast majority of these societies have not been able to raise finance to establish their own tea factories to process their green leaves.

8.3 Reasons for Poor Success of Smallholder Farmer Institutions

Different types of SFI models have been introduced to benefit the smallholder farmers in Sri Lanka. In practice, most of the SFIs have not succeeded in business despite good business opportunities (Esham & Usami, 2007; Ranasinghe, 2002). Many of the SFIs have failed to show a good performance mainly due to their internal reasons while some others have failed due to external environmental reasons. Reasons for this sub-standard performance of SFIs in Sri Lanka are briefly explained in the sub-sections below (Fig. 3).

Institutional and policy factors

Generic institutional problems in farmer cooperatives: Reasons for poor performance of farmer cooperatives and similar SFIs in general are attributed more to internal (institutional) problems of the institution. As such, there are five fundamental institutional problems that can weaken traditional (farmer) cooperatives.[10] An internal free rider problem arises when a traditional farmer cooperative distributes its profits among its members according to their patronage rather than their level

[10] A complete account of the generic institutional problems can be found in Sykuta and Cook (2001).

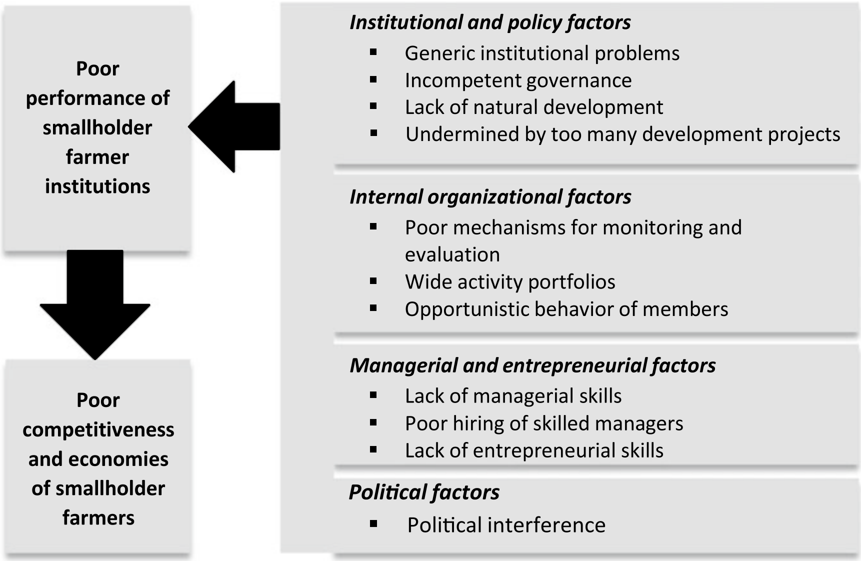

Fig. 3 Key causes for sub-standard performance of smallholder farmer institutions in Sri Lanka

of investment in the cooperative. An external free-rider problem arises when the non-members are offered same terms as members for their transactions with the cooperative. A horizon problem arises when the members cannot earn capital gains when they want to leave the institution as the shares of a traditional cooperative are not tradable and have only a nominal price. New members if any, can capture these gains by not paying a higher market price for shares. The absence of internal market for shares also creates a portfolio problem where members cannot match their business risk preferences with that of the cooperative. A control problem arises in a traditional farmer cooperative when members cannot sanction (or appreciate) the management in the absence of an active market for its shares. An influence problem arises when the voting rights are democratic rather than proportional to the level of investment.

These institutional problems that constrain levels of equity in farmer co-operatives also constrain levels of debt as lenders prefer their loans to be covered by equity in order to reduce their exposure to loan default. As a result, farmer cooperatives have struggled to finance value-adding assets (Hendrikse & Veerman, 2001). The inability of SFIs gather capital to procure assets, is a serious drawback.

Governance by incompetent boards: In many of the SFIs, the Directors and office bearers are smallholder farmers. Although they are experienced in running societies, they are not skilled to run business entities. As a result, maintenance of long-term economic success and the financial viability of the SFIs cannot be assured. Therefore, in brief, these SFIs are governed by incompetent personnel.

Lack of natural development of SFIs: State institutions normally facilitate the establishment of SFIs in Sri Lanka. Sometimes the individual smallholder farmers perform well and achieve success, but fail as collective institutions because they have not risen naturally as initiatives of smallholder farmers. The development interventions usually introduce all underlying concepts and conditions from outside. Furthermore, the competitions and group conflict among different rural groups prevent evolution of SFIs and aggravate their decline (Day & Schneider, 2018).

Undermined by too many development projects: There are times when multiple development projects, interventions, and other state assistance programs are served to the farming communities of the same geographical are of the country. There are also instances where a particular sub-set of smallholder farmers qualify for a multiplicity of programs. This scenario confuses smallholder farmers, development agents, state extension service and many more important stakeholders entrusted to assist with the development agenda. They can also be undermined by subsidies that have existed for extended periods of time. These have made the beneficiary smallholder farmers and their SFIs dependent on external support and unable to perform on their own, when the development interventions have been concluded.

Internal organizational factors

Poor mechanisms for monitoring and evaluation: Boards of directors or governing bodies of most of the SFIs mainly consist of smallholder farmers who do not possess relevant skills or qualifications. State officers who have been appointed as advisors to governing bodies also do not serve on full-time basis. Therefore, the monitoring of progress and evaluation of performance do not take place effectively. Therefore, achievement of goals and objectives of SFIs cannot be assured.

Wide activity portfolios: Another common reason for poor performance of SFIs was their attempts to undertake too many or complex activities (Chirwa et al., 2005) for which they do not have the expertise or skills to undertake collectively (Stringfellow et al., 1997). Many of the state facilitating interventions and development agencies seem to encourage such activities anticipating expansion of smallholder farmers' incomes without much regard to enhancing productivity through a narrow range of specific activities. These attempts usually fail to fully recognize the limitations for a wide range of activities through collective action. As a result, SFIs governed by smallholder farmers, underperform rapidly.

Opportunistic behavior of members: There was also the issue of smallholder farmer members of SFIs selling their farm products under contract with agribusiness partners, to other buyers when the open market prices were higher than the contract prices.[11] Smallholder vegetable and fruit farmers are specially accused of breach of supply contracts. This breach of contract has created mistrust between the SFIs and their agribusiness partners. However, when the contract price is higher than on the open market, farmers return to their supply contracts. This has disturbed the supply chain pathways making predictions difficult for the agribusiness partners. This has

[11] This is also called side sales.

been further aggravated by occasional state interferences with the open market and the prices.

Lack of trust between smallholder farmer members and the SFIs: In many SFIs, accounting officers, General Manager, and other employees are members themselves, relatives or persons known to member farmers. This may lead to bias in important decisions and activities due to vested interests. Therefore, some members tend to make business transactions outside the SFIs (out-sales) due to mistrust.

Managerial and Entrepreneurial Factors

Lack of managerial skills: Most of the SFIs are managed by smallholder farmers who do not possess managerial qualifications or skills. Therefore, SFIs are not able to draft workable business goals and objectives and cannot be directed to become sustainable business entities. Therefore, weakness of SFIs is attributed to poor management that is unable to protect these institutions against economic pressures and market issues in the wider business environments.

Poor hiring of skilled managers: Only a handful of SFIs have skillful and qualified hired agribusiness managers. Managers in some of the SFIs during their early stages, are fulltime state officers appointed by facilitating institutions on secondment basis. Managers in some other SFIs are smallholder farmers themselves or personnel known to them, creating an issue of vested interests. Managers of many SFIs lack sufficient management skills to run market-driven commercial institutions. Therefore, many SFIs suffer in terms of performance due to lack of proper business planning and management.

Lack of entrepreneurial skills: Smallholder farmers, especially the vegetables farmers in the central hills of Sri Lanka, possess good entrepreneurial attitudes (Rosairo & Potts, 2016). They show innovativeness as they like to adapt latest farming and value-adding methods; and like to try new crops and inputs. They seem opportunity-seeking through seeking for information; looking for new markets; like to make use of training programs; use opportunities presented by development projects; and make use of skills and knowledge of their colleagues. They also seem to like taking risks via investing in new technology; obtaining formal credit for farm expansion; and be first to try new methods. However, smallholders seriously lack in translating these attitudes in to sustainable entrepreneurial behavior.

Political factors

Political interference: In many areas of Sri Lanka, collective SFIs have been used by local politicians to gain advantage through promoting their supporters into governing bodies of SFIs. This is commonplace in other developing countries as well (Key & Runsten, 1999). Politicization in few cases of SFIs has been further aggravated by politically motivated officers appointed by facilitating institutions. It can be argued that some SFIs are even federated in such a way that political mechanisms at top levels but not the smallholders, could take advantage. The political influence and has not helped these institutions to achieve intended objectives. Instead, it has brought poor operational concepts such as bias and loss of autonomy in to the SFIs, and has not helped them to achieve high performance.

It is also uncertain in many instances whether the synergistic (multiplier) effect has been achieved by forming the collective SFIs. Therefore, it can be questioned whether the development spending has been able to produce a wider change in food security and poverty alleviation, through formation of SFIs. Therefore, most of SFIs developed in Sri Lanka could perform better in enhancing productivity and move further ahead as collective institutions in order to fully contribute towards food security and poverty alleviation agenda in the country, if they could avoid the problems discussed above.

8.4 Towards Sustainable Smallholder Farmer Institutions

Smallholder farmer institutions play a significant role as an institutional tool for promoting productivity and agricultural development. Sustainable SFIs could ensure food security and poverty alleviation through the empowerment of smallholder farmers. Some suitable recommendations in key areas for long-term success of SFIs and to bring about sustainable food value chains and food security, are as below (Fig. 4).

Healthy facilitation process during establishment: Facilitating institutions[12] and development agencies should use a participatory approach to allow SFIs to evolve more naturally. They should ideally go through more informal stages of development prior to registration as formal SFIs. Selection of smallholder farmers is crucial. Priority should be given to smallholders who show entrepreneurial qualities. Vision, mission, objectives and business plans of SFIs should follow a participatory approach in which smallholder farmer members are a party.

Facilitating institutions should ideally work along with the SFIs to empower them but not to exercise excessive control over them. Facilitation should be provided on a long-term basis without leaving the SFIs soon after their establishment period. Therefore, facilitating institutions should operate with well-designed exit plans (Rosairo & Esham, 2021).

Distribution of benefits: It is recommended that the profits and other benefits of SFIs be distributed among members proportionately to their level of investment in the SFI, but not their patronage. This would free the SFIs from the internal free-rider problem and other institutional problems outlined in the Sect. 6.3 above. This would provide incentive for smallholder farmers to invest and re-invest in their SFIs, which is a prime requirement in the wealth generation in the SFIs.

Separation of ownership from management: Smallholders are the natural members of SFIs. Qualified and skilled managers should be employed to completely operate and manage the SFIs. No smallholder member should take-up managerial

[12] Facilitation can be defined as all the activities and functions that an external institution or a group of institutions undertake in the process of establishing a farmer institution. Such institutions that provide the facilitation is known as a facilitating institution. In Sri Lanka, these are usually state organizations related to agriculture.

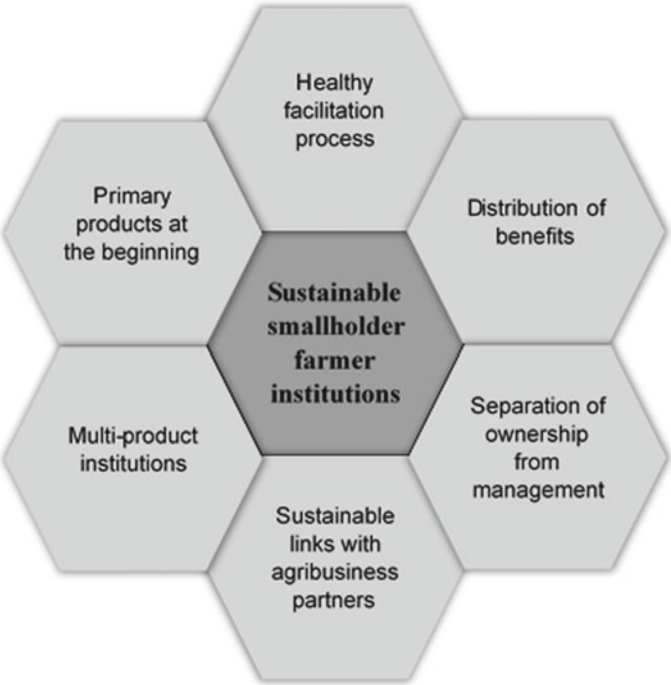

Fig. 4 Specific requirements to build sustainable farmer institutions for poverty alleviation and food security in Sri Lanka

tasks in the SFIs as a vast majority of smallholder farmers in Sri Lanka are not skilled or qualified as managers.

Establishment of sustainable links with agribusiness partners: In order to access high value markets, strong supply contracts should be established with the corporate sector and exporters. Supply contracts also should be drawn between the smallholder member farmers and the SFIs to ensure continuous supply of products for sale by SFIs.

Establishment of multi-product institutions: Establishment of multi-product SFIs is encouraged to reduce agricultural risk. This strategy will help reduce the risk of income loss due to natural disasters such as droughts, and other contingencies.

Production of primary products at the beginning: Production of processed or finished products is more profitable. However, food processing requires relation-specific assets which may require heavy capital. Their maintenance could also be expensive. Smallholder farmers in Sri Lanka are unable to make heavy investments in SFIs based on their socio-economic situations. Therefore, it is not advisable for SFIs to embark on food processing at the beginning.

9 Conclusion

Although the service and industrial sectors have been prominent contributors of Sri Lanka's Gross National Product (GNP), its economy is heavily driven by agriculture. Its scope and focus shifted from traditional scattered farming, towards commercialization during the colonial era. Large scale and export-oriented farming of economic crops were grown to improve income and to achieve agricultural development (Wijayaratna, 1997). Commercialization of non-plantation agriculture became a priority in Sri Lanka during the late eighties. New policies with integrated approaches to rural development, especially within the smallholder subsistence farming (Kudagamage et al., 2006) sector was introduced during this period. The smallholder sector that produced much of the vegetables, fruits, and rice etc. that contributed towards the food security was awarded much prominence.

The development of smallholder farming can increase the household incomes of smallholders and also reduce their household food expenditure. These contribute to alleviation of rural poverty and the reduction of income inequality. Smallholder farmers in Sri Lanka are engaged in plantation crops, non-plantation crops or livestock sectors. Smallholdings of tea, rubber, coconut, sugarcane, vegetables, fruits, paddy, broiler chicken, ornamental fish, and prawn culture are quite prominent sectors. Smallholder farmers obtain services of small labor forces which include family labor, shared labor and a small hired labor force for their farming activities. The farm income is the main source of household income of most smallholders in Sri Lanka. Therefore, smallholder sector in Sri Lanka contributes positively towards the poverty alleviation and food security.

Agricultural trade plays a crucial role in making food products available to consumers everywhere. This ensures food security. Smallholder farmers in Sri Lanka are capable of producing to meet the standards and requirements of local and international markets. They also could produce niche products in smaller quantities. Therefore, smallholder farming is a unique sector with important benefits as far as agricultural trade is concerned. Smallholder farmers in Sri Lanka are vulnerable to production costs, price fluctuations, presence of middlemen, unfavorable exchange rates and many more factors. Ever rising transport costs affect both output and input prices and trade of food (Baiphethi & Jacobs, 2009).

Smallholder farmers should be provided with better opportunities to trade their tradable surplus, and to reduce transaction costs of trade. It is mandatory to establish superior trade platforms to market smallholders' output.

Trade liberalization as well as trade limitations under policy environments in Sri Lanka shape the picture of demand and supply of food products. Both import and export of agricultural products are facilitated under the present policy context. New retail chains in Sri Lanka shows a considerable amount of progress. There has been a healthy retail shopping culture evolving in the country. The state has good policies in place to support the local retail chains to perform well. It also assists exporters of food and other agricultural products through institutions such as Sri Lanka Export Development Board, Sri Lanka Tea Board and diplomatic missions to reach global markets. Small scale farmers that produce food and other agricultural products for export receive assistance and monitoring by world famous certification agencies such as Control Union and SGS International to meet the stringent quality standards of the overseas markets (Minten et al., 2009). Collaborations between smallholder farmer institutions and agribusiness firms have benefitted the smallholder farmers in Sri Lanka and consumers in high-end markets within the country and overseas alike.

There are a number of key constraints that can affect the performance and economies of smallholder farmers. Less participatory and bureaucratic policies; insufficient coordination among institutions set-up to serve agriculture; centralized decision-making and poor infrastructure are considered as the key institutional and policy constraints. Poor status of capital and access to agricultural credit facilities are considered as key financial constraints while, small scale operations; resistance to change; poor adoption of latest technology and poor product quality are the key constraints limiting production capacity and technology. Inefficient input markets; poor bargaining position of smallholder farmers; inability to capture good markets; and post-harvest losses are the key market constraints faced by the smallholder farmers.

Agricultural decisions of smallholders who are engaged in crop and animal husbandry in Sri Lanka, are mostly household decisions. They are able to make decisions easily and rapidly due to the absence of red tapes and bureaucracy. Their overheads are low and they are mostly sole operators. Smallholders in Sri Lanka are the main growers of most crops and livestock, and they are the main producers of food products for the country. Therefore, programs to assist them in their agricultural operations are in place, to enhance the agricultural production. These are mainly aimed at reducing the cost of production and theoretically lowering the prices of most main food items, making them more accessible to people, meaning they can have access to better meals. Therefore, the place of the smallholders and the role that they play at all levels of the supply chain are crucial to achieve sustainable food security of the country.

The COVID-19 pandemic situation caused wide spread lock downs and travel restrictions throughout the country. Agricultural production and trade were affected severely causing temporary food insecurity during the early stages of the pandemic, mainly due to disruption in the village collection systems. Cultivation of crops and rearing of livestock were also affected due to lack of inputs and services such as extension. Smallholder agricultural sector was severely affected as a result. With the new regulations and practices in place, the sector could recover rapidly. The traditional rural *pola* system was completely disrupted due to regulations preventing social gathering. Trading mechanisms which were not popular during the pre-pandemic era, such as local mobile selling, hawkers, door-to-door selling, and road-side selling were adopted by smallholder farmers themselves and small-scale village traders.[13] Contract farming arrangements by local supermarket chains and exporters recommenced business engagements with smallholder farmers during mid-2021.

[13] Many of these individuals started as small-scale traders after having their jobs lost during the pandemic due to lay-offs and temporary stoppage etc.

Smallholder farmer institutions were regarded as mechanisms to achieve higher agricultural productivity; improve market access for smallholders; and enhance value-addition of smallholder farmers to achieve food security in Sri Lanka. They were also regarded as an effective strategy in linking smallholder farmers to exporters. Establishment of a formal SFIs is technically a horizontal integration of smallholder farmers. They also facilitate vertical integration via formal contracts with agribusiness partners mainly for trading of their products. Farmer institutions in Sri Lanka play a prominent role in coordinating smallholder farmers especially to manage shared resources such as irrigation water, and fisheries; procure farm inputs in wholesale for bulk discounts; obtain formal credit; process and trade of products (Batuwitage, 1998). Farmer cooperatives, farmer companies, agrarian farmer organizations, Mahaweli farmer organizations, and tea smallholder development societies are among the most popular forms of SFIs in Sri Lanka.

Smallholder farmer institutions in Sri Lanka could perform better if they avoided some of the common inherent problems they reveal. Generic institutional problems, incompetent governance, lack of natural evolution and development, and ladening with too many assistance projects were identified as some of the institutional and policy-related issues they have. They face internal organizational problems such as poor mechanisms for monitoring and evaluation of progress, embarking on too many activities, and opportunistic behavior of members. Smallholder farmer institutions in Sri Lanka also lack managerial and entrepreneurial skills, and their hiring of managers haven't been strong. This chapter also provides some recommendations for strong and sustainable SFIs.

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Structure, Performance and Competitiveness in Indian Agricultural Exports

Expanding Trade and Strengthening Global Trade Linkages

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1 Rationale

The contribution of agricultural trade in achieving economic growth, alleviating poverty and achieving food security is immense for developing countries like India. However, for safeguarding the food security for continuously rising population of the country, the prime agenda was to ensure an efficient and sustainable domestic production system. With the rising agricultural output, the country has attained self-sufficiency in the majority of the crops. The increasing output is creating huge surpluses in some commodities which need to be effectively channelized to alternate destinations. This is extremely important in the regime where all Government policies and agenda are directed towards enhancing the farmers' income. The target of doubling farmers' income can be achieved by providing an efficient trading environment that will promote, not only competition within the nation but also provide opportunities for the farmers to draw benefits in International markets. Besides, policies are required to economically divert the surplus produce within the country towards the international markets, enhancing the farmers' Income.

During the span of the last six decades, Indian agriculture made tremendous progress in terms of an increase in food grain production. Despite population increase to 1.3 billion, the country emerged from a food deficit to a food surplus nation. The ambitious growth in agricultural production clearly indicates India's trade potential.

During the twelfth ministerial conference of WTO, UNCTAD recommended that the international trade architecture needs to be enhanced. International trade can play

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a vital role in increasing food security (UNCTAD, 2021). These recommendations largely focused on essential food items and more conducive terms for enhancing trade in developing economies. Even the “2030 Agenda for Sustainable Development” recognized international trade as an engine for inclusive economic growth and poverty reduction, and important means to achieve the Sustainable Development Goals (SDGs) (The Sustainable Development Goals Report, 2020). Realizing this goal requires a multifaceted approach. To ensure access to safe and nutritious food, international trade and cross-border co-operation needs to be enhanced and cooperation through multilateral trade arrangements has an important role to play.

The importance of India in the world market can’t be denied. Over the years, India has developed export competitiveness in certain specialized products (WTO, 2020). Ever since the economic reforms began in 1991, India has maintained its position as a net exporter of agricultural products exporting around Rs. 2.52 lakh crore worth agricultural products in FY 2019–20. The major export destinations for India are the USA, Saudi Arabia, Iran, Nepal and Bangladesh. With the changing global and domestic dietary pattern, a significant change in the composition of the exported agricultural products has been observed. There has been a sharp increase in the export of the Indian marine products over the last few years and its share in total agricultural export has increased from 14.5% in 2015–16 to 19% in 2019–20 (GOI, 2021). Besides, there has been a rising demand for Indian basmati rice, non-basmati rice, spices and sugar as evident through their rising share in the total agricultural exports. Along with the surplus production, the competitive advantage has helped boost India’s export earnings. It makes evident the rising demand for Indian agricultural products and hence accentuates the need for a close examination of export diversification across commodities and geographies.

Despite, the increasing trends in agricultural exports, we have not been able to tap the desired potential. There exists huge untapped export potential (INTRACEN), which could be tapped through appropriate interventions. It has been reported that export in developing countries is highly responsive to the quality of transport facilities, availability of trade related infrastructures (Moïsé et al., 2013). The role of policies targeting constraints related to governance, infrastructural facilities along with some complementary policies such as education for improving agricultural trade performance has been highlighted by many researchers (Moïsé et al., 2013). Further, trade-growth linkages have attained due attention in the global trade research. A few studies have been carried out to examine the export-led growth and have established the hypothesis depending upon the country’s stage of development and its participation in trade. A study conducted in UAE validates a bi-directional causality between manufactured exports and economic growth in the short-run and the growth-led exports (GLE) in the long-run (Kalaitzi & Cleeve, 2018). Likewise, it has been estimated for Nigeria that a unit increase in the agricultural exports would bring a more than proportionate increase in the real gross domestic product (Gbaiye et al., 2013). Besides, the empirical support for export led growth can be deducted from the success of the four East Asian Tiger economies (South Korea, Hong Kong, Singapore, and Taiwan) (Palley, 2012). Countries such as China and Pakistan support export-led growth (ELG) hypothesis for short run (Ali & Zhaohua Li, 2018). ELG claim also supported by (Herzer et al., 2006 study on Chile); (Narayan et al., 2007 on Fiji and Papua New Guinea) but in long run GLE prevails for India and UAE (Kalaitzi & Cleeve, 2018; Mishra, 2011). Bi-directional causality (ELG-GLE) was observed in Oman, Algeria, Egypt, Jordan, Bahrain and Mauritania (El-Sakka & Al-Mutairi, 2000).

Considering these, this study provides a snapshot of Indian agricultural trade particularly agricultural exports. The study examined the trends, composition along with the performance of agricultural exports and has focused on the product and space diversification in order to understand the export dynamics. Also, the study drew inferences about the causality and export-growth linkages. The inferences would be useful in developing appropriate strategies for better targeting and managing Indian agricultural exports.

2 Data and Methods

To analyse the stated objective, the export data was obtained from UN Comtrade database at HS 02 and HS 04 digits from 1988 to 2019 for agricultural commodities. The detailed analysis was caried out for five most exported commodity groups viz.: cereals (HS 10); meat (HS 02); fish (HS 03); tea, Coffee and Spices (HS 09) and cotton (HS 52). The detailed list of commodities covered in agriculture is given in the Appendix.

2.1 *Export Performance Index*

Different indices have been reported to measure the strength of the competition among countries. Among them, Balassa's Comparative Export Performance Index (CEP) is the most commonly used index. Therefore, the analysis of comparative advantage of exports was conducted using Balassa's CEP index. CEP is a measure of export performance that shows comparison of a commodity's market share in the country compared with the percentage of exports of the commodity in total world exports. CEP index for selected commodity groups and commodities was computed. The index for export of j^{th} commodity from i^{th} country (India here) is calculated as follows:

$$\text{CEP} = \frac{(X_{ij}/X_i)}{\left(\frac{X_{aj}}{X_a}\right)} \tag{i}$$

X_{ij} = Value of export of jth product from ith country.
X_i = Total value of export from ith country.
X_{aj} = Total value of export of jth product from the world.
X_a = Total value of export from world.

Table 1 Threshold for various indices

Category	CEP	SCEP	ln (CEP)
Highly competitive	≥4.20	0.62–1.00	≥1.44
Competitive	1.73–4.19	0.27–0.61	0.55–1.43
Weakly competitive	1.00–1.72	0.00–0.26	0.00–0.54
Uncompetitive	<1.00	<0.00	<0.00

Source Boansi (2014)

The symmetric comparative export performance index is consequently defined as follows:

$$\mathrm{SCEP} = \frac{(\mathrm{CEP} - 1)}{(\mathrm{CEP} + 1)} \tag{ii}$$

Symmetric Comparative Export Performance Index (SCEP) is the symmetric form of the CEP index. It is perceived to provide the best picture of performance of a country by setting boundaries between -1 and $+1$. The closer the value to $+1$, the higher is its export performance and vice versa. The ln (CEP) was also calculated as adopted by Boansi (2014). If ln(CEP) takes a value greater than 1, the country has a revealed comparative advantage in that product. The values of CEP of at least $+1$ and ln(CEP) of at least 0 reveal competitive advantage in exports. The detailed threshold adopted from Boansi (2014) used for the classification of products is shown in Table 1.

$$\mathrm{In}\ (\mathrm{CEP}) = \log\ (\mathrm{CEP}) \tag{iii}$$

2.2 *Export Diversification Index*

In order to reap the benefits of trade, a country must expand its export basket in terms of the goods offered and also in terms of markets accessed. The more the number of goods to export, the greater is the opportunity to earn more foreign exchange. Similarly, a country must not always rely on a set of countries only for exports. This is important as in case of a volatile policy environment in the importing nation, the exporting country may incur a huge loss. Thus, a country must continue to keep adding new markets for its products. Diversification into new primary export products is generally viewed as a positive development. Hence, Export Diversification Index (DX) reveals the export strength of a country in terms of markets and products, both. The export diversification index (DX) for India is defined as:

$$\mathrm{DX}_j = \left(\mathrm{sum}\ |\ h_{ij} - x_i|\right)/2$$

where, h_{ij} is the share of the ith commodity in the total exports of the jth country and h_i is the share of the commodity in world exports. The related measure used by UNCTAD is the concentration index or Hirschman (H) index, which is calculated using the shares of all selected agricultural products in a country's exports:

$$H_j = \text{ sqrt}\left(\text{sum }(x_i / X_t)^2\right)$$

where x_i is the jth country exports of the ith product (at 2 and 4 digit classification) and X_t is the jth country's total exports. The lower the index, the less concentrated are a country's exports.

2.3 Examining Causality

Granger causality test was applied to examine the causal relationship between the variables. Accordingly, X is said to granger cause Y, if the past and present values of X help to predict Y and vice versa, which examines how one variable explains the latest value of another variable. Accordingly, if a variable Y is Granger caused by variable X, it means the values of variable X help in predicting the values of variable Y and vice-versa. The causality relationship among GDP, agricultural GDP and export of the five selected commodity groups was examined using the Granger causality procedure.

2.3.1 VAR Impulse Response

The Impulse-Response Functions (IRFs) are the $n \times n$ set of dynamic marginal effects of a one-time shock to variable j on itself or another variable i. One common format for the entire collection of IRFs corresponding to a VAR is as an $n \times n$ matrix of graphs, with the "impulse variable" (the shock) on one dimension and the "response variable" on the other. Each of the n^2 IRF graphs tells us how a shock to one variable affects another (or the same) variable.

3 Trends and Composition of Agricultural Trade

India is a signee-member of the Agreement on Agriculture (AoA) at the World Trade Organization since 1995. The AoA aimed at removing trade barriers and facilitating in place of facilitate market access for the member countries. The timelines were set for developed, developing and least developed countries to facilitate the objectives of the AoA. An analysis of data reveals the rising overall import dependence of India indicated in terms of rising net imports. The negative trade balance of India increased from Rs. 10,644 crores in 1990–91 to Rs. 1,286,948 crores in 2018–19 (Table 2).

Table 2 Trends in agricultural trade in India

Years	Agriculture exports (Rs. Crore)	Total exports (Rs. Crore)	Agriculture exports to total exports (%)	Agriculture imports (Rs. Crore)	Total imports (Rs. Crore)	Agriculture imports to total imports (%)	Net trade (Rs. crore)	Net agricultural trade (Rs. crore)
1990–91	6013	32,527	18.49	1206	43,171	2.79	−10,644	4807
1995–96	20,398	106,353	19.18	5890	122,678	4.8	−16,325	14,508
2000–01	28,657	201,356	14.23	12,086	228,307	5.29	−26,950	16,571
2005–06	45,711	456,418	10.78	15,978	660,409	3.26	−203,991	29,733
2010–11	113,047	1,136,964	10.28	51,074	1,683,467	3.41	−546,503	61,973
2015–16	215,396	1,716,378	12.55	140,289	2,490,298	5.63	−773,920	75,107
2016–17	226,652	1,849,429	12.26	164,727	2,577,666	6.39	−728,237	61,925
2017–18	251,564	1,956,515	12.86	152,095	3,001,033	5.07	−1,044,519	99,469
2018–19	274,571	2,307,726	11.90	137,019	3,594,674	3.8	−1,286,948	137,552

Source Compiled by authors from Directorate of Economics and Statistics

Despite the overall negative trade balance, India's agricultural trade balance has remained positive over the years indicating its strengthened and growing position as the net exporter of agricultural commodities. The value of net agricultural exports has increased approximately by 28 times from Rs. 4,807 crores in 1990–91 to Rs. 137,552 crores in 2018–19. This trend is continued since the economic reforms of 1991, since then India not only achieved self-sufficiency but also retained its position as the net exporter of agricultural products. Globally, the contribution of Indian agriculture is significant both in terms of production and trade. Considering India's status in cereals production along with the various initiatives for diversification towards high-value crops, emphasis on achieving self-sufficiency in pulse production and focus on oilseed crops, there is great opportunity to explore the trade potential in the global market. Albeit to accomplish it; the domestic support in terms of logistics, trade infrastructure, along with quality assurance needs to be promoted.

3.1 Agricultural Exports

Figure 1 shows the composition and trends in agricultural exports from India. The study includes all agricultural and allied commodities (see Annexure). Cereals, cotton, fish and crustacean and coffee, tea and spices hold major share in agricultural exports. Furthermore, meat and meat offals have increasingly found a place in India's basket of agricultural exports. Since 2001, cotton and cereals have been the highest contributors in India's export of agricultural goods. The performance of cereal exports from India is more or less stable due to the prevalence of rice as the major exported product in the group. It has been observed that the share of cotton exports has declined from 25% in 2001 to less than 20% in last five years. Meat and edible meat offals and fish and crustacean exports have performed well. Share of meat and edible meat offals has increased from 3.2% in 2001 to approximately 9% in 2018. India is the largest exporter of crustaceans in the world followed by Ecuador. The export share of coffee, tea and spices were stable during 2001–2018. Figure 2 exhibits the trends in exports major agricultural products from India.

Cereals: Globally, India ranks 3rd in the production of cereals. It is the 2nd largest producer of rice and wheat, globally. India's export policy for cereals has remained unstable due to their contribution towards the country's food security. Thus, the cereal exports were curbed at different stages. India exported cereals worth Rs. 427.87 Billion during 2019–20 (APEDA). The major export destinations for Indian cereals are Bangladesh, Nepal, Pakistan, Saudi Arab and UAE. Rice has always been the main exported cereal crop of India contributing around 95% to the total cereal exports in 2018. For wheat, Nepal, Bangladesh, UAE, Somalia and Korea are the top five destinations contributing around 95% (2019–20) of the total exported value.

Meat: India has the world's largest cattle population. It has 110 million buffaloes, 133 million goats and 63 million sheep. The export of animal products has a significant contribution to the Indian agriculture. Frozen bovine meat forms the major share (almost 90% in 2018) in meat export for India. However, 2012 onwards edible offal

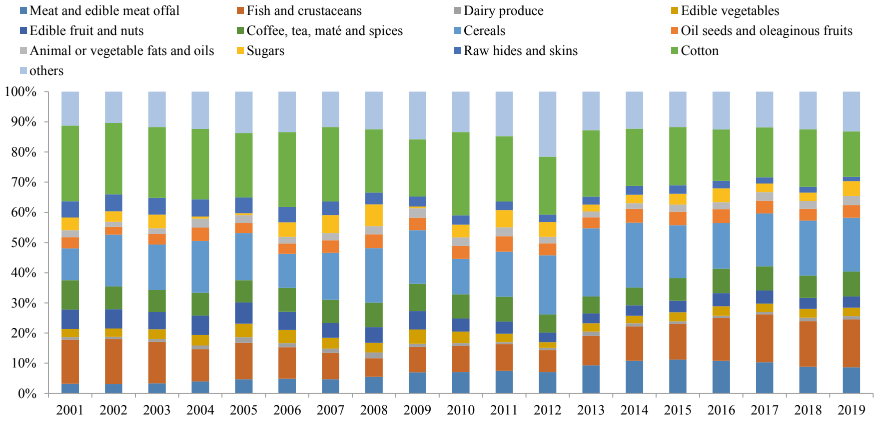

Fig. 1 Composition and trends in agricultural exports from India

was also contributing to it. It must be noted that India does not allow the slaughter of cattle and therefore the bovine meat which is shipped from India is all 'carabeef' i.e. buffalo meat from 100% APEDA certified Export Oriented Units only. There is an increasing demand for carabeef in the international market. Vietnam, Malaysia, Egypt Arab Republic, Iraq and Saudi Arabia are the main markets for Indian carabeef and other animal products. India ranks 1st in the production of buffalo meat and exports around 70% of its total production of buffalo meat. In recent years, Brazil and Argentina have emerged as major competitors for Indian buffalo meat in the global market.

Fish: Fish and fish products hold a significant importance in the global trade. These will remain the highly traded commodities with around 31% of the total global production in 2024 to export (Sumaila et al., 2016). Fisheries is an emerging and promising sector for Indian economy. India's presence in the world fish market is significant as India contributes to around 5% of the total global fish export. A vast coastline provides huge scope for India to expand in the international markets. Crustaceans are the highest exported fish product from India contributing around 70.8% (in 2018) of the total export value of fish products followed by molluscs. The technology advancement can help India to harness the export potential of fish and fish products.

Tea, coffee and spices: India is the largest producer, consumer and exporter of spices and spice products in the world. The country produces more than 50 spices and is also the largest producer of tea and coffee. The share of pepper has grown significantly over a period contributing around 24.7% in 2018. On the other hand, tea exports from India are increasing. However, the share of tea in the export value of the category (HS 09) has declined from 51.1% in 2001 to 24.4% in 2018, which is a fall by more than 50% and is a matter of grave concern. One of the prime reasons behind this is the age old tea gardens in India. The challenges faced by the tea industry are from both the supply and demand side. The tea consumption has declined world over with people shifting to healthier versions and looking forward to organic versions too, coupled with a lack of investment in technology, infrastructure, community development, and research into new agricultural inputs in India. One of the strong challenges tea and coffee growers face is from the climate change which has affected the yields and increased the costs leading to rise in local and international prices. Ginger, saffron, turmeric, seeds of few spices and nutmeg, mace and cardamoms are the emerging products under this category.

Cotton: Cotton has been an important crop and has played a dominant role in the country's economy. India is amongst the largest producer of cotton in the world and the cotton from India is exported in different forms. Cotton yarn (HS 5205) and cotton woven fabrics (HS 5210 and HS 5209) form a major share in exports of cotton products. The export value of various cotton products during 1988–2019 showed an overall increasing trend. Cotton exports were highest in 2013 (highest area and production till date), continued to decline afterwards till 2016 and then started to increase. Raw cotton (HS 5201) is an emerging product. China is the biggest buyer of India's cotton. The decline in the exports of cotton was noticed around 2014–2016, and happened due to the attack of pink bollworm which destroyed the huge crop in India and affected the domestic and exportable surpluses (Directorate of Cotton Development, 2017). Further, China introduced an embargo on Indian cotton in 2015–16 due to its own growing stocks (Fig. 2).

4 Export Performance

The study also examined the export performance based on the Comparative Export Performance Index (CEP). The analyses of export performance for the five selected commodity groups during 2011–14 and 2015–18 established only cotton as "Highly Competitive" commodity during both the periods. Globally, 75% of the world's cotton supply comes from India, China, US and Brazil. Amongst these, China and India are the top two cotton producers, contributing around 45–50% to the global cotton production (USDA, ERS) and are also the top consumers of raw cotton (HS 5201). The global importance of the commodity can be established from the fact that India alone holds around 40% to the global cotton acreage indicating that the supply fluctuations in Indian cotton market can affect global prices to a greater extent. The US and Brazil are emerging competitors of India in the cotton market. In order to remain competitive in the international market, India needs to focus on productivity enhancement and quality improvement. A deep dive into the commodities at HS 4-digit reveals that raw cotton (HS 5201) has registered an improvement in its competitiveness. Besides this, HS 5208 and HS 5209 have also shown slight improvement in competitiveness. However, decline in competitiveness was registered for cotton yarn during 2015–18 as against 2011–14. The reason behind this declined competitiveness could be due to reduced surpluses, increased cost due to pink bollworm attack. Over the years, China has been a major importer of Indian cotton. The mill use of cotton for textiles and fibre is the largest in China. From 2013–17, the Indian

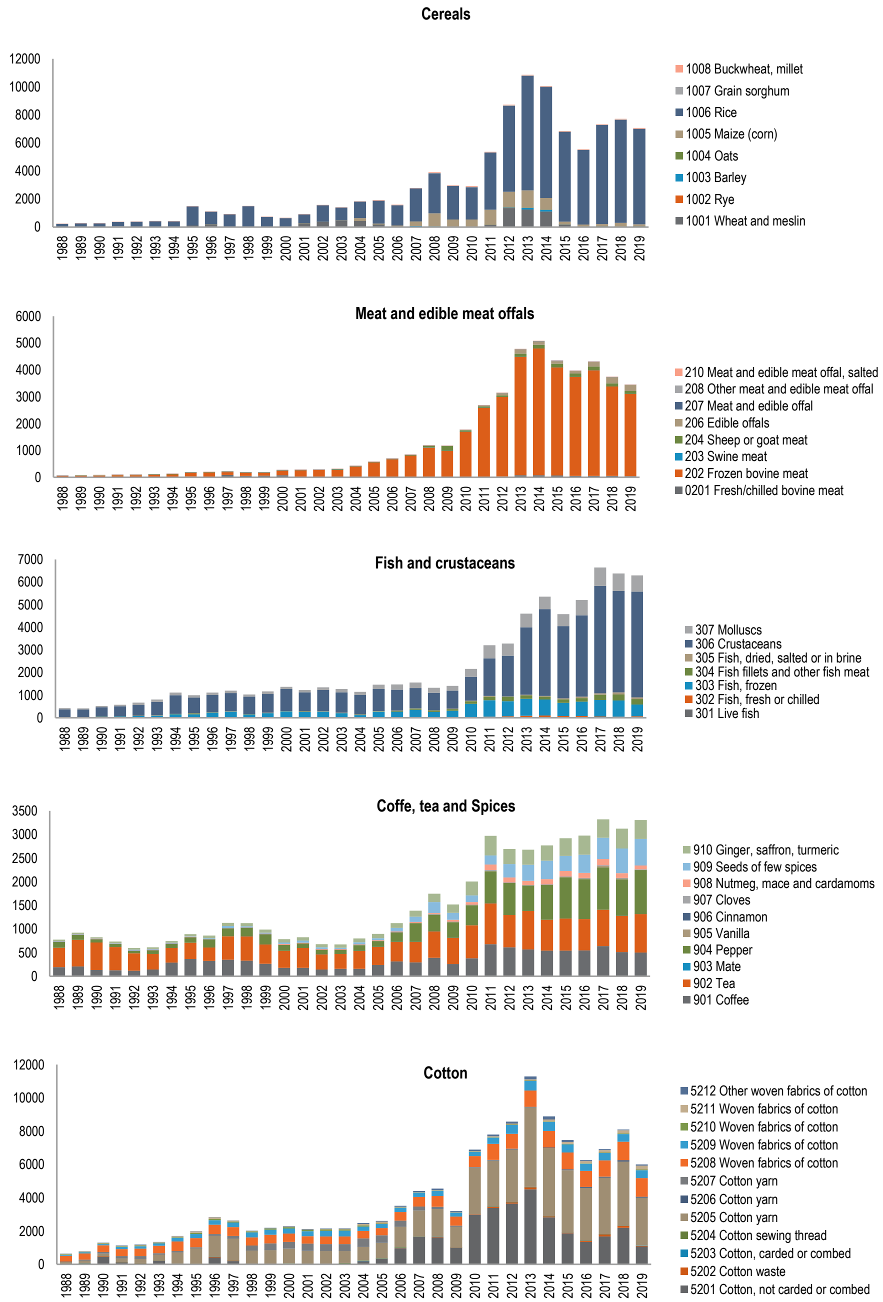

Fig. 2 Trends in export of major agricultural products from India (million $)

cotton yarn export to China has declined around 48% and China shifted its import dependence to Vietnam and Indonesia. Not only for China, the global cotton market for India especially for the major importers like European Union (EU) also became inaccessible as India witnessed a decline of 25% and 7% in the export of cotton yarn and fabric respectively during the same period (Business Standard, 2019; The Economic Times, 2019). It has been reported that this decline in cotton yarn was mainly due to the duty disadvantage that India was facing along with the withdrawal of the domestic support. Albeit, the CEP registered an increase in 2015–18 period owing to new market avenues for raw cotton. Bangladesh has emerged as strong importer of Indian raw cotton since 2016. It has been noticed that the cotton industry has started blooming in Bangladesh, Vietnam and other Asian Nations which has definitely created new markets for India. European Union is another major market for the cotton yarn.

The results indicate no change in export performance of the cereals during the period and they remained competitive. Although, within the commodity group the scenario is interesting, as rice (HS 1006) is the only commodity which is highly competitive for India during the two time periods; while maize (HS 1005) and wheat and Meslin (HS 1001) are uncompetitive as indicated through negative value of SCEP. India mainly exports non-basmati rice to Bangladesh, Nepal, Benin and Senegal, and premium basmati rice to Iran, Saudi Arabia and Iraq.

The export performance of meat (HS 02) has improved significantly from being "Uncompetitive (−0.01)" during 2011–14 to being "Weakly Competitive (0.06)" during 2015–18. This category is dominated by the exports of frozen bovine meat, India enjoys competitiveness in its exports. The performance of the other two products, edible offal (HS 0206) and sheep and goat meat (HS0204) improved in 2015–18; however, they still remained uncompetitive. The frozen bovine meat (HS 0202) exported from India largely consists of frozen boneless buffalo meat. Vietnam, Malaysia, Iraq, UAE, and Egypt have remained one of the largest importers of Indian buffalo meat. The raw boneless buffalo meat by India, also known as carabeef has found a way in Asian Nations albeit the beef is more popular in the International markets. The carabeef is not in direct consumption by individual households, most of it goes for processing and canned food industry. A discounted price as compared to beef and nearness to major consuming Asian markets has led to the strong export performance and increased export competitiveness of the frozen bovine meat (HS 0202) (The Indian Express, 2015).

The export performance of the fish and crustaceans, molluscs and other aquatic invertebrates (HS 03) has improved over the period (0.11 in 2011–14 and 0.25 in 2015–18), however, it remained weakly competitive throughout. India has emerged in the competiveness of the crustaceans (HS 0306), as the status changed from competitive during 2011–14 to highly competitive during 2015–18. Crustaceans are one of the top ten exported product class from India to US, China, Japan, Vietnam and UAE as the major export destinations. Indian crustaceans face competition in the global markets with Ecuador, Vietnam, and Canada being the major competitors. Shrimp remains the highest exported commodity in this group and found a niche market in the USA. It, however, competes with countries like Vietnam and Ecuador which have adopted more advanced technologies for its production. The cultivation is highly vulnerable as the disease catches the crop easily. India needs to make a lot of efforts to sustain its exports in the international markets and also encourage the product diversification in this category with more advanced technologies in production, harvest and post-harvest segments of the fishery supply chain.

For coffee, tea and spices (HS 09) the SCEP for India improved from 0.27 during 2011–14 to 0.35 during 2015–18. However, the classification remains same. Pepper (HS 0904), ginger (HS 0910) and seeds of anis, badian, fennel etc. (HS 0909) remained highly competitive during both the periods. While for Tea (HS 0902) India is competitive, for coffee (HS 0901) India is uncompetitive.

The results reveal that there stands huge potential for India to improve its competitiveness by addressing the major issues that have hampered their exports over a period of time. In many of these commodities, we are major exporters while we also face very stiff competition in the international markets. Without attending to quality standards and appropriate technological measures, we may not sustain the performance. India's new export policy aims at doubling exports and has given a new direction to the agricultural trade. Agricultural and Processed Food Products Export Development Authority (APEDA) and Marine Products Export Development Authority (MPEDA) have played a crucial role in enhancing the agri-exports from India. Even during the period of covid-19 pandemic, India's agri exports have registered significant growth despite the global shortages and supply chain disruptions during lockdowns. Thus, the country must focus on stable trade policy particularly in commodities with greater trade potential (Tables 3 and 4).

5 Export Diversification

5.1 Commodity Diversification

In assessing export diversification, the Herfindahl–Hirschman index was used to find India's export diversification of agricultural commodities. Figure 3 portrays the commodity diversification in India's exports of selected commodities. The commodity diversification was worked out at HS four-digit level within a broad category at HS two-digit level. Meat remains the least diversified commodity group as this is dominated by the exports of frozen bovine meat. The commodity diversification index for cereals also remained quite low and has declined overtime, as the category consists of predominantly rice exports. Commodity diversification within cotton category has almost remained stable during the recent decade.

Table 3 Export performance indices for selected agricultural exports category: CEP, SCEP and log CEP

	CEP		SCEP		log CEP	
	2011–14	2015–18	2011–14	2015–18	2011–14	2015–18
10 Cereals	**2.24**	**2.21**	**0.38**	**0.38**	**0.35**	**0.34**
1006 Rice	7.90	9.32	0.78	0.81	0.90	0.97
1005 Maize	0.94	0.21	−0.03	−0.65	−0.03	−0.68
1001 Wheat and meslin	0.61	0.07	−0.25	−0.88	−0.22	−1.18
02 Meat and edible meat offal	**0.97**	**1.14**	**−0.02**	**0.07**	**−0.01**	**0.06**
0202 Meat of bovine frozen	5.33	5.60	0.68	0.70	0.73	0.75
0206 Edible offal of bovine animals, swine etc.	0.40	0.62	−0.43	−0.23	−0.40	−0.21
0204 Meat of sheep or goats	0.42	0.62	−0.41	−0.23	−0.38	−0.21
03 Fish and crustaceans, molluscs and other aquatic invertebrates	**1.25**	**1.68**	**0.11**	**0.25**	**0.10**	**0.22**
0306 Crustaceans, whether in shell or not	3.46	4.96	0.55	0.66	0.54	0.70
0307 Molluscs, fit for human consumption	1.55	1.79	0.22	0.28	0.19	0.25
0303 Frozen fish	0.95	0.97	−0.03	−0.01	−0.02	−0.01
09 Coffee, tea, maté and spices	**1.76**	**2.08**	**0.27**	**0.35**	**0.24**	**0.32**
0904 Pepper of the genus Piper	5.26	6.31	0.68	0.73	0.72	0.80
0902 Tea, whether or not flavored	3.04	3.14	0.50	0.52	0.48	0.50
0909 Seeds of anis, badian, fennel etc.	13.17	15.69	0.86	0.88	1.12	1.20
0901 Coffee	0.56	0.61	−0.28	−0.24	−0.25	−0.22
0910 Ginger, saffron, turmeric “curcuma”, thyme	4.52	5.13	0.64	0.67	0.66	0.71
52 Cotton	**4.03**	**4.28**	**0.60**	**0.62**	**0.61**	**0.63**
5205 Cotton yarn	5.71	4.63	0.70	0.64	0.76	0.67
5201 Cotton neither carded nor combed	7.82	9.31	0.77	0.81	0.89	0.97
5208 Woven fabrics of cotton	1.82	2.51	0.29	0.43	0.26	0.40
5209 Woven fabrics of cotton	1.69	2.08	0.26	0.35	0.23	0.32

Table 4 Classification of the selected products based on SCEP

	Highly competitive	Competitive	Weakly competitive	Uncompetitive
2011–14	1006 Rice 0202 Meat of bovine frozen 0904 Pepper of the genus Piper 0909 Seeds of anis, badian, fennel etc. 0910 Ginger, saffron, turmeric "curcuma", thyme 5205 Cotton yarn 5201 Cotton neither carded nor combed	0306 Crustaceans, whether in shell or not 0902 Tea, whether or not flavored 5208 Woven fabrics of cotton	0307 Molluscs, fit for human consumption 5209 Woven fabrics of cotton	1005 Maize 1001 Wheat and Meslin 0206 Edible offal of bovine animals, swine etc. 0204 Meat of sheep or goats 0303 Frozen fish 0901 Coffee
2015–18	1006 Rice 0202 Meat of bovine frozen 0306 Crustaceans, whether in shell or not 0904 Pepper of the genus Piper 0909 Seeds of anis, badian, fennel etc. 0910 Ginger, saffron, turmeric "curcuma", thyme 5205 Cotton yarn 5201 Cotton neither carded nor combed	0307 Molluscs, fit for human consumption 0902 Tea, whether or not flavored 5208 Woven fabrics of cotton 5209 Woven fabrics of cotton	Nil	1005 Maize 1001 Wheat and Meslin 0206 Edible offal of bovine animals, swine etc. 0204 Meat of sheep or goats 0303 Frozen fish 0901 Coffee

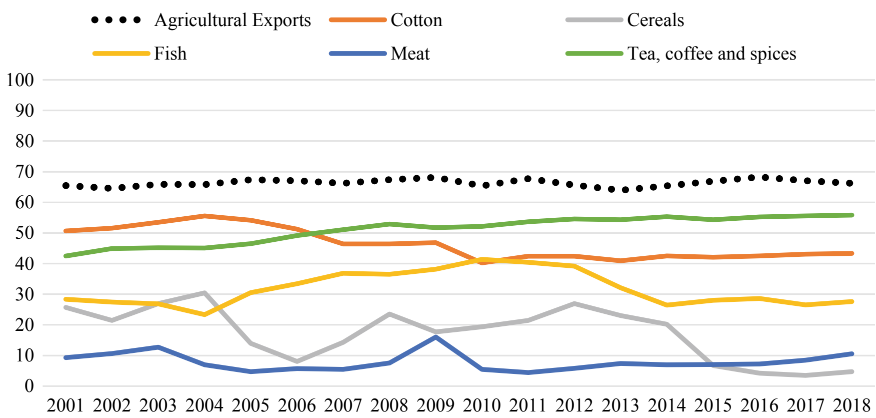

Fig. 3 Commodity diversification of agricultural products in India

5.2 Geographical Diversification

The export diversification has received considerable attention. Not many studies have been conducted on geographical diversity of Indian agricultural exports. We constructed the diversification index to analyze the structure of India's agricultural exports. Export diversification is not just about commodity but also about the expanding number of markets the country exports to. Lesser the exports are concentrated to a few markets; better it becomes for the country to establish itself as a sustainable exporter. The export concentration to a few countries actually makes the exporting country quite vulnerable. In order to reduce economic risks or the risks of volatility, geographical diversification is important. Too much dependency on few countries may affect several macro-economic parameters right from income, growth and also the employment. Furthermore, countries with concentration in few markets also raise the risk of export instability.

The diversification index was computed for majority of exported products like cotton, cereals, fish, meat and tea, coffee and spices. Higher index indicates that India already exports to a large number of existing markets for its products; a low value indicates concentration and shows the potential for expansion. The value of HH Index reveals that only cotton and meat were the commodities where the export destinations are expanding or the geographical diversification is happening. Amongst the five selected products the export diversification during 2018 was highest for tea, coffee and spices (79.4%) followed by cereals (75.2%). The latent export potential of two traditional Indian products, cotton and tea, coffee and spices can be tapped more because of their relative advantage in term of low perishability. However, it has been estimated that the diversification index for cotton has declined from 81.7% in the year 2001 to 66.3% in the year 2018.

Indian cotton is exported to approximately 170 countries globally; the number of India's trading partners has reduced overtime. The number of countries maintaining the export share of approximately 2–5% in Indian cotton exports declined from 10 in 2001 to 4 in 2018. The number of bulk trading partners remained unchanged. Singh (2020a, 2020b) using the methodology developed by the International Trade Centre, Geneva suggested 20 attractive markets for Indian cotton. Egypt is the most promising one. Similarly, more markets must be explored for all majorly exported commodities from India reducing our dependencies on few countries and maintain ourselves as a sustainable player in the global market.

Cereals have witnessed a significant increase in the diversification index (65.3% in 2001 to 75.2% in 2018) along with the increase in the number of export destinations. In 2001, the cereals were majorly exported to 98 countries while in 2018 the export destinations increased to 161 countries. India diversified geographically in terms of countries maintaining lower export shares of Indian cereals, the number of nations having less than 2% share increased from 87 during 2001 to 148 during 2018.

The diversification index of the tea, coffee and spices crops has witnessed increase from 75.6% in 2001 to 79.4% in 2018. Tea, coffee and spices are exported to nearly 145 counties and the number of countries distributed amongst the three categories based upon the relative share of export has almost remained content. Meat is the highly perishable commodity group, thus, the export value chains need proper logistics and policy facilitation. Thus, the trade happens with about 70 nations only. The diversification index for meat witnessed a sharp decline overtime from 61.2% in 2001 to 49.3% during 2018. Globally and in India, the rising importance of the marine export has been evident. The export diversification of fish remained content around 60% during 2001–18 (Table 5).

6 Export-Growth Linkages

The results of pair-wise Granger causality test are presented in Fig. 4. An attempt has been made to determine the causal relationships between India's growth and India's agricultural trade. There is bidirectional causality between exports of tea, coffee and spices and fish with GDP and agricultural GDP both. The unidirectional causality exists between cotton exports and GDP, where cotton exports Granger cause GDP. Except cereals, all selected export categories Granger cause agricultural GDP. Other studies have also confirmed this unidirectional causal link running from farm exports to gross domestic product of agriculture, which indicates that export of agricultural products Granger causes the growth in GDP of agriculture in India, which supports the export-led growth hypothesis (Ohlan, 2013). Many other studies have also established the export-led growth hypothesis with respect to India's total trade (Mishra, 2011; Ray, 2011). Kumari and Malhotra (2014) concluded bidirectional causality running from exports to GDP per capita and GDP per capita to exports. Muhammad et al. (2011) also indicated that exports are positively correlated with economic growth confirming the validity of exports-led growth hypothesis in Pakistan. Dar et al. (2013) found that the relationship between export growth and output growth is not only positive in India but this relationship grows stronger as time horizons increase; their results based on wavelet cross-correlation have shown that causal relationship is bi-directional at higher time scales. This designates that the growth in agricultural exports in general along with exports of specific commodities have led to the overall and agricultural growth of Indian economy. Impulse response function was applied to quantify the responsiveness of agricultural GDP to export of selected agricultural commodities group. The impulse response analysis indicated that a positive shock in cotton export will lead to a rise in agricultural GDP; the effects of a shock in agricultural GDP will decay overtime. The results also suggest that response of agricultural GDP to vegetable export positive shock will lead to increase in agriculture GDP with greater intensity as compared to meat, tea, coffee spices and cotton export (Fig. 5).

Table 5 Export diversification along with the share of exports with trading partners

Year	Cereals (HS 10) Diversification index	Cereals Number of countries with exports share <2%	2–5%	<5%	Meat (HS 02) Diversification index	Meat Number of countries with exports share <2%	2–5%	<5%	Fish (HS 03) Diversification index	Fish Number of countries with exports share <2%	2–5%	<5%	Tea, coffee and spices (HS 09) Diversification index	Tea, coffee and spices Number of countries with exports share <2%	2–5%	<5%	Cotton (HS 52) Diversification index	Cotton Number of countries with exports share <2%	2–5%	< 5%
2001	65.3	87	7	4	61.2	63	3	5	61.3	101	5	4	75.6	141	8	5	81.7	163	10	4
2002	71.1	116	5	5	64.7	72	4	6	61.9	109	5	4	76.4	125	5	7	82.0	161	12	3
2003	63.8	104	8	4	66.3	78	4	6	62.3	105	5	5	77.1	133	9	6	81.8	155	13	3
2004	67.0	107	7	3	70.8	82	5	6	62.7	88	4	6	77.5	131	8	6	80.7	154	12	3
2005	67.4	109	4	5	70.5	70	5	7	65.9	84	6	6	77.6	122	9	6	79.8	151	9	4
2006	70.9	112	7	5	73.4	70	5	7	69.3	93	5	6	78.8	134	10	6	74.7	149	11	4
2007	70.6	116	5	5	74.2	63	4	8	71.5	96	6	6	78.4	138	6	6	73.5	154	7	4
2008	66.6	117	5	4	70.1	62	5	7	72.5	89	9	5	79.2	139	8	6	73.7	153	7	3
2009	62.7	106	5	4	68.2	68	5	6	74.4	82	10	5	79.5	132	9	6	74.4	153	8	3
2010	62.9	112	3	5	72.9	68	6	8	71.8	93	7	6	79.4	130	9	6	64.9	156	10	2
2011	72.7	137	7	5	67.3	61	8	5	70.3	102	8	5	79.8	147	8	5	61.0	153	5	2
2012	79.1	139	9	6	67.1	66	6	6	70.9	103	7	5	80.2	148	12	3	54.2	160	5	2
2013	73.7	141	8	5	56.4	59	6	5	65.1	103	10	3	80.1	150	10	4	54.0	163	5	2
2014	75.9	139	11	4	51.6	58	4	5	64.4	102	8	3	80.1	144	9	5	62.1	164	4	3
2015	75.5	144	9	4	52.1	57	5	5	63.9	100	10	3	79.2	141	8	5	64.0	162	4	3
2016	76.3	143	8	5	49.3	52	4	5	61.1	99	8	3	79.3	125	5	7	67.2	162	6	3
2017	77.6	141	10	5	43.5	57	5	3	57.5	99	7	3	78.6	133	9	6	67.5	159	5	4
2018	75.2	148	8	5	49.6	63	6	3	60.9	111	4	5	79.4	131	8	6	66.3	161	4	4

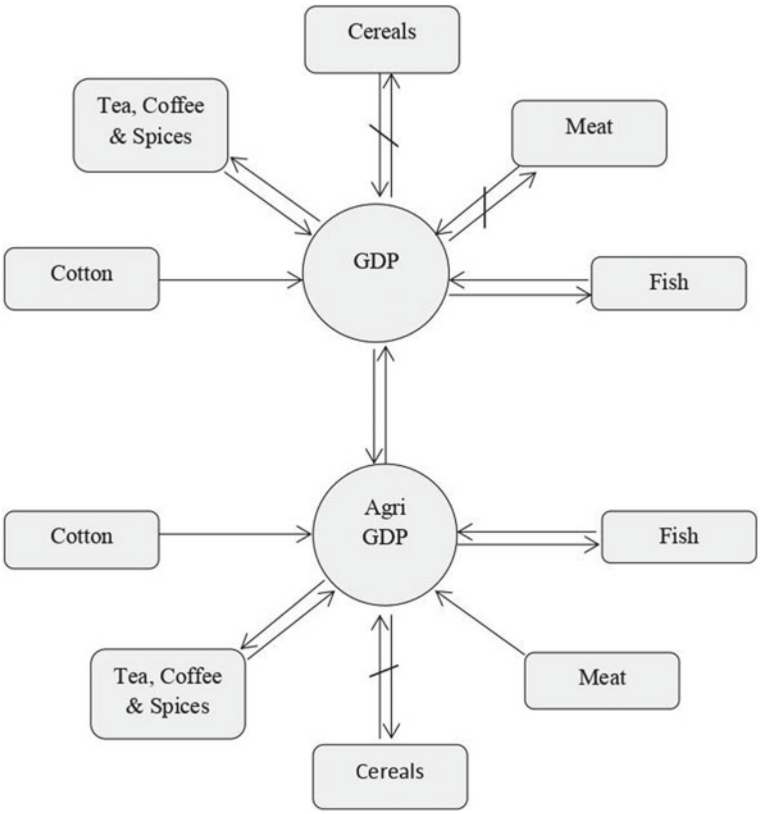

Fig. 4 Granger causality in commodity exports and agricultural growth (obs = 28)

7 Conclusions and Way Forward

Indian agricultural exports have undergone significant changes during the recent times. The study examined the trends and composition of agricultural exports, export performance and established the linkages between the economic growth and agricultural exports. Cotton and cereals have been the major contributors in agriculture exports. Also, the share of meat and edible meat offals has consistently increased during 2001–2018. Furthermore, an analyses of export performance for various commodity groups during 2011–14 and 2015–18 found only cotton (HS 52) as "Competitive" commodity. The export performance of meat and edible meat offal improved significantly from being "Uncompetitive (−0.01)" during 2011–14 to being "Weakly Competitive (0.06)" during 2015–18. Impulse response function was applied to quantify the responsiveness of agricultural GDP to export of different agricultural commodities. The Impulse response analysis indicated that a positive shock in cotton export will lead to a rise in agricultural GDP; the effects of a shock in agricultural GDP will decay overtime. The results also suggest that response of

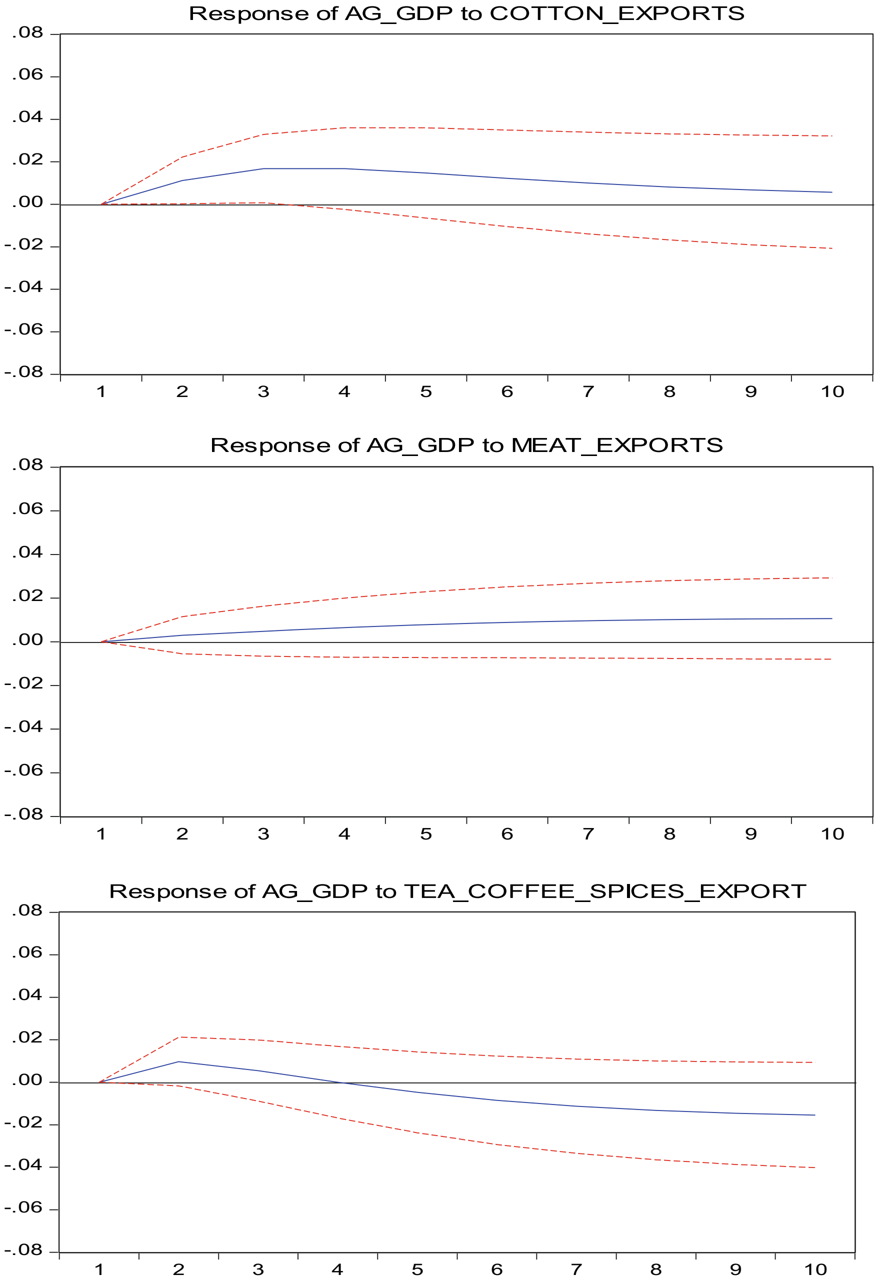

Fig. 5 Impulse response graphs for impact of shocks in exports on agricultural GDP

agricultural GDP to vegetable export positive shock will lead to increase in agriculture GDP with greater intensity as compared to meat, tea, coffee, spices and cotton export.

Agricultural sector in India faces various challenges such as stringent and ever changing global sanitary and phyto-sanitary standards, lack of adequate post-harvest infrastructure and logistics connectivity, etc. The country needs to focus on stable trade policy particularly in those commodities with greater trade potential. Also, the Sanitary and phytosanitary measures (SPS) should be taken care of strictly adhering to the International standards to prevent their negative impact on India's agricultural exports. The farmers need to be continuously sensitized about the changing trade regulations/environment and demand pattern. Export oriented production through development of clusters will help to make available sizeable volumes of identified produce to meet such requirements. These concerns need to be rightfully addressed through suitable interventions in production and postproduction phases, especially where focus clusters are being developed. Export oriented supply chains should be efficiently managed reducing the costs and making exports more competitive. With Government's focus to double agricultural exports and an Agricultural Export Policy in place, India needs to find effective solutions to become a global leader in agricultural exports too. Needless to say, effective logistic management and quality management is the need of the hour to strengthen global trade linkages.

Real time data on exports is the need of the hour. The country needs to tap the regional/local potential for export enhancement. The regional/state/local level information will be instrumental in making state export promotion policies, cluster identification, creating suitable infrastructure and addressing traceability issues. Commodity outlooks and market intelligence hold the key to success. As trade environment is highly dynamic, one currently needs to study the changes and carry out the required diagnostics. Appropriate diagnostics will help in the selection of right markets, appropriate segmentation, positioning, and targeting, and will also facilitate relevant market linkages and regional crop planning exercises too. Market intelligence would require market surveillance and monitoring of complete trade environment including trade agreements, demand pattern, regulations and certification requirements.

Appendix

List of Commodities Covered in Agriculture

HS-2 digit code	Description
01	Live animals
02	Meat and edible meat offal
03	Fish and crustaceans, molluscs and other aquatic invertebrates

(continued)

(continued)

HS-2 digit code	Description
04	Dairy produce; birds' eggs; natural honey; edible products of animal origin, not elsewhere spee or included
05	Products of animal origin, not elsewhere specified or included
06	Live trees and other plants; bulbs, roots and the like; cut flowers and ornamental foliage
07	Edible vegetables and certain roots and tubers
08	Edible fruit and nuts; peel of citrus fruit or melons
09	Coffee, tea, maté and spices
10	Cereals
12	Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit; industrial or medicinal plants; straw and fodder
13	Lac; gums, resins and other vegetable saps and extracts
14	Vegetable plaiting materials; vegetable products not elsewhere specified or included
15	Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes
16	Preparations of meat, of fish or of crustaceans, molluscs or other aquatic invertebrates
17	Sugars and sugar confectionery
19	Preparations of cereals, flour, starch or milk; pastrycooks' products
20	Preparations of vegetables, fruit, nuts or other parts of plants
21	Miscellaneous edible preparations
24	Tobacco and manufactured tobacco substitutes
41	Raw hides and skins (other than furskins) and leather
51	Wool, fine or coarse animal hair; horsehair yarn and woven fabric
52	Cotton
53	Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn

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HS-2 digit code	Description
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03	Fish and crustaceans, molluscs and other aquatic invertebrates
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05	Products of animal origin, not elsewhere specified or included
06	Live trees and other plants; bulbs, roots and the like; cut flowers and ornamental foliage
07	Edible vegetables and certain roots and tubers
08	Edible fruit and nuts; peel of citrus fruit or melons
09	Coffee, tea, maté and spices
10	Cereals
12	Oil seeds and oleaginous fruits; miscellaneous grains, seeds and fruit; industrial or medicinal plants; straw and fodder
13	Lac; gums, resins and other vegetable saps and extracts
14	Vegetable plaiting materials; vegetable products not elsewhere specified or included
15	Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes
16	Preparations of meat, of fish or of crustaceans, molluscs or other aquatic invertebrates
17	Sugars and sugar confectionery
19	Preparations of cereals, flour, starch or milk; pastrycooks' products
20	Preparations of vegetables, fruit, nuts or other parts of plants
21	Miscellaneous edible preparations
24	Tobacco and manufactured tobacco substitutes

(continued)

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(continued)

HS-2 digit code	Description
41	Raw hides and skins (other than furskins) and leather
51	Wool, fine or coarse animal hair; horsehair yarn and woven fabric
52	Cotton
53	Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn