AGRICULTURE INNOVATION SYSTEMS IN ASIA

TOWARDS INCLUSIVE RURAL DEVELOPMENT

Edited by
Lakhwinder Singh and Anita Gill

Agriculture Innovation Systems in Asia

This book looks at agricultural systems and rural economies in Asia through the prism of alternative innovation systems, alternative public policy and institutional changes.

The massive shifts within the agricultural economy in Asia, geared towards increasing production, has had a direct effect on the livelihood of a large mass of people in rural societies, causing financial and social distress. This book explores a wide range of solutions, such as the role of education, improving technical skills and human capital, along with interactive learning in R&D, harnessing ICTs and institutional innovations, to see how these problems can be alleviated. The volume looks at how these methods can help formulate alternative ways to build sustainable and inclusive agricultural societies, ensure food security, sustainable growth and agricultural productivity.

This book, rich in theoretical and empirical matter, will be useful for academics and researchers interested in agricultural innovation, development studies and agricultural economics. It will also be of interest to policymakers and thinktanks working towards inclusive social development and sustainability in Asia and the Indian subcontinent.

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2020
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
52 Vanderbilt Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Names: Singh, Lakhwinder, editor.
Title: Agriculture innovation systems in Asia : towards inclusive rural development / edited by Lakhwinder Singh and Anita Gill.
Description: Milton Park, Abingdon, Oxon ; New York : Routledge, 2020. | Includes bibliographical references and index.
Subjects: LCSH: Agricultural innovations—Asia. | Rural development.
Classification: LCC S494.5.I5 A3269 2020 (print) | LCC S494.5.I5 (ebook) | DDC 338.1/6095—dc23
LC record available at https://lccn.loc.gov/2019028322
LC ebook record available at https://lccn.loc.gov/2019028323

ISBN: 978-0-367-14666-5 (hbk)
ISBN: 978-0-429-26409-2 (ebk)

Typeset in Sabon
by Apex CoVantage, LLC

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Foreword

I come from a Punjabi farming family, and in many ways I'm a product of the Green Revolution. Growing up in India in the 1960s and 1970s, agriculture was a big part of my early life. I spent several years on a poultry farm near Jalandhar, every summer in a more remote village in Hoshiarpur and, less frequently, a few weeks on a farm near the foothills of Uttar Pradesh. In the evenings, we kids would wait impatiently for the radio talk on farming techniques – magic seeds, newfangled fertilizers, deadly pesticides and other developments that seemed oddly exciting to farmers – to end, so we could finally listen to songs and sports. When television came, the waiting became even harder.

Though I didn't know it at the time, a miracle was unfolding around us. Within a couple of decades after the devastation of Partition, Greater Punjab – Pakistani and Indian Punjab, Haryana and Himachal Pradesh – became the most prosperous region on the Indian subcontinent. Some of the changes were obvious even to a child: every day, oxen were replaced by tractors, carts by trucks and trailers and wells by tube wells. For the first time, children weren't needed on farms, so – sometimes for the first time – they were sent to schools. But the real miracle was almost invisible. In one of the most conflict-ridden and poor parts of the world, farmers, scientists and engineers were waging one of the most successful wars on poverty. Punjabis were soon producing enough to feed not just themselves but many others in poorer parts of India.

It was a miracle, but it was not unprecedented. Actually, something similar had happened in the 1940s and 1950s in the United States. Indeed, Green Revolution technologies were largely the brainchildren of US farmers, scientists, and engineers. In the 1960s and 1970s, they were transported, tested, adapted, applied, and extended across North India, almost always with US assistance.

The miracle had unfolded before my eyes, but I hadn't noticed. It was only decades later that I realized what I had lived through as a child, and only by accident. In 2015, somewhat foolishly, Jim Yong Kim, the president

of the World Bank, asked me to come up with a plan to end extreme poverty by 2030. The world still had a billion people living on the equivalent of less than US$1.90 a day, and in Africa and parts of Asia the number was still growing. Ending poverty by 2030 meant helping about 100 million people escape destitution – every year for the next 15 years.

From the poverty statistics collected by my colleagues at the World Bank, the only part of the world that had done anything like this was East Asia. So it made sense to study what countries like China, Indonesia, Malaysia, South Korea, Taiwan and Thailand had done. We wrote it all up in a paper titled "Grow, Invest, Insure: A Game Plan to End Extreme Poverty by 2030." It took us more than 50 pages to document what separates success from failure but, with Jim Kim's encouragement, I distilled it down to just three words: *grow, invest, insure*. The most important part of the strategy is that

> economies grow in ways that raise the labor incomes of the poor. This means increasing labor productivity in agriculture, which employs a large fraction of the poor. It means investing in the right infrastructure to support labor-intensive growth. And it means opening up to trade to make sure countries build on their strengths and use their resources efficiently.

During my visits to India since then, it was natural to reflect on whether poverty reduction in North India had happened in the same ways and at similar speeds as it had in East Asia. The answer is both yes and no. In the 1960s and 1970s, states like Punjab instituted many of the policies and made many of investments that East Asia was making. But in the 1980s, Punjab abandoned what was so obviously a winning game plan. It was not alone; other parts of India and Pakistan seemed inexplicably to do the same. Agricultural innovation had led people out of poverty, but progress in the region stalled well short of a broadly shared prosperity.

To understand why this happened, this collection of chapters put together by Professors Lakhwinder Singh and Anita Gill is a good place to start. The first set of chapters, written by experts in their fields, describe the features of agricultural innovation systems in Asia that are likely to lead to productive, efficient and sustainable farming practices both in conventional and plantation agriculture. The next group of chapters looks at the role of the private sector in agricultural innovation – in research, science and technology, and through franchising and similar arrangements. The third set of chapters drills down on the progress and promise of agriculture in Punjab, all now jeopardized by distortions in policy. Together they make a comprehensive set of readings for anyone who wishes to understand why Asian agriculture has stopped short of its potential and what it will take to realize it.

The volume suggests that Asian agriculture will not soon get to the levels of productivity and resource efficiency attained by US farmers unless governments address the distorted incentives facing farmers, the deficits in infrastructure investments, and the imbalances between frontier innovation and adaptation. The key, it appears, is to institute arrangements that both reflect the lessons learned from successes and failures of governments around the world and leverage the resources of the private sector. Appreciating the roles of both the public and private sectors can help Asia's farms quickly become productive, rural communities more vibrant and economies both structurally dynamic and resource efficient.

I visit India regularly and Punjab often; someday I even hope to visit Pakistani Punjab. It was during one of these trips that I met Professor Lakhwinder Singh and his colleagues at Punjabi University in Patiala. I felt both pride and pain upon hearing about their work and the problems facing my province and our country – pride because Punjabis have found ways to strive and succeed, and pain because I have not helped India at all, despite working in international development all my life. As I read the chapters in this volume, the pride grew and – in spite of the problems they describe – the pain subsided. I urge you to read them all.

Indermit Singh Gill, PhD
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6 May 2019

Preface

The agriculture sector has been undergoing a transformational change. The flow of technologies is making agriculture production increasingly more capital intensive. The recent technological innovations and information technology and its applications in agriculture sector are making agriculture skill and knowledge intensive. This dramatic change requires simultaneous development of capabilities both of the individuals working on the farms and institutions of generating and disseminating of knowledge for agriculture production, processing and marketing. The agriculture sector in developing countries is the mainstay of the poor who do not possess skills and knowledge capabilities, and institutions do not deliver usable innovations for them. The process of production, processing and marketing are turning more complex day by day and are connected to the global value chain. Thus, the relatively poor, in terms of skills and resource base, are increasingly facing exclusion. Another transformation that has been generating exclusionary tendencies in the countryside across developing countries is the science- and technology-based agriculture innovations are moving from publicly funded institutions to private corporate profit-based innovations, either making the portable knowledge more expensive or denying access to the poor. The increasing exposure of small and marginal farmers to market with fluctuating prices, especially when bumper crops are harvested, do not allow the tiny farmers to recover the cost of cultivation. This has caused the marginalized section of society to choose to leave non-remunerative occupation without providing any alternative remunerative occupation for a decent livelihood. On the one hand, the surplus workforce does not possess a skill base to be used adjusting in the job market, neither in the other sectors (service sector) in urban locations, nor are the agriculture and allied sector activities expanding at a rate that can absorb such people. This is nothing but a poverty trap. An alternative development process is required so that the agriculture production, processing and marketing can be integrated while creating a suitable institutional arrangement for the upward mobility of the workforce. This requires us to generate

learning capabilities and surplus-generated needs reinvestment and institutional framework that develop cooperative values. A suitable mix of bottom-up and top-down approaches in innovations may be in order. The agriculture innovation system approach is expected to provide long overdue solutions to the exclusionary tendencies enshrined in the ongoing agriculture development process.

Keeping in view to search for an alternative approach to leapfrog from the current tendencies of workforce dependent on agriculture for livelihood to fall in the poverty trap, a three-days IndiaLics international conference on the theme "Systems of Innovation for Inclusive Agriculture and Rural Development" was organized by the Centre for Development Economics and Innovation Studies (CDEIS), Punjabi University, Patiala, in July 2015. At this conference the scholars working in the areas of agriculture and rural development, with a perspective of inclusive growth from all parts of globe and India, participated and presented their research articles. Each research paper was assigned a discussant for providing feedback to revise the papers; revised papers were again sent to the blind reviewer to determine the suitability and quality of the research papers. Final research papers presented in this volume were selected while following a rigorous referee system.

During this period, a substantial amount of financial and intellectual support was required, which was generously rendered by several individuals and institutions. First of all, we are grateful to chapter writers for their patience, in terms of carrying out revisions and delivering them on time. Intellectual and organizational support was provided by our senior colleagues, especially Professors Inderjeet Singh Sidhu, Sukhwinder Singh, Jaswinder Singh Brar, Kesar Singh Bhangoo, Parmod Kumar Agarwal, Anupma Uppal and Rakesh Kumar Khuranna and our research students Monica Thind, Deepika Chawla and Manjinder Kaur. They all deserve appreciation and heartiest thanks. Some international participants such as Professor Mammo Muchie participated in the conference and contributed in many ways to this volume, but missed coming on board. We thank him from the core of our heart.

No project is successful without generous financial support and administrative help. We are grateful to Dr. Dipinder Singh and Mr. Parveen Thind, senior IAS officers with the Government of Punjab, for providing both. The organization of the conference and bringing out an edited volume out of it required a sustained and committed secretariat support, and we are very fortunate to have it from Mr. Baltej Singh Bhathal and Mr. Gurdeep Singh of the CDEIS. They deserve more than our plain thanks. Lastly, we express our gratitude to Punjab Mandi Board and NABARD for providing financial support. The contributions in the volume strive to provide a system of innovative perspectives to achieve inclusive rural development, and it is hoped that the volume will

initiate debate and discussion among academics and public policymakers for improving the livelihood of the people at the margins in developing countries.

Lakhwinder Singh
Anita Gill
8 May 2019

Abbreviations

AAP	Aam Aadmi Party
AAR	Annual Administrative Reports
AICRP	All India Coordinated Research Project
AIS	Agriculture Innovation Systems
AKIS	agriculture knowledge and information system
AMSC	Agro-Machinery Service Centre
APEDA	Agricultural and Processed Food Products Export Development Authority
APMC	Agricultural Produce Market Committee
ARMIS	Agricultural Resource Management Information System
ASR	Annual Scientific Report
AU	agricultural university
BCMKV	Bhuvi-care Mahindra Krishi Vihar
BJP	Bharatiya Janata Party
CAF	Central Africa
CAM	Central America
CDP	Community Development Project
CERD	Centre for Ecology and Rural Development
CFC	Common Fund for Commodities
CGIAR	Consultative Group on International Agriculture Research
COCO	company owned–company operated
CSIR	Council of Scientific and Industrial Research
CSKHPAU	Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University
DAP	diammonium phosphate
EAF	East Africa
EIR	Economic Incentive and Institutional Regime
EPW	*Economic and Political Weekly*
FAO	Food and Agriculture Organization
GDP	gross domestic product
GDPRD	Global Donor Platform for Rural Development

GLASOD	Global Assessment of Soil Degradation Guidelines
GM	genetically modified
GNI	gross national income
HAPPRC	High Altitude Plant Physiology Research Centre
HAU	Haryana Agriculture University
HHDI	Herfindahl-Hirschman Diversity Index
HLD	Higher Livelihood Diversification
HPAU	Himachal Pradesh University
HRD	Human Resource Development
HRDS	Human Resource Development Survey
ICAR	Indian Council of Agriculture Research
ICT	Information and Communications Technology
IFFCO	Indian Farmers Fertiliser Cooperative Limited
ILO	International Labour Organization
INGO	International Non-governmental Organization
IPC	International Patent Classification
IPM	Integrated Pest Management
IPR	Intellectual Property Rights
IRDP	Integrated Rural Development Programme
IRRDB	International Rubber Research and Development Board
ISRO	Indian Space Research Organisation
ITA	Indian Tea Association
ITGIC	Indian Farmers Fertilizer Co-operative (IFFCO)—Tokio insurance group in Japan
IT	information technology
KEI	Knowledge Economy Index
KFL	Kohinoor Food Ltd
LLD	Lesser Livelihood Diversification
LSAC	London Scientific Advisory Committee
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MRL	maximum residue limit
MSAMB	Maharashtra State Agricultural Marketing Board
MSP	minimum support price
MSSL	Mahindra Shubhlabh Services Limited
MSSRF	M. S. Swaminathan Research Foundation
MUF	multi-user franchises
MV	modern variety
NABARD	National Bank for Agriculture and Rural Development
NAEAC	National Agricultural Educational Accreditation Council
NAEP	National Agricultural Education Project
NAFED	National Agricultural Cooperative Marketing Federation of India Ltd
NAM	North America

NARS	National Agriculture Research System
NCDC	National Co-operative Development Corporation
NGO	non-governmental organization
NHB	National Horticulture Board
NSDP	net state domestic product
NSI	national system of innovation
NSSO	National Sample Survey Office
ODID	Oxford Department of International Development
OECD	Organisation for Economic Co-operation and Development
OPHI	Oxford Poverty and Human Development Initiative
OTC	OECD Technology Concordance
PACS	Primary Agricultural Co-operative Societies
PARC	Pakistan Agricultural Research Council
PAU	Punjab Agricultural University
PBR	plant breeders' rights
PC	producer company
PPP	purchasing power parity
PPS	public-private partnerships
PRI	Panchayati Raj Institution
PSM	Peoples' Science Movement
QEH	Queen Elizabeth House
R&D	research and development
RC	Radhakrishnan Commission
RKKs	Rallis' Kisan Kendras
RPD	Rubber Plantation Development
RPDS	Rubber Plantation Development Scheme
RRII	Rubber Research Institute of India
RSP	Rural Support Programme
RSPN	Rural Support Program Network
SAC	Scientific Advisory Committee
SAM	South America
SAPPL	Sidhhivinayak Agri Processing Private Limited
SAU	State Agriculture University
SCA	South Central Asia
SCM	supply chain management
SCPS	Social Capital and Poverty Survey
SEA	Southeast Asia
SGSY	Swaranjayanti Gram Swarozgar Yojana
SHG	self-help group
STI	science, technology and innovation
SUF	single-user franchises
TKS	Tata Kisan Sansar
TRA	Tea Research Association
TRF	Tea Research Foundation

TTRI	Tocklai Tea Research Institute
UOCB	Uttarakhand Organic Commodity Board
US	United States
UT	Union Territory
VKC	Village Knowledge Centre
VRC	Village Resource Centre
WAF	West Africa
WE	Western Europe

Chapter 1

Agriculture innovation system for inclusive rural development in Asia

An introduction

Lakhwinder Singh and Anita Gill

The global economy is undergoing a fast transformation. The emergence of new technologies is further facilitating the process of this transformation. The consequence of this is the rapid changes that are taking place within and across sectors of the economy. Studies conducted by various scholars help us to understand the process of long-term structural change and the underlined factors that determine the transformation in the industrially advanced countries of the world. The long-run changes that emerged from such studies are a continuous decline in the importance of the agriculture sector in the economy and the emergence of a dynamic industrial sector as an engine of economic growth of the economy. However, the services sector over a long period of time maintained its position at best (Kuznets, 1966). Another feature of this transformation was a somewhat similar decline in the workforce structure of the economy with a time lag. It is important to note that institutional changes facilitated this transition and any obstruction that occurred during the process was mediated by the state for realization of the full potential of epochal innovation.

The newly industrializing countries of East Asia have in recent times followed the classical structural transformation process and very successfully reached (in a relatively short period of time) a level of per capita income equal to that of the industrially advanced countries of the world. However, the sectoral income structure and workforce structure of newly industrializing countries have resembled industrially advanced countries. But the rest of the world (sub-Saharan Africa, South Asia and other developing countries) is predominantly services oriented. The income structure is largely driven by the services sector of their economies but the major proportion of the workforce continues to depend on the agriculture sector. The workforce data of ILO (2018) revealed that 26.5 per cent of the workforce of the global economy was engaged in the agriculture sector, but this workforce was 68.9 per cent in low-income countries in 2017. In Asian and Pacific countries, agriculture accounts for 28.5 per cent of the workforce. In South Asian countries, the agriculture sector was carrying 42 per cent of the total workforce. The dependency of the workforce on agriculture in Africa is as

large as 53 per cent. Two Asian giants (China and India) employed a workforce on the order of 17.5 per cent and 42.7 per cent, respectively, in the agriculture sector in 2017. This clearly brings out the fact that the agriculture sector, from the point of view of the workforce engaged in this sector, is still of prime importance.

When we compare the share of gross domestic product generated by the agriculture sector, it is evident that those countries that had observed the classical pattern of structural transformation maintained the right kind of balance between the workforce structure and output structure. However, low-income countries have a very high workforce structure dependent on the agriculture sector but their output structure shows a very low share (30 per cent). This is amply evident when we look at the GDP shares of agriculture sector in the countries of South Asia (18 per cent) and sub-Saharan Africa (30 per cent). In two emerging Asian countries, China and India, the income share of the agriculture sector in their respective economies are 9 per cent and 17 per cent, respectively (World Bank, 2017). The gap between the workforce structure and the income/output structure is quite large, and this has initiated the process of pauperization of the people living in the countryside. When we combine the mismatch of the production and workforce structure with human capital indicators, it is amply clear that exclusion of a variety of natures is rampant and intensifying over time in the rural economies of developing countries in general and South Asia in particular (Dreze and Sen, 2013). Therefore, it is most significant and urgent to bring out the process of exclusion that has been enshrined in the nature of recent economic transformation with a view towards altering this process to make the development process more inclusive. The recent developments in the economic theory of innovation system claims to provide such alternative processes of economic transformation that have the capacity to create an environment of inclusive and harmonious economic development (Lundvall et al., 2009).

The origin of the systems of innovation approach goes back to Friedrich List (1842), who coined the idea of a "national system of production." For the first time, Christopher Freeman (1982) developed the concept of a national innovation system based on the premises of Friedrich List to examine how countries build knowledge and knowledge-related institutional arrangements at the national level with the goal of promoting economic development and international competitiveness. The early literature on the national innovation system that emerged in the late 1980s and early 1990s (Freeman, 1987; Lundvall, 1992; Nelson, 1993) developed the idea of network of institutions engaged in generation and diffusion of technological knowledge that make economic actors of production more capable of increasingly supplying new goods and services. These innovative capabilities are developed by interaction among the economic actors of production and are very much rooted within the national borders. In the national

innovation system, the state played an important role to develop a basic infrastructure for generation, use and diffusion of technologies, and devising strategies for the overall economic direction of the economy. Several studies challenged this view of the innovation system and postulated an alternative idea of a learning system (Viotti, 2002; Mathews, 1999). It is argued that the innovation system is based in small developed countries, and firms introduce innovations that are new to the world. However, the learning system implies that developing countries use the knowledge developed by the advanced countries and adapt it to local conditions; this unleashes the process of diffusion and learning while making incremental innovations. These studies inspired research work at the regional (Asheim and Gertler, 2004) and sectoral levels (Malerba, 2004). The innovation system approach to understanding the economic development process, strategy and development policy is in its infancy and is largely concerned with firms as economic actors to generate, use and diffuse technological knowledge and interact within the institutional arrangements of a nation state. Thus, the system of innovation approach has neglected the most important sector of the developing economy – agriculture – where the livelihood and welfare of the people living in the countryside are concerned.

Agriculture innovation and development has undergone substantial changes over time. The origin of agriculture experimentation research stations and research laboratories happened around the middle of the 19th century, when the German government established 74 experimentation stations. The US model of national agriculture research and the extension system was based on the German model of agriculture innovations. Agriculture research stations were established in the early 1920s in the United States, and from the mid-1920s through the mid-1960s, the US agriculture research and extension system remained almost essentially unchanged (Ruttan, 2001). It was geared towards generating knowledge and diffusing technologies that enhance production. The major criticism of this system came from resource depletion and environmental sustainability. It was argued that the public agriculture research system of the United States has ignored the interests of farmers and consumers but has served business interests well. However, the US system of agriculture research and extension has remained a source of new knowledge and new technology for agriculture development. CGIAR was established for the diffusion of agriculture new knowledge and new technologies to developing countries for solving the problem of deficiency and food insecurity in the post–World War II period. The technology transfer was difficult due to topographical variations and diversity of soil conditions across regions; thus the emphasis shifted from mere transfer of technology to establishment of a science, technology and innovation system in developing countries. The agriculture research and extension system mainly emulated the US system and this science, technology and innovation system was directed to increase production and productivity for solving

food insecurity in developing countries. However, due to conducive conditions generated by the institutional arrangements and suitable climatic and soil conditions, the Green Revolution flourished in Asia. The critics have argued that the linear model of agriculture research, technology and the innovation extension system developed technologies inappropriate to social, physical and economic settings of the circumstances of the stakeholders (Hall, 2007a; Raina et al., 2014).

The literature on agriculture innovation development has recorded three sets of distinct streams: a classical national agriculture research system (NARS), an agriculture knowledge and information system (AKIS) and an agriculture innovation system (AIS). These three streams describe different modes of innovation capacity building but acknowledge the additive nature of these ideas. However, the latter two approaches emphasize interactive learning. In fact, the agriculture innovation system approach combines NARS and AKIS, and in addition to that it strengthens linkages and interaction and institutional developments to support interactions, learning and innovation and enabling a policy environment. It has been emphasized that to ensure learning and interaction among actors, the role of public sector is crucial and the market alone will not serve the purpose (Hall, 2007b). The agriculture innovation system in Asia has evolved over time but suffers from a linear approach which resulted in several problems. Apart from environmental sustainability, the exclusionary tendencies are enshrined in the process of the production system. Therefore, it has entered into a severe crisis, with small and marginal farmers finding it difficult to survive, and many have resorted to committing suicide (Singh et al., 2016). It also suffers from inadequate investment resources in R&D, lacks capabilities to promote required interaction and has limited reach and access to new knowledge and information technologies. The lack of institutional support and interaction results in non-viability of small and marginal farmers, and thus they are facing exclusion. Therefore, it is of utmost importance to bring these issues to the fore. The chapters that follow systematically examine the processes and suggest measures, including public policy, that have the capacity to mitigate such tendencies. The holistic approach is adopted by the studies to develop some alternative thinking to agriculture innovation, development and public policy.

Leonardo A. Lanzona, in "Knowledge Economy for Inclusive and Sustainable Agriculture" (Chapter 2), presents a holistic analysis of the use of the knowledge economy to achieve inclusive and sustainable agriculture development among developing countries. He has argued that there is a tendency towards shrinking the size of holdings and a majority of farming households are engaged in small-scale farming. The poor and small-sized farm households are engaged in subsistence farming, and their individual capacity to enter into global value chains is limited. The author has developed a theoretical model for using the knowledge economy for the benefit

of the small farm sector in the developing countries. He has developed the perspective of a national innovation system that allows the development of knowledge both by the science and technology-based system of innovation and interaction of users in an institutional framework. However, he has argued that developing countries spend very little on developing agriculture knowledge, and institutional arrangements are rather weak. The weak system of innovation and technical knowledge for agriculture development in the developing countries is identified by the author; he contemplates that to harness advantages in the era of knowledge economy and globalization, the developing countries should emphasize development of human capital. One pillar of human capital is education and technical skills. The author has emphasized quality of education and skill formation of the poor and small farmers of developing countries to achieve inclusive and sustainable development. Furthermore, the empirical evidence from Southeast Asia and Central Asia are compared with other advanced countries to point out how developing countries can overcome the weaknesses of the knowledge system for attaining inclusive and sustainable development. It is argued by the author that participation of the poor and small agriculture holders in global value chains is difficult in the current scenario, but he provides alternative thinking and viable options as to how small agriculture holders can participate in global value chains. He has suggested that the quality of education and social capital can allow small agriculture holders to form collectives and take advantage of the knowledge economy to develop their products, processes and social innovation for inventing their own value chains. For achieving this, he has suggested massive investment in the system of innovation by the nation.

In an empirical study, "Farmers' Awareness, Perceptions and Knowledge Gaps: Looking for Innovations in Agriculture Extension," Kamal Vatta and Garima Taneja (Chapter 3) have examined the awareness and perception of farmers about the agriculture extension system. The major attempt of the authors is to identify the knowledge gaps between the producers and users of the agriculture innovation and extension system. Scientific agriculture innovations and the extension system have concentrated on producing an increasing quantity of foodgrains while using natural resources intensively, without taking into consideration the long-term sustainability. The study is based on primary data collected from Asia's most successful Green Revolution belt – the Indian state of Punjab. It covers 2,083 farmers spread over 11 districts and all categories of farmers such as small and marginal, semi-medium, medium and large farmers in the year 2013. The authors examined the level of awareness and major challenges being faced by Punjab farmers in accessing scientific knowledge related to the production of major crops. The chapter further explores their perceptions on ill effects of intensive farming and threats of climate change. The results indicate that despite high awareness of the ill effects of intensive agriculture and their causes, the

farmers lack awareness of potential solutions for addressing these problems. The major finding that emerged from the data analysis is that access to a more scientific and better recommended set of production practices of major crops was very low and that had adversely affected the effectiveness of farm operations. The authors are of the view that the agricultural innovation extension system can be strengthened if the use of ICT in agriculture can play an important role. In this respect, the authors proposed the role of various options including web portals, mobile applications and bulk messaging services that can enhance the effectiveness of the traditional approaches of extension education. Furthermore, the study highlights the set of information which can be routed more effectively through the innovative extension tools that can add value to the farmers' decisions. The implication of all the suggestions made by the authors brings out the fact that public investment in agriculture innovation and extension system assumes great importance.

The key role played by innovations in the development of agriculture has been well augmented in the literature. However, their role in plantation agriculture in particular has been highlighted by Namrata Thapa and K. J. Joseph in Chapter 4, titled "Interactive Learning, Innovation and Performance: A Comparative Analysis of Natural Rubber and Tea." Their logic is that institutional arrangements in plantation agriculture are different from those of general agriculture. This, combined with changing production conditions and trading environment, necessitates a separate analysis of research and extension system in plantation crops. Equally, or rather more important, is the issue of the drivers of innovation – the research institutes and growers – and the relative role played by them in driving the interactive learning process for fostering innovation. Thapa and Joseph have focused on this issue by examining two plantation crops: tea and natural rubber. For tea, the discussion centres on the research activities undertaken by the Tocklai Tea Research Institute (TTRI) for the North Indian tea plantation. For natural rubber, it is the Rubber Research Institute of India (RRII), the only organization that is undertaking R&D activities in natural rubber. The two plantation crops have contracting institutional arrangements: while large growers were involved in the R&D committees in the case of TTRI, suggesting strong interaction between scientists and growers, there was a dominance of small growers in the case of rubber, suggestive of their rather negligible role in the R&D activities of the central government–run RRII. The authors examine the interactive learning process, viewed as a prerequisite for innovation, in the context of interaction of TTRI and RRII with planters and growers. In case of TTRI, although it was undertaking collaborative research work with foreign universities, there was a near absence of collaboration with research institutes. Interaction with planters, in the form of Area Scientific Committee meetings, training-cum-demonstrations and advisory visits, has more or less revealed a downward trend. Moreover, inadequate funding and the resulting cuts in manpower are manifested in

the system's inability to interact with small growers and address their specific needs.

Interaction of RRII with research institutes and universities indicated close interaction with the knowledge generating institutes. Interaction with growers in the form of contact and training programmes showed a downward trend since 2009–10. Interaction in the form of Rubber Producer Societies, however, seemed to be on the path of revival in recent years. The authors have also examined the research effort in terms of financial resources and human resources engaged in research and extension for tea and rubber, In the case of tea, the institute displayed lacklustre performance in terms of raising own resources but was able to conduct long-term research activities mainly due to externally funded projects. For rubber, major funding came in the form of budgetary support from the Government of India. However, the share of rubber research in the total plan fluctuated sharply and registered a fall over the period 2001–02 to 2013–14.

There was also a drastic fall in total manpower employed in TTRI, although the number of scientists employed grew. However, in the case of rubber, the proportion of manpower engaged in research to total manpower at the Rubber Board remained almost the same. Further, R&D expenditure per worker employed in TTRI was around twice that in RRII.

Results on research outcomes revealed that in the case of tea, meaningful research on a sustained basis has been undermined by lack of assured funding for research and a fall in manpower availability, with the result that despite evolving different clones overtime, the one evolved as far back as 1949 still dominated. Insignificant increase in productivity and limited research on tea processing were the other banes of the tea industry. In contrast, the grower-centric approach of RRII led to a successful integration of technological and organizational innovations. The growers were not only provided advisory services but also other income-generating activities. The research and extension system for rubber delivered better results compared to tea despite lower R&D intensity. However, for both TTRI and RRII, the authors highlight the need for scaling R&D and extension activities and also adequate financial support for the same.

The global agriculture innovation system is in transition. For a long period of time, the investment in the agriculture research and extension system was mainly incurred by the state across the board and relatively private investment has shown its presence in recent times. The dynamics and evolution of private agriculture research in innovation and extension system is the prime concern of scholars. Daniel K.N. Johnson has examined "Global Trends in Private Agriculture Research" (Chapter 5), the impact of private agricultural research on less developed countries' agriculture innovation and extension systems. The author has traced the origin of private agriculture research back to the 1980s and 1990s and especially its role in GM seed technologies. Among seed technologies, maize is the most important; 500

varieties in Latin America, 300 in Asia and 25 in Africa were provided by private companies. It is important to note that these varieties of maize are based on genetic material provided by publicly funded research. It is argued by the author that public investment played a complementary role in the success of private agriculture research.

The author shows the rising importance of private agricultural research and states that historically it was very small compared to its publicly funded counterpart. But now, it is by no means insignificant and a review of studies very clearly shows its importance at national and regional levels. In fact, private research has now outstripped public research at the global level, although that trend lags substantially in less developed nations. Moreover, there are striking differences in policy support across time and across nations (or even within nations). The author, after the review of recent literature on research output and intellectual property rights (IPR) protection by region, by industrial origin and by crop type, has underlined the increasing importance of private agriculture research. The author has cautioned that the private agriculture research is fundamentally governed by the profit motive and risk coverage. It is fundamentally dependent on public policy regarding regulation, intellectual property protection and generation of complementarities of education and skill base of the workforce. Therefore, it is suggested by the author that success of the private agriculture research is largely based on public policies that encourage firms to engage in agriculture research. Thus public investment in the agriculture innovation system is the precondition for private players to engage in agriculture research. He has also noted that the liberal policies of countries such as India and Thailand were helpful in allowing the participation of private firms in agriculture research.

The rise of information and communications technology (ICT) has reduced the cost of transmitting information across economic actors of production. The two emerging economies of China and India host the largest proportion of world's population, and thus agriculture sector plays an important role in providing a livelihood to workforce and food and other materials for development. In "Harnessing ICTs among Farm Households through Interactive Learning and Competence Building: Perspectives from India and China" (Chapter 6), Bibhunandini Das undertakes a comparative study of ICT intervention in the agriculture development of India and China. The author has examined the theoretical framework of the national innovation system and its suitability for an agriculture innovation system while emphasizing the institutional arrangements that facilitates the interaction and learning to building capabilities for the economic activities they are engaged in.

Bibhunandini Das has empirically analyzed how ICTs can be harnessed through interactive learning and competence building with the help of institutional interventions. To address the issue at hand, the study adopts a qualitative approach (focus group interviews) under a system of innovation

framework by undertaking two case studies in India and China. In India, the study discusses the role of the M. S. Swaminathan Research Foundation which facilitated the use of ICTs in a village in Odisha. In China, the village of Yuhang was selected to conduct focus group interviews with the help of the Department of Agriculture, which is the prime actor for ICT intervention in agriculture. The study found that institutional interventions play an important role in harnessing ICT use among agricultural farmers. The study revealed that even the poorest regions and farmers can benefit from ICT. The study reveals that institutional interventions changed both the agricultural sector and economic conditions of the farmers. The distinctive contribution of this study as claimed by the author is that the ICT intervention is mainly provided by the government in China, and platforms are created in a manner so that user and producer interact and learn from each other. The coverage is quite inclusive and benefits are spread to all involved in agriculture production. On the other hand, the Government of India is playing a relatively passive role in providing ICT-related agriculture extension services. The author suggested that to achieve inclusion, the Government of India may learn a public policy lesson from Chinese ICT interventions in the agriculture sector of the economy.

In Chapter 7, "Agriculture Innovation System and Productivity Growth across North Indian States," Anita Gill, Lakhwinder Singh and Rakesh Sharma examine the evolution of the agriculture innovation system and its spread across the globe. This study also highlights the nature and evolution of the agriculture innovation system of North India. During the early stages of the planning process, India faced food shortages and remained dependent on foreign supplies to fulfil the food supply needs of the population. Foreign dependence, in fact, derailed the developmental agenda of the Indian government and hence emphasis was shifted towards agricultural development to attain food security. The authors examine the transition of the agriculture innovation system of advanced countries over a long period of time and show how evolution occurred from private to public and again from public to private in recent times. However, it was noticed that at an early stage, private initiatives were supported by public investment in R&D and the extension system, and very recently again the private sector has emerged as a substantive player. During the phase of public sector dominance in the agriculture research and innovation system, the spread of these innovations took place in developing countries such as India. Among the various Indian regions, due to a supportive institutional system the Green Revolution succeeded only in North India. This has revolutionized agriculture productivity in two crops, that is, wheat and paddy. Gill, Singh and Sharma have thrown light on the progress of agriculture development of three states while comparing production, productivity and investment in research and development. There were glaring differences across three states examined in terms of output produced and investments made in research and the agriculture

innovation extension system. It is important to note from this study that the access to research output and extension services remained quite limited across farm categories. Smallholders have lagged far behind and this has generated exclusion. The system of agriculture innovation in North India has been organized in a manner to provide innovations in terms of developing new seed varieties that enhances productivity of food crops. Instead of diversification to become more inclusive, the public agriculture innovation is moving towards collapse, and the private sector has yet to take firm root. The presence of private players in the innovation system is exploitative and less effective. It is emphasized by the authors that the monoculture promoted by the current agriculture innovation system has generated severe environmental problems. This formidable challenge needs to be converted into opportunities to make it more sustainable and inclusive while changing the mode of investment that will focus on smallholders and environmentally friendly technologies. Thus, as suggested by the authors, to achieve this, a holistic approach towards development of agriculture innovation system by the state is badly needed.

Indian agriculture development started taking place when the developed countries of the world started moving towards warding off the adverse impact of modern agriculture. Thus the idea of ecological sustainable agriculture development was the core theme of public policy debates and discussions. Dinesh Abrol, in "Pathways for Sustainable Agricultural Transformation: Challenges before the Indian System of Science, Technology and Innovation" (Chapter 8), has analyzed the evolution of the agriculture development process and the system of science, technology and innovation. The author has presented the dynamics of chosen strategy for Indian agriculture development in relation to alternative pathways that were sustainable and inclusive. The agriculture science, technology and innovation system functioning under the Indian Council of Agriculture Research (ICAR) has mainly focused on an increase in foodgrain production. The STI system is engaged in innovations that are using higher doses of inputs such as chemical fertilizers, pesticides, insecticides and water, which has resulted in environmental degradation. The focus of the STI approach was mainly on influential farmers and neglected the needs of small and marginal farmers. Over a period of time, the STI public innovation system suffered from lack of investment and declining agricultural research and extension services. This top-down approach has not been able to accommodate the interaction of the users of the technology with the producers of technology. Thus the author has identified the major flaws in the functioning of the Indian agriculture science, technology and innovation system and its implications in terms of rampant exclusion of small and marginal farmers (they are the dominant group) and environmental degradation. Moreover, the agro-ecology is still on the margins of the mainstream research system. The increasing participation of multinational biotechnology corporate organizations is into the seed and other

input markets, and corporate farming that threatens the marginalization of small and marginal farmers. On the whole, the author points out that the emergence of large-scale monoculture has adversely affected biodiversity and sustainability. It is suggested by the author that there is a dire need to change the direction of STI to an innovation system where inclusion will be the main principle. For this it is recommended that a strong social movement is required to take forward agro-ecology to achieve balanced, sustainable and inclusive agriculture development.

It is widely recognized that Indian agriculture and smallholders are in dire straits. The crisis has evolved over a long period of time and its intensity has been increasing day by day. To address the crisis, there are several attempts both at the government and individual levels as well as by NGOs, and thus new innovations in institutions have occurred. One such unique development is institutional innovations to market farm produce with the aim to increase the share of the pie for smallholders. In this context, Sukhpal Singh examines the role of institutional innovations in achieving inclusive agricultural development. In Chapter 9, "Institutional Innovations for Inclusive Agricultural Development: A Case of Franchising in India," the author takes up the rationale for franchising in agri-business for smallholders as an alternative to other ways of reaching small farmers and/or linking them with markets. Franchising models have an edge over other modes of distribution channels. Analyzing various cases of franchising from the public (IFFCO and NAFED) and private (SAPPL, MSSL) sectors in a comparative perspective, and also the value of direct versus indirect franchising to access small farmers, the author concludes in favour of the SAPPL franchise model on the grounds that it is decentralized, does not rely on sub-franchises, has wider geographical coverage and does not ask for a minimum purchase. Also, direct franchising was found to work better, as the indirect franchising model failed. However, there are still some concerns regarding the benefits of franchising, which need to be addressed. The franchises need to go beyond their role of just being distributors. Franchises should pick up local entrepreneurs, invest in them and bring in value-added services. Franchising as an innovation happened more or less without state support to enhance their inclusive characteristics and sustainability advantage.

An important factor that determines the livelihood of the rural population is the access to technology, since agricultural productivity and surplus income generation is based on the availability of technology and the capability to use such innovations. There is a positive correlation between technology access and livelihood diversification strategies. But the adoption of new innovations is quite a risky affair, and hence farmers require increasing income and diversification to reduce risks. In Chapter 10, "Livelihood Diversification Strategy and Technology Access in Rural India: A Special Reference to Small Growers," Rajeev Sharma and Gurpreet Singh tested the relationship between livelihood diversification and technology access.

For this they developed the logit model and employed a NSSO unit level data set. The empirical evidence shows that households having better access to modern technology have more chances to maintain diversified portfolios as compared to less diversified households. Furthermore, the evidence suggests that the adoption of new technological innovations at the farm level increases household chances to promote livelihood diversity irrespective of location and farm size. Farm households that possessed a higher level of education, a greater number of family members and belonged to the upper caste have a positive effect on livelihood diversity. This result also holds true for different agro-ecological zones of the country. There are variations across the board in accessing different sources of information. The authors pointed out a bias in technology adoption against smallholders because modern technology adoption practices significantly increase with an increase in the size of landholdings. Thus, the emergence of income inequality among rural households due to technology access and capabilities promotes exclusion. The authors suggest that promoting farm household diversification livelihood strategy and technology access will help reduce exclusion of marginalized farm households.

Usman Mustafa and Umar Farooq, in "Pakistan National Innovation System for Agriculture and Rural Development: Challenges and Opportunities" (Chapter 11), explain the importance of agriculture in generation of income and employment of the workforce in the Pakistan economy. Its linkages with other sectors of the economy, apart from providing food, feed and fibre, are quite strong. It is argued by the authors that despite several constraints faced by agriculture, the sustainability and removal of poverty in the rural economy of Pakistan are mainly dependent on the development of agriculture. The agricultural sector of Pakistan has contributed substantially to the development of the economy, but it suffers from low productivity due to lack of innovations as well as non-adoption and non-availability of improved new technologies. It is generally observed that low productivity is a result of the absence of innovation culture among the farmers, especially small-scale farmers. The agriculture science, technology and innovation system has developed a disconnect between the users and producers of knowledge in the country. The authors analyzed the growth, structure and spread of the agriculture research and extension system of Pakistan and also successfully identified the flip side of the system. The manpower engaged in AIS has a relatively low level of educational qualifications. More than 50 per cent of R&D has been done by the provincial governments and one-third of the total R&D is being contributed by the federal government in Pakistan. The analysis of the research and extension system shows that there is a tendency towards a rise in the presence of private corporations in the agriculture sector. The current approach of innovation system is highly input intensive and created environmental hazards. Thus the authors concluded that the state has a bigger responsibility to increase investible resources for