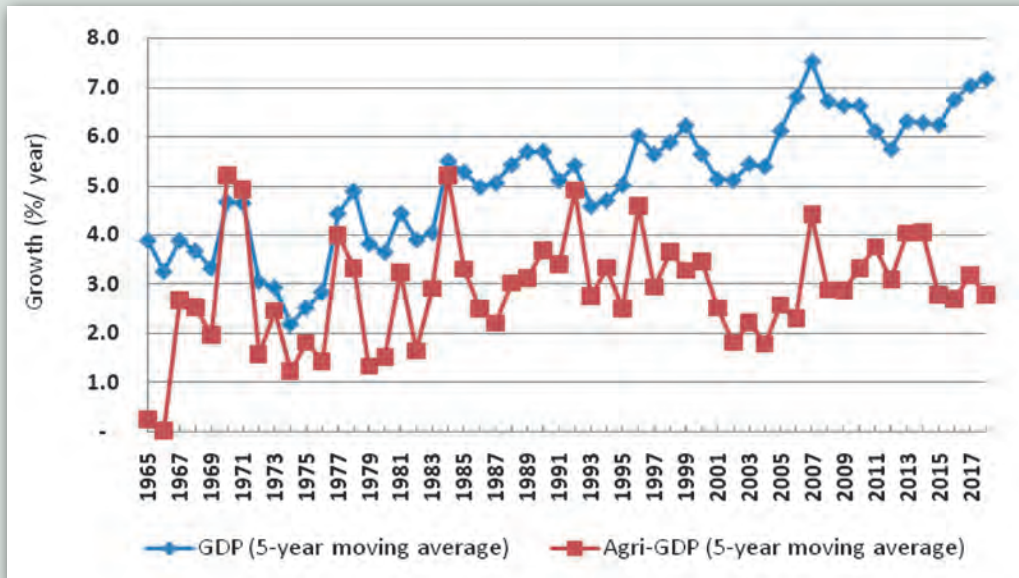


Agricultural Policy and Program Framework

Priority Areas for Research & Development in South Asia



Editors

Dr. Rudra Bahadur Shrestha
Dr. Shaikh Mohammad Bokhtiar
Dr. Ravi Khetarpal
Dr. Yam Bahadur Thapa



SAARC Agriculture Center (SAC), Dhaka
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SAARC Regional Expert Consultation Meeting on Multi-sectoral Program development for SAARC Agriculture Center through Expert Consultation, 16-18 July 2019, Dhaka, Bangladesh.

Edited by

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December 2019

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Published by the SAARC Agriculture Centre (SAC), Dhaka-1215, Bangladesh (www.sac.org.bd) and Asia Pacific Association of Agricultural Research Institutions (APAARI), Bangkok, Thailand (www.apaari.org).

ISBN: 978-984-34-7692-0

A catalogue record for the book is available from the SAARC Agriculture Center library, BARC complex, Farmgate, Dhaka 1215, Bangladesh.

Citation

Shrestha, R.B., Bokhtiar, S.M., Khetarpal, R., & Thapa, Y. B. (eds.). 2019. Agricultural Policy and Program Framework: Priority Areas for Research & Development in South Asia. SAARC Agriculture Center, Dhaka, Bangladesh, and Asia-Pacific Association of Agricultural Research Institutions (APAARI), Bangkok, Thailand. p. 376.

This book contains the papers of the Regional Expert Consultation Meeting on Multi-sectoral Program development for SAARC Agriculture Center through Expert Consultation conducted in Dhaka, Bangladesh from 16 to 18 July 2019. The program was jointly organized by SAARC Agriculture Centre (SAC), Dhaka, Bangladesh (SAC) and Asia-Pacific Association of Agricultural Research Institutions (APAARI), Bangkok. The opinions expressed in this publication are those of the authors and do not imply any opinion whatsoever on the part of SAC, especially concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

Cover Figure Credit: World Bank (2019).

Cover Design: Ms. Sanjida Aktir, Graphic Designer, SAC, Dhaka, Bangladesh.

Printed by: Momin Offset Press, Dhaka.

Price: US\$ 50 for SAARC Countries and US\$ 100 for other countries.

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**If agriculture goes wrong, nothing else will
have a chance to go right in our country**

M. S. Swaminathan

**Investments in agriculture are the best weapons
against hunger and poverty, and they have
made life better for billions of people**

Bill and Melinda Gates Foundation

Foreword



Importance of agriculture in socio-economic transformation of South Asian countries hardly needs any elaboration. The sector employs half of the workforce in the region and contributes around 18% of national income. The sector is also significant for inclusive development as poverty and undernutrition are concentrated among agricultural labour and marginal and small holders. The region also represents success story of green revolution which helped South Asian countries overcome widespread hunger and starvation through technological interventions. In fact the success and achievements of modern agriculture technology convinced and persuaded policy makers in South Asia about the gains from investments in agriculture R&D, and, almost all South Asian countries have strengthened and developed their own agricultural research systems, popularly known as national agricultural research systems (NARS).

Some studies by reputed organizations indicate that among various heads of public investments in South Asia, investments in agri R&D give best returns. Despite this, investments and supports for public sector R&D in agriculture has remained low in the region. Besides, low hanging fruits have been already harvested and agriculture is now facing several new challenges. Research is becoming more knowledge intensive and more capital intensive. All these factors necessitate upgrading level of agriculture R&D. This in turn requires more resources, enhanced capability and capacity of scientific manpower, and better labs and equipment.

Some other important developments at global level and in domestic economies also require fresh look at R&D policy in the South Asian Countries. The gap in knowledge products in agriculture between developed and developing countries is widening. Developed countries are reducing direct and indirect assistance for capacity development in agriculture in developing countries in general and South Asia in particular. Access to global technology is not as freely available as was the case in the past. Private sector is increasing its participation in agriculture R&D affecting public good nature of agri R&D. This requires appropriate IPR regimes and payment if knowledge products of private sector are to be used. All these factors underscore the need for changes in R&D policy. This book provides regional perspective and country perspective of each South Asian country based on past experience, emerging challenges and opportunities related to agriculture. The authors then provide comprehensive treatment of agriculture R&D policy in the overall policy framework of each country to meet various goals including SDGs 2030. The book is a valuable source of reference and useful guide in formulating policy for agriculture R&D and overall development of agriculture sector to meet the future need for food and nutrition and to address emerging challenges for sustainable development in South Asian countries.

Prof. Ramesh Chand

Member,

National Institution for Transforming India, NITI Aayog,
Government of India, New Delhi.

Preface



South Asia is a region with almost a quarter of the global population, majority of whom lives in rural areas and depends on agriculture for their livelihood. Hence, the region's economy is dominated by Agriculture. Although the region, endowed with large arable land, possesses huge potentiality for sustainable agricultural development, the agricultural sector has challenges like smallholding farms, lack of access to quality inputs including improved seeds and fertilizers, weak mechanization and infrastructure development, inefficient value chain, limited technology, and extreme climate change effects. This situation propels producers to sustainably increase food production, researchers to develop improved technologies with stress tolerance and high yielding varieties of crops and breeds of animals, policy makers to formulate enabling policy environment, and development agents to proactively involve themselves in the process of sustainable agricultural development.

Considering the regional challenges and opportunities, as one of the Centres of Excellence, the SAARC Agriculture Center (SAC) based in Dhaka, Bangladesh, has been pursuing a multi-sectoral work plan on six thematic areas, namely, Crops, Horticulture, Livestock, Fisheries, Natural Resource Management, and Agricultural Policy.

This publication, "Agricultural Policy and Programme Framework: Priority Areas for Research & Development in South Asia" is the outcome of a regional expert consultation meeting on "Multi-sectoral Programme Development" held on 16-18 July 2019. I am confident that it would be very useful for developing programs for SAC in the coming years.

I wish to express sincere thanks to Asia Pacific Association of Agricultural Research Institutions (APAARI), Member States of SAARC, Thematic Experts, authors, and reviewers for their contribution. My sincere appreciation goes to Dr. Rudra B. Shrestha, Senior Program Specialist (Policy Planning), SAC; Dr. Ravi Khetarpal, Executive Secretary, APAARI; and Dr. Y.B. Thapa, Adjunct Professor, Agriculture and Forestry University, Nepal, for their outstanding contribution in bringing out this publication.

Last but not least, I would like to express my sincere gratitude to H.E. Prof. Dr. Ramesh Chand, Member, NITI Aayog, Government of India for his supports.

Dr. S. M. Bokhtiar
Director, SAARC Agriculture Center
Dhaka, Bangladesh

Acknowledgment

We would like to express our sincere gratitude to SAARC Agriculture Center (SAC) and Asia Pacific Association of Agricultural Research Institutions (APAARI) for their vision and untiring efforts to organize a regional consultation meeting on “Multi-sectoral Program development for SAARC Agriculture Center through Expert Consultation”, 16-18 July 2019 at Dhaka, Bangladesh. The present volume “Agricultural Policy and Program Framework: Priority Areas for Research & Development in South Asia” is the product of this consultative meeting of experts and stakeholders, which would be much useful for both SAC and APAARI while developing and prioritizing programs for South Asia in the future.

We would like to appreciate the SAARC Member Countries, particularly the Ministry of Foreign/ External Affairs and Ministry of Agriculture; SAARC Secretariat; National Expert Focal Points; Thematic Experts; Reviewers and all the stakeholders including USAID/ USDA, IRRI, CIMMYT, CIRDAP, IFPRI, Action Aid, AFA, and BARC for their constructive supports in this endeavor.

We would like to express our sincere gratitude to H.E. Prof. Dr. Ramesh Chand, Member, NITI Aayog, Government of India for his invaluable supports.

Last but not least, we are grateful to Dr. K. S. Varaprasad, Dr. Norah Omot and Mr. Vishwanath Kumar Sah from APAARI, and Dr. Pradyumna Raj Pandey, Dr. Nasreen Sultana, Dr. Ashis Kumar Samanta, Mr. Kinzang Gyeltshen, Dr. Younus Ali, Md. Abdul Salam, Md. Saifur Rahaman, Md. Emdadul Hoque, and Ms. Sanjida Aktir from SAC for their contributions in the whole process of publishing this book.

Acronyms

ACP	Agriculture Contingency Plan
ADS	Agriculture Development Strategy
AOI	Agricultural Orientation Index
ASTI	Alaskan Satellite Telecommunications Infrastructure
BBIN	Bangladesh, Bhutan, India and Nepal
CEA	Controlled- Environment Agriculture
CGIAR	Consultative Group on International Agricultural Research
CPEC	China Pakistan Economic Corridor
EEZ	Exclusive Economic Zone
E-NAM	E-National Agriculture Market
FBS	Farmer Business School
FDI	Foreign Direct Investment
FTE	Full Time Equivalent
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GEM	General Equilibrium Model
GFCF	Gross Fixed Capital Formation
GLOF	Glacier Lake Outburst Floods
GMP	Good Management Practices
GNH	Gross National Happiness
GVA	Gross Value Added
HACCP	Hazard Analysis and Critical Control Points
IDI	Inclusive Development Index
INDC	Intended Nationally Determined Contributions

IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IUU	Illegal, Unreported and Unregulated
MFIs	Microfinance Institutions
MPI	Multidimensional Poverty Index
MRL	Maximum Residue Level
MSR	Marketed Surplus Ratio
MSs	Member States
PSL	Priority Sector Lending
R&D	Research and Development
RNR	Renewable Natural Resources
RTF	Right to Foods
SAARC	South Asian Association for Regional Cooperation
SAC	SAARC Agriculture Center
SAI	Sustainable Agriculture Intensification
SME	Small and Medium Enterprises
SOEs	Stated Owned Enterprises
SUN	Scale Up Nutrition
TCARD	Technical Committee on Agriculture and Rural Development
VC&RI	Value Chain and Rural Infrastructure
VCD	Value Chain Development
WASH	Water, Sanitation and Hygiene
WEF	World Economic Forum

Highlights of the Book

- This Book has ownership of the SAARC Member States' (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) National Expert Focal Points with invited Thematic Experts
- Consultation program on 'Multi-sectoral Program Development for the SAARC Agricultural Center for the period 2020-30' in collaboration with Asia-Pacific Association of Agricultural Research Institutions (APAARI), held in Dhaka, 16-18 July 2019 provided the Book's cornerstones
- Includes the agricultural development status, challenge/ constraint, opportunity, prospect and priorities with emphasis in R&D and innovations country-by-country in a handy way
- Provides a South Asia overview with synthesis on agri-development's six themes: natural resource management; risk, uncertainty and insurance; inclusive development; marketing, agro-processing and trade integration; modernizing agrarian structure; and policy and advocacy
- Has a South Asia wide overview of six sub-sectors: crops, horticulture, livestock, fisheries, natural resource management, and R&D and extension with empirical rigor and conceptual rig
- Quantifies agricultural growth process and their phases for some 26 commodity groups during 1961-2018, and offers reference growth scenarios for 2020-30 inviting discussion and improvements
- Is a Companion Volume for the researchers, professionals, policy makers, managers and interest lobbies from the governments, universities, international organizations, donors and development partners, business communities and civil societies to act with synergy for technological revolution 4.0 in agriculture and allied industry.

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Chapter 1

Policy and Program Priorities in Agricultural Research & Development in South Asia

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Abstract

South Asian agriculture is constrained with small scale farms, lack of access to inputs, weak mechanization and infrastructure development, limited technology advancement, less competitiveness, weaker inter-country connectivity, and extreme climate change effects. Combined efforts from the SAARC Member States is crucial to address these common issues and challenges through formulating and adopting common policies and programs. This paper is based on secondary information, literature review and as an outcome of regional consultation meeting in 2019. In addition, we reviewed the policies and programs in South Asian countries and statements of different levels of meetings including 4th Agriculture Minister's Meeting, fifteen policy and program priorities are identified: i) increasing investment in agricultural R&D; ii) rural revitalization in agriculture and rural-based resources; iii) access and affordable standardized quality of agricultural inputs; iv) incentivizing smallholder farmers and linking with markets access; v) efficient distribution of agricultural products; vi) promotion of underutilized neglected nutrition rich crops; vii) promotion of private sector engagement; viii) piloting and scaling-up of sustainable agricultural technologies, building climate resilience and natural resource management; ix) promotion of animal and aquatic feeds and nutrition; x) eradication of Peste des Petits Ruminants (PPR), cooperation on Anti-Microbial Resistance (AMR), and zoonotic diseases/pathogens measures; xi) combating transboundary plant, aquatic, and animal diseases and pests; xii) policy harmonization on regional trade of agricultural inputs and products; xiii) policy harmonization on material transfer agreement; xiv) management of ICT based statistics; and xv) formulation of legislations and regulations favoring commercialization of agriculture. Effective collaboration among the North-South, South-South, and multi-stakeholders is imperative to attain the targets set forth in the South Asia for achieving the SDG indicators collectively.

Keywords: Challenges, opportunities, policies and programs, South Asia

Background

South Asia is home to nearly 1.74 billion people in 2015 and projected to grow to 2.04 billion in 2030 and 2.29 billion in 2050 (United Nations, 2019). Despite the decline in the population growth, additional 300 million people will be added to the region by 2030, posing a serious challenge to achieve the Sustainable Development Goals (SDGs). In South Asia, nearly 22% of the world's population reside, and out of that population more than 50% are engaged in agriculture (UNESCAP, 2016). About 30% of the 700 million poor people are in absolute poverty with income less than US\$1 per capita daily (World Bank, 2019). Real GDP per capita growth is also being challenged, particularly in countries with rapidly growing populations, like those in Africa and South Asia regions with some of the highest levels of food insecurity and malnutrition in the world (FAO et al., 2019). South Asia has modest levels of inequality on the basis of *Gini Coefficients* for consumption per capita range between 0.28 and 0.40 depending on the country, much lower than in China, Mexico, or South Africa, and also revealed that countries with a higher income per capita are characterized by greater inequality (Martín et al., 2015).

Half of the land area of South Asia is under arable category, while in the world as a whole it is only 11%. Globally, around 30% of the world's populations suffering from multiple micronutrient deficiencies. Further, around 10 million children die each year before they attain the age of 5 years, and 2 out of 5 below the age of 5 years are stunted and malnourished. Therefore, the food and nutrition security challenge need to be addressed with appropriate policies and programs. Nearly half of the world's malnourished children are suffering from a number of development and infrastructure gaps (UNESCAP, 2016).

Agriculture sector is the major means of food security, nutrition improvement, growth of economy, and the major source of livelihoods. In Figure 1, we show how the performance of the economy in terms of the Gross Domestic Product (GDP) growth rate in tandem with the Agri-GDP growth rates in South Asia during the period 1961-2018. Notes that these growth rates are five year moving averages, i.e., the growth rate of GDP is 4% in 1965, and that of Agri-GDP is 0.3% (of the average of growth rates for five years 1961-65), and for forth; this moving average of the GDP and Agri-GDP growth rates is taken to smoothen the seasonal effects due to weather and other facts, and to observe the cyclical and secular trends in the growth rates of the economy and the agricultural sectors that may be associated with policies such as economic liberalizations, regional co-operations, development of science and technology and so forth.

Figure 1 presents the economic growth and its relation with agriculture in South Asia during 1961-2018, and draw policy options. For example, if the GDP growth rates are expressed as function of the Agri-GDP growth rates, the regression coefficient comes out to be 0.395; implied that for every one percent increase in the GDP from the predicted trend line, the agriculture sector needed to expand by 2.56% points (Figure 2).

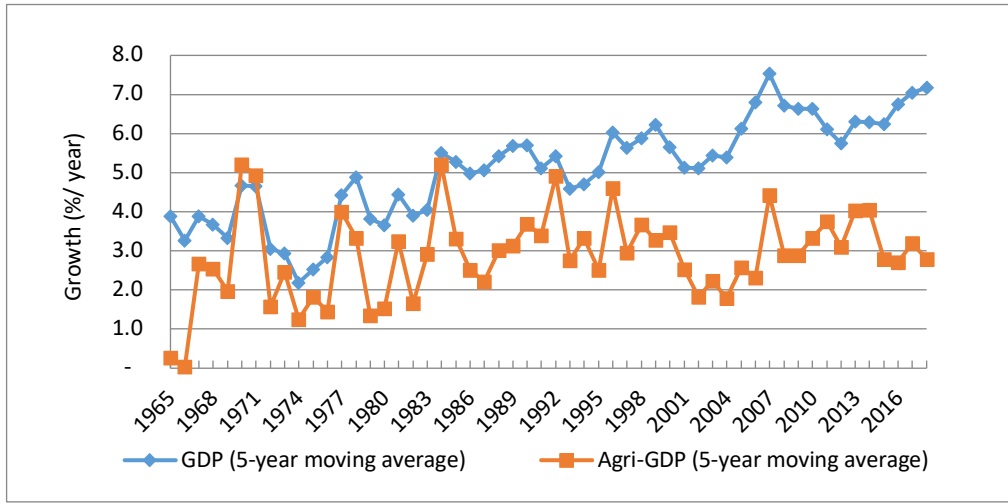


Figure 1. Agriculture, forestry, and fishing, value added (annual % growth as five-year moving average ending the year shown) in South Asia

Source: World Bank (2019)

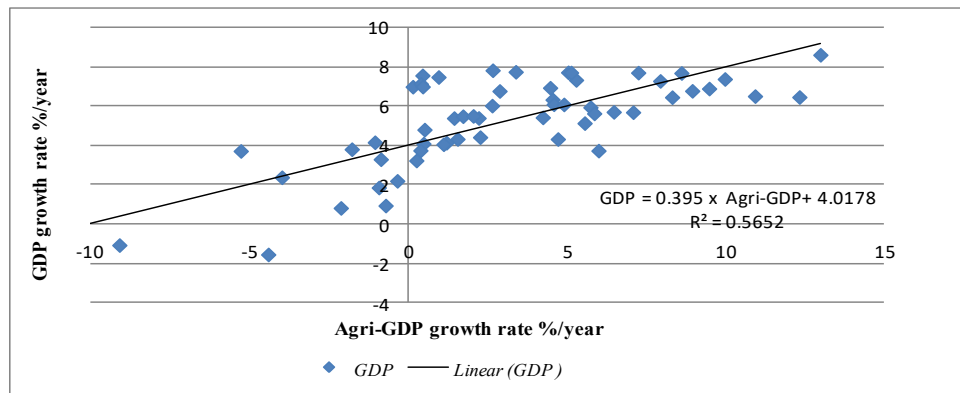


Figure 2. GDP growth rate as dependent on Agri-GDP growth rate in South Asia (1961-2018)

Source: World Bank (2019)

Besides the above-discussed the relation of the overall economic growth with the agricultural sector performance, we now turn to discuss the phases in the growth of agriculture during 1965- 2018, and their prospects for the next decade. The agricultural performance in the region seems to have two phases. **First**, the agricultural growth rates were increasing (though with high fluctuations) during 1965-1990; this is also the period of the green revolutions. **Second**, the agricultural growth rates have stagnated during 1990-2018, which is the period of post-green revolution, and the economic policy regime of internationally open and liberal policies. Here, the SAARC has an important role to revive the acceleration of agricultural growth rates, among others.

The agriculture sector employs about 60% of the poor and rural workforce in South Asia, and over 80% of the world's small and marginal farmers belong to this region; here agribusiness development plays a crucial role in reducing the poverty and improving the food and nutrition security (World Bank, 2019). However, South Asian agriculture continues to encounter major challenges such as the lack of technology for productivity improvement and value-chain efficiency, followed by the low investments in R&D, lack of human resources and infrastructure development. Climate resilience, environmental sustainability, enhanced biodiversity uses and conservation, adaption of modern tools and technologies, strengthening markets, value-chain and stability of food supply are the key research priorities towards achieving targets of the SDGs. The World Bank (2019) pointed out that South Asian countries are constrained by overuse of fertilizers, over-extraction of groundwater and climate change extremes. Indeed, agriculture sector in this region is adversely affected by extreme climate change events such as increased temperature, uncertain patterns of rainfall, floods, landslides, hailstones, hurricane, typhoon, etc. (Shrestha & Bokhtiar, 2019). Further, the agriculture downstream coastal areas have been encountering problems with the river desiccation, groundwater depletion, water pollution and sedimentation, salinization and salt water intrusion, soil erosion and nutrient depletion, and dynamic changes in the coastal wetland systems.

Integration of crops, horticulture, livestock, fisheries and resource management sectors is imperative to address food and nutritional security. Policy gaps in food security, natural resource management, sustainable development, agriculture based rural industry, employment generation, risk management, role of youth and women, capacity development, and knowledge management are the important areas to be addressed. Shrestha et al. (2016) suggested that the major intervention areas are markets and value chains, resilience to climate change, research & development, and adopting more productive technologies in South Asia. There are some common issues and challenges in the region that need to be addressed from the common forum where SAARC Agriculture Center (SAC) has been taking charge on. SAC developed regional agriculture program in 2007 that guided the SAC in formulating the programs for last 10 years from 2007 to 2017 (Kabir & Akter, 2007). Similarly, Gurung et al. (2017) suggested common challenges and priorities in the region. Further, several international and regional bodies have also been working in South Asia towards achieving the food and nutritional security through research and innovations in agri-food systems.

This book has been prepared considering the agricultural research challenges and priorities of SAARC Member States (Gurung et al., 2017), Sustainable Development Goals (SDGs) of United Nations (UNESCAP, 2016), existing challenges and opportunities, Agriculture Ministerial Meeting Statements, and recommendations of different forums and consultation programs.

Current Situation: Economy, Poverty and Hunger in South Asia

South Asia remained the fastest growing region in the world last year; growth moderated from 7.2% in 2017 to 6.9% in 2018 (World Bank, 2019). In the last two years, government consumption and investment grew fast in South Asia. The strong domestic demand resulted in very strong import growth of around 15.6% in both years, which is nearly twice as high as export growth (Figure 3).

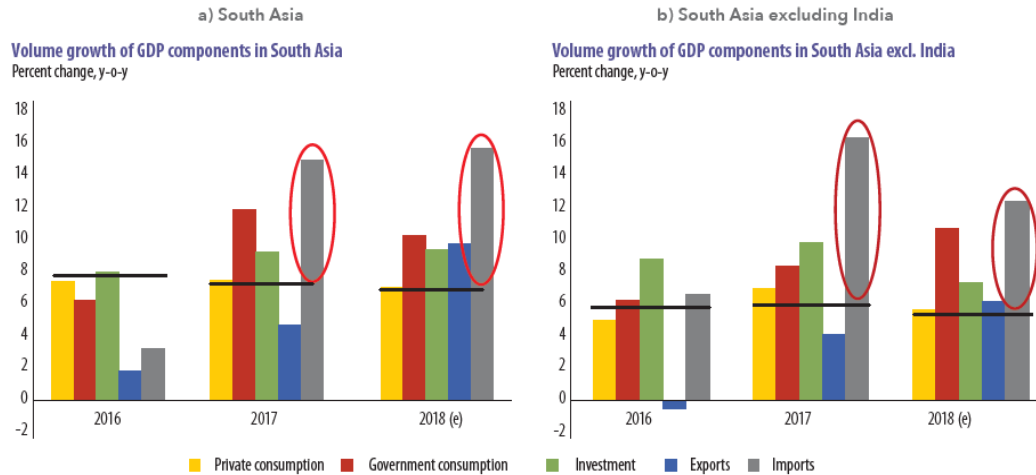


Figure 3. Volume growth of GDP in South Asia

Source: World Bank (2019)

Multidimensional Poverty Index (MPI)

Poverty in South Asia is still severe. OPHI (2018) defined the Multidimensional Poverty Index (MPI). The global MPI is three dimensional internationally comparable measure of acute poverty for over 100 countries, situated in developing regions, which incorporates the simultaneous deprivations that each person experiences in ten indicators related to education (year of schooling and school attendance), health (nutrition and child mortality), and living standards (cooking fuel, sanitation, drinking water, electricity, housing and assets). Poverty exists everywhere, however most of the poor people live in Sub-Saharan Africa (42%) and South Asia (41%) (OPHI, 2018). East Asia, despite having the largest population, has much smaller share of the world's multidimensional poor people. OPHI (2018) estimated that the MPI in South Asia is 0.143, which is lower than Sub-Sahara Africa (0.317), while much higher than in Arab States (0.098), East Asia and the Pacific (0.025), Eastern Europe and Central Asia (0.009), Latin America and the Caribbean (0.033), and Global MPI (developing regions (0.115) (Table 1).

Table 1. Regional analysis of MPI for South Asia and other regions

Developing Regions (UN Statistics Division)	MPI ¹	Headcount ratio (H) ²	Intensity (A) ³	Number of poor people (millions) ⁴	Population coverage by MPI
Arab States	0.098	19.2%	50.8%	65.7	85%
East Asia and the Pacific	0.025	5.9%	43.1%	117.7	94%
Eastern Europe and Central Asia	0.009	2.4%	38.3%	3.5	43%
Latin America and the Caribbean	0.033	7.7%	43.2%	39.7	81%
South Asia	0.143	31.3%	45.8%	545.9	95%
Sub-Saharan Africa	0.317	57.7%	54.9%	559.4	99%
Global MPI (developing regions)	0.115	23.2%	49.5%	1.33 billion	91%

Source: OPHI (2018, P. 13)

Note: ¹The Multidimensional Poverty Index (MPI) ranges from 0 to 1; ²The headcount ratio is the percentage of the population with deprivation score of 1/3 or above; ³The intensity is the average percentage of weighted deprivations among the poor; ⁴The number of poor people uses 2016 population figures.

Analyzing the MPI in the South Asia, it is much higher in Afghanistan (0.273), Pakistan (0.228), Bangladesh (0.194), Bhutan (0.175), Nepal (0.154), India (0.1221), and Maldives (0.007), which indicates that the extreme poverty is concentrated in Afghanistan, Pakistan, and Bangladesh (Table 2).

Table 2. MPI in South Asian countries

Country	Year	MPI (MPI = H×A) ¹	Headcount ratio (H) ²	Intensity (A) ³	Number of poor people ⁴	Vulnerable to poverty ⁵	In severe poverty ⁶
Maldives	2009	0.007	1.9	36.6	8,020	5.3	0.1
India	2015/16	0.121	27.5	43.9	364,225,000	19.1	8.6
Nepal	2016	0.154	35.3	43.6	10,217,460	24.3	12.0
Bhutan	2010	0.175	37.3	46.8	297,894	17.7	14.7
Bangladesh	2014	0.194	41.1	47.3	66,916,352	21.5	16.2
Pakistan	2012/13	0.228	43.9	52.0	84,772,711	14.5	24.7
Afghanistan	2015/16	0.273	56.1	48.7	19,442,025	18.0	25.1

Source: OPHI (2018, P. 48)

Note: ¹The Multidimensional Poverty Index (MPI) ranges from 0 to 1; ²The headcount ratio is the percentage of the population with deprivation score of 1/3 or above; ³The intensity is the average percentage of weighted deprivations among the poor; ⁴The number of poor people uses 2016 population figures; ⁵Vulnerable to poverty shows the percentage of the population that experiences 20%–33.32% of weighted deprivations; ⁶In severe poverty shows the percentage of the population with an intensity of 1/2 or above.

Prevalence of Undernourishment

The prevalence of undernourishment in the South Asia is severe. The trend of prevalence of under nutrition (PoU) in the South Asia is decreasing but still higher than the world average (FAO et al., 2019). The PoU has decreased to 14.9% in 2014-16 from 20.4% in 2004-06. The Southern Asia currently accounts for the largest share (35%) of global number of undernourished people. The undernourished people in the world decreased from 14.7% in 2000 to 10.6% in 2015 (FAO et al., 2019). However, this rate of decline has considerably reduced by 11% in 2016 (Figure 2). The estimated number of undernourished people worldwide increased to 815 million in 2016 from 777 million in 2015. In South Asia, the number of undernourished people has decreased by 45 million from 313 million in 2004-06 to 267 million in 2014-16.

Program Development Approach, Values and Principles

This book has been prepared as an outcome of a regional consultation meeting on “multi-sectoral program development for SAC” held in Dhaka 2019. This book is useful for SAC to guide in formulating programs in the long-run and for Member States to formulate policies addressing the current regional issues and challenges in agricultural research and development. The contents in the book incorporates the current situation of agricultural research and development (R&D), priority issues, challenges and opportunities, and policies of Member States as reflected in country specific papers contributed by National Experts; and thematic analysis contributed by Thematic Experts in six thematic areas such as crops, horticulture, livestock, fisheries, natural resource management, and agricultural policies. Furthermore, the papers were cross-analyzed and cross-verified by Thematic Review Panelists along with intensive experts’ group brain storming. The program development is feasible and implementable with significant impacts if it is based on suitable values and principles (SADC, 2013). This policy and program development is based on the following values and principles:

Regionality-	policies and programs address the common issues in the regional level comprising eight Member States.
Coherence-	policy and program framework are consistent with global, regional and national initiatives.
Harmonization-	policies and programs are harmonized and consistent with the demand and necessity of the Members States.
Solidarity-	policies and programs ensure a maximum level of cohesion between Member States (MSs) and the MSs provides financial, human and institutional resources to improve the living standards and prosperity of the region.

Regional integration-	Policies and programs activities, which integrate region to facilitate free movement of factors of production, goods and services as well as the promotion of regional specialization based on the comparative advantages.
Complementarity-	policies and programs are complementary to programs at the national level.
Subsidiarity-	programs and activities are carried out at levels where they can best be handled.
Environmental sustainability-	policies and programs are considered in promoting the region's natural resources along with technical feasibility, economic sustainability, and social acceptability that would contribute to the sustainable development.
Partnership-	adhering to the SDG17, programs are effective with functional partnerships between South-South and North-South, and concerned stakeholders in the agriculture and related disciplines.

Challenges and Opportunities in Agricultural R&D

The South Asia has been facing some major challenges for development outcomes such as the economic growth, structural transformation, employment creation, poverty and hunger, food and nutrition security, and environmental management. The 2030 Agenda for regional agricultural development includes eradicating poverty in all its forms (SDG-1); zero hunger (SDG- 2); decent work and economic growth (SDG- 8); industry, innovation and infrastructure (SDG- 9); reduce inequality within and among countries (SDG-10); sustainable consumption and production (SDG-12); climate action (SDG-13); and revitalize the global partnership for sustainable development (SDG-17) (UNESCAP, 2016).

South Asian countries have made remarkable progress in food production during the past three decades and paving ways transforming the region from a food-deficit into a food-sufficient region. However, further productivity enhancement is a challenge to feed the growing population in the region. Varietal development with higher productivity and stress tolerance is a continuous process to keep pace with the growing food demand. For example, rice is an important staple crop, and has huge opportunities to enhance yield in South Asia. Use of innovative genomic tools and knowledge in combination with conventional breeding-selection may be an appropriate strategy to direct the rice improvement and for the desired genetic grain yield enhancement. The other option is to improve breeding efficiency through digitization of plant breeding management to double the annual yield gain in the next couple of decades. Similarly, use of the modern technologies such as gene editing, double haploid approaches for productivity enhancement - need consideration for infrastructure and human capacities enhancement in the region.

Loss of biodiversity in farm lands is a concern in the context of sustainability. As few as nine crops account for two-thirds of the global food output, and on-farm crop diversity has declined significantly over the decades as farmers have switched from the traditional production systems that utilize farmers' varieties and landraces to the modern production systems depending on the released varieties. The world's livestock production is based on about 40 animal species, with only a handful providing the vast majority of global output of meat, milk and eggs. Soil biodiversity is under threat in all regions of the world, leading to deterioration of the soil health. Over half of all production in the inland fisheries is not designated by species. Forests cover 30.6% of the world's land area and even though forests continue to shrink, the rate of annual net-loss of forests has decreased significantly over recent decades. Sustainability and diversification of production systems through the use of modern technologies such as barcoding needs a fresh look in South Asia.

South Asia is still far behind in attaining the targets on food and nutrition security because of inefficient distribution system. Establishing efficiency in food marketing, efficient value-chain development and food distribution system are prominent challenges in the region, which widened the marketing margin and consequently hurt to both producers and consumers. Policy initiatives in the flow of products within the countries and trade flow across the countries in the context of economic liberalization, open trade regime of WTO and biosecurity compliances for transboundary movement of diseases and pests along with agricultural commodities are crucial in the region.

Climate change is the main concern in agriculture sector. The biodiversity of food crops is important because it is the foundation of food systems and makes production systems more resilient and makes them withstand the effects of climate change. Upscaling of climate resilient best technologies is an opportunity to be exploited in the region. An effort has been made to consolidate the Intended Nationally Determined Contributions (INDC) to reduce the effects of climate change and in most of the countries in South Asia.

Public research investments are rather limited in South Asia and there is a need to enhance the role of private sector, NGOs and farmer associations. Importance of role of women and youth in agriculture needs to be up-scaled considering the rural revitalization policies and regional experience.

Development sectors such as adaptation strategies to reduce global warming, mitigate climate change affects, infrastructure including surface and air transport networks, communication networks, disaster management, energy including renewable energy have a direct or indirect bearing on achieving the food and nutrition security. Integration of various development disciplines of agriculture consisting of crops, horticulture, natural resources, livestock, fisheries, input marketing, agro-processing, food marketing and distribution system, regional trade, and cross-cuttings with agro-biodiversity, poverty, and gender and youth inclusion are crucially considered in developing the

Program Framework. Based on the group brain-storming in the regional consultation program, the following issues/ challenges, opportunities and program activities are derived in Table 3- 8.

Crops Sector

Table 3. Issues/ challenges, opportunities and programs in Crops Sector

Issues/Challenges	Opportunities	Program Activities
Low productivity.	Potential to increase productivity.	<ul style="list-style-type: none"> ▪ Development/ exchange and effective technology transfer of high yielding crop varieties. ▪ Development of intensive and best-bet crop production practices/ systems. ▪ Crop diversification with the inclusion of vegetables, spices, pulses and oilseed crops in cereal systems. ▪ Adoption of integrated plant nutrient management and integrated pest management (IPM) system. ▪ Weather and pest incidence forecasting for reducing risks/ losses.
Climate change.	Increase cultivated area (e.g. mountainous and saline prone area) and crop diversification.	<ul style="list-style-type: none"> ▪ Develop and adopt short duration and multi-stress (abiotic & biotic) tolerant field crop varieties. ▪ Adoption of improved crop management options including conservation practices to adapt in changing climate. ▪ Strengthening R&D in climate smart agricultural technologies.
Food and nutrition security.	Diversified nutrition rich crop varieties for different agro-ecological regions.	<ul style="list-style-type: none"> ▪ Development & exchange of fortified crop varieties (e.g. zinc, iron, vitamin A) of field crops. ▪ Promote underutilized nutrition rich traditional crops. ▪ Increase cropping intensity with crop diversifications. ▪ Application of GAP, certification and harmonization among the SAARC countries. ▪ Adopt integrated farming systems.
Post-harvest losses.	Development and adoption of improved and safe handling technologies.	<ul style="list-style-type: none"> ▪ Selection of non-lodging & non-shattering crop varieties. ▪ Adopt agricultural mechanization in the value chain. ▪ Implement effective value chain development programs, including agro-processing. ▪ Develop efficient marketing system linking farm to table.

Issues/Challenges	Opportunities	Program Activities
Lack of quality seed availability.	Potentiality to develop and sharing seed varieties.	<ul style="list-style-type: none"> ▪ Increasing seed replacement rate. ▪ Effective implementation of SAARC seed bank, SAARC seed bank information system, SAARC seed forum, and seeds without borders among the South Asian countries. ▪ Harmonization and standardization of the seed testing laboratories, and establish & operationalize the regional reference laboratories. ▪ Minimize the informal seed trade and foster the regional seeds trade. ▪ Effective measures to manage the transboundary disease and pest in field crops.
Capacity development.	Knowledge & skill development of scientists, technicians, development agents and farmers.	<ul style="list-style-type: none"> ▪ Organize observation tour, traveling seminar and training programs for scientists, technicians, development partners and farmers among the SAARC countries. ▪ Long term training programs (Master and PhD) for the scientists/ scholars/ extension workers in best universities in South Asia.

Horticulture Sector

Table 4. Issues/ challenges, opportunities and programs in Horticulture Sector

Issues/Challenges	Opportunities	Program Activities
Low consumption of fruit and vegetables (F&V).	Increased consumption of F&V (at least 50%) of the current level.	<ul style="list-style-type: none"> ▪ Increase year- round availability and affordability of F&V and behavior change to increase F&V consumption through awareness program.
Low productivity of F&V, flowers and spices.	Increase yields through efficient use of resources and technologies.	<ul style="list-style-type: none"> ▪ Develop technology to increase yields of F&V, flowers and spices, and market promotions.
Climate change effect: biotic and a-biotic stresses.	Promotion of climate resilient technologies/ practices.	<ul style="list-style-type: none"> ▪ Develop and identify the best climate resilient technologies and transfer to the MSs.
Food safety concerns.	Promotion of GAP and harmonization of Maximum Residual Level (MRL) standard and monitoring.	<ul style="list-style-type: none"> ▪ Regional agreement and commitment among the food safety authorities in SAARC States and beyond. ▪ Awareness creation of safe foods to the stakeholders along the value chain of agriculture products.
Post-harvest loss (PHL) and waste.	Reduction of PHL not to exceed 10-15% from field to market.	<ul style="list-style-type: none"> ▪ Investment in necessary infrastructures development for post handling, storage, transportation and processing.

Issues/Challenges	Opportunities	Program Activities
Marketing inefficiency leads to higher marketing margin.	Strengthening market linkage through the producers' associations, cooperatives and private sector engagement.	<ul style="list-style-type: none"> ▪ Public-private partnership for marketing development. ▪ Direct market linkages development. ▪ Development of market infrastructures. ▪ Improve marketing information system. ▪ Promote private sector engagement through market system approach.

Livestock Sector

Table 5. Issues/ challenges, opportunities and programs in Livestock Sector

Issues/Challenges	Opportunities	Program Activities
Genetic improvement and conservation of indigenous livestock and poultry genetic resources.	Large diversity and genetic variability in the SAARC region.	<ul style="list-style-type: none"> ▪ Breed improvement through traditional & molecular approaches. ▪ Establishment of SAARC gene bank for breeds/ strains of regional importance. ▪ Sharing of genetic resources amongst SAARC MSs.
Livestock and poultry health.	Develop technologies for better health management.	<ul style="list-style-type: none"> ▪ Prevention, control & eradication of transboundary and zoonotic diseases. ▪ Establishment of bank of vaccine & diagnostics for prioritized trans-boundary animal diseases. ▪ Establishment of SAARC referral laboratory for regionally important diseases. ▪ Promotion of herbal usages and Insight Segmentation and Registration Toolkit (ITKs) for protecting livestock health.
Inadequate feed and fodder resources.	Locally available feed ingredients/ industrial/ agricultural wastes/ unconventional feed ingredients.	<ul style="list-style-type: none"> ▪ Use of local grasses/ crop residues/ agricultural wastes for formulation balanced diet. ▪ Cost effective feed formulation for livestock and poultry. ▪ Promotion of high yielding fodder production using advanced technologies. ▪ Promote silage/ hay for lean periods. ▪ Share fodder seeds/ root slips under the "SAARC - Seed Without Border" programme. ▪ Adaptive trials for high yielding fodder varieties. ▪ Community pasture land management.
Biosecurity & biosafety for livestock and poultry farming.	Safe and healthy livestock & poultry products.	<ul style="list-style-type: none"> ▪ Good management practices for livestock & poultry.

Issues/Challenges	Opportunities	Program Activities
Antimicrobial usages & antimicrobial resistance.	Public health concerns.	<ul style="list-style-type: none"> ▪ Awareness development on antimicrobials & antimicrobial resistance. ▪ Alternate feed additives (nutraceuticals/ functional food/ herbal residues/ prebiotics/ probiotics).
Natural calamities.	Safety nets of livestock & poultry.	<ul style="list-style-type: none"> ▪ Establishment of SAARC Feed Bank. ▪ Development of low cost shelter facility. ▪ Controlling disease outbreaks.
Climate change.	Green livestock production.	<ul style="list-style-type: none"> ▪ Promotion of climate resilient breed and prevention of alien pathogens. ▪ Feeding strategies to reduce greenhouse gas emissions. ▪ Data base on greenhouse gas emission from South Asian livestock.
Capacity building for skilled human resources.	Expertise for livestock and poultry sector.	<ul style="list-style-type: none"> ▪ Genetic and reproductive improvement program. ▪ Advancement in veterinary diagnostics, biologicals and vaccines. ▪ Disease surveillance and monitoring for better livestock health. ▪ Characterization and conservation of unexplored livestock & poultry. ▪ Formulation of balanced ration to mitigate greenhouse emission. ▪ Hygienic milk/meat production for ensuring food safety. ▪ Value addition to livestock and its products for better economic returns. ▪ Establish medium to large scale dairy and poultry farms, small ruminants, and pigs.
Policy formulations.	Harmonization of policies for better regional cooperation.	<ul style="list-style-type: none"> ▪ Establish regional data base for risk assessment. ▪ Review of existing policies regarding trade and transfer of livestock & their products. ▪ Promotion and incentivize of import and export of livestock & livestock products.

Fisheries Sector

Table 6. Issues/ challenges, opportunities and programs in Fisheries Sector

Issues/ Challenges	Opportunities	Program Activities
<ul style="list-style-type: none"> ▪ Habitat degradation, resource depletion and loss of biodiversity. ▪ Lack of exploratory survey on stocks, population, species and carrying capacity. ▪ Lack of infrastructure for deep-sea fishing and huge post-harvest losses. ▪ Illegal, unreported and unregulated (IUU) fishing. 	<ul style="list-style-type: none"> ▪ Assurance of food safety and quality - export potential. ▪ Alternative livelihoods support to fishermen during non-fishing and banned fishing seasons. ▪ Security of fishermen along the maritime boundaries. 	<ul style="list-style-type: none"> ▪ Utilize derelict water bodies and aquaculture in seasonal water bodies. ▪ Germplasm exchange among the SAARC MSs. ▪ Enhance research, training & capacity development. ▪ Good aquaculture practice (GAP) in fisheries. ▪ Establishment of Brood Banks and Seed Certifications system. ▪ Promote farm-made fish feeds using local ingredients. ▪ Exchange of genetically improved and pure gene pool among countries.
<ul style="list-style-type: none"> ▪ Excess use of drugs and chemicals in aquaculture. ▪ Use of formalin, pesticides and fungicides in fish processing, processed fish (dried, fermented). ▪ Lack of credit, insurance, illegal moneylenders for promoting fisheries promotion. ▪ Fish disease, emerging new pathogen, parasites. 	<ul style="list-style-type: none"> ▪ Traditional, pesticide-free fish processing practiced. ▪ Biodiversity conservation using different in-situ and ex-situ measures in nationals and transboundary water bodies. ▪ Compliance strict law on chemical and drugs use. 	<ul style="list-style-type: none"> ▪ Disease surveillance and monitoring. ▪ Aquaculture diversification and water budgeting. ▪ Encouraging fishermen to use smart technology- cage culture and GPS. ▪ Institutional linkages and capacity building. ▪ Transboundary policy formulation and technology dissemination, farmers exchange and training. ▪ Technology development to reduce cost of production in fish farming.

Issues/ Challenges	Opportunities	Program Activities
<ul style="list-style-type: none"> ▪ Limited trade of fish products within South Asian countries. ▪ Low quality, inbred and genetically poor fish seeds. ▪ Least attention in mollusk and sea-weed farming. ▪ Climate change impact in fisheries and aquaculture. 	<ul style="list-style-type: none"> ▪ High demand of fisheries products in the region and beyond. ▪ Coastal and estuarine area potential for mariculture of finfishes, mollusks, crustacean and seaweeds, technical assistance from Southeast Asia. 	<ul style="list-style-type: none"> ▪ Fish biodiversity management in trans-boundary rivers/ waters. ▪ Promote public-private partnership. ▪ Minimize tariff and non-tariff barriers in fish trade in the region. ▪ Collaborate for mariculture development in countries with coast. ▪ Promote ecosystem health and bio-security of fishes. ▪ Promote climate smart fisheries.
<ul style="list-style-type: none"> ▪ Higher post-harvest loss/ waste throughout the food supply chains. ▪ Stocks are overfished - unsustainable fish harvest. ▪ Little or no molecular characterization of fish in Afghanistan, Sri Lanka, Nepal & Bhutan. ▪ No comprehensive inventory/database of species, ecosystems and genes of fisheries. ▪ User conflict – water abstraction for irrigation and fisheries. 	<ul style="list-style-type: none"> ▪ Value addition with immense possibility. ▪ Many potential species for domestication and little need to introduce exotic species. 	<ul style="list-style-type: none"> ▪ Develop technologies to minimize and post-harvest losses/ wastes. ▪ Develop captive breeding techniques and establish selective breeding programs to develop important traits in exotic fish species. ▪ Micro propagation of selected seaweed to enhance the seaweed farming. ▪ Capacity and partnership building. ▪ Develop comprehensive inventory/database of species, ecosystems and genes of fisheries.

Natural Resource Management

Table 7. Issues/ challenges, opportunities and programs in NRM Sector

Issues/Challenges	Opportunities	Program Activities
Climate vulnerability.	<ul style="list-style-type: none"> Climate resilient agricultural practices. 	<ul style="list-style-type: none"> Adaptation of climate resilient agricultural practices in different agro-ecosystems. Climate smart agroforestry practices for SAARC countries. Biochar application to enrich soil carbon and mitigation GHG.
Salinity.	<ul style="list-style-type: none"> Develop salinity tolerant crops varieties. Salinity management practices. 	<ul style="list-style-type: none"> Adaptation of saline tolerant crops e.g. Sesame and varieties e.g. BRRI dhan-47 for better crop production. Use of organic matters for reducing salt stress effects.
Drought.	<ul style="list-style-type: none"> Water management. Drought tolerant crops and varieties. 	<ul style="list-style-type: none"> Adoption of water saving practices (AWD, drip irrigation etc.) and crop management to increase water use efficiency.
Deforestation.	<ul style="list-style-type: none"> Community forestry, medicinal plant and non-wood forest product. 	<ul style="list-style-type: none"> Sustainable management of community based non-wood forest product and community forestry in the hilly and floodplain areas.
Degradation of soil organic matter (SOM) & soil fertility.	<ul style="list-style-type: none"> Restoration of SOM and soil fertility. 	<ul style="list-style-type: none"> Conservation agriculture for sustainable soil health and profitable crop productivity. Organic matters e.g. biochar for increasing soil carbon and improvement soil health.
Soil and water pollution.	<ul style="list-style-type: none"> Strategies for remediation of organic and inorganic contaminants. 	<ul style="list-style-type: none"> Measure the Health Risk Index (HRI) and determine the toxic limit of heavy metal.
Acid soil management.	<ul style="list-style-type: none"> Reclamation of acid soil (<pH 5.5). 	<ul style="list-style-type: none"> Amendment with lime (Dolomite) and biochar.
Micronutrient deficiency in agriculture.	<ul style="list-style-type: none"> Micronutrient enrichment. 	<ul style="list-style-type: none"> Bio-fortification with iron (Fe) and zinc (Z) by variety selection and micronutrient fertilizer application.
Shrinkage of arable land.	<ul style="list-style-type: none"> Land and crop zoning. 	<ul style="list-style-type: none"> Policy support to protect arable land from non-agricultural purposes.
Degradation of NRM.	<ul style="list-style-type: none"> Sustainable water management. NRM policy review. 	<ul style="list-style-type: none"> Sustainable management of watersheds to continuity supply water. NRM policy and strategies to address degradation.

Agricultural Policy

Table 8. Issues/ challenges, opportunities and programs in Agricultural Policy

Issues/Challenges	Opportunities	Program Activities
Land Use Policy <ul style="list-style-type: none"> ▪ Land Use Act is not in place in many countries. ▪ Arable land quantity and quality are dwindling. 	<ul style="list-style-type: none"> ▪ Formulation and implementation of land use policy and Act. 	<ul style="list-style-type: none"> ▪ Awareness and sensitization of the implementation of land use act and policies. ▪ Mobilizing parliamentarians for formulating and implementing Land Use Policy and Act. ▪ Using Contract Law for land lease uses.
Forestry Policy <ul style="list-style-type: none"> ▪ Endangered flora and fauna species. 	<ul style="list-style-type: none"> ▪ Successful multi-agency management approach (MAMA). 	<ul style="list-style-type: none"> ▪ Develop policies for promoting NTFP, flora and fauna, and wildlife conservations. ▪ Promotion of geo-ecosystem friendly agriculture. ▪ Promote MAMA in community, national forest and conservation areas.
Water Resources Policy <ul style="list-style-type: none"> ▪ Declining fresh water sources, and marine pollution with plastics and acids. ▪ Increasing fluctuations in hydrological cycles. ▪ Receding glaciers and ice caps. 	<ul style="list-style-type: none"> ▪ Sites available for water reservoirs. ▪ Technology available for ground water recharging and uses. 	<ul style="list-style-type: none"> ▪ Formulate policies on water resource management (conservation/storages, uses and trading). ▪ Conservation, explore and proper utilization of water resources. ▪ Effective implementation of acts, regulations. ▪ Develop technologies for increasing agri-productivity of water.
Biodiversity Policy <ul style="list-style-type: none"> ▪ Decline in phyto-genetic and animal genetic pools. ▪ Underinvestment in developing native plant and animal species. 	<ul style="list-style-type: none"> ▪ Advances in the crop and animal breeding. ▪ Advance in genetic engineering and bio-technology. 	<ul style="list-style-type: none"> ▪ Promote multi-lateral and bilateral agreement to exchange varieties and breeds. ▪ Promote biotechnology for crops and animals. ▪ Increase investment for native plant and animal species, and underutilized crops. ▪ Germplasm sharing among MSs, and establish gene banks.

Issues/Challenges	Opportunities	Program Activities
Risk & Uncertainty		
<u>Climate Change Policy:</u> <ul style="list-style-type: none"> ▪ Lack of climate change prevention act and regulations. ▪ Increasing the emissions of GHGs. ▪ Lack of disaster management policy in agriculture. 	<ul style="list-style-type: none"> ▪ Climate change budgeting. ▪ Green climate fund established. 	<ul style="list-style-type: none"> ▪ Formulation and implementation of climate change acts. ▪ Promote climate smart agriculture including conservation agriculture. ▪ Promote climate resilient technologies and practices to adaptation and mitigation measures and reduce GHGs emission. ▪ Develop disaster management policy to reduce losses.
<u>Agricultural Insurance Policy:</u> <ul style="list-style-type: none"> ▪ Weak database and lack of weather based indexing of yields. 	<ul style="list-style-type: none"> ▪ Time series on climate (temperature, sunshine, precipitation) and agriculture productivity available. 	<ul style="list-style-type: none"> ▪ Prepare regional and national data base for weather index insurance. ▪ Create and promote weather based indexing insurance scheme in agriculture. ▪ Increasing awareness on agri-insurance. ▪ Capacity building of Member States in using models on weather index insurance, econometrics/ statistical tools.
<u>Conservation of Soil Environment Policy:</u> <ul style="list-style-type: none"> ▪ Growing pollution of land, water and soils from agro-chemicals, industrial effluents and plastics. 	<ul style="list-style-type: none"> ▪ Availability of Environmental Management Guidelines, and principles of taxation in public economics. 	<ul style="list-style-type: none"> ▪ Develop policies and implement waste management. ▪ Increase capacity of the 4-R principles (reduction, reuse, recycling and recovery).
Food Safety, Food and Nutrition Security		
<u>Food and Nutrition Security Policy:</u> <ul style="list-style-type: none"> ▪ Severe in food and nutrition insecurity that threatens to livelihoods for large number of people. 	<ul style="list-style-type: none"> ▪ Faster growth in food supplies than that of population. ▪ Improvements in Water, Sanitation and Health (WASH) services. ▪ Availability of Food-Based Dietary Guidelines (FBDG). 	<ul style="list-style-type: none"> ▪ Rational and effective distribution of foods and agricultural products. ▪ Promote nutrition sensitive agriculture including underutilized crops. Using food based and life-cycle based approaches to intuition. ▪ Integrate agriculture with WASH to improve food and nutrition security (availability, accessibility, utilization and stability). ▪ Localize the FBDGs for Recommended Dietary Allowances.

Issues/Challenges	Opportunities	Program Activities
<p><u>Food Safety Policy:</u></p> <ul style="list-style-type: none"> ▪ Lack of food safety acts, regulations and standards. ▪ Lack of harmonization on food safety rule and regulation in South Asia. 	<ul style="list-style-type: none"> ▪ Availability of Codex, OIE, HACCP standards and procedures. ▪ Trade integrated with SPS, GAP, GMP etc. 	<ul style="list-style-type: none"> ▪ Formulate food safety acts and authorities are available in some countries. ▪ Harmonize rule and regulation for food safety and regional trade.
<p>Inclusive Development</p> <p><u>Agricultural Policy:</u></p> <ul style="list-style-type: none"> ▪ Low investment in agriculture R&D. ▪ Reluctance to retain in agriculture profession. ▪ Neglect of resource poor/marginal farmers, women, OBCs and non-commercial crops. 	<ul style="list-style-type: none"> ▪ Commercialization of agriculture. ▪ FDI available. ▪ Increasing commitments for inclusive, board based and gender-sensitive approaches. 	<ul style="list-style-type: none"> ▪ Increase investment in agriculture R&D. ▪ Formulate necessary acts and regulations to implement policy. ▪ Policy incentives to farmers to retain in agriculture by promoting SMEs. ▪ Capacity development in agricultural economies sector modeling. ▪ Business incubation among the OBCS and women.
<p><u>Agri Input Supply Policy:</u></p> <ul style="list-style-type: none"> ▪ Imbalances between excess demand and inadequate supply of inputs including improved seeds and agro-chemicals. ▪ Input industry is complex: capital, technology, energy and raw materials. 	<ul style="list-style-type: none"> ▪ Increasing seed replacement rates. ▪ Higher demand of inputs including improved seeds, agro-chemicals, fertilizers and equipment. ▪ Private sectors available. 	<ul style="list-style-type: none"> ▪ Policy shift to bio-fuels. ▪ Enhance access to FDI for input industries, technology development and transport. ▪ Shifts to the low-input requiring, nitrogen fixing and conservation agriculture practices. ▪ Policy incentives and promote private sectors engagement in inputs industry.
<p><u>Agricultural Labor Policy:</u></p> <ul style="list-style-type: none"> ▪ Agricultural labors are less productive and huge labor migration/ out-migration. 	<ul style="list-style-type: none"> ▪ Agricultural labor available. 	<ul style="list-style-type: none"> ▪ Formulate policies and strategies for rural revitalization retaining economically active population in agriculture. ▪ Skill development of agriculture labor. ▪ Ensure decent works in agriculture.
<p><u>Credit Policy:</u></p> <ul style="list-style-type: none"> ▪ Lack of savings in agrarian economy. ▪ Hesitation of banking industry to invest in agriculture. 	<ul style="list-style-type: none"> ▪ Excess capital with regional and international development banks. ▪ Microfinance Institutions (MFIs) available. ▪ Growth of co-operative organizations. 	<ul style="list-style-type: none"> ▪ Increase access of microfinance programs to the farmers. ▪ Formulate policies and regulations for assuring investment from banking industries to the small holder farmers. ▪ Priority sector lending to agri-inputs, agriculture, agribusiness and agro-processing industry.

Issues/Challenges	Opportunities	Program Activities
<p><u>Livestock Development Policy:</u></p> <ul style="list-style-type: none"> ▪ Inadequate feed and fodders, health care and animals sheds. ▪ Weak database in livestock products marketing and economics. 	<ul style="list-style-type: none"> ▪ Higher income elasticity of demand for dairy, meat and poultry products. ▪ Willingness of banks to lend credit in livestock sector. 	<ul style="list-style-type: none"> ▪ Develop policy measures to capture market demand of livestock products. ▪ Develop data base on production and marketing of livestock products. ▪ Harmonize the food safety, processing and quarantine standards.
<p><u>Agribusiness Promotion and Marketing Policy:</u></p> <ul style="list-style-type: none"> ▪ Lack of contract act and agricultural marketing act. ▪ Under-investments in infrastructures (yards, transport, processing, storage, cold-chains etc.). 	<ul style="list-style-type: none"> ▪ E-NAM platforms are available. ▪ Increasing involvement of women and youth towards agribusiness sector. 	<ul style="list-style-type: none"> ▪ Formulate contract act and marketing act in agriculture. ▪ Increase investments in infrastructures (yards, transport, processing, storage, cold-chains). ▪ Promote rural revitalization through establishing small and medium enterprises and encourage economically active populations in agriculture. ▪ Harmonize the Cooperative Acts and Company Acts.
<p><u>Economic and Trade Integration:</u></p> <ul style="list-style-type: none"> ▪ Less volume of agricultural trade in the region. 	<ul style="list-style-type: none"> ▪ Effective functioning of SAFTA and SAARC for trade. ▪ Diverse products are available in diverse agro-ecological settings. ▪ Growth trade beyond the SAARC region. 	<ul style="list-style-type: none"> ▪ Formulate trade harmonization and trade facilitation measures. ▪ Reduce the tariff and non-tariff trade barriers and foster trade of most tradable products. ▪ Improve the competitiveness of the products (quality, quantity, price, sustainability and products delivery).
<p>Policy and Advocacy</p> <p><u>Food Sovereignty, and Right to Foods:</u></p> <ul style="list-style-type: none"> ▪ Inadequate legal, institutional and judicial arrangements for the right to foods. 	<ul style="list-style-type: none"> ▪ Commitments in the Constitutions of the SAARC Members States on Right to Foods (RTF). 	<ul style="list-style-type: none"> ▪ Develop policies and guidelines on promoting RTF. ▪ Advocate ensuring RTF.

Review of Agricultural Policies and Programs in South Asia

Policies in agriculture may differ depending on the agro-geography, climate, soil structure, water availability, technology advancement, specific commodities, and even it varies within district, country and region. In fact, policies and programs need to be formulated on the basis of existing challenges, constraints, and opportunities that are feasible to attain significant impacts. In this section, we are discussing the major policies adopted by the SAARC countries.

Agricultural Policy in Afghanistan

The Government of Afghanistan developed strategic policy “*National Comprehensive Agriculture Priority Program (2016-2021)*” aiming to overall development including food and nutrition security, good governance and economic development (MAIL, 2016). The strategic framework has been implemented in achieving the core national objectives of self-reliance, increase income and generate employment. It comprises the **six key priority areas**: i) climate-change sensitive natural resource management; ii) wheat and cereal production; iii) development of industrial and high value horticulture crops and vegetables; iv) livestock development; v) food and nutrition security, and vi) institutional reform. As Afghanistan has huge potentiality in agricultural development aligning with food and security agenda (Nigel et al., 2018), these strategic priorities would be highly useful for achieving the national objectives.

Agricultural Policy in Bangladesh

The Government of Bangladesh (GOB) developed the *National Fisheries Policy* in 1998 aiming alleviate poverty through enhancing the fisheries resources and production, creation of self-employment and improvement of socioeconomic conditions of the fishers, and eventually contribute to meet the demand for animal protein. *National Livestock Development Policy- 2007* was developed to accelerate economic growth and reduce rural poverty through livestock sector development. The policy is more focused on sustainable improvement in productivity of milk, meat and egg. Furthermore, the GOB adopted *National Food Policy Plan of Action – 2008* with main objectives to foster agriculture and livestock production for increasing dietary diversity, increasing the micronutrient daily intake and improving food security in the country. The GOB introduced Agriculture Input Assistance Card Program in 2010 through which farmers have given a smart card that allowed them to open a bank account and receive cash to purchase inputs.

National Livestock Extension Policy– 2013 was formulated emphasizing veterinary public health and food safety, provide effective extension services, and make linkages the research and extension services. Similarly, the *National Agricultural Policy- 2013* was developed aiming to promote agricultural diversification and make the nation self-sufficient in food through increasing production of agricultural crops. In addition, *Export Policy- 2015 (2015-18)* was formulated prioritizing diversification of export agricultural products (for example, herbal and tea).

Agricultural Policy in Bhutan

The Royal Government of Bhutan developed a *Food and Nutrition Security Policy- 2014* (MOAF, 2014) to ensure the fundamental rights of Bhutanese for affordable, adequate, safe, nutritious and culturally acceptable food. Agriculture Land Development Guideline- 2017 (DOA, 2017) is in pace of implementation to prevent land degradation,

appropriate use of land, increase crop productivity, rural urban migration, and improve ecosystem. The MoAF's 12th Five Year Plan (FYP) 2018-2023 emphasized agricultural enterprise development and commercialization in agriculture to maximize contribution in the nation's economy. The Royal Government of Bhutan (RGoB)'s policy is to harness opportunities in enhancing agriculture, livestock and forests-based enterprises as declared in the Economic Development Policy- 2016 (RGoB, 2016).

Similarly, the Government of Bhutan formulated many sectoral policies such as National Forest Policy- 2012, National Irrigation Policy- 2012, Water Act of Bhutan- 2011, Water Policy- 2002, National Environment Protection Act- 2007, Biodiversity Act of Bhutan- 2003, National Disaster Management Act- 2013, Biosafety Act of Bhutan- 2015, Pesticides Act of Bhutan- 2000, Seeds Act of Bhutan- 2000, Plant Quarantine Act- 1993, Forest and Nature Conservation Act- 1995 (NCB, 2019).

Agricultural Policy in India

India's Constitution lists agriculture only as a state subject, the central government, on grounds of agriculture being a subject of national significance, is an important sector in agricultural policy, which is implemented with co-financing by the governments at the Union, State, and Panchayat levels. In 2015, the government replaced the Planning Commission with the newly formed National Institution for Transforming India (NITI) Aayog to foster greater involvement of the state governments in the economic policy process. The central government's Ministry of Agriculture, which in 2015 became the Ministry of Agriculture and Farmers' Welfare (MAFW), provides broad guidelines for agricultural policies. Some important missions in their chronological orders are:

- i. National Agricultural Development Plan (*Rashtriya Krishi Vikas Yojana, RKVY*) operates since 2007-08 to cover diverse set of activities: crop development, horticulture, mechanization, natural resource management, marketing, animal husbandry, dairy development, and extension. It also focused on bringing the green revolution to eastern India, crop diversification, soils reclamation, shifting rice fallow area in eastern India to pulses and oilseeds, and controlling foot and mouth disease.
- ii. National Food Security Mission (NFSM) operates since 2007-08 to increase the production of wheat, rice and pulses as well as the promotion of commercial crops like cotton, jute and sugarcane. The strategy is to provide financial assistance to promote and extend improved technologies, e.g. seed, micronutrients, soil improvement, pest management, machinery, and irrigation, as well as farmer capacity building. Since 2016-17 several new such initiatives were undertaken to increase the production of pulses.
- iii. National Innovations on Climate Resilient Agriculture (NICRA) was launched in February 2011. The project has three major objectives of strategic research,

technology demonstrations and capacity building. Assessment of the impact of climate change simultaneous with formulation of adaptive strategies is the prime approach under strategic research across all sectors of agriculture, dairying and fisheries. Evolving climate resilient agricultural technologies that would increase farm production and productivity vis-à-vis continuous management of natural and manmade resources constitute an integral part of sustaining agriculture in the era of climate change. The **four modules of NICRA**– natural resource management, improving soil health, crop production and livestock – are aimed at making the farmers self-reliant.

- iv. Rainfed Area Development Programme (RADP) started since 2011-12 to ensure agriculture growth in the rain fed areas. It aims at improving quality of life of farmers' especially, small and marginal farmers, by offering a complete package of activities to maximize farm returns. RADP focuses on Integrated Farming System (IFS) for enhancing productivity and minimizing risks associated with climatic variabilities.
- v. National Mission on Oilseeds and Oil Palm (NMOOP) restructures since 2014, the earlier Integrated Scheme of Oilseeds, Pulses, Oil Palm, and Maize (ISOPOM), along with the tree-borne oilseeds and oil palm area expansion. Operating through three mini-missions (oilseeds, oil palm, tree-borne oilseeds), the NMOOP seeks to increase the production of vegetable oil through support for many kinds of improvements in inputs and practices, such as seeds, nutrient management and sprinkler irrigation.
- vi. *National Agro-forestry Policy-2014*, focused to resolve the bottlenecks that had emerged at the interface of existing policies for agriculture, forestry, water and environment, recognizing that land use by its very nature must be integrative. Agro forestry (incorporating trees and shrubs into farmlands and rural landscape) is a useful strategy for such farmers to increase the productivity from their land as well as to increase the resilience to climate change impacts.
- vii. Mission for Integrated Development of Horticulture (MIDH) brings together since 2014-15; the earlier National Horticulture Mission, the Horticulture Mission for North East and Himalayan States, National Bamboo Mission, National Horticulture Board, Coconut Development Board, and Central Institute for Horticulture.
- viii. National Mission for Sustainable Agriculture (NMSA) operates since 2014-15 to make agriculture more productive, sustainable, remunerative, and climate resilient. The mission has two major components: rain fed area development and soil health management.
- ix. National Mission for Sustainable Agriculture (NMSA) operates since 2014-15 to make agriculture more productive, sustainable, remunerative, and climate resilient,

it also works to mitigate the effects of drought and increase the area under irrigation.

- x. Prime Minister's Agricultural Irrigation Plan (*Pradhan Mantri Krishi Sinchai Yojana: PMKSY*) since 2015-16 is in place to mitigate the effects of drought and increase the area under irrigation. The scheme aims at providing end-to-end solutions in irrigation supply chains, with respect to water sources, distribution network and farm-level applications. It also introduced "soil health card", creating protective irrigation by harnessing rain water at micro level through "Jal Sanchay" and "Jal Sinchan", and micro irrigation is also incentivized to ensure "Per drop-More crop".
- xi. Paramparagat Krishi Vikas Yojana (PKVY) launched in 2015, is an extended component of Soil Health Management (SHM), which aims at supporting and promoting organic farming. The scheme promotes Participatory Guarantee System (PGS), which operates outside the framework of "Third Party Certification".
- xii. Pradhan Mantri Fasal Bima Yojana (PMFBY) (Prime Minister Crop Insurance Scheme) is being implemented from 2016 for buying crop insurance, which remains compulsory for indebted farmers and voluntary for others. Electronic technology is expected to be used for estimating yield losses and for depositing payments in producers' bank accounts. Although the PMFBY premiums are calculated on an actuarial basis, farmers pay 1.5% of the sum insured for Rabi crops, 2% for Kharif crops and 5% for horticulture and commercial crops. With such agricultural comprehensive policies, the GVA per worker in agriculture has begun to rise rapidly in India. The agriculture policies such as above, together with other fields of the agrarian economy, have contributed to the policy of doubling the farmers' income during 2017-23.

Agricultural Policy in Maldives

Country Programming Framework (CPF) was formulated in 2017 to focus the priorities for the next five years in guiding as a road map and a medium term framework for programming in the country. The government of Maldives developed *Agricultural Development Master Plan- 2009* (for 2010-2025) incorporated the overall perspectives, particularly from inputs to production and value chain of major high value crops.

Agricultural Policy in Nepal

The Government of Nepal developed agricultural policies, consistent with the MDGs and Sustainable Development Goals (NPC, 2017) are in implementation. The major policies are National Seed Policy- 2000, National Tea Policy- 2000, National Fertilizer Policy- 2002, National Coffee Policy- 2003, National Agricultural Policy- 2004, National Land Use Policy- 2012, Climate Change Policy- 2011, Agribusiness Promotion Policy- 2005, Agrobiodiversity Policy- 2007, Dairy Development Policy- 2007, and Rangeland Policy-

2012. Further, recently Ministry of Agriculture and Livestock Development developed a long-term plan for 2015- 2035, Agriculture Development Strategy (ADS)- 2015 (MoAD, 2015). ADS envisaged accelerate economic growth and contributes to improve livelihoods and food and nutrition security through a self-reliant, sustainable, competitive, and inclusive agriculture through four strategic components: commercialization, productivity, competitiveness and governance (MoAD, 2015). It has four flagship programs: i) Food and Nutrition Security Program (FANUSEP); ii) Decentralized Science, Technology, and Education Program (DSTEP); iii) Value Chain Development Program (VADEP); and iv) Innovation and Agro Entrepreneurship Program (INAGEP). The Constitutional provisions of Co-operative Federalism with 3-tiers (Central, Provincial and (Rural) Municipality) and agriculture in Concurrent List of all three tiers of governments, the agricultural policy implementation agencies are in evolving stages.

Agricultural Policy in Pakistan

The Islamic Republic of Pakistan formulated the major policies related to agricultural research and development; namely, National Agriculture Policy- 1980, National Commission on Agriculture- 1998, Framework for Economic Growth- 2011, and National Food Security and Agriculture Policy- 2017. These policy frameworks looked for inclusive growth through structural reforms, productivity enhancement, and youth engagement along with national food security. Pakistan Vision- 2025 (GOP, 2014) envisaged stabilizing the macroeconomic measures with inclusive growth and zero-hunger through adoption of innovative technologies and cost-effective approaches in agriculture. In order to reduce the effects of climate change extremes, the GOP developed a Framework for the Implementation of Climate Change Policy (2014-2030).

Agricultural Policy in Sri Lanka

The Government of Sri Lanka developed National Agricultural Policy- 2007 with clear vision to build agriculture sector environmentally prudent, economically productive and socially improving secure in food and nutrition. It complies with the Sustainable Development Goals (SDG); in particular, SDG- 1 (No poverty), SDG-2 (Ending hunger), SDG-5 (Gender equality), SDG- 8 (Decent work and economic growth), SDG- 12 (Responsible production and consumption), SDG- 13 (Climate action), and SDG- 15 (Life on land) (SLCARP, 2017). This policy envisaged **nine core components**: i) increased sustainable agricultural production and productivity; ii) research, development and innovation; iii) food and nutritional security; iv) food safety; v) environment vulnerability and resilience; vi) market development; vii) private sector involvement; viii) extension and empowerment of farmers, and; ix) information systems and communication.

Policy Gaps and Priority Agendas

Gurung et al. (2017) suggested **ten priority areas for agricultural research**: i) seed and planting material system, including varietal exchange, certification, regulation and marketing; ii) delivering framework for piloting and scaling-up of sustainable agricultural technologies; iii) biosecurity engagements; iv) agricultural policy and research gaps for building resilience; v) harnessing ICTs to increase agricultural production; vi) analysis of agricultural marketing and value chain reforms; vii) development and utilization of regional databases; viii) agroforestry systems for sustainable agriculture; ix) animal and aquatic feeds and nutrition; and x) agricultural trade (formal and informal barriers).

Thimphu Agriculture Ministerial Meeting (2019) declared: to promote sustainable agriculture for enhancing agricultural productivity, competitiveness, rural growth and to ensure food and nutrition security; promote climate resilient agricultural strategies and technologies; promote multi-sectoral approaches and actions; intensify agricultural research, innovations and development; strengthen cooperation to expand agro-processing and building competitive agricultural value chains; develop mountain and hill agricultural research to develop economically and environmentally sound sustainable mountain/ hill agricultural practices; facilitate gender mainstreaming and attracting youth and women in agriculture; operationalize the SAARC Food Bank to enable the Member States to avail food grains; operationalize the SAARC Seed Bank to facilitate the exchange of high-quality germplasm of the popular crop varieties; facilitate the exchange of advanced genetic materials of the popular crops, livestock, poultry and fisheries; assess and adopt appropriate measures for addressing the issues related to transboundary animal diseases (TAD), emerging zoonotic diseases/ pathogens, and antimicrobial resistance; transboundary and invasive diseases and insects pests of crops; implement recommendation of the SAARC CVO's Forum and Global Strategy for Eradication of Peste des Petits Ruminants (PPR); SAARC's Cooperation on Antimicrobial Resistance (AMR) and Antimicrobial Use (AMU); prepare SAARC Agriculture Vision-2030; and realign its strategies to the priorities and activities proposed by 9th TCARD and 4th SAOM.

Meanwhile, Dixon et al. (2001) focused some strategic priorities for poverty reduction include farming system management, sustainable management of soil and water resources, human capital, market-based intensification and diversification, agricultural information and knowledge systems, natural resources and climate, science and technology, globalization and market development, price information systems in South Asia. Shrestha & Bokhtiar (2019) suggested to promote climate smart agriculture through improved crops varietal development, information and knowledge management, institutional and human resource development, financial access to smallholder farmers,

technical supports, and agriculture insurance program could reduce the effects of climate change.

In reviewing with the agricultural policies of the SAARC Member States, Ten Priority Areas for agricultural research (Gurung et al., 2017), Thimphu Statement of the 4th Agriculture Ministerial Meeting (2019), SAARC Senior Agriculture Officials meeting (Thimphu 2019), Ninth TCARD meeting (Thimphu 2019), and SAARC Multi-stakeholders meeting (Thimphu 2019), following **Fifteen Priority Areas** of policies and program issues are recommended:

- i. Increase investment in agricultural R&D with reference to the share of AgGDP to the national economy. The research areas should focus on developing the high yielding and stress tolerance (biotic and abiotic) in crops, vegetables, livestock, and fisheries.
- ii. Policies should address the rural revitalization in agriculture and rural based resources by promoting small and medium enterprises (SMEs) that could retain economically active population in agriculture.
- iii. Availability, accessibility and affordability of quality agricultural inputs (improved seeds/ seedlings, breeds, fertilizers, equipment, and capital).
- iv. Policies towards incentivizing smallholder farmers linking to the markets that could reduce marketing margin- increase farmers' share and reduce consumers' prices of the products.
- v. Efficient marketing and distribution system management of agricultural products that could contribute to improve food security.
- vi. Promote underutilized neglected nutrition rich crops for achieving food and nutrition security.
- vii. Promote private sector engagement through market system approach throughout the agricultural value chains.
- viii. Piloting and scaling –up of sustainable intensive agricultural technologies, adopt the climate smart agriculture to build climate resilience and natural resource management.
- ix. Promote animal and aquatic feeds/ fodders/ nutrition that could reduce the consumers' price of the products.
- x. Eradication of Peste des Petits Ruminants (PPR), Antimicrobial Resistance (AMR), and zoonotic diseases/pathogens measures.
- xi. Combat transboundary plant, aquatic, and animal disease and pest.
- xii. Policy harmonization on regional trade of agricultural inputs and products to enhance regional trade by reducing tariff and non-tariff barriers.
- xiii. Policy harmonization on material transfer agreement so that improved, high yielding and stress tolerance crop seeds, and genetic resources of plants and animals could be transferred from one country to another countries in the region.

- xiv. Adoption of ICT based statistics to increase agricultural production and productivity in the region.
- xv. Formulation of legislations and regulations favoring commercialization of agriculture e.g., Contract Farming Act, Land Leasing Act, Agriculture Land Use Act, Agribusiness and Marketing Act, etc.

According to (WEF (2019), the world stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. For 2030, it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society. The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a **Fourth Industrial Revolution “Technological Revolution 4.0”** is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres.

Acknowledgement

We would like to express our sincere gratitude to the National Experts for contributing country status papers, Thematic Experts for contributing thematic papers, Thematic Review Panelist, members in group brain storming, Dr. Ravi Khetarpal and APAARI team, and Dr. SM Bokhtiar and SAC team for their invaluable supports in this endeavor.

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Chapter 2

Agricultural Research and Development: Policy and Program Priorities in Afghanistan

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Abstract

Agriculture is the foundation of Afghan society and the source of livelihoods for about 80% of the total population. It contributes 25% of the national Gross Domestic Product (GDP), employs about 45% of the national workforce, and provides a source of income for 44% of total households in the country. The agriculture sector is diverse, ranging from field crop production in irrigated and rainfed areas, to horticulture and extensive livestock production. Farming households include small farm households, which are more subsistence oriented, while middle- and large-sized farms predominantly produce crops for commercial purposes. The Government of Afghanistan identified Seven Strategic Priorities in agriculture sector under the National Development Plan to improve service delivery, food security, and greater productivity for enhancing national revenue. The seven strategic priorities includes: i) climate-sensitive natural resources management; ii) wheat and cereal production; iii) horticulture value-chain; iv) livestock production; v) food and nutrition security; vi) institutional reform and; vii) capacity development. These priority areas are focused on many of the normative integrated activities such as research and extension; integrated pest management; input delivery systems management; quality control; quarantine; farmer organizations; public private partnerships; data and information management; policy and legal framework; and governance and coordination.

Keywords: Policy, production, productivity, strategy

Background

Afghanistan is a landlocked country located in South-Central Asia. Afghanistan is bordered by Pakistan in the south and east; Iran in the west; Turkmenistan, Uzbekistan, and Tajikistan in the north; and China in the far northeast. Its territory covers 652,000 km² and the most of the part is covered by the Hindu Kush Mountain range (Meredith, 2007). Agriculture is the foundational basis of Afghan society. Approximately 80% of the population is engaged in agriculture directly or in secondary or tertiary activities. Realizing as the agriculture is the backbone and main engine of the economic development,

Afghanistan's former agricultural infrastructures have been restored, while considerably more remains to be done. As new possibilities in the development of infrastructure and technologies emerged, agricultural producers, processors and traders are demanding increased assistance in identifying new markets for their products. Agricultural practices in Afghanistan represent an evolving narrative – while some farmers are engaged in subsistence farming, intensive farming has proved to be profitable so as the government increase investments in a range of services and create enabling policy environment.

The Seminal Planning Framework for development has been the *Afghan National Development Strategy (ANDS) - 2008*, within which a *National Agricultural Development Framework (NADF) - 2009* was developed. A series of 22 National Priority Programs (NPPs) were formulated following the Kabul Conference in 2010, of which the Ministry of Agriculture, Irrigation and Livestock (MAIL)'s priorities were reflected within two programs i.e. Agriculture and Rural Development (ARD) Cluster's NPP1 that dealt with water, irrigation and natural resources, and ARD NPP2 that framed broader agricultural priorities in production, market development and food security. This also includes the formulation of various agricultural sub-sectoral policies and strategies such as policies in wheat, poultry, food and nutrition, women in agriculture, medicinal plants, etc. This shift realign the broader priorities of the Ministry of Agriculture into seven key areas with specific focus on creating an enabling environment for farmers to create surplus in agricultural products; increase on and off-farm employment; and generate income through increased exports. Strategic Priorities identified in order to underpin the capacity of MAIL to support and enable the achievement of targets under these priority areas.

Situation in Agricultural R&D in Afghanistan

Agriculture is the main source of livelihoods for more than 80% of the Afghanistan people. About 12% of the country's total land is arable, 5.6% (3,600,210 ha) irrigated, 5.8% (3,734,494 ha) rainfed, 0.2% (117,642 ha) fruit trees, 0.1% (82,450 ha) for vineyards, 27.0% (17,404,540 ha) barren land, 7.4% (4,778,750 ha) sand cover, 2.8% (1,781,045 ha) for forest & shrubs, 47.0% (30,243,985 ha) for rangeland, 0.8% (497,236 ha) for permanent snow, 0.5% (306,855 ha) for built-up and 2.9% (1,845,976 ha) for water body & marshland (Figure 1) (FAO, 2016).

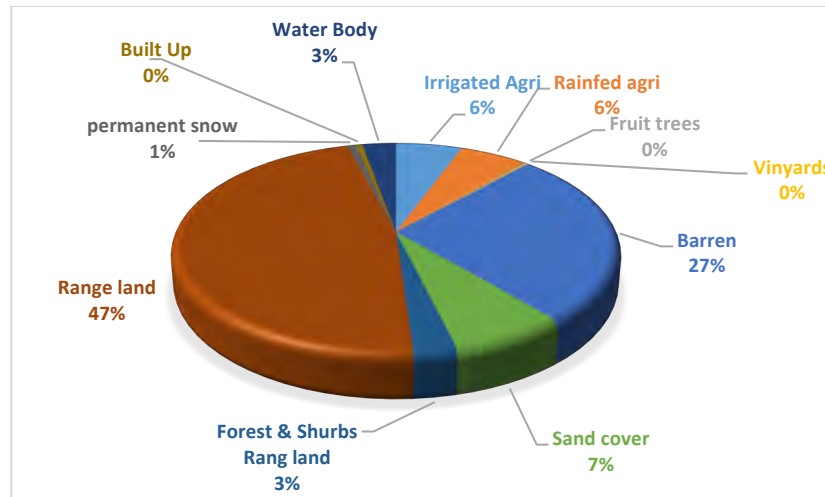


Figure 1. Land cover of Afghanistan (ha)

Source: FAO (2016)

Agriculture has been the mainstay of the people economy, although several decades of war and drought have depressed agricultural activities and contributed to the degradation of the natural resource base (WCS, 2010). Recognizing that poverty is a major challenge in Afghanistan, MAIL is prioritizing its policies and programs to achieve the Sustainable Development Goals (SDG- 1), more specifically targeting on SDG- 5, SDG- 6 and SDG- 7 on building resilience for the poor; mobilize resources to address poverty in all its forms and develop pro-poor policies that target gender and increased investment in providing opportunities to eradicate poverty. Similarly SDG- 2, MAIL is empowering women to increase food production at the household level and at the commercial scale, and improving food security for the women and vulnerable groups of people.

There has been a steady and fluctuating growth in agricultural productivity since 2007. It contributed to generate 1.3 million Full-Time Employments (FTE) both on and off-farm. Agriculture holds great possibility for increasing and generating FTEs for the coming years. Similarly, horticulture sub-sector has produced significant returns to farmers and traders. Over 2 million people are involved in this sector generating revenues in excess of US\$ 700 million contributing to 6.7% of overall GDP and 34% of agricultural GDP (CSO, 2013). Similarly, livestock production contributes 3.8% of the total GDP and 15% of agricultural GDP valued at US\$ 684 million. Exports from this sector continue to be modest, amounting to US\$ 116 million per annum.

The World Bank in its Agricultural Sector Review (World Bank, 2014) document divides the challenges encountered agricultural sector into two major categories: intensive agriculture -movers of agribusiness, and extensive agriculture- targeting the poor (MAIL, 2016). First, approximately 33% of Afghans are food insecure, and suffering from chronic

malnutrition with rates 41%, to which agriculture bears a strong connection. Second, the largest impediment to realizing value chain enhancement in agriculture is the size of farms and farm-holding patterns in the country. Emphasis must be placed on organizing medium to large farm holders to create economies of scale where production inputs and outputs are rationalized to increase production and raise national incomes.

The farmers who engage in subsistence farming including landless farmers and itinerant *Kuchi* animal herders must be targeted by concerted efforts to address poverty alleviation through complimentary programs such as the Citizens Charter, and in the case of the *Kuchis* through expanded livestock extension efforts. Both strategies require addressing a host of issues such as legal land ownership, pasture and rangeland management right of passage, access to water resources, provision of agricultural inputs; conflict resolution mechanisms, etc.

Challenges and Opportunities in Agricultural R&D

The current structure of the organization is incompatible with its stated vision of being a dynamic and a farmer centric organization. The existing structural organization of the ministry reflect the past 40 years of war experiences and diminished agricultural systems. In addition, the emerging challenges is climate change and its effects, Afghanistan remains extremely vulnerable to multiple, unpredictable and recurrent natural hazards. Conflict and natural disasters, particularly flood, drought, landslides and earthquakes seriously affect the availability of food staples, cash crops and animal production. Without inadequate supports, traditional coping mechanisms may not be sufficient to ward off food insecurity. Weak land management, water control systems, limited market access and linkages limited road networks, poor food value chains (including storage, processing, and marketing channels), weak agricultural research and technology innovation (Sultana et al., 2018) and poor technology dissemination, lack of agriculture credit, and low institutional capacity are the major challenges for agricultural research and development in the country

Recent years have seen remarkable growth in the production of industrial crops such as saffron, liquor ice, pistachios, turmeric, pine nuts, ferula and an array of valuable medicinal crops. MAIL provides technical assistance and support to marketing efforts in promoting medicinal and industrial crops. It is estimated that more than 360,000 full time equivalent (FTE) jobs will be generated with an additional 360,000 ha of horticultural land by 2024 and the horticulture sector alone would contribute US\$ 3.23 billion compared to US\$ 1.4 billion in 2012 (CSO, 2013). Whilst the overall significance of expansion of livestock is primarily focused on providing interventions that address poverty alleviation by providing additional 604,000 new FTE and doubling poultry production resulting in contribution of a further US\$ 274 million to the National GDP. This includes increased opportunities for exporting agricultural products to neighboring countries.

Review of Agricultural Policies and Programs

The National Comprehensive Agriculture Priority Program is viewed as a noteworthy contributing factor to the overall development including food and nutrition security, good governance and economic development agenda of the Government of Islamic Republic of Afghanistan. The strategic framework in achieving the core national objectives of self-reliance, increased income and employment generation, the **six key priorities** have been identified (MAIL, 2016). These strategic priority areas are: i) Climate-change sensitive natural resource management (NRM); ii) Wheat and cereal production; iii) Development of industrial and high value horticulture crops and vegetables; iv) Livestock development; v) Food and nutrition security and vi) Institutional reform.

Climate Change-Sensitive Natural Resource Management

Despite of occurring frequent climate change events and subsequent natural disasters, Afghanistan remains with rich in natural resources such as 1.7 million hectares of forest (2.63% of the total area), and 30.1 million hectares of rangelands (46.84% of the total area) (WCS, 2010). These resources have a significant economic, social, and cultural value. Although Afghanistan has acknowledged advances in cataloguing its natural assets, passing laws and developing policies, further progress has been constrained by contested land ownership, land grabbing, etc.

As climate change becoming a global priority, MAIL is currently adopted COP21 framework. MAIL engage its abilities to adapt sustainable ways to address adverse effects of climate change through awareness-raising of the climate change phenomenon and its effects on agriculture and livelihoods. MAIL coordinates closely with National Environmental Protection Agency (NEPA) and Ministry of Rural Rehabilitation and Development to address the climate change issue. MAIL recognizes the crucial need to protect and build upon its existing NRM base to ensure a curative and causative approach. Through structured programs on agricultural adaptation, farmers, herders, and particularly women are better positioned to plan and implement low-cost interventions. The overall objective of the NRM strategy is to ensure the program supports sustainable economic development of communities, which depend on natural resources (forests, rangelands, natural vegetation and ecological areas), create green environment, conserve soil, water, and protect biodiversity. The strategy is focused to enhance economic growth of the country through strengthening communities in utilizing natural resources.

Forestry: Community-based forest sustainable management (e.g. conservation, restoration, afforestation, development, sustainable harvesting and value adding to the products) is one of the pillars of forest sector in order to attain economic development and sustainable rural livelihoods. A cluster activities are delivered, such as strengthening or creating community-based institutions in forest management and Forest Management Associations (FMA) to take charge of fruits and nut tree production as a broader

component of a potentially lucrative value chain, which will be supported at district level. At the Provincial level, forest management are facilitated through Forestry Research Centres (FRCs) linked with existing research stations. Research are focused on propagation of drought resistance (adoptable) species. Finally, improving urban greenery for urban ecosystem management and improving peri-urban based supply farms to meet the requirements of plants, shrubs, saplings, etc. These activities are supported by institutional and human resource development at national and sub-national levels in line with institutional reform.

Rangeland and medicinal plant management: Community-based sustainable management, conservation, restoration, improvement, and development approach are used to manage sustainable utility of rangelands and wild medicinal plants to support and develop sustainable livelihoods of local communities and nomads. This will require local communities to actively conserve and maintain 210,000 ha of rangeland by introducing rotational grazing practices covering of 205,000 ha over 5 years. Innovative approaches to engaging communities in watershed management, and the establishment of local producer groups and associations are undertaken through mobilization and capacity building. In addition, 11 Forages Seed Production and Propagation Centers will also be set up.

Protected area management: This is a main area of the program focused on inculcating ownership and sustainable conservation and management of protected areas and wildlife. This is supported by the enforcement of relevant law and commitment to the relevant International Conventions to develop biodiversity and strengthen eco-tourism. With the similar models, protected areas will gradually be expanded at national level from 0.34% to 2% (CSO, 2013). Furthermore, the combination of cataloguing and prioritizing indigenous fauna and flora through scientific surveys in all 9 targeted protected areas will be carried out with expansion of tourist facilities and the promotion of community- managed models resulting in additional income and employment generation, which is more focused to attain SDG -11 and SDG -12.

Institutional and Human Capacity Development

The development of capacity to deliver technical supports through farmer learning resource centers. This will include a critical realignment of staff and function at provincial level (Provincial Agriculture, Irrigation and livestock- PAIL) based on the establishment of a professional hub for national resources planning and technical support to NRM planning. Furthermore, the PAILs will support the promotion of community- based NRM governance, which will involve mobilizing, establishment and registration of active community-based groups/associations.

Hence, over the next five years a variegated approach of short and long term measures will be undertaken in sustainable forest management including of maintaining and improving rangelands, improving production and strengthening value chains for medicinal plant

cultivation, and enforcing protected areas and indigenous wildlife. In addition, links will also be developed between rural and peri-urban communities to build social awareness of the value of urban eco-systems and the provision of greenery for major cities to reduce air pollution levels. This strategy will be underpinned by a concerted capacity development of MAIL over the next five years as it shifts custodianship of common assets into community hands, and identifies key areas of medium to long-term income generation for communities entirely reliant on forest and non-forest products.

Improving Irrigation Systems

Irrigated land will increase from 2.45 million ha to 2.7 million ha impacting of 650,000 households in the next five years. However, adopting a *Farmer-Centric Approach* in making available and distributing water, irrigation is beyond just physical works and will require concurrent social management interventions through Irrigation Associations and Clustered Community Development Councils.

Investment in irrigation and agriculture provides a unique opportunity to foster economic growth, increase rural employment and enhance food security especially in rural areas. The Ministry of Energy and Water (MEW) manages primary irrigation infrastructure, MAIL is responsible for developing and managing irrigation systems and networks – these include on-farm water management, watersheds and rangeland water resources. MAIL aware of its commitment under SDG for ensuring an equitable approach to the provision of water access to all. Over the next five years, MAIL is committed to an accelerated rehabilitation and construction program of physical works. This will be driven by the National Irrigation Program (NIP) targeting increase production and productivity through irrigation and improved water management practices with a long-term focus to achieve pre-war irrigated land of 3.1 million ha in the next ten years.

Achieving the aforementioned target will require creating inter-ministerial coordination between MAIL, MEW and MRRD at the national planning stage in Kabul, and at the implementation level at sub-district level. The NIP comprises three components, as summarized below.

Component-1: Irrigation Physical Works to achieve 3.1 million ha irrigated land (pre-war status) through restoration and bringing new areas under irrigation by 2025 (improved irrigation services for additional 900,000 ha through rehabilitated irrigation schemes, and 120,000 ha new land under irrigation). This will contribute to increase production from the current 5.8 million Mt of food grains to 8 million Mt, providing a greater opportunity to reach food security for the population.

Component-2: Enhance Irrigated Agriculture will improve input supports along with research, transportation, and extension of irrigation related technologies. This will result in increased land and water productivity through water saving technologies, and expansion of irrigated areas through saved water.

Component-3: Institutional Strengthening (Public and Private Sectors) will revolve around the establishment and reform of legislation, policies, institutions and improved management to promote investment in the Development of Irrigation and participation of private sector. This will result in more transparent frameworks, regulations, and a restructuring of Irrigation Department to implement irrigation development across Afghanistan. There will be significant emphasis not only on institutional strengthening of the Irrigation Directorate at all levels, but also establishment of Irrigation Associations at community level complimenting the emerging discourse on the future roles of Community Development Councils (CDCs) through the Citizens' Charter.

Although maize and rice are the major commodities of the national diet, wheat remains the primary strategic priority crop for food security and self-sufficiency in the country. However, the productivity per unit area is very low (2.5 Mt/ha under irrigated and 1 Mt under rain-fed conditions) compared to the neighboring countries amounting to a shortage of more than one million tons of wheat grain annually. The deficit amount of wheat and wheat flour compensated by commercial importing from Tajikistan and Pakistan.

The overall objective of the National Wheat Program (NWP) is the sustainable development of the wheat sector in order to achieve self-sufficiency, improve food security and better response in case of emergency and crises across the country through private sector engagement and incentivizing farmers with well-tailored agricultural packages. Given the economic and dietary importance of wheat, MAIL is committed to address chronic food insecurity, storage of grain surplus and the availability of high quality certified seed. MAIL anticipates an expansion of additional 110 thousand hectares of irrigated and rain-fed under wheat cultivation, increase current yield for irrigated land from 2.45 to 3.1 Mt/ha and rain-fed from 1.03 to a minimum of 1.3 Mt/ha. This sector faces numerous challenges in acquiring high quality agricultural inputs, incentivizing private sector investment to strengthen market elements of the value chain and ensuring aging seed is constantly replenished by new high-yield location-specific varieties.

The NWP will be undertaken in two phases; the first phase focusing on short-term objectives. Hence, Phase- I will mostly work aligning available technologies in order to reduce the wheat yield gap. These technologies will be further disseminated to farming communities through extension services, using a combination of Regional Research Stations and selected staff at the Provincial Agriculture, Irrigation and Livestock Department (PAIL) through the technical hub of Farmers Learning Resource Centers (FLRCs). This will entail strengthening human resource capacity to conduct wheat research and seed production programs in order to provide effective public services in a sustainable manner. Effective linkages will be strengthened at the District Agriculture, Irrigation and Livestock Departments (DAILs) through the Extension Directorate, where Integrated Agricultural Service Centers (IASCs) will reach out to farmers and private sector agents, promoting best practices. Alongside the on-going activities started under the

first phase, the second phase will focus on longer-term objectives involving standardization and expansion of the adaptive research, and basic research activities (e.g. molecular breeding) in order to develop new varieties and effective service delivery and sustainable wheat sector development within the country.

Rice and maize, the next most important crops, are also far from meeting consumption requirements. MAIL is developing a comprehensive rice strategy that includes focus on improved cultivation techniques and develop varieties (1 million Mt 2021) and develop rice value chain by encouraging the private sectors.

Storage and Strategic Grain Reserves (SGR) will remain a high government priority, with a minimum 200,000 Mt of SGR capacity, within which MAIL will play a crucial role of incentivizing farmers and serve as an emergency food security instrument alongside the Emergency Preparedness and Response program. In turn, other ministries will ensure market and pricing stability, availability to market, and control emergency, and crises to balance food security, and price stabilization through market support mechanisms.

The longer-term view adopted by MAIL is to create an environment where the private sector begins to take an increasing lead in harnessing the potential of semi-commercial and small commodity producers into commercial enterprises aimed at accelerated cereal, rice and maize production. Domestic industries such as milling of cereals will require further strengthening to reduce Afghan dependency on value-added commodities. This will allow MAIL to invest more resources and time to focus on research and development of new seed varieties, reduction of losses, provision of adequate storage and emergency distribution, regulatory and trade-related issues. The Strategic Priorities will be an intrinsic reliance on adequate irrigation, timely availability of high quality inputs (certified seed, agronomic packages), agricultural credit packages, value-addition activities and a pronounced role for the private sector.

High Value Horticulture Crops and Vegetables

Horticultural crops cover approximately 360,000 ha, accounting for 14% of the total irrigated area, employing more than 2 million people in the various steps of the value chain, where some 90,000 are involved in the non-farm economy. The perennial horticultural crops: grapes, pomegranates, almonds, pistachios and vegetables- are strategic important and most of them are exportable commodities. The horticulture subsector contributes US\$1.4 billion to the national GDP (6.7% of NGDP) and 34% of agriculture GDP. The horticulture subsector has grown at the rate of 5.5% per year over the past decade and has the potential of expanding further, raising farm incomes, generating productive jobs and improving food security in the rural and urban communities. According to World Bank (2014), with the current growth rate of 5.5% per year, the sub-sector is expected an expansion covering 400,000 ha and contributes US\$1.6 billion annually to GDP by 2024 (MAIL, 2016). Additional expansion of the horticultural

land -base is possible with the right investments in rehabilitation of irrigation schemes. Additional increase in yield of 2% per year are feasible through better extension and adoption of improved orchard management and IPM practices. Together, the horizontal and vertical changes stated below could raise the GDP to about US\$ 3.23 billion by 2024 (compared to US\$ 1.4 billion in 2012).

The sustainable development of the horticulture sector is designed with need-based and demand - driven extension services aimed at increasing production and productivity with following **eight strategic** measures.

- Expansion of the Horticulture Land-base (Horizontal Increase) by 12,400 hectares per year from 2014 to 2018 through investments in the rehabilitation of the irrigation schemes, on-farm water management and adoption of water-use efficient irrigation systems.
- Increase Productivity at 5 to 10% per year through a combined package of interventions including adaptive research, improved crop, orchard and pest management, timely availability of high quality inputs, access to credit, and effective extension system.
- Develop Promising Value Chains based upon the selection of a few fruit and nut crops in which Afghanistan has had an historical added advantage in the export markets. A high levels policy decisions and considerable collaborative mechanism needed to ensure in formulating enabling environment for the growth of Small and Medium Enterprise (SMEs) that could compete with the imported products.
- Infrastructure and Market Development is closely linked to the above strategic measure, but with an increased emphasis on incentivizing the private sector to invest in strengthening producer groups for utilizing cold storage facilities, refrigerated transport and shipping, and processing of horticultural crops.
- Support the Private Sector in upgrading processing facilities through Public Private Partnership (PPP) initiatives with the assistance of the Ministries of Commerce, Industry and Economy along with Afghanistan Investment Support Agency (AISA). In addition, specific rules and regulations, standards, quality control and associated measures will be set up and updated to promote production, processing as well as marketing, import and export of the necessary inputs and outputs and due investments will be stimulated with customized credit packages for enhancing SMEs.
- Develop nurseries by increasing access to improved and certified seeds and planting materials.
- Expand the area under protected agriculture by expanding the growth of the off-season production of vegetable crops, which has been remarkable increased over the last decade. The Government should encourage further production of vegetable crops under plastic greenhouses and tunnels through production of hybrid seeds and

subsidized production of plastic sheeting, metallic tubing and drip irrigation pipes and fittings.

Livestock Development

The livestock sector contributes significantly towards Afghan economic growth and employment as well as import substitution for livestock products. In 2012/2013, the contribution of livestock to GDP was estimated to be 3.1%, decreased from 3.8% in 2011/2012 based on current prices (World Bank, 2014). This sector provides 15% (US\$ 680 million) of the agricultural GDP and creates about 1.1 million full-time equivalent jobs, 15% of which are off-farm (MAIL, 2016). It also provides an exclusive livelihoods for Afghanistan's nomads, who follow traditional grazing routes across the country. Livestock has potentiality to increase yield, income and employment.

Considerable potentiality exists for the expansion and semi-commercialization of the livestock industry. The progressive farmers have begun to generate income from livestock production, especially in peri-urban areas where there is better access to a rapidly growing demand for animal products. This is especially true in the case of semi-commercial dairy and poultry production, but also increasingly, seasonal fattening of sheep and goats as and when market prices of feeds and meat allow a profit to be made.

The demographic projections is estimated to be 47,602,000 in 2025 and 70,553,000 in 2045 (CSO, 2013). In order to meet the growing demand for food, the livestock sector will have to increase the number of animals and increase the level of productivity. The former will entail consideration of the appropriate carrying capacity in view of key challenges for instance related to livestock feed availability.

The broad-based objective of the National Livestock Development Program (NLDP) is to increase production of fodder, dairy, meat and poultry and link with improved market access. MAIL is committed to improving animal health, productivity and enhancing the key role played by women in this sector. In addition, aquaculture will, once again, be explored in a systematic way to understand how uptake of cultivating a high protein source can be undertaken. Practical income diversification activities such as apiculture and sericulture amongst others, will add to farmer coping strategies and provide localized income generating opportunities.

The NLDP will have two key areas of emphasis: i) Animal Health and Veterinary Public Health; and ii) Animal Production, which covers management, breeding, nutrition and marketing. As the livestock industry of Afghanistan is based upon two distinct and largely traditional production and management systems, both of which are practiced at more than subsistence level of production.

Under Animal Health and Veterinary Public Health, MAIL has following sub-components:

- Animal health service delivery enabling sustainable, and cost effective services to reach the majority of livestock keepers through innovative PPP approaches. MAIL will oversee the required regulations on importing, domestic manufacturing and distribution of veterinary medicinal products. In addition, MAIL will gradually improve the quality and outreach of veterinary education, training, and best practices by veterinarians and veterinary para-professionals in line with international standards. The private sector should be incentivized to provide input and elements of service delivery through MAIL- fostered backward and forward linkages.
- Disease prevention and control through the establishment of a national animal disease surveillance network, known as the Sanitary Mandate Contracting Scheme, linking the provinces to a Central Veterinary Diagnostic & Research Laboratory in Kabul. This allows improved disease surveillance and the implementation of a flexible and responsive set of disease prevention programs, which have an important economic impact on livestock production. In addition, greater control over import and enhance export of animal products where strict border inspection with quarantine, sampling and testing for certification for safety for animal or human health and the environment will be undertaken.
- Veterinary public health will provide strengthened regulations on food safety for imported and domestically produced products of animal origin. This will involve the establishment of an inspectorate for ante and post-mortem meat inspection of animals being slaughtered for human consumption, and establishment of laboratory facilities for testing for biological, chemical or physical hazards present in food products derived from animals, both domestically produced and imported.
- Animal health extension continues to raise awareness and encourages farmers to invest in disease prevention interventions to prevent the spread of animal diseases, especially those transmissible to humans. In addition, greater animal disease prevention and control through stronger quarantine and monitoring practices will be enforced to prevent the spread of transboundary diseases.
- Strengthen animal breeding policy and research into production performance of indigenous breeds, especially small ruminants, cattle and poultry which are perfectly adapted to the current management systems, coupled with the gradual introduction of exotic genes into production systems. Currently average milk production of crossbred cows is 10 liters/day with average animal management, increasing to 15 liters/day with improved animal husbandry.
- Increased availability and quality of animal feed will continue with greater coordination between research into developing commercial feed products that also exploit by-products of agricultural crops to meet the demands of emerging and commercial livestock farmers. In addition, efforts will be invested in developing integrated systems for increasing fodder production for diet supplementation of

dairy cattle, sheep and goats during the winter months when production levels fall to very low levels.

Focusing on the demand-side, MAIL incentivized the private sector to access credit and some technical supports, development of national associations in dairy and poultry, build the capacity of dairy unions and other institutions, and smallholders and address issues around achieving a high quality and consistent supply of products for the market on a semi-commercial and commercial set-up.

Food and Nutrition Security, and Resilience Building

Afghanistan is suffered with high-levels of food insecurity (33%) and severe malnutrition. MAIL should have greater efforts and focus in improving the utilization of nutritious food through dietary diversity (e.g. kitchen or commercial gardening) and food safety.

MAIL prioritized Afghanistan Food Security and Nutrition Agenda (AFSANA) to improve feeding and food preparation practices in a systematic and sustainable manner. This will move beyond a project-based approach. It emphasizes the needs of women engaged in the agricultural sector, providing technical support to meet women's needs in nutrition-sensitive agriculture, launching urban and pre-urban agriculture, small-scale agro-based enterprises, enhancing women's skills development training programs at community level is crucial.

Maintaining a crosscutting institutional philosophy, MAIL will establish a unit to contribute to the planning off, and implement the national EPRR (emergency preparedness, response and resilience) strategy in line with pre-agreed responsibilities. In addition, the Ministry will strengthen Weather Early Warning Systems at its Research stations, explore innovative options around crop insurance and focus on development of disaster management techniques. The provision of specific extension services to urban women farmers is an important component in sustainability of urban food production beyond just the provision of inputs.

At the central level, focus on building institutional capacity on early warning and preparedness and adopting an agriculture-specific policy. At sub-national level, using its comparative advantage of its significant national outreach at district level and agricultural practices, it will work towards establishing a multi-ministerial regional level designated coordination mechanism to improve the quality of response in a timely manner, and activities that are anticipatory as well as mitigation-orientated.

Institutional Reform

Reform at the MAIL will require a critical focus on mid-level and senior leadership positions, in addition to a functional review and re-profiling of the various positions, leading to a smaller, agile and responsive institution. Reformed management practices

must reflect renewed emphasis on leadership and professional qualities that motivate and support junior staff. Furthermore, MAIL will undertake to provide requisite training to new staff at the center and its provincial and district staff to bridge the distance between farmer and service providers. Building on the current memorandum of understanding between MAIL and Ministry of Higher Education, the options of tailor-made trainings, joint and awarded research and curricula development with the agriculture faculties across the country will be explored. Similarly, cooperation with Ministry of Education will be made to address the quality of agriculture schools curricula with a specific focus to recruit graduates within MAIL system or on the farm.

In line with the seven priorities, the Ministry envisages a fundamental change in its structures. The Kabul centric approach is no longer responsive or compatible with its mission of placing farmers at the core of its mission. The mechanism of the Citizens Charter, including MAIL's investment in Extension Services are providing a new reality on the ground and it challenges the institution to adapt to new practices and ways of doing business. In fact, the process of change has already begun with the identification of 34 new provincial Directors, who have been interviewed and are waiting assignment. The process of reform is continuous and will include changes at all levels of the institution.

The current structure at provincial level is referred to as Department of Agriculture Irrigation Livestock (DAILs). PAILs will undergo significant change in terms of its management and technical profiles. Apart from housing a small management team the PAILs will host Farmer Learning Resource Centers (FLRCs). It shall provide technical and knowledge sharing functions to its clients at the provincial level. The FRCs will train the re-profiled male and female extension officers from the districts, commercial and lead farmers, who in turn will assist farmers at the district level through demonstration plots including modern agricultural and other knowledge sharing techniques. The PAILs, unlike the past, will not attempt to emulate MAIL functions at the provincial level with exception of coordinating data and information that will be disseminated upwards from the districts so that PAILs can attenuate their technical requirements. Based upon a comprehensive assessment, it is envisaged MAIL will minimally centrally retain its 'corporate functions' in form of its relevant departments such as Planning & Policy, Personnel, Deputy Ministerial Posts, Ministerial Support Systems, Procurement, Regulatory Functions, Finance, Legal Department and relevant Corporate Services.

Recommendation of Priority Programs

On the basis of discussions in the previous sections, following programs and projects are recommended.

- i. Develop improved crop varieties having characteristics of drought resistant and high yielding for wheat, forage legumes and vegetables.

- ii. Access of agriculture inputs including improved seeds, chemical fertilizers, and equipment and develop skill labor.
- iii. Water resources development program to improve water resources use efficiency, educating farmers to improve irrigation systems along with technical supports on agricultural practices, institutional strengthening, and infrastructure development.
- iv. Enhancing wheat production and productivity program is crucial for improving the food security situation in Afghanistan.
- v. Programs to increased livestock productivity and improve household incomes, in particular for women-headed households, improve local capacities for livestock rearing, fodder production, dairy processing and dairy marketing.
- vi. Agriculture and livestock development programs focusing on efficient agricultural value chain development. It should link with productivity and output, infrastructure and market linkages. It should prioritize on potato and onion, reduce post-harvest losses, and improve farm incomes of farmers.
- vii. Trade facilitation in the South Asian region, particularly among the neighboring countries to smooth flow of inputs and outputs that could contribute food and nutrition security.
- viii. The capacity building programs to improve the capacity and performance of core line ministries, community organizations, public extension services and relevant private sector entities and focus on national priority programs. It includes technical assistance for preparation and implementation of capacity building programs, and training to civil servants on project management, monitoring and evaluation.
- ix. Climate-sensitive natural resource management to protect and conserve the Afghanistan's forests, rangelands, and protected areas. Fostering an integrated approach for conservation of natural resources including agriculture, livestock and irrigation sectors. Strategic focus to be given on community-based natural resource management, natural forest (pistachio and chilghoza/ pine-nuts), community-based rangeland and medicinal plants management and watershed management including soil erosion control in upper catchments by biological measure, agroforestry and urban forestry, establishment and management of protected areas in vulnerable areas and buffer zones.
- x. Cooperatives development for enhancing economics of scale in agriculture of smallholder farmers.
- xi. Promote community livestock and agriculture approach along with associated programs to be implemented for improving nutrition security in Afghanistan.

Conclusion

Afghanistan's economic development and stability rely on the growth of agriculture. Moving Afghanistan from an economy that was built on the consumption of foreign aid to

one that is built around rising productivity through agriculture is vital for a sustainable, stable and developed Afghanistan. Agriculture is critical to Afghanistan's food security and a key driver of economic growth. Most Afghans live in rural areas relying on small or medium agriculture and animal husbandry for their livelihood and their family sustenance. Agriculture also creates employments and investments opportunities for people living in urban areas. A key pillar of Afghan government economic strategy is to raise national productivity by increasing investments in agriculture. Therefore, economic progress in the agricultural industry is very important to boosting the incomes and increasing food supplies of the poor. Agricultural sector can only be further developed if and only if everyone in the society willing to take the responsibility to sustain a society that have sufficient food supply for our future generation.

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Chapter 3

Agricultural Research and Development: Policy and Program Priorities in Bangladesh

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Abstract

Bangladesh's agriculture has highly benefited from consistent policy framework backed up by substantial public investments in technology, rural infrastructure and human capital. Bangladesh's rural economy, specifically agriculture, has been a powerful driver of poverty reduction. Bangladesh has made remarkable progress in agricultural development and structural transformation has taken place over the years. Production of various agricultural commodities (crops, livestock, fisheries and agro-forestry) have increased and diversified. Increased rural credit for farm and non-farm sectors and separate credit program for more than 10 million farmers contributed towards financial inclusion of the rural households. Nearly half of Bangladeshi workers and two-third in rural areas are directly employed in agriculture, and about 87% of rural households rely on agriculture for their income and livelihoods. A shift in production from rice to high-value and higher-nutrition crops significantly reduced malnutrition, triggered more rapid growth in incomes, and created more and better jobs in the value chain in agriculture. In addition, agriculture can be a potentially powerful source of employment generation, especially for youth and women through more efficient and competitive value chains. Bangladesh is on a path to pursue its agriculture sector in a bid to overcome mounting challenges in an increasingly globalized world, insuring food and nutrition security and at the same time continuing with the country's rapid development strategy. Despite significant development, Bangladesh agriculture is always exposed to risk due to climate change vulnerability. Formulation of research and development program in line with more eco-friendly policy would be the driving approach for sustainable agriculture in Bangladesh.

Keywords: Agriculture, research, development, policy planning, Bangladesh

Background

Bangladesh is a lower-middle income country located in South Asia with over 160 million inhabitants on a landmass of 147,570 km². It is the most densely populated countries in the world. In fact, Bangladesh is experiencing rapid urbanization with 3.5% of urban population growth annually (World Bank, 2015). Since its independency in 1971, Bangladesh has undergone a significant economic and social development. In the past decade (2005-15), the economy has grown at 6% and poverty has dropped by nearly one third. However, Bangladesh continues to face numerous political, economic, social and environmental challenges including political instability, corruption, poverty and overpopulation.

Agriculture plays a key role as a main supplier of food, source of livelihood, growth and employment. Almost half of Bangladesh is are employed in the agriculture sector. In 1971 the agriculture sector contributed more than 60% to the GDP (FAO, 2011), however the share of GDP in agriculture has declined (14.23%) sharply over the years as part of the structural transformation process of development. This declining trend in growth of the agriculture sector is mainly attributed to a gradual loss of cultivable land, adoption and dissemination of new technology and lack of sufficient support for agricultural research and extension in the country (Onneshan, 2014).

Rice is the dominant crop, covering 75% of cropped areas and representing 70% of the value of crop output. The production of rice has scaled up from 10 million tons in 1971 to over 34.90 million tons in 2017-18, which led to achieving rice self-sufficiency. Fish and fisheries are important for the livelihoods, food and income generation of the people of Bangladesh. This sector contributes about 4.65% to GDP, 20.60% to Agri-GDP, and 4.04% of export earnings. About 1.25 million people are directly employed and over 12 million additional rural people indirectly earn their livelihoods from fisheries related activities.

Loss of arable land, rising sea levels, frequent flooding and extreme weather patterns constitute the main threats to food security. Food security is also constrained by low level of productivity, profitability, and high yield gap; slow rate of take up of new technologies; inadequate level of private sector investments in agricultural value chain; fluctuations in agricultural production; and limited resources for building resilience to climate change.

The average maximum temperature in Pre Monsoon, Monsoon, Post Monsoon and Winter season were 32.6, 31.5, 30.5 and 26.5°C, respectively in 2017/18, where average minimum temperature for those seasons were 22.4, 25.5, 21.4 and 13.9°C, respectively (BBS, 2018). The average rainfall in Pre Monsoon, Monsoon, Post Monsoon and Winter season were 453, 1733, 210, and 44 mm, respectively in 2017/18, where relative humidity for those seasons were 74, 86, 80 and 73%, respectively.

Well-conceived strategies, improved management practices and effective targeted investment with right mix of policy and political commitment are imperative to achieve

sustainable agricultural development. In this context, prioritization of research based policies is essential for technology generation (BARC, 2011). With these above considerations comprehensive research and development programs under different sub-sectors of agriculture are deemed imperative to generate pragmatic solution for food and nutrition security in Bangladesh.

Situation of Agricultural R&D in Bangladesh

Agriculture is the single largest producing sector of the economy and contributes about 14.23% to the total Gross Domestic Product (GDP) from the cropped areas 154,783,77.6 of Bangladesh (Table 1).

Table 1. Statistics on Bangladesh agriculture

Total family (no.): 2,86,95,763.00	Single cropped area (ha): 2,222,063.20
Farm holding (no.): 1,51,83,183.00	Double cropped area (ha): 3,929,070.60
Cultivable land (ha): 8,585,207.40	Triple cropped area (ha): 1,772,148.00
Irrigated land (ha): 7,614,572.00	Quadruple Cropped area (ha): 14,980.00
Current fallow area (ha): 402,172.40	Net cropped area (ha): 7,950,390.00
Cropping intensity (%): 195	Gross cropped area (ha): 15,478,377.60
Contribution of agriculture sector to GDP (%): 14.23 (constant price)	

Source: BBS (2018)

Crops

Crops is the major part of Bangladesh agriculture and contributes about 7.48% to the GDP of the country (BBS, 2018). Due to natural calamities like flood cyclone, drought, etc. loss of production in both food and cash crops are almost a regular phenomenon. Rice, Maize, jute, sugarcane, potato, pulses, oil seeds, wheat, spices, tea and tobacco are the principal crops of Bangladesh. Crop diversification program, credit supply, extension work, research and input distribution are the major policies pursued by the government. The country is now on the threshold of attaining self-sufficiency in food grain production. The area under major cereal crops increased remarkably in 2017/18, particularly for Aus and Aman rice, where Boro area decreased slightly (Figure 1). Minor cereal crops area also in increasing trend. The area under wheat, pulse and tobacco were decreased where the area under maize, jute potato and tea were slightly increased.

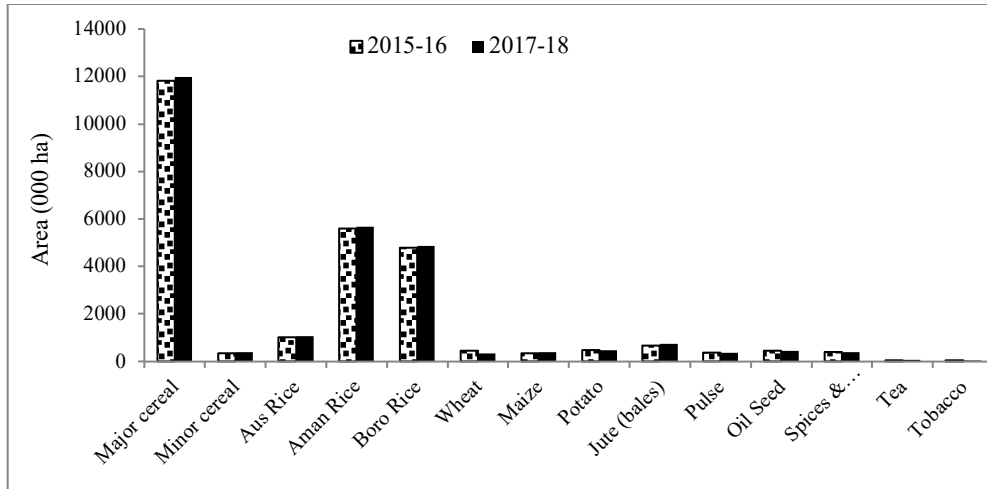


Figure 1. Area under different major crops

Source: BBS (2018)

The production of major cereal crops increased remarkably in 2017/18, contributed by increased production of Aus rice and also Aman rice (Figure 2). Minor cereal crops production also in increasing trend. The production of wheat, pulse and tobacco were decreased, while the production of maize and jute slightly increased.

Natural calamities like Flood, excessive rainfall, flash flood, rush of water, cyclone, hailstorm, tornado, tidal bore etc. hampered the production of different crops. Aman rice damaged 734,905 Mt/bales, followed by Aus rice 64,482 Mt/bales and Jute 33,895 Mt/bales in 2018 (BBS, 2018).

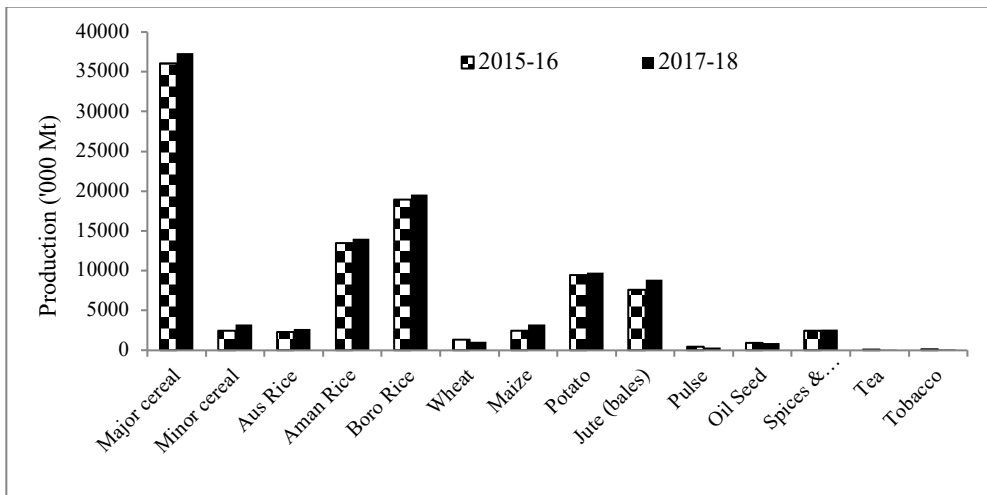


Figure 2. Production under different major crops

Source: BBS (2018)

Bangladesh imports a remarkable quantity of agriculture products; higher quantity of wheat, followed by edible oil and rice and sugar (Table 2). There is a number of trade barriers between India and Bangladesh as Indian side requires longer time for clearance and required voluminous documents, authorization and certification from a number of institutions. The demand and supply gap of rice seeds is being partly filled by import of hybrid seeds from China. Currently, China meets more than 90% of Bangladesh’s import demand for rice seeds.

Table 2. Import of agricultural products

Commodity	Quantity ('000' tons)		
	2015-16	2016-17	2017-18
Rice	357	278	3840
Wheat	4183	6164	6264
Sugar	2051	2468	2442
Edible oil	4373	4621	4759

Source: BBS (2018)

Horticulture

The production of Brinjal is the highest, followed by tomato, cabbage, pumpkin and cauliflower (Figure 3).

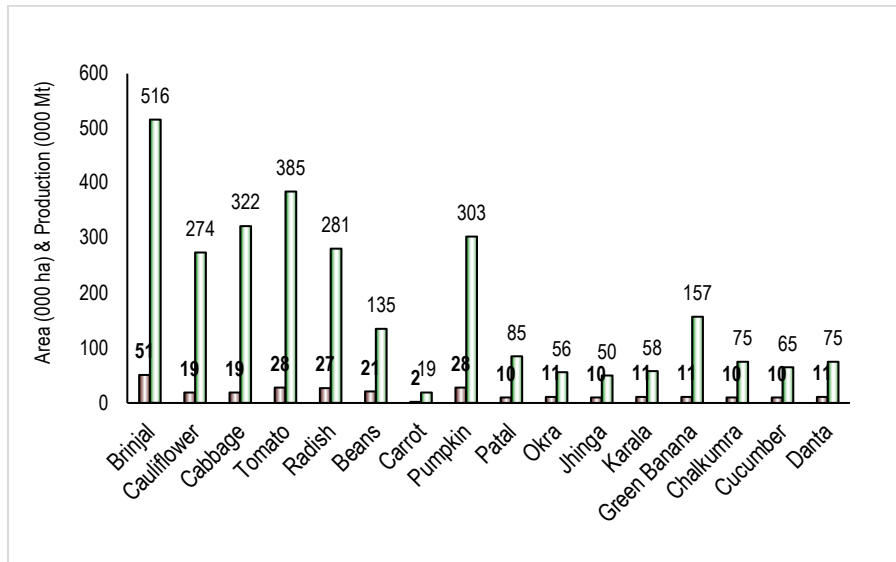


Figure 3. Production of horticultural crops in 2017/18

Source: BBS (2018)

Mango production is the top fruit crop, followed by jackfruit, banana, pineapple, and papaya (Figure 4).

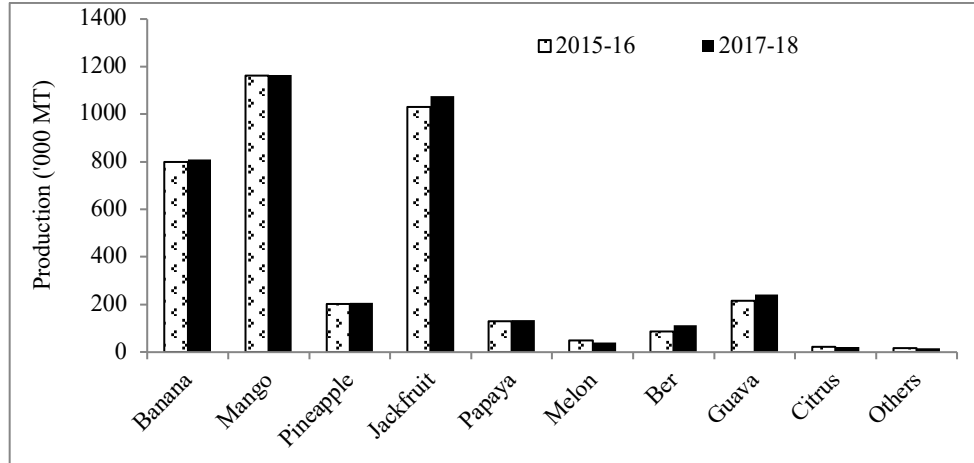


Figure 4. Production of fruits during the year of 2017/18

Source: BBS (2018)

Livestock

The livestock sub-sector is important from the perspectives of crop cultivation, food-security, poverty reduction, nutrition, and employment generation in the country. Poultry and dairy farming has also certain specific advantages over crops, fisheries and forestry, as they require less land and are least influenced by seasonality. The major constraints affecting the livestock productivity are: absence of appropriate breed, shortage of quality feed and fodder, absence of appropriate technology for improving the feed efficiency of feed stuffs, inadequate veterinary coverage, inadequate technologies for disease diagnosis, poor/lack of epidemiological information about major livestock disease, strategic disease control program, poor/lack of appropriate quality control, poor/lack of preservation techniques for livestock products and bi-products, absence of systemic marketing network and their products and value addition (Ali & Hossain, 2016). Contribution of livestock in GDP is about 1.54% with the growth rate of 3.40%, share of livestock in agricultural GDP (Current prices) is 13.62%, about 20% people are employed directly, where 45% are engaged indirectly (BBS, 2018; DLS, 2018).

The status of demand, production and availability is presented in Table 3. Considering the estimation of BBS (2018), the population was projected at 16 Crores 14 Lakhs as of 2018. The demand of milk is 150.29 million tons, whereas the production is about 94.06 million tons; availability of milk is 158.19 ml/day/head, which is much lower than that of requirement 250 ml/day/head; meat demand is 72.14 million tons, whereas it is produced about 72.60 million tons; meat availability is 122.10 gm/day/head against 120 gm/day/head requirement; egg demand is 1712.88 Crore number, whereas it is produced about 1552.00

Creore, and egg availability is 95.27 eggs/year/head, which is lower than that of requirement 104 eggs/year/head.

Table 3. Demand, production and deficiency of milk, meat and eggs (2017/18)

Products	Demand	Production	Deficient/surplus	Availability
Milk	150.29 million tons (250 ml/day/head)	94.06 Million tons	- 56.23 Million tons	158.19 (ml/day/head)
Meat	72.14 million tons (120 gm/day/head)	72.60 million tons	+ 0.46 million tons	122.10 (gm/day/head)
Egg	1712.88 Creore number (104eggs/year/head)	1552.00 Creore numbers	- 160.88 Creore numbers	95.27 (eggs/year/head)

Source: DLS (2018)

Fisheries

Bangladesh is rich in fish wealth. In the innumerable rivers, canals, tanks and other low lying and depressed areas and paddy fields that remain under water for about 6 months in a year and cover nearly 12 million acres, tropical fish of hundreds of varieties are cultivated. Rice and fish constitutes an average Bangladeshi's principal diet. Hilsa, lobsters and shrimps are some of the fish varieties that are exported to foreign countries. Having the Bay of Bengal in the south of the country enjoys geographic advantage for marine fishing. Fishing sector in Bangladesh contributes about 3.14% to the total Gross Domestic Product (GDP) of the country (BBS, 2018). Among the agriculture sector, the gross value growth rate is higher (12.17%) in fishing sector (BBS, 2018). The total fish was produced 38.78 Lakh tons in 2015/16, which is increased year after year and attained 42.77 Lakh Mt in 2017/18 (Table 4).

Table 4. Sector-wise fish production in inland and marine fisheries (2017/18)

Sector of Fisheries	Water Area (Hectare)	Production (Mt)	% of Production	Productivity
A. Inland Fisheries				
Inland Open Water (Capture)				
River and Estuary	853,863	320,598	7.50	376 kg/ha
Sundarbans	177,700	18,225	0.43	103 kg/ha
Beel	114,161	99,197	2.32	869 kg/ha
Kaptai Lake	68,800	10,152	0.24	148 kg/ha
Floodplain	2,712,618	768,367	17.97	283 kg/ha
Total Capture Fishes	3,927,142	1,216,539	28.45	
Inland Closed Water (Culture)				
Pond	391,753	1,900,298	44.43	4851 kg/ha
Seasonal cultured water body	136,622	216,353	5.06	1584 kg/ha
Baor	5,488	8,072	0.19	1471 kg/ha
Shrimp/Prawn Farm	258,681	254,367	5.95	983 kg/ha
Crab	9,854	11,787	0.28	1196 kg/ha
Pen Culture	5294	11,015	0.24	2081 kg/ha
Cage Culture	1.29 lakh m ³	3,523	0.10	27 kg/m ³
Total Culture Fishes	797,851	2,405,415	56.24	
Total Inland Fisheries	4,724,993	3,621,954	84.69	
B. Marine Fisheries				
Industrial (Trawl)		120,087	2.81	
Artisanal		534,600	12.50	
Total Marine Fisheries		654,687	15.31	
Total production in Bangladesh		4,276,641	100.00	

Source: BBS (2018)

Fish and fisheries products are the major exportable commodities in Bangladesh, which was estimated 68,936 Mt with worth 4,309.94 Crore Taka¹ in 2017/18 (Table 5).

Table 5. Annual export of fish and fish product (2017/18)

Fish and Fish Product	Frozen Shrimp/Prawn	Frozen Fish	Chilled Fish	Dry fish	Salted/dehydrated fish	Crab & Kuchia	Shark fin/Fish Maws	Others	Total
Quantity (Mt)	36,167.77	8,265.26	8,889.85	3,143.93	213.62	11,435.33	0.50	819.46	68,935.72
Value (,000000TK)*	3,527.07	276.29	214.80	42.59	26.60	217.53	0.12	4.96	4,309.94

Source: BBS (2018)

¹ One US\$ equivalent to 80.59 Taka

Agricultural Policy

Agriculture contributes 14.23% to the country's GDP and employs 41% of the labor force (BBS, 2018). Bangladesh is also one of the most densely populated nations of the world (964 persons/ km²) with an estimated population of 142.3 million of which 75% live in rural areas (BBS, 2010). The country is suffering from one of the lowest land–man ratios of the world (0.2 ha per person), making challenge in achieving food security (Rahman & Salim, 2013).

Bangladesh has designed and implemented various agricultural policies for the transformation of agriculture sector through rapid technological progress aimed at alleviating poverty and raising the standard of living of its increasing population (Rahman, 2003). The process started from the early 1960s to diffuse High Yielding Varieties (HYV) of rice technology with corresponding support in the provision of modern inputs, such as chemical fertilizers, pesticides, irrigation equipment, institutional credit, product procurement, storage and marketing facilities (Rahman, 2003). However, the diffusion of HYV technology went through various cycles, 1970s; 1980s and at the late 1980s in response to policy reforms aimed at liberalization of the procurement and distribution of agricultural inputs and a reduction of import duties on agricultural equipment (Hossain & Mokaddem, 1994). As a result, irrigation coverage increased dramatically to 51.5% of gross cropped area in 2000/2001 from 22.5% in 1980-1981 (Praduman et al., 2008). In addition, various policies were also undertaken gradually from the 1990s, aimed at ensuring food grain availability and food security in the long run. However, the realization of these aims remained unfulfilled as the country is still identified as a food deficit nation with occasional self-sufficiency in some years (Alam et al., 2011). Therefore, agricultural productivity growth and efficiency improvement remain a top priority in order to meet food needs for its rapidly increasing population.

Challenges and Opportunities in Agricultural R&D

Challenges in Agricultural R&D

Despite its transformation from a country of chronic food shortages to one of food self-sufficiency, Bangladesh still faces food security challenges. Around 40% of people in rural Bangladesh live on less than US\$ 1.25 per day and 60% of that income is spent on food. In rural Bangladesh, 66% of the labour force depends on farming and majority of farmers (81%) have farms less than 0.6ha of lands (BIHS, 2011). Despite of greater efforts made in agriculture, this sector is constraints with following challenges:

i. Degradation of natural resources

The growing population rely on limited natural resources. Cropped land is declining at the rate of 0.87% per year and annually losing approximately 80,000 ha due to urbanization

and building of new infrastructure, soil erosion, river erosion, soil fertility decline, depletion of soil organic matter, water logging, soil salinity, pan formation, acidification and deforestation. Water erosion accounts about 40% due to washing away of topsoil and depositing sand on the croplands from upstream. Riverbank erosion and siltation are chronic concerns for Bangladesh. About 1,200 km of river bank are eroding and more than 5,000 km of river banks face erosion-related problems. During the last three decades the Jamuna, Ganges and Padma rivers have consumed about 180,000 ha (BWDB, 2009; MPO, 1987). The river bank erosion is expected to increase further with the rise of water flow in the rivers due to global temperature rise and increased ice melting in the Himalayas.

ii. Low agricultural productivity

Smallholding farms (0.02 to 1.0 ha), inefficient use of limited water resources, degradation of soil quality and failure to adopt known modern technologies and practices are the reasons of low productivity. Indeed, there is a wide gap between farm yields and experimental stations. The yield gaps even in the favorable agri-ecological regions often exceed 40% of the farmer's achievable yields with good practices.

iii. Weak research extension linkage and technology delivery

The National Mainstream Extension Approach of DAE, DLS and DOF does not have the capacity to cope with the emerging challenges in each sector on the scale needed. Equally, research scientists are only slowly adjusting the research agenda to meet the needs of farmers and producers. Despite a long history of Farmer Field Schools in the country there is a very limited amount of "action" or "adaptive" research being practiced.

iv. High post-harvest losses

There is huge post-harvest loss in agriculture; 12% in paddy, and 30% in vegetables and fruit. Agro-processing into finished or semi-finished products, packaging in appropriate containers, proper storage could reduce post-harvest losses.

v. Weak farmers' to market linkages and value chains

The lack of organized markets for selling farm products is a major problem in Bangladesh. The agricultural markets are constrained by poor infrastructure, lack of storage and processing facilities, poor roads and communication system, unfair practices of middlemen, etc. The marginal and small farmers are often facing the problem of marketing their products and are not getting a fair price due to the existence of trade syndicates. Farmers are vulnerable by the exercise and influence of market power (rural traders, wholesalers, retailers, and processors). Formation of farmers' groups is one possible way to create better market linkages and ensure fairer competition in prices and curb exploitation of middlemen. Value addition and supply chain investments including processing, packaging, storage and transportation at the local and national levels are the

priority areas for the intervention. Product standardization, food safety, sanitary and phyto-sanitary measures are important for quality products and export potential.

vi. Scarcity of availability of agriculture labour

The contribution of labour in the agricultural sector is decreasing over the years. The participation rate of the labour force in the agricultural sector increased between 2000 and 2002/03 with a rate of 0.4 % but since then it has decreased (BER, 2009). The participation of women in agriculture remained almost the same in 1988 and 2000 (59% and 58% respectively); but compared to 2000 and 2008, women's participation has increased by 8%. The labour force engaged in agriculture has decreased to 47.3% in 2010 from 51.3% in 1999/2000. If this trend continues, the contribution of labour in agriculture might decrease to 39.55% by 2021. Bangladesh, being a traditional Muslim society, women's participation in economic activities in general and in agriculture in particular has remained low.

vii. Farm mechanization

Mechanization in agriculture sector is going on with the increased use of power tillers, irrigation equipment, threshers, drum seeders, maize shellers, rice milling machines, improved storage, cool-chain and transportation, etc. Farm machinery, such as weeders, threshers, winnowers, centrifugal pumps etc. are developed and manufactured locally with locally available materials. Manually operated weeders and sprayers are used widely. A few hundreds of pedals and power operated winnowers are also being used (Roy & Singh, 2008).

viii. Food quality and safety problems

Bangladesh faces significant problems with food contamination through poor handling practices, and deliberate adulteration. It has adverse health effects to the human life. The challenge is how to create a hygienic food system backed up by inspections and improved practices among food producers, handlers, as well as building awareness of consumers.

ix. Inadequate institutional credit

While demand for credit is increasing with the advent of new technologies and high value crops, the supply side has remained less vibrant. The volume of institutional credit is conspicuously low and the proportion of the public sector in the total volume of institutional credit is even smaller. According to BBS (2017), about 25% total disbursement of rural credit is delivered by the public sector.

x. Increased environmental shocks and livelihood risk

The prevailing high incidence of poverty and population density makes Bangladesh extremely vulnerable to climate change and natural disasters (flooding, tropical cyclones and storm surges). Bangladesh is rated extreme in the Climate Change Vulnerability Index 2011 as the sixth most cyclone-prone country in the world, and first rated flood prone

country in terms of human exposure. It is affecting lives and livelihoods and puts a strain on agricultural production and limits investments due to preoccupation with high risk. The most vulnerable regions in Bangladesh are 14 coastal districts in the south and 6 districts of the haor (wetland ecosystem) basins areas in the North-east.

xi. Population growth

Growth rate of population stands at 1.26% (BER, 2009). Population is increasing @ 2 million per year and the population projected to be 233 million by 2050 (BER, 2009), which is great challenge for agriculture and food supply, economic development, manage environment and meeting other basic needs (food, education, and health).

xii. Imbalanced use of fertilizers

About 60% of arable lands of Bangladesh are deficient in N, P, and K. Organic matter content of soils is much below the critical level of 1.5% (Karim, 1997). Farmers normally use urea in recommended doses. Because of high prices, they apply P and K fertilizers at the rates that are far below the recommended amount. Chemical fertilizers are not normally integrated with organic manures. It is thus evident that farmers virtually do not use balanced fertilizers that are necessary for high productivity.

xiii. Inefficient water use

Water use efficiency in Bangladesh is extremely low. On the average, 25-30% of irrigation water is used by crops and the rest is lost due to faulty flood irrigation system (Karim, 1997; Mondal, 2005). Conservation of rain water during monsoon is virtually non-existent that could be utilized for irrigating crops during dry season. Studies show that irrigation with surface water instead of underground water might reduce the vulnerability to hazards of climate change. Irrigation cost is relatively high due to high price of diesel.

xiv. Pests and diseases

The use of fertilizers, quality seeds, and irrigation together cannot ensure sustainable production unless timely and appropriate measures for the management of pests and diseases are simultaneously pursued. It is important to note that the incidence of diseases and pests has lately become very severe due to the adverse effects of climate change, particularly rise in temperature (IPCC, 2007). It is estimated that 4-14% of rice yield in Bangladesh is lost every year by different insect pests. Bacterial leaf blight (BLB) and nematode (ufra) are now the serious diseases in rice. Technologies resistant to pests and diseases are still very limited.

xv. Unfair price of agricultural products

Farmers do not have either Farmer's Association or Farmer's Co-operative to bargain for fair prices of their produces. They are thus forced to sell their produces at low prices to

intermediaries. Since the farmers are often unable to meet procurement requirements (14% moisture content, etc.), they cannot sell their produces at the price fixed by the government.

xvi. Insufficient investment in research

Investment in agricultural research in Bangladesh now stands at only 0.20 of GDP (Karim, 1997) even though agriculture has significant contributions to GDP and employs huge labour force (BBS, 2018). Low investment has resulted in the under functioning of National Agricultural Research System (NARS). Scopes for promotion and training of potential scientists in different fields are also limited due mainly to fund constraint.

Opportunities in Agricultural R&D

i. Protection of arable land

It is essential to review the present land use policy with the relevant experts, professionals, and farmers' representatives and update it based on their comments and suggestions. The policy should be put into operation immediately to stop further loss of arable land. Khas lands that are arable should not be diverted for housing as planned by the government. Such lands should be distributed to landless farmers and used exclusively for agricultural purposes.

ii. Adaptation/ mitigation to climate change

Bangladesh Rice Research Institute (BRRI) has developed BRRI Dhan 40, 41, and 47 that are salt tolerant. CIMMYT and BARI may be urged to develop tropicalized wheat varieties. It is also necessary to use biotechnology or gene transfer technology to develop varieties tolerant to salinity, flood, and drought. There is also a need to develop HYVs in pulses, oilseeds, spices, and fruits since improved technologies in these areas are few. Country does not have its own supply of hybrid varieties of rice, vegetables, and other crops. In the circumstances, the government should urge BRRI, BARI, and other NARS institutes and private companies & NGOs to develop their own hybrid variety program of these crops within the country. Climate change must be integrated into national development plan of the government. Besides, political commitment must be ensured to mitigate the problems—flood, sea level rise, and salinity intrusion of agricultural land in particular. Mitigation measures include the use of renewable energy, reduction, and efficiency in the use of fossil fuels, afforestation, early warning system to disaster management, preventing felling of green trees, especially in coastal areas, etc. The Ministry of Agriculture estimated US\$ 5 billion to implement *Climate Change Strategy and Action Plan 2009* for the next 5 years.

iii. Fertilizer management

To encourage the use of balanced fertilizers, chemical fertilizers must be integrated with organic manures and subsidy benefit on non-urea fertilizers should continue. Farmers should gradually reduce their dependence on the use of chemical fertilizers to maintain

soil fertility. It is essential that the government clearly spells out the need for balanced fertilizers in its new NAP in the interest of sustainable crop production. International Federation of Organic Agricultural Movement (IFOAM) has been in operation in 92 countries of the world. Bangladesh proposed to be a member of IFOAM to motivate farmers to use organic fertilizers.

iv. Water management

For efficient use of water, irrigation should be applied at the appropriate growth stages of crops. Growing crops under minimum tillage, relay cropping and mixed cropping practices may also be strengthened for rainfed cropping. Farmers may be motivated to grow low- water requiring crops like pulses, wheat, etc. Ponds are constructed and rain water could be used for surface irrigation. Diesel price should be substantially cut to reduce irrigation cost or subsidized to the resource poor small and marginal farmers.

v. Pests management

More resistant varieties should be developed using both conventional breeding and biotechnology to control the pests. It is also necessary to expand biotechnology and IPM practice to other economic crops, such as oilseeds, pulses, spices, and fruits. The new NAP should emphasize the importance of the use of these environment-friendly frontier technologies. Recently, BARI has developed sex pheromone trap technology for the control of shoot and fruit borer in brinjal and cucurbits.

vi. Quality seed production

If the target of 20-25% seed replacement rate to be met, BADC's current seed production program needs to be strengthened. To achieve this, present breeder's seed program of NARS institutes should be expanded. Besides, private sector and NGOs are to be supported by the government for the production of quality seeds by providing credit on easy terms. Likewise, farmers need to be motivated to produce quality seeds. For this, they should be given massive training on seed production, preservation and processing.

vii. Credit management

The *National Agricultural Policy (1999)*, Ministry of Agriculture proposed an institution named "Agricultural Credit Foundation" following the model of "Palli Karmo Sahayak Foundation" (PKSF) with objective to meet the demand for credit by marginal and small farmers. An institution should be established along with necessary manpower and other facilities to cater to the needs of credit to the farmers without any collateral requirement. The credit should be disbursed before planting time and realized at the end of the cropping season or after the harvest of the crops. The institution must have an in-built provision for strong monitoring unit to monitor the use of credit at regular intervals by its staff.

viii. Fair price of produces

Government is urged to procure the produces directly from the farmers raising the present ceiling to at least 10% of the total production. Storage facilities may at the same time be established in rural areas following the experience of SHOGORIP that is likely to allow the farmers to store their produces and sell the same at better prices when the demand is high. Alternatively, government might encourage to establish farmers' cooperatives to ensure fair price of their produces. Formation of "Agricultural Prices Commission" is also suggested for fixing the prices of farmers' produces.

ix. Return to research investment

Different studies indicate that the investment in agricultural research is highly rewarding and beneficial (Nagy, 2000). The Government is, therefore, urged to raise the investment to at least 2% of GDP as recommended by World Bank and FAO. The increased investment will certainly encourage scientists to develop technologies to cope with the hazards of climate change and disseminate the same at farmer's level.

Review of Agricultural Policies and Programs

i. Producer-oriented policy decisions

During the past three decades, the self-sufficiency in rice has become dominant in the food security and agricultural policy in the country. Therefore, the GoB is directly assisting farmers by enhancing the use of inputs, increasing credit facilities and guaranteeing support prices through public procurement.

ii. Increasing fertilizer's subsidies

In the past years, a special focus has been placed on fertilizers. In 2010, the GoB introduced the *Agriculture Input Assistance Card program*. Through this program, farmers are being given a smart card that allows them to open a bank account through which they directly receive cash to buy inputs. The trend in fertilizers' subsidy has been constantly increasing from 35 (US\$ 503 million) in 2007/08 to 119 billion Taka (US\$ 1 billion) in 2012/13. However in 2013/14, subsidy to fertilizers has decreased by 28%, accounting 86 billion Taka (US\$ 1 billion). In 2014/15, the government subsidized fertilizers about 2.2% of total public expenditure.

iii. Increasing credit provision to smallholder farmers

Credit disbursement in the agriculture sector has been one of the preferred instruments of the government to face the global financial crisis in 2010 and the previous food crisis. Public and private commercial banks increased the agriculture credit disbursement target to US\$ 1.4 billion for FY 2008/09 (13% higher than the previous year). Subsequently, in order to enhance agricultural production and diversification, the GoB has encouraged

banks to expand farm loans (agricultural loans are around 6% of total loans) through the Bank of Bangladesh, which issued directives to commercial banks to meet the working capital needs of small farmers making it mandatory for every bank to deliver agricultural loans. The GoB also reduced the interest rate from 8 to 2% for loan disbursement to enhance the production of pulses, oil-seeds and spices during 2007-2014.

iv. Sustained price stabilization and domestic procurement

The GoB maintains public food stocks with two goals: to provide price and profit incentives to farmers and food to all consumers. Projections for storage capacity will continue to expand over the next few years, reaching about 2.6 million tons by 2020. According to National Social Security Strategy, the increasing expansion of food-grain storage capacity indicates that public stocks will be leveraged for emergency program and food transfers will be integrated with cash transfers (IFPRI, 2014).

v. Promoting food and agricultural diversification

One of the major objectives of the 7FYP (2016-20) is to ensure that the country's agricultural sector is profitable, sustainable and competitive through the promotion of agricultural diversification. Increasing crop diversification is crucial for increasing productivity, for ensuring human nutritional security, maintaining soil health and increasing cropping intensity, and the income generation of farmers.

The National Agricultural Policy (MOA, 2013) aims at promoting diversification in agricultural crops, e.g. potato, pulses, oilseeds, vegetables, fruits and spices, under the *Crop Diversification Program*. *National Food Policy Plan of Action* (MOFDM, 2008) aims to intensify agriculture diversification, crop production and boosting livestock production for increasing dietary diversity and stabilizing the micronutrient daily intake. The *National Livestock Development Policy* in 2007 aimed at accelerating economic growth by reducing rural poverty through sustainable improvement in milk productivity, meat and egg production, including processing and value addition. *National Livestock Extension Policy* (2013) focuses on veterinary public health and food safety issues, producers' organizations, extension services, linkages among research and extension, and smallholder livestock farming constraints. Similarly, the National Fisheries Policy in 1998 aimed at enhancing the fisheries resources and production; alleviating poverty through the creation of self-employment and improvement of socioeconomic conditions of the fishers; meeting the demand for animal protein; achieving economic growth and earning foreign currency by exporting fish and fisheries products.

vi. Consumer-oriented policy decisions

The GoB uses two broad approaches to increase access to food: short-term actions, which aim primarily at relieving immediate distress by directly transferring food or cash (known as social safety net programs), and long-run policies and programs aim to raise incomes of

the poor through employment generating activities. Although these initiatives started as early as mid-1970s, there has been a notable evolution over the years, such as the transformation from relief programs to development programs and the conversion of ration price subsidies to targeted food distribution and/or conditional cash transfers.

vii. Public food grain distribution system

The GoB provides emergency relief during periods of natural disasters, alleviating chronic food insecurity through targeted food distributions and stabilizing the market price of food, especially rice. To maintain food stocks, the GoB relies on procurement of rice and wheat from farmers through government-to-government deals. Food distribution is being implemented through two channels: the first, the non-monetized, which does not involve sales, but includes targeted safety net program and the subsidized food sales (Open Market Sales), which sells rice and wheat under the Public Food Grain Distribution System.

viii. Diversifying exports and increasing incentives

The GoB has introduced new *Export Policy (2015-18)* (MoC, 2015) aims at prioritizing and attaining diversification of export agricultural products. With a view to transform Bangladesh into a middle-income country by 2021, the new export policy has been announced that farms will have their duty and value-added tax (VAT) removed to increase agricultural production. With regard to the shrimp and fish export sectors, the policy has proposed tax and loan facilities in order to rehabilitate the sector and the policy will provide the shrimp' exporters with loans as working capital from banks at 9% interest rate. Furthermore, the export policy has identified agro and herbal products as emerging sectors, therefore, the tea sector has been identified as a potential new area in which exports could be increased to 100 million from the current volume of 66 million a year.

Policy Implications and Recommendations

Policy Implications

Successful production and marketing of high-value products require a range of interventions and investments including a change in policy towards an enabling environment to private sector; infrastructure development; improved access to credit; research and development; capacity building and international trade. Following are the policy implications:

- i. The development of productive high-value products will require significant and sustained investment in the areas: the development and distribution of better seeds of high yielding varieties; improved breeds/broods for livestock and fisheries; improved disease and health management practices; processing of high value products; and post-harvest management. These investments must be a priority for improved functioning of high-value product chains. Support is needed for improvement of

- public and private seed sector, hatcheries, and nurseries for enhancing distribution of HYV seeds, fingerlings and day old chicks. There is serious concern on the quality deterioration and adulteration of agricultural inputs, (specifically, fertilizers, feeds). Strategic action is needed to improve quality of agricultural inputs and its distribution.
- ii. Huge post-harvest losses in fruits and vegetables and inadequate cold storage facilities are a big constraint in Bangladesh for transformation of high value agriculture.
 - iii. The horticultural crops in Bangladesh are prone to heavy doses of contamination with toxic chemicals, food borne bacteria and pathogens due to exposure of the crops to indiscriminate spraying of chemicals. Food contamination exposure also occurs due to lack of processing capacity and poor access to technologies to store harvested produce.
 - iv. As high-value product value chains are more demanding in food safety and quality standards. Greater attention is required for certification and quality enforcement (for both inputs and outputs) and for adherence to quickly changing standards. This requirement includes the strengthening, reforming and enforcement of institutions such as the Department of Agricultural Marketing (DAM), the Hortex Foundation and specific quality certification systems. It is necessary to promote Good Agricultural Practices (GAP) and Good Post Harvest Management (GPHM) practices and traceability of products.
 - v. Strengthening needed in laboratory and testing infrastructure to make them compatible with international standards. This will require modern equipment, skilled manpower, and enforcement of Hazard Analysis and Critical Control Points (HACCP) operations to control all types of food contamination. The Bangladesh Standards and Testing Institution (BSTI) currently lacks the capacity and equipment to carry out some of the more demanding tests. Proof of adherence to these tests will be increasingly important in export markets as well as for more demanding local markets.
 - vi. Capacity building is required for extension systems, food quality and safety regulations, improved technologies, agricultural markets.
 - vii. Establishment of agro-export and processing zones along with better vertical linkages between the farmers and buyers can help to overcome some of the risks inherent in the marketing of high value products.
 - viii. A better regulatory framework and management structure of local markets are needed. Local markets are currently governed by a multitude of institutions and the fees charged to traders and farmers are often not clear and transparent. Moreover, the fees collected in markets often go towards other purposes other than market development and service provision for farmers and traders serving merely to increase transaction costs for participants in the value chains leading to lower prices for producers and higher costs for consumers. Appropriate marketing infrastructure is also essential for sustained growth of high value agriculture. Efficient transportation and product handling is a crucial requirement for trade of agricultural products. This

- requires investments and improved maintenance of roads and port infrastructure, improvements in railway container handling and enhanced air cargo capacity.
- ix. Assembly and wholesale market infrastructure is inadequate and Bangladesh would benefit from upgrading these markets. Most of the assembly, wholesale and retail markets are highly congested and lack of much-needed basic facilities such as potable water, toilets, sewage systems, loading spaces, and storage facilities.
 - x. Easy access to timely credit might benefit actors in agricultural value chains.

Recommendation for Agricultural R&D

The following recommendations are made for further improvement in agriculture sector in Bangladesh:

- Revise the present land use policy and should be enacted and put into operation immediately to stop further loss of arable land. Khas lands that are arable should not be diverted for housing.
- The twin problem of arable land loss and population growth to be addressed by the government simultaneously to ensure production sustainability and food security.
- The government should urge BARI, BRRI and other NARS institutes, private companies and NGOs to develop their own hybrid variety program of rice, vegetables and other crops within the country.
- To encourage the use of balanced fertilizers, chemical fertilizers must be integrated with organic manures. Farmers should be motivated to reduce their dependence on the use of chemical fertilizers to maintain soil fertility.
- Strengthen irrigation facilities, minimum tillage, relay cropping, mixed cropping practices, and low-water requiring crops like pulses, wheat, etc.
- Expand biotechnology and IPM practice to other economic crops, such as oilseeds, pulses, spices, and fruits for the management of pests and diseases.
- Training and technology dissemination on quality seed production, preservation, and processing.
- A new institution/foundation following the model of Palli Karmo Sahayak Foundation (PKSF) should be established along with necessary manpower along with easy access of credits to marginal and small farmers.
- Establish storage facilities in rural areas to store farmers' produces and sell during lean periods with better prices. Establish farmers' cooperatives to ensure fair price of their produces could be better option.
- Investment in agricultural research is highly beneficial. So the government should increase the investment at least 2% of GDP. The increased investment will certainly encourage scientists to develop technologies to cope with the hazards of climate change.

Recommendations of Priority Programs

1) *Crop sequences for increasing cropping intensity and productivity in Bangladesh (Crops)*

Background and Justification

The challenge of SDG is doubling the agricultural productivity by 2030 from the limited land resource. In order to produce more food within a limited area, the most important options are i) to increase the cropping intensity producing three or more crops over the same piece of land in a year and ii) to increase the production efficiency of the individual crop by using optimum management practices.

Oilseed and pulse are the important group of crops which are mostly grown in rabi season but area of those crops decreased due to increasing cultivation of irrigated Boro rice. Recently with the development of short duration varieties of rice, mustard, potato, pulse and jute, opportunities have been created to accommodate four crops in same piece of land in a year. Rapeseed mustard production can be increased up to 20-25% only by replacing traditional variety with high yielding short duration varieties like BARI Sarisha-14 and BARI Sarisha-15 in the existing rice based cropping system.

On farm Research Division of BARI also have developed and tested some promising four crops based cropping system in different locations. Potential adoption of mustard, Mungbean and potato in T. Aman-Fallow-Boro-Fallow cropping system would generate employment and additional income for the rural poor and producing more of these crops utilizing fallow and under-utilize lands in the country. Considering the above facts, the project may be undertaken for increasing cropping intensity and productivity by growing four crops in a year in a same piece of land.

Objectives

- Analyze the comparative agronomic performance and economic return of different cropping sequences for increasing cropping intensity and productivity.
- Dissemination and adoption of location specific crops based cropping pattern.
- Increase farmers' income for improvement of livelihood.

2) *Community based smart agricultural water management interventions for climate resilience in Bangladesh (Crops)*

Background and Justification

Climate change is a significant and long-term change in the statistical distribution of weather patterns over periods of time that range from decades to millions of years. Climate change likely to reduce agricultural production by 10-50% by 2050 and beyond, if we do not start adapting now. Due to shortage and inconsistencies in surface water supplies, ground water acts as the mainstay for agriculture in our country. Agriculture is the major

user of water in Bangladesh, with rice cultivation as the single most important economic activity. Presently, about 80% of groundwater is used for irrigation, of which 73% is used exclusively by Boro farmers. Conservation agriculture (CA) based tillage technology permits direct seeding of rice in untilled soil or minimum tillage following un-puddled transplanting of rice, which is a good water saving technology. Besides of this other crops like maize, wheat etc. sowing in strip tillage methods can save irrigation water 25-33% compared to conventional tillage. The Conservation agriculture (CA)-based tillage and crop establishment options such as strip or reduced tillage, and raised beds, may hold potentiality to increase yield, reduce crop establishment costs including irrigation, and increase income of the farmers. Groundwater irrigation will therefore remain crucial to sustain agrarian growth to meet Bangladesh's future food requirements. Therefore, it is imperative to understand the issues and challenges of groundwater use and to evaluate options for its sustainable management.

Objectives

- Develop/validate and dissemination of water saving cropping pattern.
- Adopt low water required high value/high yielding crops.
- Develop community based intervention system on water saving technologies.

3) *Intensive production of fruits and vegetables under fruit tree based agroforestry system for food and nutrition security (Horticulture)*

Background and Justification

Agroforestry is an ancient practice and now it is becoming an integral part of the traditional farming systems in Bangladesh. Different kinds of fruit orchard especially mango, litchi and some types of mixed orchard are increasing day by day in Bangladesh as the decreasing of agricultural labor. This increasing trend of orchard is creating a negative pressure on agricultural food production. Vegetables are the major and common source of vitamins and minerals. Chandha et al. (1994) reported that per capita vegetables consumption is 28 gram against daily requirement of 200 gram in Bangladesh.

So, it needs to produce, make availability and also consume more vegetables round the year and hence, different orchard may be undertaken as vegetable-fruit based agroforestry system. Apart from recycling nutrients and improving soil nutrient availability, this system also helps reducing erosion risks and organic matter losses (Lehmann et al., 2000). Some vegetables are susceptible to high temperature and in that case partial shade of fruit tree may minimize the temperature and help the proper growth and yield of vegetables. Besides of this, a fruit tree needs minimum 3-4 years for profitable fruiting and at that time the orchard land remains fallow, which is a good option for high value vegetables production. But, with the growth of fruit tree, its canopy coverage increased and creating shade increasingly with the increase of tree age. So, it needs to analyze the suitable combination of different vegetables with different age of different fruit trees.

Objectives

- Increase productivity and profitability of fruit tree based agroforestry system.
- Improve land use efficiency.
- Improve farmers' livelihood through income enhancing.

4) Improvement of local breed of cattle through artificial insemination at the rural level (Livestock)

Background and Justification

Improvement of cattle in the rural agricultural farming plays an important role for livelihood. Rearing of traditional cattle results in lower meat and milk production even with improved diet management. The growth of traditional cattle is relatively poor because of their genetic character. However, the growth characteristics can be increased through crossing with high productive breed. Natural mating between traditional cow and high productive ox does not often gain satisfactory result. In that case artificial insemination (AI) is easy and successful approach for breeding and can be adopted in the rural areas. In Union level there is AI centre and technical assistant is engaged with AI activities. Actually Siemen of high productive ox(or exotic breed) is preserved at the laboratory located at Upazila and Zila level. During AI siemen is placed in to the reproductory organ of traditional cow and eventually it conceived. Through this breeding method adequate number of traditional cows can be fertilized and the generation with higher productivity of milk and meat can be achieved.

- Increase milk and meat production of traditional breed through artificial insemination.
- Popularize this practice among the rural farming and income generation through increased production.

5) Rearing of poultry at the household shed through semi scavenging method for income generation (Livestock)

Background and Justification

Poultry keeping is an integral part of multi-species subsistence livestock farming in Bangladesh. The method of keeping poultry under the subsistence farming has been characterized as the backyard poultry farming. This is the oldest and traditional system of keeping poultry in almost 95% of the rural households of Bangladesh (BBS, 2017). Backyard system in Bangladesh is a low-input and low-output system which mainly comprises of indigenous genetic resources and crossbreds birds housed with minimum facilities. This system allows the bird free-movement for scavenging food sources and in most of the cases, the birds are supplemented with kitchen waste, family food leftovers and self-produced food grains by the farmers. Chicken, ducks and pigeon are the most common

backyard poultry species of Bangladesh. The eggs and meat of the backyard poultry farming is mainly used for home consumption and the surplus are for income generation, particularly by the women who spend this money to support children's education and to mitigate family's financial gap in severe needs what help them to be empowered in the male-dominated rural families of Bangladesh. Poultry rearing through farming systems approach in the rural household is deemed attractive income generation way for better livelihood improvement.

Objectives

- Increase meat and egg production in rural farming through poultry rearing.
- Enhance nutrition availability for the farm family.
- Increase family income and employment opportunity.

6) *Mix polyculture of fishes in seasonal ponds of Bangladesh (Fisheries)*

Background and Justification

Against the backdrop of declining fish catches from open waters in Bangladesh and increasing malnutrition, excellent opportunities exist for small scale aquaculture development in rural areas, where majority of households have ponds or ditches. These water resources are presently either unutilized or underutilized. Small farmers constitute the bulk of the population in Bangladesh and there is urgent need to improve the efficiency of utilization of limited resource base of these small farmers. Most farmers in rural areas have access to water bodies such as seasonal mini ponds, ditches and canals which retains water for 5 to 6 months (from June - November). Farmers can effectively utilize these water areas for fish culture either for their subsistence or as commercial enterprises. To minimize the growing gap between demand and supply of fish low-cost feed ingredients and fertilizers should be used for increased production of fish. Mixed culture of several fast growing species such as mirror carp (*Cyprinus carpio* Lin.), red tiliapia (*Oreochromis niloticus* Lin.), silver carp (*Hypophthalmichthys molitrix* Val.) and Thai sharpunti (*Puntius gonionotus* Bleeker) of different feeding habits and behaviour can best utilize the above mentioned water bodies. Mixed culture can even show symbiotic effects, when one species improves the environmental conditions and food supply for others (Hossain et al., 1997). Therefore, the program will be carried out to study the growth of some fast growing species in seasonal mini ponds and to assess the productivity of fish in mixed culture.

Objectives

- See the growth performance of different fish species in seasonal ponds.
- Increase fish production and farmers income generation through improved management practices.

7) Agricultural policy and trade

- Development of producer's market in urban and semi urban areas with cold storage and other facilities providing supply chain of quality agri food items.
- Farmers to market linkage development, regulatory framework & market information system.
- Promote transboundary seed systems among the neighbor countries.
- Adoption of precision agriculture farming through mechanization in rural agriculture.
- Sustainable adoption of policy for standardizing of production, quality control and marketing of agri-foods through suitable quarantine guidelines among the SAARC countries.

8) Cross-cutting

- Development of integrated farming with crops, livestock, fisheries and agroforestry through holistic approach.
- Development of in-situ training facilities for farmers, producers, traders and other stakeholders for capacity build up.
- Intensification of agriculture through adoption of biologically feasible, environmental friendly and economically viable technologies for attaining food security.

Conclusion and Way Forward

Bangladesh agriculture has achieved significant changes over the past several decades. Despite of a large number of challenges, an agricultural revolution has taken place through development and adoption of modern varieties, mechanization of tillage operation, irrigation and other management technologies. Subsistence agriculture getting today is more commercial nature than ever before. Technological change coupled with market forces has greatly influenced Bangladesh agriculture. Highly committed research efforts showed technological progress, as evidenced by release of high yielding varieties of various crops management technologies by NARS institutes (BARI, BRRI, BJRI, BSRI, SRDI, BFRI (Fisheries), BFRI (Forest), BTRI, BINA, and BLRI). Universities and private organizations also played significant roles in research and technology development as well as transfer. The greatest challenge for the future agriculture lies in making agricultural research and extension more client-oriented and demand driven under climate change induced vulnerability. Therefore, integrated and systems base research to develop new technologies and bottom up participatory technology extension approach is suggested for sustainable development in agriculture.

Necessary considerations in line with agricultural policy can be driven factors to achieve a breakthrough in agriculture: formulate collaboration and target-oriented eco-region-wise systems research program for technology development, cutting-across disciplines and

institutions within and outside the NARS; prioritize resource-based and demand-driven research program with focus on marginal and smallholders and emerging market opportunities; promote sustainable management system for diversified ecologies focusing more on rainfed, backward, marginal, and fragile areas; focus on ecosystem health and bio-security of fishes and animals; promote efficient input management in the farm production systems; develop low irrigation water requiring crop production systems; public-private partnership on agricultural R&D; create agricultural development teams to respond to community-expressed needs; and establish a national program to monitor and evaluate program, especially for the purposes of upscaling.

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Chapter 4

Agricultural Research and Development: Policy and Program Priorities in Bhutan

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Abstract

Tremendous progress has been made in the agriculture sector since the start of planned agriculture development in 1961. A larger size of the population (57.2%) are still depend on agriculture for their livelihoods and this sector contributes to 17.37% of the national GDP. It is instrumental in increasing food production to ensure household food security, alleviate poverty, substitute imports through increased domestic production, generate marketable surplus, enhance household income and generate employment opportunities. Over the last plan period (2012-2017) production of major cereals increased by 28% and vegetables production increased by 33%. Limited agriculture land (only 2.75% of total land mass is under cultivation), impacts of climate change induced variability, rural- urban migration and outmigration (65%), farm labour shortage, diminishing share of public investment (2.4% of national budget during the 12th Five Year Plan), and a nascent agro-enterprise sector are some of the challenges constraining agriculture development. In context of evolving socio-economic dynamics and against the backdrop of climate extremes, Bhutan has set major priorities for agriculture development in the 12 Five Year Plan (FYP). Some of these include crop breeding for climate resilience, capacity development and access to climate change impact studies and modeling tools to effect robust policy decision, and investment in protected agriculture as an important approach to sustainable agriculture intensification and enterprise development in agriculture.

Keywords: Agriculture, climate change, food security, enterprise development, Bhutan

Background

The Renewable Natural Resources (RNR) sector comprising agriculture, livestock and forestry is a key component of Bhutan's economy and livelihood. Agriculture in Bhutan is still essentially a traditional subsistence-based mixed farming system integrating cropping, livestock rearing and forest products (FAO, 2019). Over 49.1% of the country's rural population still depends on the sector for employment and livelihood (NSB, 2017a).

The sector's share of GDP contribution stood at 17.37% in 2018 (NSB, 2018), which is decreasing alongside increasing share of other sectors, in particular, hydropower and construction industries. In terms of subsector growth, crops registered a faster growth, while livestock and forestry sectors have seen slow growth (Dizon et al., 2019). Forest constitutes more than 71% of country's total geographical area (MoAF, 2019) providing vital socio-economic services and cultural benefits to the country. The share of RNR Sector to National GDP in absolute terms has increased from Nu.12,178 million¹ in 2010 to Nu. 22,008 million in 2015, an increase of more than 80%. The RNR sector continues to play a pivotal role in achieving the nation's primary objectives of achieving food self-sufficiency, food security and poverty reduction.

Situation on Agricultural R&D

Demographic and Geographic Condition

Bhutan has a relatively young demography with the population's a median age at 26.9 years as of 2017 – an increased by 4.6 years from that in 2005, which is attributed to increasing life expectancy. At the national level, the sex ratio is 110 males per 100 females (NSB, 2017b). With a low population growth rate of 1.3%, old age dependency ratio² is expected to rise, with consequent strain on the country's productive population and its resources. The average household size is 4.6 (NSB, 2017a), and the population density is 19 persons per km², making Bhutan one of the least populated countries.

Despite its small land area, Bhutan is known for its rich and exceptional biodiversity, and is host to a number of globally threatened wildlife species including tiger, leopard, snow leopard, red panda, golden langur, takin, black-necked crane and white bellied heron. Pristine and near-virgin forested landscapes is as a result of the nation's sound conservation policies where by law at least 60% of the country's land must be covered by forest in perpetuity. More than 51% of Bhutan's geographic area is maintained under a network of national parks and biological corridors. Bhutan is also blessed with abundant water resources in the form of snow, ice, glaciers, freshwater lakes, rivers and streams.

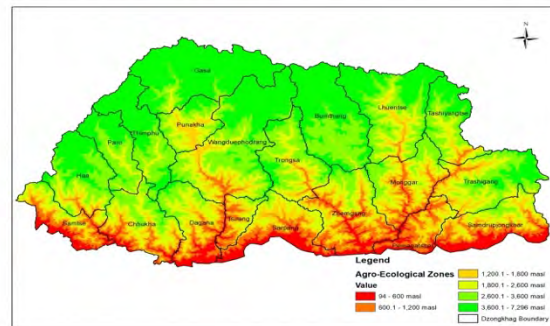


Figure 1. Agro-ecological zones of Bhutan

Source: MoAF (2018a)

¹ Equivalent to US\$ 173.97 million (as of September 2019) and US\$ 305.45 million (as of September 2019)

² Dependents of old age 65 years and above as a percent of population aged 15-64

Bhutan has great geographical and agro-climatic diversity. The country's landscape begins from subtropical plains, traversing up to the snowcapped Himalayan mountain ranges, with elevations ranging from 100 meter to over 7,000 meters above sea level (MoAF, 2018a) (Figure 1). According to MOAF (2015), around 50% of the geographical area of Bhutan is located in slopes greater than 50%. The country is divided into six agro-ecological zones: wet-subtropical, humid-subtropical, dry-subtropical, warm temperate, cool temperate and alpine. The wet-subtropical, humid-subtropical and dry-subtropical zones are located in the Himalayan foothills in the southern belt and are characterized by high humidity and heavy rainfall, with temperatures ranging from 15°C to 30°C all year round (NSSC, 2010). Warm temperate and cool temperate zones are found in the main central valleys, characterized by cool winters and hot summers with moderate rainfall. Summer temperature usually ranges from 15°C to 26°C, while winter temperatures range from -4°C to 15°C. However, even within same agro-ecological zone, the agro-climate varies due to elevation and aspect. These agro-ecological zones host diverse vegetation. Thick deciduous trees mostly make up the largely dense forest coverage in the sub-tropical areas while the temperate regions hold a myriad of varieties of trees and shrubs including species of pine, oak, birch and rhododendrons. Alpine zones nurture a range of coniferous trees (NBC, 2014; NSB, 2017b).

Agriculture– Status and Progress

The agriculture sector in Bhutan has come a long way since the introduction of plan development process in 1961. It provides livelihood to 57.2% of the country's total population (MoLHR, 2016). This sector now has the national mandate to increase food production to ensure household food security, alleviate poverty, substitute imports through increased domestic production, generate marketable surplus, enhance household income and employment opportunities. Of late, the agriculture sector is seeing transformation with a marked shift in its emphasis from subsistence to commercial farming. Hence, the sector has the responsibility to make farming attractive to youth and stem rural urban migration besides offering opportunities in sustaining growth and in partaking equally in economic process as well as in sharing the fruits thereof.

Production & Productivity of Agricultural Crops

Bhutan's diverse agro-ecological features favour the cultivation of wide varieties of major agricultural and horticultural crops like rice, maize, citrus, cardamom and vegetables, including potato. In the 11th Five Year Plan (2012 – 2017), rice and maize production increased by 10.7% and 28.8%, respectively (Table 1). However, the production of wheat and other cereals significantly dropped by 24% and 32%, respectively since 2012, indicating waning interests by farmers in growing these crops, and also as result of shifting priorities. Oilseeds, grain legumes and pulses production did not record any significant change throughout the plan period.

Table 1. Production trend of important food crops.

Crop name	Production (Mt)					
	2012	2013	2014	2015	2016	2017
Paddy	78,014.0	75,228.0	77,038.0	80,261.0	85,090.0	86,385.0
Maize	73,024.0	75,715.0	77,244.0	83,714.0	82,035.0	94,052.0
Wheat	5,038.0	4,286.0	3,465.0	3,730.0	2,521.0	3,833.0
Other cereals*	10,624.0	8,601.0	6,698.0	6,845.0	7,121.0	7,236.0
Oil Seeds**	1,245.0	1,641.0	1,473.0	1,292.0	1,314.0	1,536.0
Grain legumes & pulses	698.0	1,302.0	1,642.0	1,395.0	1,476.0	1,230.0
Total	168,643.0	166,773.0	167,560.0	177,237.0	179,557.0	194,272.0

Source: DoA (2019)

*Other cereals: Buckwheat, barley and millet **Oil Seeds: Mustard, ground nut, soya bean, sunflower, pyrilla and niger ***Grain legumes and pulses: Rajma bean, mung bean and lentil.

Vegetables including potato recorded significant increase in production by more than 61% and 33%, respectively (Table 2). The period also saw a significant increase in production of two major spices - ginger and cardamom. Ginger production increased by around 57% and while expansion in cultivation area driven by increasing demand drove cardamom production up by as high as 249%. Apple, fruits and nuts production slightly increased (around 5% and 7%, respectively) while production of citrus decreased by 43% in comparison to that of 2012, due mainly to pest and disease, old and unproductive trees and loss of orchards to other land use forms.

Table 2. Production trend of important cash crops

Crop Name	Production (Mt)					
	2012	2013	2014	2015	2016	2017
Vegetables	43,026.0	46,778.0	49,681.0	52,044.0	56,216.0	69,427.0
Potato	43,000.0	50,390.0	53,612.0	49,359.0	58,820.0	57,223.0
Ginger	5,014.0	3,756.0	4,983.0	7,434.0	10,871.0	7,859.0
Cardamom	643.0	1,162.0	1,781.0	2,091.0	2,736.0	2,245.0
Mushroom	4.0	19.0	17.0	19.0	82.0	122.0
Citrus	49,501.0	33,469.0	45,226.0	15,977.0	42,003.0	28,017.0
Fruits & Nuts	17,364.0	14,773.0	16,415.0	17,967.0	18,282.0	18,600.0
Apple	7,666.0	8,032.0	7,051.0	5,308.0	6,587.0	8,039.0

Source: DoA (2019)

Crop productivity has also showed a significant increase over the years. Productivity of major cereals like rice, maize and wheat show an increasing trend over the last 16 years, while area under cropping has registered a declining trend (Figure 2).

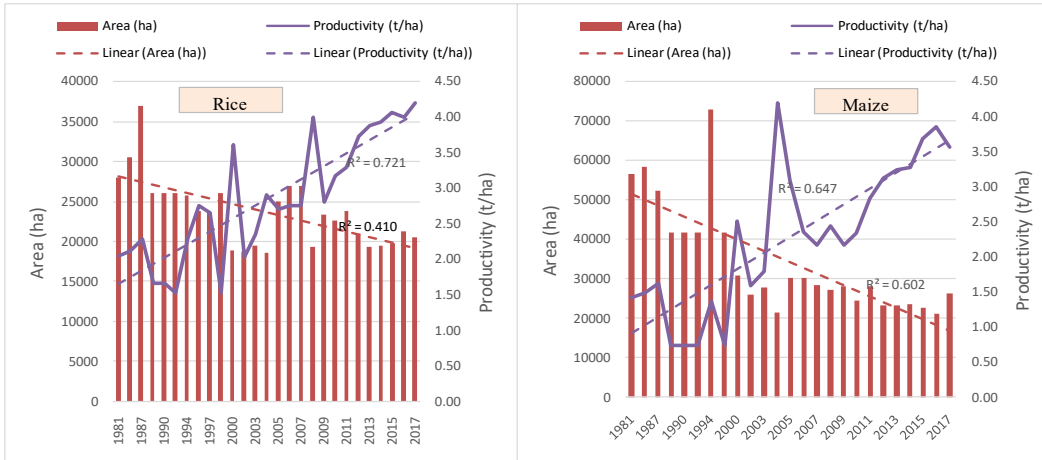


Figure 2. Rice and maize production area and productivity (1981-2017)

Source: RSD (2018)

On the other hand, data for potato, one of the most important of horticulture crops for Bhutanese farmers, show an increase in both the area under cultivation as well as productivity (Figure 3).

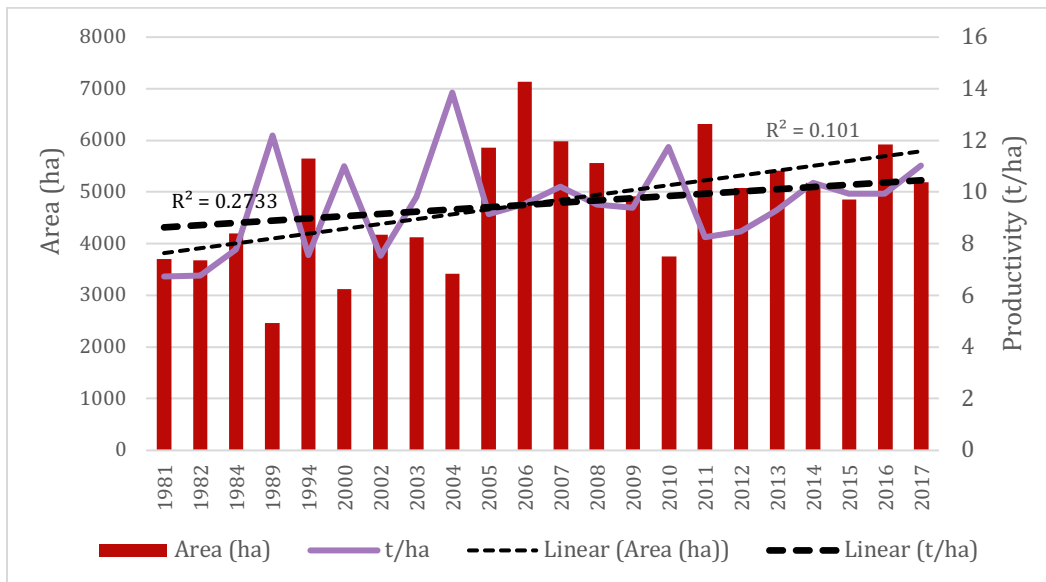


Figure 3. Potato production area and productivity (1981 - 2017)

Source: RSD (2018)

Agriculture Trade and National Self-Sufficiency

Agriculture sector (excluding livestock and forestry) alone contributed 10.64% of the total 17.37% contribution to the GDP by the RNR sector (NSB, 2017b). Review of data available with the National Statistics Bureau show that the GDP from agriculture sector has grown at an average of 4.72% annually since 2012, and it was valued at Nu 17, 513.39 million in 2017. It has thus significant contribution in improving the livelihood of rural communities.

The combined export value of Bhutan’s major agriculture export commodities (citrus, apple, potato, vegetables and cardamom) in 2017 was Nu 2,394 million, showing a marked increase from 2013 value of Nu 1,663 million. The export volume on the contrary has slightly decreased from 54,056 Mt in 2013 to 47,830 Mt in 2017. Between the years 2013 and 2017, cardamom exports increased by around 147%, followed by vegetables (42%) and potato (10%) (Figure 4). Cereal imports for the same period drastically increased from 54,031 Mt to 90,021 Mt (RSD, 2018). Bhutan’s self-sufficiency rates (SSR) in 2016 for fruits and potato were 132% and 162%, respectively, while the country achieved 61.16% self-sufficiency in cereal and 95.54% self-sufficiency in vegetables (DoA, 2019).

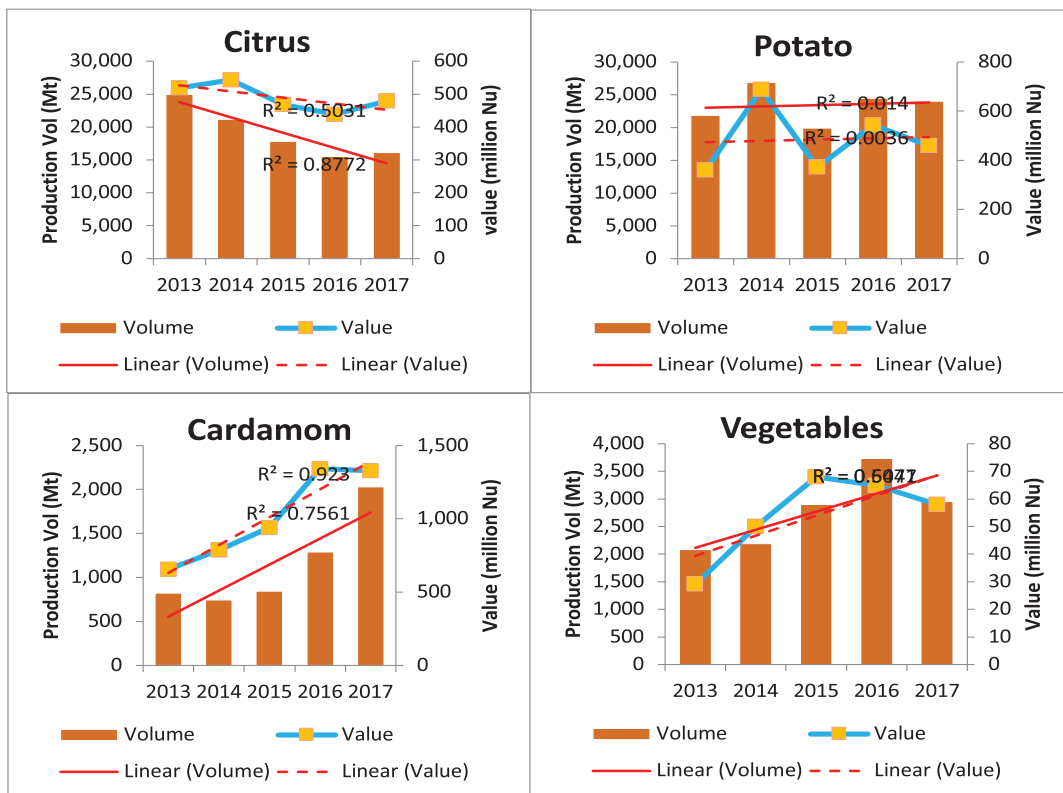


Figure 4. Export trend of important cash crops (2013-2017)

Source: RSD (2018)

Agriculture Infrastructure and Rural Economy

The Ministry of Agriculture and Forests (MoAF) pursued rural prosperity and inclusive development as one of the development objectives of the 11th FYP. The agriculture sector therefore invested immensely in strategic areas like enhancing rural connectivity, marketing, irrigation, innovative energy sourcing and in mitigating human wildlife conflict (HWC). In the 11 FYP, about 10,982 acres of land were brought under farm mechanization, and improve rural accessibility 5,363 km of farm roads were built or renovated, bringing the total length of farm roads in the country to 11,196 km (MoAF, 2018b). As part of the effort to reduce drudgery in farming and to make it attractive, the government distributed 1,200 power tillers and mini tillers, all available to farmers at subsidized hiring rates. About 90.47 km of new irrigation channels were constructed and 2,405 km renovated between 2012 and 2017, thereby increasing farm area under assured irrigation to 67,955 acres.

A number of interventions were also carried out to make farming households resilient to impacts of climate change. Over 1,885 greenhouses were supplied to farming households to promote protected agriculture. Additionally, a total of 3,752 farming households adopted bio-gas plants as an alternative source of clean energy. Around 212 water harvesting reservoirs were also set up to address water scarcity in farming in addition to a number of climate smart irrigation technologies.

Further, in order to enhance rural economy, three RNR associated state owned enterprises were established in 2016, including one for the agriculture sector – the Farm Machinery Corporation Limited (FMCL). These entities work in fostering agriculture commercialization and agribusinesses as one of the key avenues to achieve food security and address unemployment, as well as to aid in the gradual shift from a subsistence and small holder farming system to an enterprise based agriculture.

Agricultural Research and Development

Research in agriculture as a strong driving force in meeting global food supply and in contributing to agriculture growth worldwide is well-founded. Research-driven agriculture development, emphasizing knowledge-based and data driven agricultural production is instrumental not only in achieving food security but also in managing natural resources in the face of emerging challenges like declining soil fertility, land degradation, increasing cost of inputs, human resources scarcity and vagaries of climate change.

The establishment of the Centre for Agricultural Research and Development (CARD) in Wangdue in west central Bhutan in 1982 marked the beginning of formal agriculture research in Bhutan. With initial focus on field crops research, it expanded to fruits and vegetables, and thereafter made tremendous contribution to agriculture and rural development. Over the years, the four agriculture research and development centres (ARDCs) generated a number of technologies such as better performing crop varieties, improved farming methods, plant protection measures, postharvest and water management interventions, and progressive extension system and rapid agriculture services. Since 1988, these centres have released a total of 250 improved crop varieties that include 23 biotic and abiotic stress tolerant rice varieties (Lakey et al., 2019) (Figure 5). More than 50% of the total rice and over 60% of the maize areas are cultivated with improved varieties. Average rice productivity has increased by over 104% from 2.05 Mt/ha in 1981 to 4.20 Mt/ha in 2017.

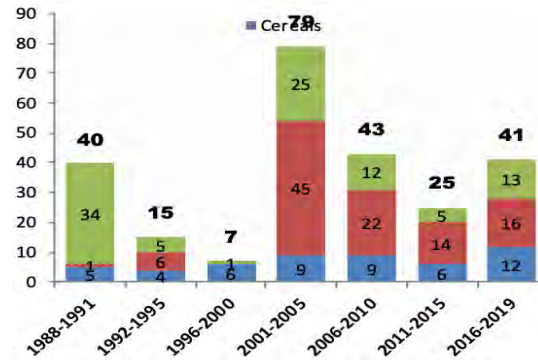


Figure 5. Crop varieties released (1988-2019)

Source: DoA (2018)

Human Resource Development

The Department of Agriculture is one of the government agencies directly responsible for agriculture sector development in Bhutan. The department, with its three divisions, four Agriculture Research and Development Centers, and seven central programs, has regular staff strength of 812. Seven officials have doctoral degrees, while there are 57 with Masters’ degree, 199 with Bachelors and the rest hold postgraduate diploma and diploma qualifications.

The department operates with three functional divisions: the Agriculture Production, Agriculture Research and Extension and the Agriculture Engineering Divisions. These divisions are supported by six central programs; namely the National Soil Services Centre, National Mushroom Centre, National Plant Protection Centre, National Seed Centre, National Post Harvest Centre and the Agriculture Machinery Centre. Four Agriculture Research and Development Centres located at strategic agro-ecological zones cater to the agriculture research and development needs of their respective mandated regions. At the grass root level, the department’s agriculture extension personnel spread across the country’s 20 districts forms the required conduit between the department and the ultimate service beneficiary – the farming communities.

While the research centres and central programs could be considered adequately staffed with qualified personnel, staffing structures are not uniform across various agencies within the department. Further, capacities of the district agriculture sector or the extension system still have not developed, and their numbers often are not concomitant with farming household size or the geographic area their service is expected to cover. The department also lack professional expertise in agriculture economics, plant breeding, biotechnology, climate change studies, and biostatistics.

Challenges in Agricultural R&D

Agriculture development in Bhutan faces a number of challenges – both inherent in its geography as well as due to evolving social and economic dynamics. Some of the key constraints are:

i. Limited productive agricultural land

Bhutan is characterized with rugged landscape and mountainous terrain where most of its rural farmland are isolated. The per capita available land in the country is around 0.6 acre (GNHC, 2009) and only about 2.75% of the country's total land area is under cultivation (DoFPS, 2016). More than 30% of the total agricultural land is situated on slopes as steep as 50% or more (NSSC, 2010) - considered unsuitable for cultivation by international standards, but due to limited land, farmers are forced to cultivate even on such steep slopes. This has also constrained Bhutan's agriculture to a largely subsistence one due to the limitations placed on farm mechanization and large scale farming. On the other hand, agricultural land is increasingly being left fallow due to rural-urban migration. There are 54,524 acres (dryland: 46,704 acres and wetland/paddy fields: 7,820 acres) of land left fallow as of 2017 (DoA, 2017b). This dire situation is further compounded by the increasing loss of agriculture land to competing demand for infrastructure development.

ii. Climate change impacts and disasters

Evidence of climate change trend and its impact on livelihoods are becoming a pressing concern. Wester et al. (2018) argued that more dramatic change in climate in the region. The region is expected to experience higher uncertainty in total rainfall and monsoon periods, temperature increase and extreme weather events and associated disasters. Climate variability will also have considerable impact on the glaciers and snows in the Himalayas which are the source of drinking water, irrigation and hydropower.

Despite Bhutan's commitment to remain carbon neutral, and its status as a negative carbon, the country is not immune to the impacts of climate change. Climate change and climate induced disaster will have significant impact due to its dependence on climate-sensitive sectors such as agriculture, hydropower and forestry. Bhutan's Intended Nationally Determined Contribution (INDC)- 2015 and Action Plan for Adaptation (APA)-

2016 (MoAF, 2016) also identified Agriculture and Food Security, Water Resources and Forest and Biodiversity as vulnerable sector to adverse climate change impacts. These are already evident in the increasing incidences of crops and livestock loss, decreasing crop yield, shift in vegetation pattern, unusual outbreaks of pests and diseases, drying of water sources, delayed sowing and transplantation due to late monsoon and loss of soil fertility due to erosion and landslides. Risk of Glacier Lake Outburst Floods (GLOF) is imminent with Bhutan's mountains holding 2,674 glacial lakes of which 24 are categorized as potentially dangerous (Tenzin et al., 2019). Glaciers are also receding ever faster. Conversely, precise and steadfast weather information and services supported by agromet decision support system for farmers are presently almost non-existent.

iii. Dynamics of rural urban migration

Bhutan's urban population increased from 30.9% to 37.8% between 2005 and 2017, and is largely attributed to migration (GNHC, 2019). Better employment opportunities in non-agriculture sectors has led to increased outflow of rural folks to urban areas. A survey carried out by the MoAF in 2013 shows a significant extent of outmigration with 65.6% of the rural households reported to have out-migrated. Lack of employment (42.5%) topped the reason for migration followed by lack of access to services that are available in urban centres (MoAF, 2014b). Urban centers are hence, increasingly getting congested and confronted with environmental and socio-economic setbacks while rural areas face issues of abandoned households. Younger generation move out or do not choose to go back to farms in the hope of opting for non-agricultural means of livelihood.

The resultant effect of outmigration are an ageing farming population, aggravated labor shortages, feminization in farming, increased fallow lands and incidences of human-wildlife conflicts, all of which contribute to a fast distorting farming sector. About 17% of households have left about 16.7% of agricultural land uncultivated or fallow (NSB, 2017a), which is one of the significant threats to farming systems (FAO, 2019). Human Wild life Conflict (HWC) continues to be a recurring threat to the country's efforts toward sustainable agriculture as well as its primary mandate of environmental conservation (MoAF, 2019b). On the other hand, increasing population in urban centres increases demand for foods while the farming population is on a downward slide.

iv. Diminishing share of public investment in agriculture

Investing in agriculture is an effective strategy for reducing poverty, inequality and hunger in countries where this sector employs a larger share of the population (Lowder et al., 2016). However, a review of the investment trajectory from the 1st to the 11th FYP on Bhutan's agricultural development phase reveals that public investment in agriculture sector has continuously diminished over the years (Figure 6). Share of resource allocation reduced from as high as 38.9% in the 4th FYP (1976-1981) to just 2.6% in the 12th FYP (MoAF, 2018b). Agriculture and its associated businesses are highly volatile and risky venture. Risk

transfer mechanism and insurance schemes are lacking while Foreign Direct Investments (FDI) and private sector investments in agriculture are minimum.

The national public fund outlay for the agriculture sector spending in Bhutan is significantly less. This is in stark contrast to global trend where governments of middle income countries have started investing substantially in research into food and agriculture (Pardey et al., 2016). Closer home, Sri Lanka recorded the highest agricultural research spending at 0.62% of its agriculture GDP amongst SAARC nations (Stads et al., 2019).

v. Underdeveloped agro-enterprise and value chain development

For a number of years spanning several plan periods, the Ministry of Agriculture and Forests (MoAF) emphasized the importance of agriculture and livestock production. The traditional focus of this sector has therefore been largely on quantity of production, pest control, animal health, input supplies, and extension services, etc. Product development, product quality and focus on intermediaries along the whole value chain as required by markets have been largely overlooked.

Other than a few agro-enterprises in Bhutan, enterprise development in agriculture sector are largely characterized by informal home-level operations. Though a diverse range of agro-climatic conditions allows production of a variety of crops and rearing of livestock, achieving the economy of scale for full commercialization has been a challenge. Inadequate capital and limited access to modern technology, low skills, high transportation and labor costs leading to high cost of production are some major factors constraining agriculture enterprise development. This is exacerbated by lack of targeted supports to business ideas and startups in up-scaling them beyond home or backyard levels.

The concept of self-sufficiency emerged as early as 2nd FYP (1967-71) while the national goal of economic self-reliance was outlined as a development priority since the 5th FYP (1981-86). However, much work is needed with the current account deficit recorded at 29.5% (NSB, 2017b), one of the highest in the world. Food import (mostly rice, meat, dairy and vegetables), mainly from India in 2015 alone was valued at Nu 5.29 billion as against the country's agriculture export of just Nu. 2.65 billion (MoAF, 2019b). Bhutan's own experience during the 2008 global food crisis is a stark reminder and a forewarning of what it would mean for country that depends excessively on food imports.

Review of Agricultural Policies and Programs

Agriculture being a mainstay of rural economy, Bhutan has several policy instruments and legal frameworks in place to provide the agriculture sector an enabling environment to develop and sustain. The *Food and Nutrition Security Policy of the Kingdom of Bhutan - 2014* (MoAF, 2014a) emphasizes the fundamental rights of Bhutanese to affordable, adequate, safe, nutritious and culturally acceptable food. With land resources at the core of farming, the Department of Agriculture has put together the Agriculture Land Development

Guideline - 2017 (DoA, 2017a) to strategize land development and land use to prevent land degradation and address issues of low crop productivity, rural urban migration, and to enhance ecosystem services. The Land Act - 2007 (NCB, 2019) grants the Ministry of Agriculture and Forests (MoAF) the sole rights to review and approve the conversion of wet land (paddy fields) to other land use categories.

The MoAF's 12th Five Year Plan (FYP) identifies and sets forth agricultural enterprise development and commercialization as an integral approach to diversifying the nation's economy. This is expected to help realize the Royal Government of Bhutan (RGoB)'s policy priority of harnessing opportunities in broadening agriculture, livestock and forests-based enterprises as reiterated in the *Economic Development Policy 2016* (RGoB, 2016). The Guideline for RNR Enterprise Development 2019 (MoAF, 2019a) that the ministry put together aims to operationalize these policy priorities. Additionally, in response to market incentives, evolving farm dynamics, and the opportunities associated thereof, the MoAF is providing added impetus to niche products through higher value crops, encapsulating their entire value chain, in strategic production zones.

In terms of analyzing approaches through a climate resilient integrated landscape perspective since farming is a complex mix and interaction of forest, agriculture, soils, water, biodiversity, pasture and climate, several acts are in place to address the closely interlinked objectives of food security, rural development, economic prosperity and climate change mitigation and adaptation. These include the Constitution of Bhutan, Fiscal Incentives - 2016, National Forest Policy - 2012, Water Policy - 2002, National Irrigation Policy - 2012, National Environment Protection Act - 2007, Biodiversity Act of Bhutan - 2003, Water Act of Bhutan - 2011, National Disaster Management Act - 2013, Biosafety Act of Bhutan - 2015, Pesticides Act of Bhutan - 2000, Seeds Act of Bhutan - 2000, Plant Quarantine Act - 1993, Forest and Nature Conservation Act - 1995 (NCB, 2019).

Recommendations of Priority Programs

1) *Agricultural policy in view of climate change effects (Agricultural Policy)*

Background and Justification

Agriculture is the predominant economic mainstay of livelihood to over 70% of South Asia's 1.3 billion people, and contributes to around 22% of the region's Gross Domestic Product (GDP) (Wang et al., 2017). However, South Asian countries are likely to be the most severely affected by impact of climate change (Bandara & Cai, 2014; Sivakumar & Stefanski, 2011). Bandara & Cai (2014) indicate a rise in temperatures in Bangladesh, India, Nepal, Pakistan and Sri Lanka, with observed climate-related effects like seasonal water scarcity, extreme weather patterns, increased disease and pests incidences- all negatively affecting crop productivity. The Intergovernmental Panel on Climate Change (IPCC)'s simulation models for South Asia predicted that the annual mean temperature will

increase by 1.3 – 3.5°C while the precipitation patterns are expected to be change anywhere in the range of 13-34% by 2100 (IPCC, 2013).

Bhutan has its own share of serious problems as a result of climate change. Rice blast disease in 1996 where farmers lost 80-90% of their harvests and Turcicum leaf blight in 2007 affecting 50% maize harvest. Further, Bhutan is increasingly seeing incidences of extreme weather events like glacial lake outburst floods (GLOFs), hailstorm, and flashflood with high intensity rain in 2004, 2013 and 2015 (Chhogyel & Kumar, 2019) damaging hundreds of acres of maize and rice crops as well as a number of irrigation channels and agriculture land. Although several agencies including UN and Bhutan’s Ministry of Agriculture & Forests (MoAF) have released reports on climate change adaptation and mitigation, there is a dearth of scientific studies on climate change effects on food productivity, prices and food security in Bhutan.

Climate change (CC) extreme events induced losses on agriculture production and their subsequent impacts on food security are suggested through empirical studies (Holzworth et al., 2015; Van Wijk et al., 2014). Hence, it is crucial to develop capacity on the requisite tools to assess CC impacts on small holder farmers – one of the most vulnerable of sections - and the broader implications on food security. Presently, agriculture professionals in the country lack capacity in modeling climate effect on agriculture productivity and food security irrespective of whether it is the use of Global Computable General Equilibrium Models (GEMs) or a range of other farm household models that include dynamic simulation, multi-agent models or a combination of these. Such empirical studies will enable policy analyst and policy makers to develop CC adaptation measures to address likely repercussions.

Components/ Activities

- Build capacities in modelling climate change impact on agriculture productivity and food security.
- Capacity building on farm household models for integrated analyses of food security to effect strong decision-making.
- Facilitate access to soft components such as crop, climate and econometric models to support research in and forecasting of climate variability impacts on agriculture and food security.

2) Crops Sector

Background and Justification

Given its geographical features, Bhutan’s agriculture sector is highly susceptible to the effects of climate change (Parker et al., 2017). In spite of the efforts put into agriculture development, a rise in the number of extreme weather associated occurrence substantiate that climate change can affect agriculture and livelihoods in Bhutan. Incidences of climate

hazards like excessive rains, flash floods, windstorms, hailstorms, and droughts including outbreaks of pest and diseases are becoming increasingly regular in the country. As a consequence, crop damages and decline in yield and reduction in production can have immense adverse implications on the country's food security. Hence, as reiterated by Gioli et al. (2019), elaborate social protection systems and proper climate adaptation interventions needs to be put in place to counter these challenges. Food security will be severely undermined unless resilience to climate change is enhanced.

After its institution in 1982, formal research in Bhutan has had made significant contribution to enhancing rural food self-sufficiency and food security. R&D in cereal crops made considerable progress and brought about significant changes in rural food self-sufficiency as well as in the dietary regimes of the larger Bhutanese population. Breeding initiatives in rice, wheat and maize have generated improved varieties with average productivity in rice alone showing an increased by over 104% from 2.05 Mt/ha in 1981 to 4.20 Mt/ha in 2017 (Lakey et al., 2019). More than 60% of the maize farming area is covered with improved maize varieties.

Simulation models predict a mean summer and winter temperature increase of 2.8°C and 2.1°C over 2040-2069 for Bhutan (Chhogyel & Kumar, 2018). These including predictions in heavy precipitation accompanied by high intensity and frequency of droughts and heat waves indicate serious implications on cereals crop production and subsequent consequences on food security. Although, the Department of Agriculture has introduced, developed and officially released 250 different crop varieties with superior agronomic traits, seed replacement ratio for most of these crops still remain low due to a weak national seed system. Progress made in developing these resistant varieties is being negated with the very superior traits breaking down.

Therefore, it is imperative that in addition to other forms of climate change adaptation in agriculture, Bhutan will also require to strengthen her capacity in developing crop varieties that are resistant to drought, heat, pest and diseases stress as well as other forms of biotic and abiotic strains.

Components/ Activities

- Establish a functional national plant breeding systems including introduction and or development of hybrid crop varieties to enhance climate resilience and crop productivity.
- Mainstream participatory plant breeding and varietal selection methods in the formal plant breeding systems to exploit farmer's local knowledge to enhance and ensure adoption of new varieties to strengthen climate resilience.
- Re-emphasize seed health as an important quality parameter, and institutionalize systemic research in seeds and improve infrastructure and human capital in seed testing.

3) Protected horticulture & enterprise development (Horticulture)

Background and Justification

Protected agriculture have immense potential in enhancing agriculture productivity and provide key answers to issues of limited arable land besides offering avenues to attract and retain youth in farming. Globally, the area under protected agriculture which generally includes plastic film mulch, low tunnel plastic houses and greenhouses, have expanded multiple-folds in the last two decades or so (Castilla, 2012). Area under greenhouse alone is estimated to have increased from 200,000 ha to 2 million ha between the late 1980s and 2010. China and Japan make up for the largest proportion in area increase under protected agriculture in Asia. Most greenhouses are of medium-level technologies involving natural radiation to heat and wind to cool, and vegetables are the most common crops grown while some employ for ornamentals to a certain degree (Takeshima & Joshi, 2019). Vertical farming as a system of maximizing land use for crop production has also seen major progress both in terms of technological breakthroughs and in its adoption.

With an average land holding of 2.2 acres (NSB, 2017a), and a total arable land of only 2.73%, increase in agriculture production through conventional expansion of agriculture land in Bhutan is severely constrained. Besides, maximizing production by bringing additional land resources under tillage can offset climate resilient interventions as well as risk countervailing the very principles of sustainable agriculture. Protected agriculture along with intensive farming technologies like vertical gardens, hydroponics and aeroponics are therefore viewed as viable alternative in not only counteracting climate change impacts through efficient use of water and other inputs but also in its immense potential to attract youth entrepreneurs into agriculture and thereby create jobs. At different scale of operations, these technologies offer opportunities in enhancing productivity and in transforming horticulture farming.

Drudgery in farming, crop damage by wildlife, limited landholding, declining soil fertility and water scarcity are the emerging challenges that agriculture development faces. Figures from Agriculture Statistics 2017 (DoA, 2017b) indicate a declining trend in farming population and in the last plan period Bhutan's farming population has decreased by around 26%. This exerts huge pressure on agriculture production, food security and enhance household income and reduce food imports. On the other hand youth unemployment is on the rise with a current overall youth unemployment rate of 15.7% of which 56.0% is found in urban areas (NSB, 2019).

Protected agriculture, particularly in the horticulture sector with emphasis on vegetables and culinary herbs and vertical gardens in urban areas offer multiple benefits of growing a variety of high-value vegetables in marginal area, maximize space and inputs utility with increased productivity and year-round production, reduce chemical inputs and food miles, increase food security, generate employment, acts as carbon sink and improve

aesthetics of urban landscapes. The government's recent pro-business initiatives such as the Priority Sector Lending (PSL) helps for financing and stimulating such commercial, high-tech, high intensity production systems to drive entrepreneurship in agriculture.

Components/ Activities

- Promote low cost structure for protected farming of vegetables and other priority horticulture crops.
- Establish high-tech infrastructure for protected farming of vegetables and other priority horticulture crops. These structure could include automated climate controlled greenhouses, hydroponics, and vertical gardens.
- Build research and technical capacities of agriculture professionals in protected agriculture through collaboration with relevant institutions.

4) Forestry or natural resource management (NRM)

Background and Justification

Bhutan is known for its unique ecological diversity and exceptional conservation initiatives. As per the article 5 of the constitution, at least 60% of the country's land must be covered by forest in perpetuity, and it is strictly illegal to kill or trap any wild animals (RGoB, 2008). The country has more than 51% of geographical area secured under national parks and biological corridors. Despite its small size, Bhutan hosts 11,284 species of plant and animals, which constitutes 0.8% of the world's flora and fauna (RSPN, 2019). Bhutan's forests serve not only as pool of biodiversity but provides "long-term stores of carbon which mitigate the adverse impacts of climate change" (WWF, 2011). The sequestration capacity of Bhutan's forest is estimated at 6.3 million tons of CO₂ equivalent, differentiating it as one of the few countries in the world with negative carbon emissions. Hence, natural forest ecosystems in Bhutan have long been established as a prime driver that supports farming communities' resilience against climate change. Forest and biodiversity have played significant role to livelihood and economic prosperity of the Bhutanese where communities directly rely on them as source of livelihood, income generation and entrepreneurship. Bhutan is popular for its environment friendly policies and strategies that are drawn from traditional and Buddhist values that recognize nature as the domain of spirits. Bhutan's commitment toward sustainable development, carbon neutral development and environmental conservation is also visible in various bilateral and global engagements and agreements.

Conversely, forestry and biodiversity sector is also facing challenges arising from continued pace of socio-economic development. Key threats include human wildlife conflicts, excessive grazing, unsustainable harvesting of forest products, poaching forest and wildlife products, forest fires, infrastructure development and climate change (MoAF, 2018b). In the order of its contribution to national economy, the forestry sector's GDP share

has declined from 16% in 1981 to 2.6 in 2015 (NSB, 2018). Additionally, the livestock and forestry sectors have registered very slow growth as opposed to agriculture and its sub-sectors (Dizon et al., 2019).

In light of Bhutan's economy being largely driven by a singular sector – hydropower, and against the backdrop of increasing trade deficit and growing unemployment, Bhutan's policy priorities demand diversification in the economy to stimulate growth. Forest and non-wood forest products that are primarily used for subsistence purposes have potential to be developed into value added enterprise and cottage industries (Dizon et al., 2019). The Economic Development Policy 2017 that outlines the economic roadmap for Bhutan also underscores the need to add value, develop integrated wood-based industries and enhance the competitiveness of the wood based industry (MoEA, 2016) as a means to diversifying the country's economic base. At the same time, livelihood and development opportunities need to be integrated in order to leverage communities' support in conservation efforts even as the country's forest wealth provides livelihood opportunities. Utilization of natural resources and their sustainable management thus have to also maintain the balance between ecological requirements and economic and socio-cultural needs.

Components/ Activities

The primary proposed priority in an effort to increase the contribution of forestry sector to the nation's economy and communities' livelihood include:

- Enterprise development in high value niche forest products to generate employment, enhance livelihood while promoting conservation, social responsibility and sustainable utilization.

5) Livestock sector

Livestock farming comprises an important component of farming, and farmers depend on livestock for a range of products from source of food and cash income to transportation, fertilization and raw materials, among others. For highlanders, livestock rearing is the economic mainstay. Increasingly, commercial livestock rearing is gaining momentum in the country. Livestock sector contributed 3.89%, second to crops and horticulture (9.95%), followed by forestry at 2.68% contribution to the agricultural sector GDP. The livestock sector focuses on increasing the production and productivity of livestock and enhancing self-sufficiency in dairy products, meat and eggs (MoAF, 2019). The sector aims to develop livestock farming to a profitable business, increase rural income, and generate employment opportunities.

However, livestock farming in Bhutan is mostly at subsistence level with very few commercial farmers. Livestock sector is faces challenges such as lack of quality inputs, shortage of fodder, low productivity, etc. Further, production risks also primarily comprise livestock diseases, wildlife predation, and limited access to and affordability of inputs. On

the post-production front inadequate processing and storage facilities plague the sector's growth. Meat production is further exacerbated by the strong inherent religious sentiments against animal slaughter. The resultant impact is the negative trade balance arising solely out of high dependency on imports and lower self-sufficiency in meat which stands at 33.51%, in contrast to the self-sufficiency ratios for dairy products and eggs which stood at 92.53% and 100% respectively in 2017 (MoAF, 2019b).

Some of the strategic priorities to achieve productivity and self-sufficiency in livestock products are livestock breed improvement, improving feed and fodder production and supplies, introducing new livestock production technologies, facilitating access to markets, improving available infrastructures in rural areas, initiating farmer's co-operatives, and sustainable use of available resources (DoL, 2019). Institutional capacity of farms need to be enhanced so that they are able to invest in research and development as well as provide breeding stock for pig, poultry, cattle and fish production. The role of private sector engagement should be recognized to complement and work in collaboration with research centres, extension agents and community worker. There is need for an increased access to artificial insemination (AI) programs.

Components/Activities

- Fast track dairy input intensification program for improved access and availability of high yielding breeding stocks and heifer production through AI and innovative technologies.
- Render dairy farming economically viable and socially attractive through accelerated dairy value chain and enterprise development program with added emphasis on product and infrastructure, and marketing development using integrated approach.

Conclusion & Way Forward

Agriculture is not only the mainstay of economy in Bhutan but a way of life for a significant majority of its population. Farming is entrenched in its history and has deep cultural roots. With new evidences pointing to a rise in world hunger and with the world's population expected to hit around 9 billion by 2050, food production will have to be increased by an estimated 60%. The situation is all the more dire for smaller nations like Bhutan, constrained as it is by a number of geographical and socio-economic challenges. Climate change and its implications are no longer impending risks – it is a grim reality.

Bhutan needs to put in concerted measures along with coherent policies not only for food security and national self-reliance, but also meeting targets of the SDG 2030 goals. Amongst many others, some of the immediate priorities for the agriculture sector within the working framework of South Asian Association for Regional Cooperation (SAARC) and the SAACR Agriculture Centre include building capacity as well as ensuring access to globally used tools for empirical studies, analysis, and predicting climate change impact

on food security to effect strong policy decisions. Given Bhutan's dietary habit and the role of cereals in enhancing food security, emphasis needs to be placed on revamping its plant breeding system to enable development of climate resilient crop varieties, and thus help move away from heavy dependence on some major cereal varieties whose traits may be close to breaking down. Bhutan needs to look at cashing in on the unlimited economic avenues offered by its rich and diverse natural resources.

Fast-tracking inputs intensification to improve access to high-yielding breeding stocks and emphasis on product and infrastructure development in dairy industry can play key roles in lowering its livestock import driven trade deficits. A range of protected agriculture technologies offer economic opportunities as well as provide alternatives as part of Sustainable Agriculture Intensification (SAI) to improve environmental efficiency of agriculture. Knowledge building with innovative business models in protected horticulture can help drive Bhutan's new impetus on agriculture entrepreneurship.

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Chapter 5

Agricultural Research and Development: Policy and Program Priorities in India

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Abstract

Agriculture is crucial for ensuring food, nutrition and livelihood security of India. Global climate change, degradation of natural resources, changing lifestyle and dietary pattern, however are considerably affecting and will continue to affect the food supply and access through direct and indirect effects on crops, soils, livestock, fisheries and pests. The task is more challenging because more than 85% of farmers of India are marginal and small with poor coping capacity and 52% of country's net cultivated area is rainfed and exposed to abiotic and biotic stresses. The farms are also diverse, heterogeneous and unorganized. Therefore, concerted efforts are required for adaptation to reduce the vulnerability of agriculture to the adverse impacts of climate change and making it more resilient. There is a need to develop policy framework for implementing the research and development programs so that the farmers are saved from the adverse impacts of environmental changes. Development of technologies and their adoption at speedy rate by the farmers are essential for making Indian agriculture more productive, profitable and climate resilient. The chapter discusses the priority areas of agricultural research and development to make agriculture the engine for growth of other sectors of Indian economy.

Keywords: Climate-smart agriculture, environmental footprint, farmers' income, improved technologies, sustainability

Introduction

India is the 7th largest country in the world in terms of area with diverse ecosystem. Agriculture is crucial for ensuring food and nutrition security and livelihood improvement of Indian people. The sector engages almost two-third of the workforce in gainful employment and accounts for about 16% share in India's Gross Domestic Product (GDP). Indian farming system is diverse, heterogeneous and unorganized. Moreover, almost 60% of country's net cultivated area is rainfed and exposed to biotic and abiotic stresses and even the irrigated system is dependent on monsoon. Flood is also a major problem in many parts of the country, especially in eastern part, where frequent flood events take place. In addition, frost in north-west, heat waves in central and northern parts and cyclone in

eastern coast also cause havoc. In recent years, the frequency of these climatic extremes is getting more due to the increased atmospheric temperature, resulting in increased risks with substantial loss of agricultural production.

Indian agriculture has made tremendous progress over the years (Table 1). However, it is also facing unprecedented challenges in recent years. In current year, food grain production has touched all time high of about 285 million tons (Mt). Production of all crops has established a new record with rice 113 Mt (paddy 170 Mt), wheat 100 Mt, course cereals 47 Mt, maize 29 Mt and pulses 25 Mt. The country also harvested a record production of horticultural crops, livestock, fisheries and aquaculture. Indian agriculture sector is credited with making the country not only self-sufficient in food grains in early 1970s but has enabled it to export agricultural commodities worth 1.30 lakh crores during 2018/19.

Along with numerous accomplishments, newer challenges have also been cropped up to the forefront. The ever-increasing population and income have raised the demand for food but the resource base that was responsible for increasing the production has been shrinking. Rising cost of cultivation has adversely impacted the profitability; consequently, farming no longer remains an attractive option. In addition, growth rate in productivity of many crops has become stagnant. This is further compounded by the challenges of global warming. Indian agriculture, therefore, faces twin challenges of increasing production and productivity along with profitability of farming on one hand and maintaining the environmental security and sustainability on the other. Low and uncertain income, degraded natural resource base, growing labor and energy shortages and threats of climate change are making Indian agriculture highly vulnerable and unsustainable. Uncertainties in monsoon and market are increasing the disparity and drudgery of farmers in almost all parts of the country that made Indian agriculture seems to be in a cross-road once again. Green Revolution helped the country in attaining and maintaining self-sufficiency in food grains from early 1970s to date (Table 1).

Table 1. Trends in production (million tons) of agricultural commodities in India

Commodity	1950-51	2017-18	Increase (x)
Food grains	50	284	6
Vegetables and Fruits	25	282	11
Milk	17	176	10
Egg (billion)	1.80	95	53
Fish	0.75	10.5	14

Source: DoACFW (2019)

Although it made the country proud, resulted in several second generation problems such as soil, water and air pollution; emission of greenhouse gases, and loss of biodiversity. Coupled with this, the growing population and rising per capita income have generated huge demand. While the population is likely to increase to more than 1.6 billion before

near-stabilization by 2030, the food demand is expected to rise up to ~400 million tons (Mt) by the year 2050.

Hence, an agricultural growth rate of 4% per annum is necessary not only to meet the growing demand of food, feed and fodder but to continue to have 8-9% growth in gross domestic product (GDP) to reduce poverty and support the overall economic growth of the country. Although agricultural production in the country is increasing, yet the economic contribution of agriculture to India's GDP has been declining steadily from 57% in 1950s to about 16% in 2018-19 (Figure 1). Agriculture is, however, the largest economic sector and plays a significant role in the overall socio-economic fabric of the country with more than 55% of its population directly or indirectly dependent on agriculture. The future requirement of food grains, vegetables and fruits in 2020 and 2050 indicate a growth rate of 1.1% for food grains, 2.4% for vegetables and 3.7% for fruits to maintain self-sufficiency.

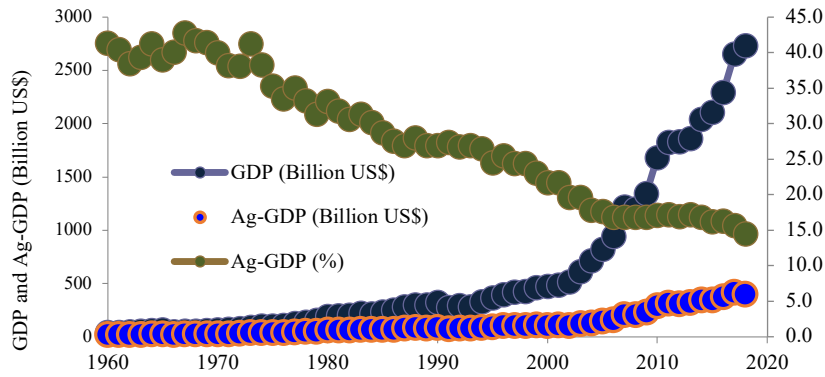


Figure 1. Trends in gross domestic product and contributions of agriculture in India

Source: DoACFW (2019)

Increasing population and income have changed the demand for food with a substantial increase in demand for quality products of fruits/vegetables and livestock. In addition, concern for environment protection and globalization has put tremendous pressure on Indian agriculture. In fact, increasing demand for water by the industry and household sectors, shrinking agricultural land due to urbanization, and consequent rising energy demand in agriculture sector are likely to be the binding constraints in future. The major challenges before Indian agriculture are its marginal land holdings, widening production disparities between irrigated and rainfed areas (ratio of irrigated to rainfed yield range from 1.25 to 3.30), degradation and depletion of natural resource base, climate change, increase in non-agricultural demand for land and water, inadequate mechanization, labour shortage, inefficient use of inputs, wastage of agricultural produce due to inadequate post-harvest operations, lack of awareness among farmers for modern crop production methods, ineffective extension services, inefficient financial resources for investments,

high levels of consumption services resulting in wastages and above all low per-capita income for farmers. These challenges have to be addressed through improved technologies without compromising the sustainability of natural resource base. The chapter identifies the priority areas for R&D in various sub-sectors of Indian agriculture.

Priority Areas for Agricultural R&D

Research and development in Indian agriculture needs a major re-orientation to address the emerging challenges and uncertainties. Indian agriculture should readjust itself from productivity to profit-driven; discovery to delivery-driven; output to outcome-driven; self to society-driven; process to product-driven; long-term to short and medium-term oriented; qualitative to quantitative oriented; knowledge to resource generation oriented; individual to team oriented and public fund to private fund-driven. In recent time, several steps have been initiated to reorient the functioning of research and development organizations in the country. Increasing farmers' income, besides increasing productivity and improving quality of crops, has become the main thrust of agricultural research. Improving and sustaining the natural resource base have also taken the central stage. Environmental pollution and climate change have emerged as the major drivers of research and development of in the country. Scientific community should embrace these changes and challenges to reorient the research programs for making Indian agriculture productive, profitable, climate resilient and sustainable.

The Department of Science and Technology (DST) and Technology Information, Forecasting and Assessment Council (TIFAC, An autonomous body under DST, Government of India) constituted a Global Technology Watch Group: Sustainable Agriculture. The Group identified suitable technologies, prioritized those using a standard methodology and submitted its report in 2019 (TIFAC, 2019). Some of the priority areas of research and development in the context of Indian agriculture, as prioritized by the Group, have been identified below.

Crops Sector

Development of crop varieties with higher yield potential and resistant to multiple biotic and abiotic stresses should be one of target of crop improvement program. The yield ceiling should be raised and the yield gap narrowed while maintaining sustainable production. Development of new varieties with higher yield potential and stability is complementary to bridging the yield gap. Efforts should also be made to improve efficiencies of water, nitrogen and other inputs. Conventional breeding has to be strengthened with modern biotechnological approaches like marker-assisted breeding and development of transgenic. To address these issues, a few prioritized technologies are mentioned below (Pathak et al., 2019).

ii) Development of multiple stress (biotic and abiotic) tolerant varieties

Climate change has an intense effect on agriculture since increasing climate variability causes un-predictable and frequent occurrence of many abiotic and biotic stresses. Therefore, crop plants often encounter more than one stress at a time. Thus, developing crop plants tolerant to multiple stresses is the need of the time. Pyramiding stress-tolerant QTLs, candidate genes, and alleles in elite cultivars would generate such plants. For the rainfed ecosystem, ICAR-NRRI in collaboration with IRRI, the Philippines has recently developed drought and submergence tolerant rice varieties by stacking QTLs for the respective stresses (Sandhu et al., 2019). As a result, two varieties, CR Dhan-801 and CR Dhan-802, have been released for commercial cultivation. Moreover, seven other varieties having tolerance to multiple stresses (one for submergence and salinity, two for drought and heat, and four for drought and submergence) have been released under the project Stress-Tolerant Rice for Africa and South Asia (STRASA) initiated by IRRI. Rice plants for multiple biotic stress tolerance and combined biotic and abiotic stress tolerance are yet to be developed, though the effort has been made to develop multiple abiotic stress-tolerant rice varieties.

iii) Advanced genome-editing technology (CRISPR-Cas9) for greater genetic gains

The rapid advancement of genome editing technologies allows us to disrupt genes efficiently, remove deleterious alleles, alter SNPs, transmute an allele from non-functional to functional, and to some extent, site-specific knock-in of exogenous genes. The editing technologies have been demonstrated to greatly reduce the breeding cycles and offer rapid genetic gain in crop plants like never before. Since editing is the fastest available technology to rapidly and precisely increase the frequency of the beneficial alleles in any genetic background, it remarkably increases the rate of genetic gain. Although the most popular application of CRISPR/Cas9 is to knock-out a gene, recent development of CRISPR/Cas-based base editing and improved-homology-directed repair technologies enable to modify precisely a targeted single nucleotides or a region of the genome. Those advanced CRISPR technologies could be harnessed for more precise genetic gain for accumulating favorable alleles.

iv) Efficient seed delivery system and seed bank for contingency measure

As soon as a superior variety is released, its' seed should reach farmers so that the genetic gain/superiority is realized in their field. Therefore, an efficient seed delivery system is one of the key players behind the popularization of a variety. Quality seed production and accessibility to the farmers' could be ensured by licensing of released varieties for decentralized production and distribution as one of the methods. Distribution of small packs of seeds, better coordination with extension or development programs, public-private partnerships, and farmer-based seed production and supply initiatives can significantly improve the efficiency of the seed delivery system (Varshney et al., 2018). It

is considered that farmers from developing countries usually save and reuse their seeds. However, according to a recent report from the 'Access to Seeds Foundation,' farmers buy improved seeds if accessible; they buy seeds mostly from local markets, not from big seed companies. Regional companies are active in marketing varieties from public research institutes (GON & BMGF, 2016). Hence, for an efficient seed delivery system to be in place, local markets and regional companies should also be kept in the loop. A seed bank is a kind of gene bank where seeds are stored to preserve genetic diversity and make them available to the public when there is a need. Seed banks are extremely valuable to allow faster recovery from any natural disaster, which may cause a huge loss of biodiversity, including various plants and agricultural crops. Other adverse agricultural situations like mid-season droughts, late monsoon, cyclones, flash-floods, heat and cold waves, and poor germination of seeds may cause severe crop losses, and farmers may need to get immediate access to seeds to re-sow the same crop or contingency crop. In those situations, the local seed banks/community seed banks may play a crucial role in supplying the required seeds in the desired quantity to the affected farmers. The community seed bank is a way of self-sufficiency at the local level and can also contribute to the seed supply chain in a contingency situation.

iv) Crop varieties with high nutritional quality and bio-fortification

Most of the people from developing countries depend on primary staple foods lacking essentials vitamins and mineral nutrients. Consumption of poor diets has adverse health effects. If staple food crop varieties bred for enriched nutrient composition and density, they could satisfy primary dietary energy demand and provide the essential nutrients required for a healthy body. The Harvest Plus program emphasizes to bred staple crop varieties with micronutrients like iron, zinc, and vitamin-A. Golden rice is an exemplary bio-fortified crop for Pro-vitamin A (β -carotene) that is naturally absent in rice seeds. Likewise, maize, cassava (Chiedozi, 2011), sweet potato (Harvest Plus, 2010), and banana (Paul et al., 2017) have been bio-fortified with increased Vit-A content. Golden rice and other Vit-A enriched crops has great potential to prevent vitamin-A deficiency (VAD) syndrome in the resource-poor developing world. Similarly, iron bio-fortified rice and pearl millet in Philippines and India have increased iron stores and decreased iron deficiency in reproductive-stage women and school children, respectively (Hass et al., 2005; Finkelstein et al., 2015). Recently, Zn fortified rice variety, DRR Dhan-45, have been released by ICAR-IIRR, Hyderabad. Interestingly, ICAR-NRRI released two rice varieties, CR Dhan 310 and CR Dhan 311, with increased protein content.

v) Integrated pest management with ecological engineering and pest forewarning

Integrated Pest Management (IPM) is an effective and environment friendly approach for pest control that uses a blend of various pest management tools. Pest surveillance and ecological manipulation are some of the main components of IPM. Pest surveillance is

achieved by pest forecasting/forewarning so that necessary control measures can be taken as a preventive step. Availability of data on the pest population dynamics in response to weather variables facilitate pest forecasting. Proper forecasting of pest abundance helps to determine types and times of control measures. Ecological manipulation had evolved and came up with a new concept called ecological engineering, which is the purposeful manipulation of habitat for plants and the beneficial organisms. Ecological engineering for pest management mainly focuses on increasing the diversity, abundance, and function of natural enemies in agricultural habitats by providing refuges and alternate/supplementary food resources (Horgan et al., 2016). For example, ecological engineering effort in China, the habitat was manipulated by growing nectar-producing flowering plants combined with trap plants on the rice bound fields that reduced the intensity of pesticide use and nitrogenous fertilizers (Lu et al., 2015).

Horticulture Sector

Indian horticulture sector makes significant contribution in rural employment generation and farmers income. Increase in demand for horticultural produce due to greater health awareness, rising income, export demands and increasing population poses the challenge for further increasing of the production and productivity of horticultural crops. India continues to be the largest producer, consumer and exporter of spices and plantation crops in the world. Horticulture sector has moved significantly despite many challenges and shortcomings. To meet the increase demand of the horticultural crops, vertical growth, through the use of new cultivars, efficient water and nutrient management, effective plant health management coupled with strategies for reduced post-harvest losses could be the approach. Some of the prioritized technologies in horticulture sector are mentioned below.

i) Production and supply of quality seed/planting materials of improved varieties

Seed is the basic and most critical input for sustainable agriculture. Seed can contribute 15-20% of total production of a crop. At present private seed sector plays major role in high value low volume crops like vegetable and flowers but low value high volume seed of cereals, pulses and oilseeds are still dominated by the public sector seed corporations. At present 15 State Seeds Corporation and 2 national level seeds corporations (National Seeds Corporation of India & State Farms Corporation of India) are functioning in the country apart from different SAU, ICAR Institutes, KVKs, which are primary stakeholders for breeder seed production. As adequate infrastructure, breeders and better monitoring and management system available in ICAR institutes, mostly emphasis is given on production of most adapted varieties like short duration, long duration varieties, drought resistant and flood tolerant varieties, etc. Similarly, production of Horticultural fruit plants, vegetable seedlings, flowering seedlings are also maintained properly in public sectors and supplied to farmers as per their requirement. But, so many private nurseries have been emerged to cater the need of fruit saplings, and forest plants recently.

ii) High density planting for water, nutrient and energy-saving

Accommodation of maximum possible number of plants per unit area to get maximum possible profit per unit of the tree volume without impairing the soil fertility status is called the High Density Planting (HDP). The underlying principle of a HDP is to make the best use of vertical and horizontal space per unit time and to harness maximum possible return per unit of inputs. It is possible by use of proper dwarfing planting material, regular training and pruning and use of growth regulators, adopting suitable planting geometry and crop management practices like mulching, fertigation and mechanization system. The HDP gives higher yield with quality fruits and reduces cost towards nutrient and water management as well as harvesting of fruits. Water and fertilizers are applied through drip irrigation system whereas harvesting and spraying are mechanized.

iii) Post- harvest processing (cleaning, sorting, grading, pre-cooling, waxing, packaging, storage) and ICT-based supply chain of produce

- **Cleaning:** Cleaning method includes removal of soil dust, adhering debris, insects and residues.
- **Sorting:** Sorting is done by hand to remove fruits which are unsuitable to market and storage due to damage by insects, diseases or mechanical injuries.
- **Grading:** Remainder crops are separated into two or more grades on basis of colour, shape or visible defects.
- **Precooling:** Removal of field heat from commodities i.e., room cooling, forced air cooling, hydro cooling, etc.
- **Waxing:** Waxing reduces transpiration and respiration rates, but other chemicals can be incorporated specially for reducing microbial spoilage. Waxes generally used are paraffin wax, bee wax, etc.
- **Packaging:** Proper packaging reduces wastage of commodities by protecting them from mechanical damage, dirt, moisture loss and other undesirable physiological changes and pathological deterioration.
- **Storage:** The basic principle of storage is to reduce the rate of physiological processes like respiration, transpiration, ripening and other biochemical changes. Ex- zero energy cool chambers, cold storage freezing, controlled atmosphere storage, modified atmosphere storage.
- **ICT based supply chain of produce:** IT can help reach the large number of farmers, which otherwise is not possible. The areas where ICT can help are farmers' education, back up services, commercial information and selling produce.

iv) Crop diversification with horticulture based integrated farming system

Horticulture-based Integrated Farming System aims at combining farm enterprises like fruit crops, vegetables, flowers, field crops, dairy, poultry and goatry and vermi-

composting for realizing profitable and sustainable agriculture. Integration of different enterprise with crop activity will provide ways to recycle products and waste materials of one component as input through another linked component and reduce cost of production of the products.

V) Organic farming for horticultural crops

Organic farming in horticultural crops can be defined as an approach where aim is to create integrated, humane, environmentally and economically sustainable agricultural production systems. Number of organic production methods, viz., Biodynamic, Rishi Krishi, and Panchagavya are being practiced by a large number of farmers. Appropriate varieties suitable to agro-climatic situations, crop rotation and inclusion of legumes as cover/inter crop or as green manure need to be included in the production system. Development of techniques to enhance the nutritive value of composts through incorporation of various organic waste, rock phosphate, dolomite, lime, cakes, bio-fertilizers, ash, bone, blood, fish-meals should be taken up. In order to minimize the impact of insect, pest, disease and weeds, various methods such as cultural, mechanical, use of predators, parasites, bio pesticides, bio-agents etc. need to be integrated.

Livestock Sector

Livestock sector provides livelihood, essential commodities and services to more than 60% of the Indian population. India has more than 190 million cattle, out of which 142 million are non-descript and 50 million are crossbreds; 109 million buffaloes; 148 million goats; 74 million sheep, 9 million pigs and other animals. Livestock production provides more economic stability to farmers, particularly in the case of dry land and rainfed areas than crop production. The prioritised technologies are mentioned below:

i) Improved shelter, feed, fodder, probiotics and pasture management

Food and shelter play an important role in livestock health and production. The shelter should have sufficient floor space for the designated animal and with proper ventilation and drainage facilities. Feed should be balanced with concentrate mixture, greens and/or roughages and should be fed at proper time. Any new feed should be introduced gradually. In ruminants, provision of synchronized diet helps in getting optimal production from the livestock. Good quality fodder helps in minimizing the production cost along with improvement of health status and production of animals particularly the ruminants. As animals have more microbes than their body cells, administration of probiotics and prebiotics helps in aiding the health and production parameters. Importance of probiotics increases when we administer oral antibiotics to the animals. Community grazing/pasture lands, if managed judiciously or rotation-wise, benefit is enjoyed by all. In addition, creation of fodder fences by planting fodder trees also helps in aiding the alleviation of fodder problem.

ii) Semen cryopreservation and artificial insemination from adapted animals

Proper selection of semen fitting to the agroclimatic condition, cow to be inseminated and available resources of the farmer are the most important factors in present day breeding policy. In high stressful environments and for less resourceful farmers breeding policy should focus on indigenous breeds. Otherwise, as on now the breeding policy is only successful mostly in patches. The adapted animals or indigenous breeds with desired milk production traits or draught ability to be inseminated to match the challenges arising from the climate change. Besides the requirement of good pedigree bulls, provision of proper cryopreservation for the semen is important for achieving good conception rate. The availability of cryocans and liquid nitrogen in sufficient quantity and at the desired time is very much important for the effort to be successful. Besides that, there is lack of adequate training policy, which should be strengthened to get the ground level workers skilled in artificial insemination.

iii) Livestock health care and management for emerging diseases

Livestock health mostly depends upon the quantity and quality of skilled manpower employed for the treatment of the animals. In present situation the livestock: veterinarian is too high, resulting in lapses in attending the cases at proper time. The transport system revolution is helping for quick mobilization of not only animals, but for viruses and other pathogens also. Improper use of antibiotics is also responsible for antimicrobial resistance which may result in panic condition in near future. Climate change or change in temperature, humidity and other environmental parameters aiding in emergence and spread of emerging diseases. A nodular skin disease is now prevalent in Eastern India and slowly spreading to other parts of India was not even its presence in India, previously. Thus, in addition to the manpower, diagnostic centres number should be increased and their infrastructure and services must be strengthened for early and better diagnosis. The awareness about emerging diseases should be spread through print and electronic media along with awareness campaigns at endemic zones. The vets and para-vets should be trained and updates should be given as and when required about necessary preventive and curative measures.

iv) Nutrition improvement with controlled feed supplement

In livestock feeding feed constitutes about 65-70% of day-to-day investment and controls both production and health of animals. If fed with a balanced diet the animal provides optimal yield. But getting a balanced diet with available raw ingredients is not easy and requires additional supplements to be supplemented. In times of high growing period, bypass fat and bypass protein particularly sulphur containing amino acids lysine and methionine need to be supplemented, whereas in egg laying period more of calcium needs to be supplemented. The milking animals or pregnant animals also need supplementation for taking care of the production trait or the foetal needs. Thus, the quality of feed

supplement, if proper, helps in optimizing nutrition and helping the animal achieving the target. If feed supplements are regulated properly, farmers will be benefitted. Even the idea of slow release or controlled release of feed ingredients is being tried now-a-days like neem coated urea in agriculture for efficient use of nutrients. Synchronisation of nutrient supply and restricted feedings helps in ruminant sector.

V) Promotion of small ruminants in drought-prone districts

Small ruminants serve like poor farmers ATM whenever they need money during any financial challenging condition they face. They need very less time to mature, thus financial benefit can be earned within six months to one year of time. They don't need costly house and also never compete with human food ingredients. Handling is also very easy and they adjust to hardy conditions. Thus, small ruminants should be promoted in drought prone districts. These areas are mostly rain-fed, uplands or medium lands where fodder trees can be grown for small ruminant feeding. This small effort can help millions of farmers with minimal incentives from Government, but with proper scientific awareness about production practices and critical inputs for small ruminant rearing along with provision of village level extension workers like pranimitra's for promotion of vaccination, deworming and first hand treatment of the small ruminants.

Fisheries Sector

The fisheries and aquaculture sectors have significant contributions to food security and livelihood in India. India is the second largest producer of fish contributing about 6.3% to the global fish production and is also the second major producer of aquaculture. The sector provides livelihood for 14 million people in the country. Considering the uncertainties of the climate change and other stresses on fisheries the following technologies may be given priority.

i) Brackish water aquaculture

Brackish water is the mixture of fresh and salty water usually contains between 0.5 and 30 grams of salt per litre, having specific gravity between 1.005 and 1.010. Brackish water aquaculture focuses on the production of quality fin and shell fish that are found in the creeks, lagoons, and estuaries through rational rearing. The brackish water resources of India include estuaries, coast line, back waters, mangroves and lagoons including salt affected lakes etc. In India, two strategies are followed for improving brackish water aquaculture. Short-term strategies includes: improvements in traditional system of farming, development and dissemination of low-cost farm-made feed, control of diseases, development of suitable breeding technology and seed production, and improved production through good aquaculture practices like, biofloc and periphyton based system, are the best options available. Long-term strategies includes development of organic farming, genetic improvement of shrimp stock through selective breeding, improved and

intensive culture methods, adoption of cage farming of fishes, etc. Major brackish water aquaculture species includes finfish (Asian sea bass, *Lates calcerifer*; milk fish, *Chanos chanos*; mullets, *Mugil spp.*; Pearl spot, *Etroplus surtensis* and Cobia/ black king fish, *Rachycentron canallum*) and shell fishes (Tiger shrimp, *Panaeus monodon*; Pacific white shrimp, *Penaeus vannamei*; banana shrimp, *Fennoeropenaeus mergiuiensis*; Indian white shrimps, *Fennoeropenaeus indicus*; redbtail shrimp, *Fennoeropenaeus penicillatus*; kuruna shrimps *Marsupenaeus japonicas*; Mud crab, *Scylla serrata*, and *Scylla tranquebarica*. Among all these, shrimp farming is the most prevalent forms of brackish water aquaculture in India.

ii) Periphyton based Carp culture

Periphyton or 'aufwuchs', is the complex form of sessile aquatic biota with associated detritus, attached to submerged substrates. The group consists of algae, filamentous bacteria, attached protozoan, bryozoan, rotifers and also the free-swimming microorganisms. They are minute sessile organisms living within a slimy matrix on submerged objects (bamboo stems and branches, jute sticks, tree branches or other materials used as substrates) including the free-living organisms associated with this matrix have been greatly contributes to the system primary productions. Traditionally, periphyton-based practices have been used to catch fish in open waters in various parts of the worlds and the practice is known as *Acadja* in West Africa, *Katha* in Bangladesh, *Samarah* in Cambodia, *Xeng* in Assam and *Phum* in Manipur, India. For example, in river or large water bodies fishermen install bushy substrates where fish breeds and feed and shelter for some times and some period fishermen catch the fish. For developing sustainable and cost-effective aquaculture (i.e. reducing supply of external feeds, chemicals and energy inputs), it was conceptualized that periphyton production in ponds will provides adequate feed to the culturable fishes, especially, herbivores or filter fed fishes. Provisioning of substrates into the water column helps in growth of bio films and periphytons in natural water bodies. Periphyton contribute substantially to primary productivity of the shallow freshwater ecosystems and thus provides energy input to both detritus and grazing food chains within the ecosystem. Periphyton plays a significant role in serving as the diet for wide range of aquatic organisms like fish, snails, chironomids, mayflies, oligochaetes, crustaceans etc. in natural environment. Energy demands will be higher in high productivity aquaculture systems and stimulation of periphyton (benthic algae, detritus or aquatic plants) production reduces the demands of supplementary food requirements in the aquaculture systems. Benthic algae rarely grow on the bottom of ponds due to lack of enough light, however, provisioning of hard substrates, or mats under water helpful for production of a film of bacteria and colonies of invertebrates. Fish can graze these concentrated forms of periphyton food more efficiently than filter feeder fishes (planktonic algae) along with water quality improvements.

iii) Cage culture and Pen culture of fish

Both cage and pen cultures are types of enclosure culture, and involve holding culturable aquatic organisms captive within an enclosed space whilst maintaining a free exchange of water. The two methods (cage and pen culture), however, are distinct from one another that a cage is totally enclosed on all, or all but the top, sides by mesh or netting, whereas in pen culture the bottom of the enclosure is formed by the lake or sea bottom. Cages in freshwaters are used for food fish culture and for fry to fingerling rearing. Cage culture is an emerging technology through which fishes are reared from fry to fingerling, fingerling to table size or table size to marketable size while captive in an enclosed space that maintains the free exchange of water with the surrounding water body. Commercial cage culture mostly used for high-value fish culture using compound feeds in finfish culture species i.e. salmon (Atlantic salmon, coho salmon and Chinook salmon), most major marine and freshwater carnivorous fish species (including Japanese amberjack, red seabream, yellow croaker, European seabass, gilthead seabream, cobia, sea-raised rainbow trout, Mandarin fish, snakehead) and an ever increasing proportion of omnivorous freshwater fish species (including Chinese carps, tilapia, *Colossoma*, and catfish). In India cage culture in inland water bodies was initiated for air breathing fishes in swamps, for raising major carps in running waters in Jamuna and Ganga at Allahabad and for raising carps, snake heads and tilapia in lentic water bodies of Karnataka. Thereafter the cages have been used for rearing fry in many reservoirs and floodplain wetlands to produce advanced fingerlings for stocking main water bodies.

iv) Waste water aquaculture

The sewage effluent fed aquaculture has been more prevalent in countries like China, Taiwan, Malaysia, Thailand and Indonesia. In India, rearing of fish in sewage fed ponds have become very popular in West Bengal and also adopted in other states like Uttar Pradesh, Madhya Pradesh, Maharashtra, Tamil Nadu, Kerala, Karnataka and Bihar. For fish culture sewage water of stabilizing tank as well as the water after dilution can be utilized. Air breathing fishes are more suitable to be cultured in sewage treatment ponds as they can survive in water with lesser dissolved oxygen content. Therefore, air breathing fish like *Clarias batrachus*, *Heteropneustes fossilis*, *Channa spp.*, and *Tilapia mossambicus* are the preferred choice for culture in sewage treated ponds. Carps, (Silver carp, catla, rohu, mrigala, common carp and grass carp in a ratio of 25:15:10:25:20:5) being very sensitive to low dissolved oxygen content i.e., difficult to survive in sewage stabilizing tanks. Therefore, diluted sewage has been used and higher stocking density (10000 nos/ha). In sewage fish culture, the production is very high and cost effective.

Natural Resource Management

Per capita man to land availability ratio is the lowest in India and the per capita water availability would fall below 1500 m³ by 2025 (Singh, 2019). About 120 Mha of the total

land area is suffering from various types of degradation (NAAS, 2016). The priorities should, therefore, focus on using better technologies for land and water management under the overall gambit of natural resources management to combat land degradation and vagaries of climate change, maintain sustainable crop production and to improve the livelihood of the rural poor. Water and energy securities are emerging as important and vital issues in India. Most of the river basins in India and elsewhere are experiencing moderate to severe water shortages. Over-exploitation of ground water is also a major concern. The challenge for agriculture in the coming decades will be to increase productivity of agricultural lands for fulfilling the food demand of the country. Therefore, producing more with less inputs of land, water, nutrients, energy, labour or capital besides minimal risks and variability needs to be addressed while taking into consideration of both ecologic and economic dimensions of sustainable agriculture. The concept of eco-friendly agricultural systems, therefore, needs to be promoted at a larger scale. The technologies should get priority for sustainable natural resource management.

i) Enhancing efficiency of agri-inputs

To enhance the efficiency of agri-inputs (water, nutrients, energy) novel, precision-agriculture technologies and management practices will be exploited. Nano-formulation for smart, slow release and host specific nutrients and chemicals molecules will be developed. Bio-fertilizers and natural processes on nitrogen fixation and nutrient cycling should be enhanced for higher efficiency.

ii) Water conservation, storage and use of poor quality water

To conserve the resources and reduce pollution, efficient management systems will be developed for use of poor quality water, bio residues and other sources of wastes in a sustainable manner. To enhance water use efficiency and conserve natural resources, pressurized, low cost, efficient and demand driven irrigation scheduling tools should be developed.

iii) Conservation agriculture

To sustain the soil and environment health, enhance resource use efficiency, productivity and profitability; zero tillage, residue retention and crop intensification and diversification to be promoted in irrigated as well as rainfed agro-ecologies. To reclaim degraded resources for agriculture, conserve and enhance national wealth of natural resources and biodiversity. Soil organic matter, carbon sequestration, soil physical, chemical and microbial properties should be enhanced for sustainability.

iv) Climate-resilient agriculture

Adaptation and mitigation technologies will be developed to enhance the resilience of crops to the climatic risks particularly contingent planning in the rainfed areas.

v) Microbial inoculations

Microbe based technologies for nitrogen fixation, nutrient recycling, remediation of degraded natural resources, bio-residue management, alleviation of abiotic and biotic stress in the changing climate scenario and maintenance of soil fertility and productivity. Bio-prospecting microbes for novel molecules, genes/alleles for enhancing agricultural productivity in changed production system.

Agricultural Policy

Higher input use efficiency and reduction in the cost of production are necessary for increasing profitability and competitiveness of Indian agriculture. This will need adoption of appropriate policies to guide the public investment to develop hardcore infrastructure, enhance efficiency of information and input delivery system and reduce production losses. These developments on the production side should be supported with participation of private sector in agricultural markets and trade, and an incentive system to promote market-led agricultural production. The production to consumption system should witness value creation with use of post-harvest technology. This can be done when infrastructure is in place and necessary manpower to manage them is available. Thus, development of agripreneurs and encouraging rural youth to take up income generating primary and secondary agriculture will be essential. The following are the priority areas of policy research for making agriculture an economically viable profession.

- i) Promoting investment and efficiency of interventions for higher and inclusive agricultural growth.
- ii) Strengthening seed sector for increasing productivity and profitability

Seed is the basic and most vital input of agriculture. Without quality seed, other inputs and technologies are of little value. Good quality seeds along with recommended doses of other inputs provide uniform and rapid germination, healthy crop establishment and subsequently good crop harvest and higher profit. Seed replacement rate has a strong positive correlation with productivity of crops. Production and supply of high-quality seed, therefore are fundamentals to modern agriculture. In India, seed supply to farmers is taken care of through formal seed sector managed by Government systems (Research Institutions, State Government Farms, University Farms and KVKs); formal seed sector managed by registered seed growers (NGOs, Private Companies); and informal seed sector managed by unregistered seed growers and farmers. Each of these contributes about 30-35% to country's seed supply. The Govt. managed seed sector should improve the timeliness of procurement and delivery to the farmers. The registered private seed growers, on the other hand should ensure stringent quality control and reaching the farmers of remote areas. Wherever they take up seed production in farmers' field, they should involve the farmers (farmers' participatory seed production mode) so that farmers learn how to produce

- quality seed. A large amount of seed production is being handled by the unorganized seed sector, wherein seed traders directly purchase from growers and distribute with various trade names. Control on production and marketing of seeds of unorganized private sector is limited because of multiplicity of seed traders and small seed companies. They may be brought into the formal sector with training and support for capacity building to follow the rules of seed certification, quality control and marketing. Quality seed for crops like rice, the local seed system should be strengthened.
- iii) Promoting sustainable systems to promote use of alternate energy sources in small-scale agriculture and commercial secondary agriculture.
 - iv) Enhancing corporate investment in the value chains with participation of small farmers.
 - v) Assessment of changing research priorities to enhance the role of R&D in agricultural development.
 - vi) Promoting agricultural marketing and efficient distribution system of agriculture and foods products.

Cross Cutting Areas

i) Mechanization in agriculture

Farm machinery and equipment provide a package of technology to (i) increase land productivity by improved timeliness of operations, reduced crop losses and improved quality of agro-produce; (ii) increase efficiency of inputs used through their efficient measurement and placement; (iii) increase labour productivity by using labour saving and drudgery reducing devices, and (iv) reduce cost of cultivation. Improved agricultural tools and equipment are estimated to contribute to the food and agricultural production in India by savings in seeds (15-20%), fertilizers (15-20%), time (20-30%), and labour (20-30%); and also by increase in cropping intensity (5-20%), and productivity (10-15%). Presently, India is the largest manufacturer of tractors in the world accounting for about one third of the global production. The highest concentration of tractors is in northern India for land preparation. The estimated levels of mechanization of various farm operations in India are: 40% for tillage, 30% for seeding/planting, 37% for irrigation and 60% for threshing of rice, 70 % for threshing of wheat and 15% for threshing of rest of the crops and 35% for plant protection. Machinery is also important to harness available moisture at the time of tillage and sowing, hence dry land areas also experienced growth in farm machinery. Farm machines like rotavator, ferti-seed-drill, raised bed planter and laser leveler boost water use efficiency of little water/moisture that is available; thereby enhancing productivity in dry land areas. As energy and water are becoming scarce, technology using less energy and saving water and conserving soil moisture will become popular on Indian farms in years to come. Similarly, the farm inputs particularly seed, fertilizer and agrochemical are

becoming costlier day by day and machines for precise application of these inputs will be in demand. The policy interventions required to overcome the constraints are incentives for saving of water, carbon credits for climate change mitigation, subsidy and incentive for installation of resource conserving infrastructure, trainings to farmers for skill development, public awareness generation, development of effective, low-cost, environment-friendly herbicides, accurate weather forecasting, development of post-harvest facilities and refining of technologies to make them simple, cheap and effective. Top prioritized technologies are mentioned below.

- **Rotary tiller to reduce energy footprint:** Tillage is an operation performed to obtain a desirable soil structure for a seedbed. Rotary tiller or rotavator is a tillage machine designed for preparing land by breaking the soil with the help of rotating blades suitable for sowing seeds. It can be performed both the primary and secondary tillage applications could be conjugated in one stage. Despite of their high energy consumption, since rotary tillers have the ability of making several types of tillage applications in one stage, the total power needed for this equipment's is low. Fuel expenses saving can be to the tune of 15% to 35%; puddling in wet fields is done smoothly, quickly and efficiently, loosening and aerating soil up to depth of 125 mm-1500 mm.
- **Bed former-cum-seeder/ planter for saving water and drainage:** Bed planting system is referred to the planting and cultivation of crops on raised beds. Generally wheat and some other crops are planted on raised beds. Study found that planting wheat on raised beds has improve yield, increased fertilizer use efficiency, reduced herbicides dependence, less lodging of crops and saved seed, fertilizer and irrigation water. The implement will form beds and simultaneously undertake sowing in rows on the bed formed. The field capacity of machine is 0.26 ha/h. The approximate cost of equipment is Rs. 40,000. The cost of operation is about Rs. 4500/ha as compared to Rs. 3400/ha in conventional method. It saves about 20-30% water and 20% seeds. Improves yield by 05-10%, Saves seed and fertilizer by 25-30%, Saves irrigation by 30-35%, Prevents lodging of crop, Facilitates easy mechanical weeding and reduces herbicides dependence, higher benefit-cost ratio, more energy efficient and cost effective when planting is done on reused/permanent beds.
- **Laser land leveller:** Undulated land is one of the important factors for less input use efficiency that leads to the less germination, poor crop establishment, and low yield due to unequal water distribution and soil moisture. Though, traditionally farmers level their fields using animal drawn or tractor-drawn levellers, which do not precise level or graded the field and consequence of this uneven distribution of irrigation water resulting in water logging conditions in low-lying areas and soil water deficit at higher spots. The advanced method to level or grade the field is to use laser-guided levelling equipment. Laser levelling provides a very accurate, smooth and graded field. This allows for ideal control of water distribution with negligible water losses.

Laser levelling improves irrigation efficiency and reduces the potential for nutrient loss through better irrigation and runoff control.

- **Zero tillage/strip tillage/reduced tillage technology:** The Zero tillage system is a specialized type of conservation tillage consisting of a one-pass planting and fertilizer operation in which the soil and the surface residues are minimally disturbed (Parr et al., 1990). The surface residues of such a system are of critical importance for soil and water conservation. Weed control is generally achieved with herbicides or in some cases with crop rotation. In strip tillage practice the seedbed is divided into a seedling zone and a soil management zone. The seedling zone (5 to 10 cm wide) is mechanically tilled to optimize the soil and microclimate environment for germination and seedling establishment. The inter-row zone is left undisturbed and protected by mulch. Strip tillage can also be achieved by chiselling in the row zone to assist water infiltration and root proliferation. Reduced/minimum tillage is a type of conservation tillage that helps to minimize soil disturbance and allowing crop residue to remain on the ground instead of being thrown away or incorporated into the soil.
- **Use of solar pump for irrigation:** Solar pumps are good alternatives for irrigation, which serves as a cost effective mode of irrigation with low maintenance requirements. In addition, solar water pumps operate with zero carbon footprints. The environmental impact caused by the use of diesel pump is often not known to people. The main advantage of a solar water pump is that it uses sunlight with no cost at all. As a solar water pump minimizes the dependence on electricity or diesel, once installed, there is no recurring cost of electricity or fuel.

ii) Protected cultivation and vertical farming

Protected farming is a cropping technique wherein the microclimate around the plants is regulated partially or fully as per the need of the plants that are grown. With the advancement in agriculture various types of protected cultivation practices suitable for a specific type of agro-climatic zone have emerged. Farming practices in vertically stacked layers, vertically inclined surfaces and/or integrated in other structures are known as vertical farming. Structures, such as in a skyscraper, used warehouse, or shipping container are also used for vertical farming. The modern ideas of vertical farming use indoor farming techniques and controlled-environment agriculture technology, where all environmental factors can be controlled. Such facilities often utilize artificial control of light, environmental control (humidity, temperature, gases) and fertigation. Some vertical farms use techniques similar to greenhouses, where natural sunlight can be augmented with artificial lighting and metal reflectors. The flexibility of location is the greatest strength of vertical farming, especially in combating climate change. A few prioritized technologies are mentioned below:

- **Plastic low tunnel:** It is a small semi-spherical structure frame made of metal, wood, or plastic and covered with polyethylene or fiber-reinforced plastics to create a

protected environment. Plastic low tunnels are flexible transparent coverings that are installed over rows of individual beds of transplanted vegetables to enhance the plant growth by warming the air around the plants (microclimate) in open field during winters. These help in warming the soil and protect the crop against the hails and snow and advance the crop by 30–60 days than their normal season. This low-cost technology is very simple and highly profitable for off-season cultivation and catching the early market. However, a major problem in tunnels is faced in watering, weeding, and harvesting, which involves removal of cover and again putting them back.

- **Hydroponics:** Hydroponics is the art and science of growing plants in a solution of water and nutrients in which the roots are supported by a means other than soil. This technique may be used from small domestic crops to large commercial farms. In this type of cultivation, water carries nutrients, an ideal solution of macro- and microelements that is essential to meet all the plants' needs. Whatever the environment (soil or water) in which the plants grow, they absorb the nutrients in the form of ions dissolved in oxygen and, as for the water, whenever the nutrients and oxygen are absorbed, they have to be replenished. It is a soilless cultivation method that stimulates plant growth while controlling the amounts of water, dissolved minerals and oxygen. Hydroponics may be used to grow the most varied types of plants, vegetables, flowers, shrubs and herbs.
- **Trench underground greenhouse:** This is a unique, innovative, very simple, cheap, and useful underground greenhouse structure for the hilly region and thus has unlimited potential in the region. This may be of any convenient dimension. However, a trench of 30 × 10 × 3-ft size is ideal. In this pit type of structure, wooden poles are used to hold UV-stabilized polyethylene film. The polyethylene is also covered by an additional or woollen or cotton sheet polyethylene film during night to reduce the heat loss during extreme winter. The structure does not require much skill in its construction and management. Its cost is lowest among all other greenhouses, and being an underground structure, heat loss is minimal and temperature retention is high and thus yields good crop. Strong winds do not affect polyethylene cover much and hence it is long lasting. This structure is therefore being recommended as the most suitable greenhouse for the hilly region.
- **Fogponics:** Fogponics is a derivation of aeroponics wherein the nutrient solution is aerosolized by a diaphragm vibrating at ultrasonic frequencies. Solution droplets produced by this method tend to be 5-10 µm in diameter, smaller than those produced by forcing a nutrient solution through pressurized nozzles, as in aeroponics. The smaller size of the droplets allows them to diffuse through the air more easily, and deliver nutrients to the roots without limiting their access to oxygen.
- **Aeroponics:** Aeroponics or air-culture uses the application of nutrient dissolved mist over exposed plant roots, which enable growth without soil. Aeroponics is usually regarded as a type of hydroponics since water is used as the nutrient dissolution

medium. The suspended plant roots are enclosed in a sealed chamber and the plant canopy is exposed to outside. For small plants a sheath of cell foam is compressed and wrapped around the bottom stem and inserted in to the aeroponic setup. Trellising is fixation of wooden or metallic supporting frames, with the plant body. The plants grow vigorously in an aeroponic system due to the sterile environment and abundant oxygen present in the chamber.

Initiatives of Government of India

i) National Mission on Sustainable Agriculture (NMSA)

The NMSA launched in 2010 is one of the eight missions under *National Action Plan on Climate Change* (NAPCC) to address adaptation and mitigation approaches on agriculture systems of India. The NMSA seeks to address issues regarding sustainable agriculture and aims at devising appropriate adaptation strategies for ensuring food security, enhanced livelihood opportunities and economic stability. The NMSA has identified 10 key dimensions for adaptation. These include improved crop seeds, livestock and fish culture; water use efficiency; pest management; improved farm practices; improved nutrient management; agricultural insurance; credit support; markets; access to information and livelihood diversification.

ii) Rainfed Area Development (RAD) Schemes

Govt. of India has initiated various schemes for the RAD since 1990. It focuses on Integrated Farming System (IFS) for improving productivity and minimizing the risks associated with climatic variability. Under this system, crops/cropping system is integrated with activities like horticulture, livestock, fishery, agro-forestry, apiculture, etc. to enable farmers not only in enlarging farm returns for sustaining livelihood, but also to offset the negative impact of drought, flood or other extreme weather events on agriculture.

iii) National Agroforestry Policy (NAP)

The NAP (2014) provides a platform to stimulate the growth of agroforestry in India. It will encourage farmers for agroforestry as an integral component of farming system which will lead to meet the ever increasing demand of timber, food, fuel, fodder, fertilizer, fiber, and other agroforestry products; conserving the natural resources and forest; protecting the environment & providing environmental security; and increasing the forest / tree cover. Agroforestry is known to have the potential to mitigate the climate change effects through microclimate moderation and natural resources conservation in the short run and through carbon sequestration in the long run. Agroforestry species are known to sequester as much carbon in below ground biomass as the primary forests, and far greater than the crop and grass systems.

iv) Pradhan Mantri Krishi Sinchai Yojana (PMKSY)

The PMKSY (2015) not only focuses on creating sources for assured irrigation, but also creating protective irrigation by harnessing rain water at micro level through 'Jal Sanchay' and 'Jal Sinchan'. Micro-irrigation is to be popularised to ensure 'Per drop-More crop'. The PMKSY adopts State level planning and projectized execution that allows States to draw up their own irrigation development based on District Irrigation Plans and State Irrigation Plans.

v) Agriculture Contingency Plan

Central Research Institute for Dryland Agriculture (CRIDA), ICAR has prepared district level Agriculture Contingency Plans in 2015 in collaboration with state agricultural universities using a standard template to tackle aberrant monsoon situations leading to drought and floods, extreme events (heat waves, cold waves, frost, hailstorms, cyclone) adversely affecting crops, horticulture, livestock and fisheries.

vi) National Initiative for Climate Resilient Agriculture (NICRA)

The NICRA is a network project of the Indian Council of Agricultural Research (ICAR) launched in 2011. The project aims to enhance resilience of Indian agriculture to climate change and climate vulnerability through strategic research and technology demonstration. The research on adaptation and mitigation covers crop, livestock, fisheries and natural resource management. The project consists of four components viz. strategic research, technology demonstration, capacity building and sponsored/competitive grants.

vii) Government of India's other Initiatives

National Food Security Mission (NFSM) (2007), Mission for Integrated Development of Horticulture (MIDH) (2014-15), National Mission on Oilseed and Oil Palm (NMOOP) (2012), Rashtriya Krishi Vikas Yojana (RKVY) (2007), Pradhan Mantri Fasal Bima Yojana (PMFBY) (2016) and Paramparagat Krishi Vikas Yojana (PKVY) (2007) emphasize on implementation of climate-resilient technologies. Government of India announces new multi-billion dollar scheme to implement solarisation of farm irrigation on a national scale. It was a moment of validation for the scientific community when the recent Union Budget (2018) of India brought to light a new scheme called *Kisan Urja Suraksha Evam Utthaan Mahaabhiyan* (KUSUM), for promoting solar farming. With an allocation of US\$ 21.8 billion, the government plans to start building 10,000 MW solar plants on barren lands, providing 1.75 million off-grid agricultural solar pumps. Through the scheme, farmers' income levels are projected to rise as they will be given an option to sell surplus power generated to the local power distribution companies.

Conclusions

Ensuring food and nutritional security, improving rural livelihood along with environmental security in a sustainable manner, will remain the major goals of the agricultural development planning. India will strive to help achieve these goals through development of improved agricultural technologies along with their efficient and effective modes of dissemination. It is estimated that the annual growth in the productivity of food grains should be more than 1.5% and that of horticultural crops more than 3% to meet this goal. This will essentially require development of improved varieties of field and horticultural crops with desirable traits under the changing environmental scenario. At the same time, technology will also be needed to increase the input use efficiency to reduce the cost of production and enhanced value addition to make Indian agriculture profitable, competitive and attractive to rural youth. In addition, value addition through processing will help in reducing colossal losses on one hand and increase the income of the farmers on the other. Indian agriculture is ready to take up the proposed research programs keeping in mind the recent developments in the field of science, agriculture and economic environment and accelerate the growth in total factor productivity thereby contributing to technology-led growth. The priorities presented in the article will help achieve these targets. These programs should be pursued in participatory mode and organizational collaboration for their effective implementation. The SAARC should collaborate to address these challenges in a holistic manner through different collaborative and outreach programs and linkages.

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Chapter 6

Agricultural Research and Development: Policy and Program Priorities in Maldives

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Abstract

Agriculture sector is becoming more crucial for overall socio-economic development and improving livelihoods. Maldives agriculture is distinguished from elsewhere in the region as fisheries and aquaculture is the prioritized areas, which need different approaches to be considered in formulating programs. The way farming is practiced and perceived in the country has changed drastically in the last few decades opening new pathways and seeking modern solutions that address needs of farmers, consumers and natural resources. Consequently, improvements are needed in key areas including fisheries, horticulture, livestock and natural resource management. This would require more exploring opportunities in the specific areas in order to carry out programs that require financial and technical collaboration among the SAARC countries. Similarly, policy priorities must focus in developing research, infrastructure, capacity development, link production to markets, address cross-cutting issues, and collaboration with concerned stakeholders.

Keywords: Fisheries, climate change, policy and programs, Maldives

Background

Maldives recognized the importance of agricultural research and development as an imperative for holistic development in the country. However, agriculture being a significantly minor sector in terms of contribution to national Gross Domestic Product (GDP) as this notion has not been properly reflected in the relevant policy and program designs of the last few decades (World Bank, 2017). Following the commercialization objective of agriculture activities in the early 1980's, institutional effort has been given to demonstrate applications of various agricultural inputs in order to avoid total dependence on local resources (Liebregts et al, 2005). These policies and programs are characterised as having ideas which favoured the direction towards green revolution during the late 1960's (UNDP, 2013). As part of this effort, hybrid seeds and planting varieties were prioritized to adopt in the island agricultural systems. Similarly, various synthetic fertilizer formulations were adopted as well. Maldives has optimised its agricultural practices based

on the practices adopted by neighbouring countries, specifically India, Sri Lanka and Bangladesh (FAO, 2017).

The first agriculture center was established in 1980's and an agricultural nursery was established at capital Male' to supply agricultural inputs (mainly planting materials and agrochemicals) to farmers in 1982. Currently, there are two established agriculture centers in the country. First, the northern agriculture center in HDh Hanimaadhoo houses extension and research officers who carry out various research and advisory activities throughout the country. The research activities are mainly focused on varietal testing trials of crops, agrochemicals and livestock. Second, the southern agriculture center is run under a public private partnership. Currently the main activity of this center is to conduct trials on five selected crops; cucumber, papaya, pumpkin, watermelon and chili under the import substitution program. Apart from that, a tissue culture laboratory was established in the early 2000's that focused on banana seedling production

Situation of Agricultural R&D

Crops Sector

Historically few grain crops such as finger millet and rice were grown extensively in the islands. With gradual increase in global trade of rice, wheat and sugar, the production of these crops have been phased out from commercial agriculture (John & Peter, 2005). Hence, the main staple foods (except coconut and fish) are now imported. Another reason for decline in cropping activities has been due to increased land value with adoption of agricultural land for other development activities. Similarly, limitation exist for production of pulses, oil seed crops and fibre crops. Nevertheless, the government has been focusing on increasing the production of breadfruit, cassava, taro and banana due to its potential use in food security. Currently, only few producers are involved in growing these crops on commercial basis. Hence, the focus is on encouraging production in both homesteads and commercial plots in order to increase household consumption of local crops.

Horticulture Sector

Horticulture remains as the prominent industry for Maldivian agriculture sector. Tropical fruits such as mango, banana, passionfruit, guava, watermelon, melon, papaya and pineapple are the major fruit crops produced across the country. Similarly, vegetable crops comprise of *Solanaceae* and *Cucurbitaceae* family, which include mainly chili, tomato, brinjal, squash, bitter gourd, and cucumber (Figure 1). Apart from that, dwarf beans and various lettuce varieties are also produced. Additionally, betel leaves and coconut (both tender and mature) remain amongst the most economically important crops. Moreover, the existing coconut plantations that are part of the natural vegetation of the islands have been an important contributor to the economy. Most leafy vegies and a selected few vegetables are grown in various hydroponics systems.

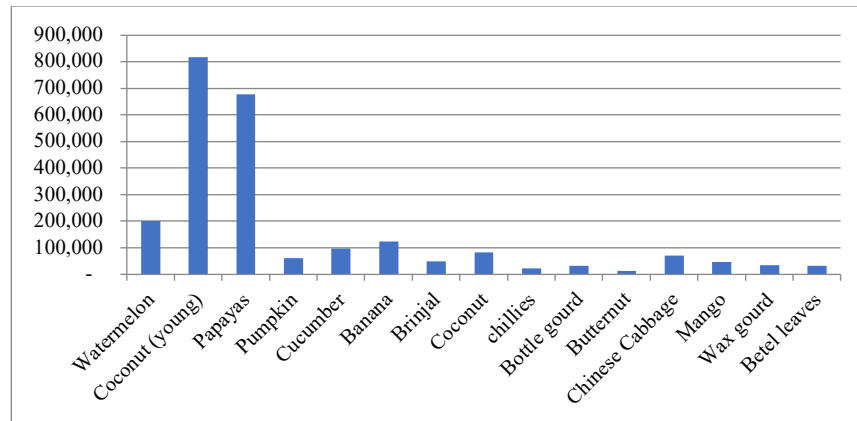


Figure 1. Horticultural crops traded in Male' central market in 2018

Source: MoFMRA (2018)

Livestock Sector

Goats and poultry ventures are found in few notable islands. Livestock is rarely used in an integrated farming with horticultural activities. Historically, few cattle farms were operated in the central atolls. However, these activities proved that commercial ventures involving large ruminants are not economically feasible in the country. Currently, there is fewer than 15 goat husbandry venture across the country. Traditionally, poultry was raised in combination with crops in home gardens that had notably assisted in pest management, soil improvement and natural resource utilization. Even now, there is a good market for fresh meat and eggs in the country. Live birds and goats are also in high demand during religious holidays.

Fisheries Sector

Fisheries sector plays an important role in the national economy in terms of employment, rural income, export earnings and revenue generation. Like agriculture, this sector has also experienced a decline in contribution to GDP since 1978. However, more recently the growth rate of the fisheries sector has increased. Total employment in primary fishing has declined from a high of 22,000 during the late 1990s to around 15,000 due to increased mechanization of primary fishing and labor- capital substitution. Nonetheless, the productivity has been increasing with the nominal value of fish exports having increased from just below US\$ 40 million in 1999 to around US\$ 88 million in 2004. This is based on improving international fish markets rising prices and the addition of new products for exports. Despite the expanded capacity in collector vessels and land-based freezing facilities, total fish landings of major tuna species have been declining (Figure 2). Additional capacity in collector vessel and land-based freezing is expected to increase in coming years. Following this, the private sector contribution in fish storage facilities,

processing and distribution facilities is expected to increase in coming years. Maldives aims to maintain its key comparative advantage: maintaining an economically efficient and low cost fishing fleet. In the long- run, the ultimate choice will be how to reduce the country’s relative dependence on low value commodity production. In the last 10 years, the government and private sector focused on the development of aquaculture and mariculture sector. A significant investment has been made to expand grouper fisheries and sea-cucumber farming. Most recently, there has been progress on expanding diamond-back squid fisheries activities.

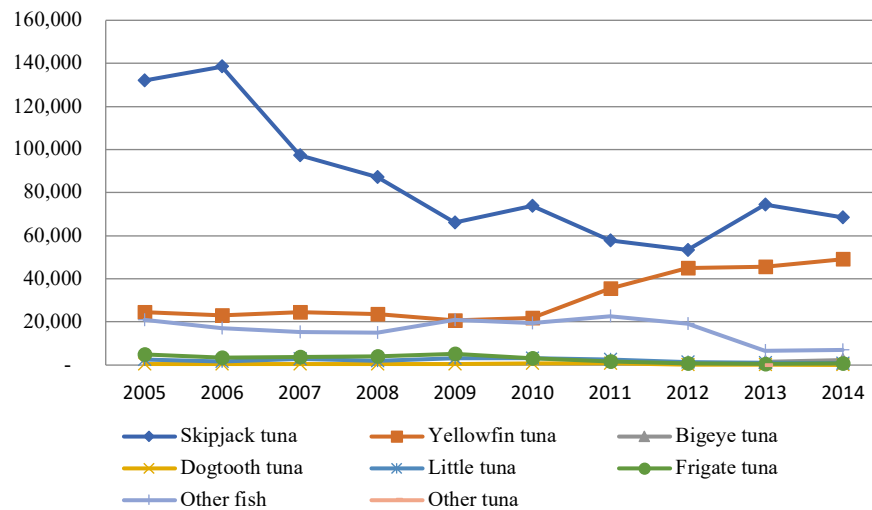


Figure 2. Total fish catch (Mt) by type of species (2005-14)

Source: MoFMRA (2018).

Natural Resource Management

Agricultural production systems in the country can be broadly grouped into three categories: i) home-garden production or land assigned for residential needs; ii) communal plots in inhabited islands leased for farming monthly, yearly or seasonal basis with or without tenure as per the regulations of the respective island council; iii) farming activities carried out in uninhabited islands that are leased for a 5 to 21 years. There are currently 75 uninhabited islands leased (however, not exclusively) for agriculture purposes. Land as a resource is in high demand as other prominent economical activities such as local-tourism related activities compete for the same land. In inhabited islands, rurality is soon becoming non-existent as planned residential areas are ever getting closer to farm land. In these islands farm land allocation is done under the authority of respective island councils. Hence, the lease processes differ between islands depending on their land-use-plan, size of available land, number of farmers etc. Also, as part of this process, the leasing policy is reviewed annually.

Land and soil management practices remain ad hoc and unplanned as minimum tillage, cover crops and mulching are not practiced on regular basis. Soil nutrition can be assumed to be in deficit at most farms as major organic matter incorporation is through imported manure and compost with little or no on-farm composting. Consequently, these practices demand regular use of synthetic foliar fertilizers as well. Irrigated agriculture is dominant in the main production areas. Groundwater has been used as the main source for irrigation.

Agricultural Policies

National agricultural policy encompasses production activities and natural resource management is in the process of drafting. This policy fill a major gap in the enforcement of agricultural mandates of the country. Currently, Ministry of Fisheries, Marine Resource and Agriculture (MoFMRA) mandate clashes with that of environmental protection agency (EPA), Maldivian Food and Drug Authority (MFDA) and Local Government Authority (LGA) on several matters regarding agriculture land management and regulation of farming activities. Agriculture programs are formulated based on the Governments' Manifesto which forms the *National Agricultural Strategic Action Plan (SAP)*. Recently, SAP has been formulated for the next 5 years. Another important policy document is the *Agricultural Development Master Plan 2010-2025* (MoFMRA, 2009).

Cross-cutting Activities

In Maldives, few agriculture products are processed, while none of the agricultural products are exported. The major processed products are taro chips, moringa leaves, breadfruit chips, banana chips, chili and various coconut products. On the other hand, canned yellow fin tuna is one of the signature fisheries products being exported. Additionally, fresh and frozen tuna is also exported to Asia. In general, there are various projects focused on the development of value-addition activities.

Another important cross-cutting area is the national biosecurity services in relation to transboundary diseases of plants, livestock, and quarantine services. MoFMRA (2018) reported that the frequency and introduction of pests and diseases have been increased. This is determined by the incident reports and level of resources engaged in the management of these issues. Also, there has been a rapid increase in imports of various planting materials and seeds for both ornamental and commercial agricultural purposes leading to urgent review of national biosecurity and phytosanitary measures. This calls for national and regional level activities on phytosanitary harmonization measures and improvement national regulatory standards.

Climate change mitigation and adaptation activities are the most prominent cross cutting activities (Shrestha & Bokhtiar, 2019) that has greater impact on simultaneous improvement of all the thematic areas. Climate change is a looming threat that calls for immediate changes at both grassroot and policy level. Agroecological or climate-smart

agricultural practices in the production systems are to be promoted in order to strengthen and empower farmers. For this, integrated farm management approaches must be encouraged at policy level focusing on incentivizing the agriculture.

Challenges and Opportunities in Agricultural R&D

Maldives has unique geographical and topographical characteristics compare to other countries in the region. Historically, these features have contributed in shaping the agricultural practices applied in the production systems (MoFMRA, 2018). The agricultural practices include use of high synthetic fertilizer and pesticides, predominant reliability on foreign labour in commercial farming, and heavy foreign input dependency and lack of land conservation practices. The arable land area is merely 4000 ha with limited small scale of production (FAO, 2018). With limited land area coupled with generally poor soil, characterised by low nutrient content and low organic matter allows only horticultural activities. Hence, the culmination of these practices with focus on productivity enhancement have led to the gradual degradation environmental and decrease in food quality. Nonetheless, this work would be challenging as it requires reorientation of agricultural advisory activities along with adjusting requirements of both producer and consumers. Specific challenges and opportunities with respect to thematic areas are as follows.

Crops Sector

Most of the challenges exist in field crop production revolve around the lack of production technologies with higher yields, lack of fertile soils, ground water salinity, and lack of suitable crops. Additionally, few native crops such as taro and chili have been faced with persistent diseases that has threatened the cultivation of these crops throughout the country. Appropriate features for field crops that are suitable for Maldives's context include, short duration, high yielding and open-pollination varieties. New field trials could be carried out to test these crops for its suitability in Maldives's environment.

Horticulture Sector

The long-term dependency on foreign sourced inputs is one of the biggest challenges facing this sector. Moreover, the application of sustainable practices is lacking in the production systems. These include lack of on-farm composting, green manure application, mulching, legumes incorporation and crop rotations (Adheel, 2017).

Horticultural crops faced another biggest challenge is the frequent insect pest outbreaks in notable horticultural crops during the dry season. These insect pest outbreaks include, coconut hispine beetle (*Brontispa Longissima*), papaya mealy bug insect (*Paracoccus Marginatus*), gypsy moth (*Euproctis Fraterna*) and tropical army worm (*Spodoptera Litura*).

Recently, there have also been unmanageable pest incidents leaf gall of stone fruit plants, crown disease of taro and virus diseases in local chili varieties in some of the native crops.

There is ample opportunities for regional collaboration for crop genetic diversification in horticultural crops in the country. Also, with the increase in live plants and seed imports there is a growing need for improvement in regulatory and enforcement standards in sanitary and phytosanitary measures and its harmonization at country and regional level.

Additionally, there is opportunity for investments in women and youth-led agribusinesses. Moreover, investments and research on urban horticultural techniques and technologies could be quite relevant to meet the raising demand from tourism sector for fresh local food. With coconut being one of the economically important crops, there is a need to allocate new areas for coconut stands to replace the current stock that is becoming unproductive.

Furthermore, there is booming plant-nursery industry involved in the production of both food plants and ornamental plants for tourist and local market. The possible areas of expansion floriculture, indoor farming, medicinal plants and spice production.

Livestock Sector

There are many challenges for large-scale livestock production. These include, lack of land for fodder/pasture production and unavailability of local breeds. In poultry, day-old birds and feeds are imported as well. Consequently, all current production is targeted for eggs rather than meat. There is also difficulty in enforcement of biosecurity measures on farms as well as during import and export of live animals and related products. Moreover, national veterinary services need to improve to meet the demand of farmers. In this respect, regional trade of vaccines and other veterinary medicine is of great importance.

To expand livestock production, it is crucial to improve the existing biosecurity, veterinary and quarantine regulations. Research on feed and feed-additives for poultry and goats using local resources is relevant in current scenario. Similarly, research and field experiments on suitable livestock breeds can be conducted in the country with collaboration and expertise from the region. Additionally, there is huge opportunity to reintegrate livestock with the horticultural production to improve natural resource use and reduce imported compost and fertilizers.

Fisheries Sector

Various sources indicated a possible declining fish stocks in some species such as yellow fin tuna. Also there have been temporary pressure on local fish aggregations all this effecting the outlook for GDP contributions. Capital substitutions for labor, even though promising has affected in reducing employment in fishery sector. Several factors that appear to be affecting fisheries sector development include continued public sector involvement in the tuna fishery industry impeding private sector investment. Also, there

is inadequate physical infrastructure for fisheries and limited institutional and human resource capacity, particularly at MoFMRA. Possibly most important is the sector's continued vulnerability to external shocks from fluctuating tuna prices in the world market. The current export product mix is highly dependent on products facing highly mature markets that has high product diversity. Most importantly, climate change coupled with rising world fuel prices and a major decline in global tuna prices would leave the fisheries sector in Maldives.

There is ample opportunities in targeting export markets as well as fresh fish markets with new products, optimizing net national benefits rather than production. Maldives has proven its ability to export fresh and frozen yellow fin. Therefore, it is well to aim at exporting high quality fresh and frozen products for direct consumption. Nonetheless, it is important to ensure all Maldivian fisheries are developed sustainably, incorporating modern-day fisheries management principles and approaches. Additionally, improving collection and analysis of scientific statistical data is crucial in order to design appropriate fisheries management plans. Designing new and reviewing existing reef fisheries management plans is needed to ensure their proper implementation. Moreover, strengthening the capacity of stakeholders in fisheries and marine resource management could be vital for the success of this sector. There is also a need for improving licensing of subsistence fishing and local market fleets in order to ensure that resources are used sustainably and to adopt international best practices. Strengthening MoFMRA's monitoring capacity is to be carried out for controlling heavy seasonal poaching activities. There is opportunity to reinforce sustainable use of bait fish and implementation of the existing bait fish management plan. Additionally, supporting the establishment of seed production facilities to support the sustainable development of the aquaculture sub-sector is to be considered. Encouraging the production of domestic fish feeds using by-products of local fish-processing activities in order to support the sustainable development of the aquaculture sub-sector is to be carried out.

Introduction of financing instruments and credit facilities for aquaculture development could catalyze the expansion of aquaculture activities. Lastly there is a need to provide aquatic animal health and services and certification to facilitate marketing of aquaculture. All these activities could be tied with regional interests in developing collaborative programs.

Natural Resource Management

Policy and regulation constrained to incentivize farmers for a long-term management of farm land. For instance, land lease for farming is in rotational basis in most inhabited islands. There is also more disposition towards seasonal farming. Additionally, land fees levied to farmers do not encourage to utilize leased area for maximum efficiency. These customs prevent land owners and farmers from implementing sustainable resource management practices. Consequently, irrigation practices utilized by most farmers are

excessive and causes strain on ground water resources. Currently, policies on ground water use are lacking. Many major agriculture areas face salination issues and water shortages in dry season. Many on-farm practices are to be changed to improve these issues. For instance, very few farmers use drip irrigation systems, mulching is not practiced in vegetable farming and no specific irrigation routine is adopted in dry season. Furthermore, current farms are designed in a way that inadvertently increases evapotranspiration. These also cause salt intrusion to soil profile and exacerbate issues arising from pest and diseases. Moreover, there is lack of infrastructures, weak human capital for effective and efficient management of agricultural natural resource-base, and lack of skill and technologies such as Geographical Information System and context specific Geo-Positioning Systems for monitoring natural resources.

There is a huge opportunity to incorporate sustainable land management practices as part of routine agricultural practices. In this respect, specific focus can be given to introducing alternative production systems such as organic farming, permaculture, agroforestry and dynamic farming systems. Also, collaborative work could be carried out on water conservation technologies and soil management techniques. In this regard experiments on biochar production and its use could be carried out.

Review of Agricultural Policies and Programs

In the current Strategic Action Plan, there are significant gaps with regard to crop improvement programs. There is not direct actions plan that take in to account farmer knowledge as an asset in building resilient yet profitable agribusinesses. Moreover, there is a lack of specific program for promoting alternative, context specific sustainable production systems (MOPND, 2007).

Policies with clear mandates for sustainable management of agricultural natural resources must be in place. These encompass, mandates for water and soil management. Policies may also incentivize sustainable practices at farm level, island level and national level (MoFMRA, 2009). Additionally, a national campaign on promotion of local food and support for farmers is needed to prioritize quality local food production and reduce strain on natural resource use. This campaign can also encourage youth and women participation in agriculture in order to reduce dependency on foreign labour and increase the proportion of skilled labour. There is also a need to promote fresh food consumption at local level to strengthen local food production and at the same time improve nutritional security.

Additionally, there is a new policy on the management of agricultural pesticides. This is an important step toward judicious management of agrochemicals and promoting standards for healthy food production. It would be equally important to promote and encourage the use and distribution of biological pesticides and alternative pest management options. The government mandates to encourage sustainable farming practices to promote local safe food consumption.

Current research policies focus mainly on improving research infrastructure of both public and private sector. Hence there is little work on obtaining subscription from prominent agricultural knowledge producers such as agricultural journals and publications, designing and conducting farmer involved research programs, improved research information dissemination mechanism and assessment and monitoring of research data application at practical level. There are policy gaps in identification and mandating priority areas for agriculture research in both private and public sector.

Recommendations of Priority Programs

i) Traditional high yielding fruit crop improvement program (Horticulture)

Background and Justification

In existing production system there are many tropical fruit varieties that are either introduced or naturalized or have been native species for a long time. These crops include, guava, mango, passionfruit, papaya and other varieties. These crops constitute large portion of the home garden production and consumption. Hence, they are not used in commercial farming because of limitations in using landraces in commercial farming. However, these crops have traits such as high adaptability to Maldivian soil and climate. Therefore, dwarf or semi-dwarf varieties for short duration and early yielding fruit crops developed from merging these traits could alleviate certain issues faced by farmers. Most prominent of these issues include complete dependence on imported seeds and planting materials and high input; especially fertilizer requirement. In general, the imported hybrid varieties have low adaptability to waterlogging, heat stress and issues arising from shallow soil profile. Most of the current commercially cultivated varieties are originally developed for production in Thailand, china and India where there are considerable differences in soil and seasonal weather conditions. Moreover, in a food security point of view it is important to have crop varieties that could be sourced from the country. Food systems based on foreign inputs add to the already existing vulnerability, especially in times extreme event or natural disaster. Furthermore, some of the traits described earlier might have potential to be used elsewhere other than Maldives. Hence, a regional collaboration could be useful in exploring the potential of traditional varieties for crop improvement. A research project on plant breeding on selected crop varieties for improvement could be of immense use for Maldives and the region (Lindgren & Wei, 2003).

Objectives

- Explore and utilize traditional or native varieties in commercial production.
- Harness and develop crops with traits that are suitable for Maldivian environment.
- Enhance collaboration with regional institutions for joined crop improvement program.

ii) Some recommendations of priority programs under thematic areas

Crops:

- Food security programs focusing on breadfruit, taro, cassava and sweet potato.

Horticulture:

- Fruit crop improvement programs focusing on local breeds.
- Promoting landscaping and nursery activities.
- Research in to stock-less farm nutrient management.
- Application of local knowledge for context specific innovations.
- Urban agriculture focusing on herbs, medicinal plants and leafy greens.
- Promotion of underutilized vegetable crops, low cost water harvesting and water management technologies.

Fisheries:

- Climate change adaptation and mitigation in fisheries.
- Expanding on existing mariculture and aquaculture research.
- Low cost fish processing and handling techniques and technologies.
- Processing and value addition technology development.
- Fuel efficiency and alternative energy use in fisheries sector.
- Fisheries based food safety and quality.

Livestock:

- Growing local and tourist market for local meat and eggs.
- Huge potential in livestock and crop integration.
- Livestock integration mechanism in horticulture.

Natural Resource Management:

- Sustainable food and fodder production in managed forests.
- Scientific use of forest resource for food production and resource conservation.
- Capacity building on NRM management and monitoring using GIS and other tools.
- Coconut based agroforestry systems.

Agriculture policy:

- Promoting agro-tourism for income generation of farmers in Maldives.
- Piloting and scaling up of sustainable agricultural technologies and climate smart agriculture.
- Access to agricultural inputs; organic fertilizers, improved seed varieties, credit access.
- Strengthening the implementation of food standards and safety policies.
- Capacity building through graduate and postgraduate programs.

Cross-cutting:

- Harmonising Sanitary and Phytosanitary measures at national and regional level.

Conclusion and Way Forward

There are many challenges facing various areas in the agriculture sector in Maldives. While some of the challenges require short-term, immediate, and long-term solutions carried out under planned regional programs. Some of the most immediate challenges relate to the land, labour and diversification of farming practices. To achieve the best results, efficient resource use and appropriate programs to be developed in line with regional demands. The regional level program that share resources and expertise are most ideal way to deal with some of the more pressing challenges.

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Chapter 7

Agricultural Research and Development: Policy and Program Priorities in Nepal

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Abstract

The contribution of agriculture to national Gross Domestic Product (GDP) is remarkable in Nepal. National Agriculture Policy- 2004 and Agriculture Development Strategy (ADS) (2015-2035) are the major guiding policies for agriculture sector development. Besides, there are around 15 sub-sectoral and commodity specific policies for agricultural research and development. The policy priority of the country has been highly emphasized in agricultural development, however the program and budget allocation have been given less priority that exerted the growth rate slow. The public investment in agriculture sector is around 2% of the national budget and the budget allocated for research is only around 10% of the total agricultural budget. Rice, maize, wheat, fresh vegetables, apple, banana, goat, dairy, poultry, fresh water fish, cardamom, tea, ginger, mushroom are the priority agricultural commodities in the country. The production and productivity of these commodities are increasing but at slower pace. This sector is less competitive with lower productivity of land and labor. In fact, the youth are less attracted towards agriculture and the trend of migration from rural to urban and to out-migration is increasing, consequently the lands are left fallow, the import swelling and export shrinking, thus creating huge trade deficit in the country. Hence, the government of Nepal should effectively implement agriculture policies, programs along with effective monitoring for commercialization of agriculture. Furthermore, to combat with the global and regional issues related to agriculture and rural development, effective coordination and collaboration among the SAARC nations need to be strengthened.

Keywords: Agricultural development, policy priorities, regional cooperation

Background

Agriculture accounts for 26.5% of GDP and is the major source of Nepalese economy (MoF, 2019). However, agriculture is subsistence based employing almost 2/3 of the

population with the productivity of agriculture labor about US\$ 835, which is around one fourth of the productivity in the rest of the economy (MoAD, 2015). Agriculture land is characterized by small holding (0.68 ha/household), which was decreased significantly (43%) in last 20 years and 51% of farmers have less than 0.5 ha. According to CBS (2011b), the average productivity of agriculture land in Nepal is US\$ 3278/ha with nominal average farm income of US\$ 708.3¹ per household and average farm income of US\$ 144.25 per capita, which constitutes around 27.7% of total household income (CBS, 2011b).

The annual growth rate of agriculture sector is quite fluctuating. The growth pattern of national GDP has shown similar trend with agriculture sector growth rate, indicating that the agriculture sector has direct influence to national economy (Figure 1). The growth rate of agriculture sector within a past decade ranges from 0.01% (FY 2015/16) to 5.1% (FY 2016/17) with an average annual growth rate of 2.9% (MoF, 2019). However, the share of agriculture in National GDP is decreasing from 35.86% in 2008/09 to 27.9% in 2017/18 but the contribution of agriculture in real value basis is increasing from 201.5 billion to 264 billion (Figure 2).

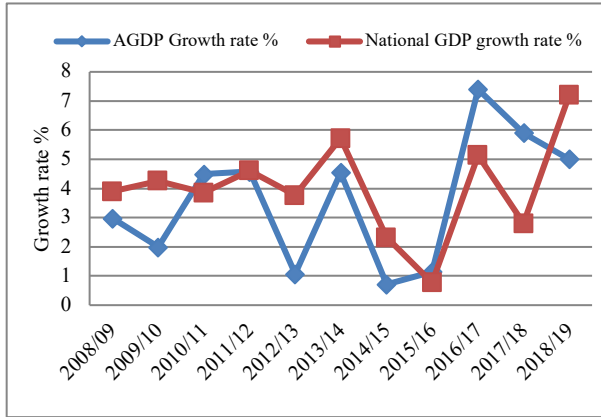


Figure 1. Trend of GDP and AGDP growth rate (2008/09-2018/19)

Source: MoF (2019)

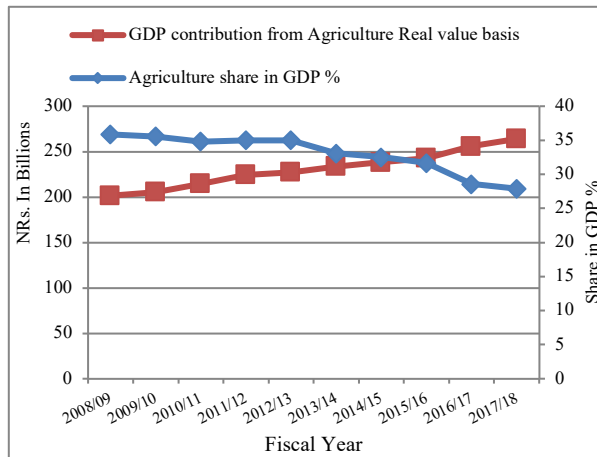


Figure 2. Trend of AGDP in value basis and agriculture contribution in GDP (2008/09-2017/18)

Source: MoF (2019)

¹ 1 US\$ = NRs 80 (2011)

Situation of Agricultural R&D

Nepal is richly endowed with agro-biodiversity. Most Nepalese farmers grow diversified crops in order to protect against erratic and uncertain weather and other unfavorable agronomic conditions. Rice, maize, millet, wheat, barley and buckwheat are the major staple food crops. Vegetable farming is a growing enterprise in Nepal. Area of vegetable has increased by 26% from 235,098 ha in 2009/10 to 297,191 ha in 2018/19 (MoALD, 2019). Recently, youth are attracted towards precision and protected horticulture enterprises. Nepal is progressing towards advanced technologies in vegetable farming as grafting in tomatoes, True Potato Seeds (TPS) production and tissue culture in potato, fertigation technologies (Pradhan, 2016). Nepal exports orthodox tea, large cardamom, coffee and zinger. Livestock is one of the important sources of household income and supply nutrition to the farm households, source of manures, and provides draft power as well.

Fresh water fish culture is another emerging enterprise in Terai whereas rainbow trout in the hills and in the lower mountains. Cereals contribute 28.58%, vegetable crops 16.75%, fruits 5.35%, meat 8.53% & milk 7.94% in the total AGDP of the country (Figure 3). Forest covers around 6.61 million hectares area (44.75%) of the total area of the country (NPC, 2004; 2017; 2018). Nepal has abundant water resources, with over 6,000 rivers and streams, and annual surface water availability is around 225 billion m³ (WECS, 2011).

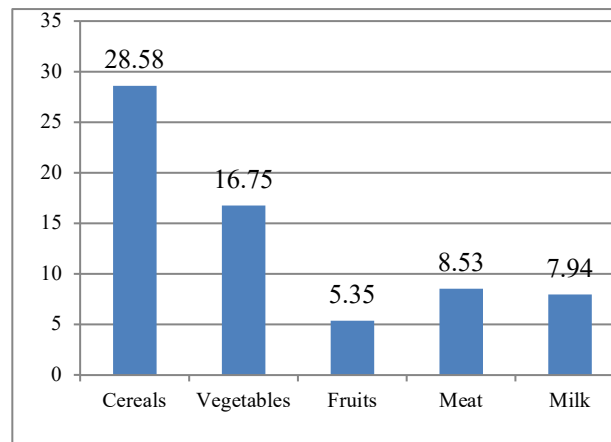


Figure 3. Contribution of agricultural commodities in AGDP (%), 2017/18

Source: MoALD (2019)

Public Sector Investment in Agricultural R&D

The budgetary allocation for the last 5 years shows that the budget allocated for agriculture (excluding irrigation, land management, forestry) was around 2.5% of the national budget. The annual average increment of the total national budget is around 17% whereas the annual increment for agriculture budget is only around 6% (Figure 4). Similarly, the budgetary allocation for agricultural research is very nominal, which is estimated to be around 10% of the agricultural sector budget & around 0.2% of the national budget. The annual increment of budget for agricultural research is only around 6% (MoF, 2019). Investment in agricultural R&D is imperative to cope up with changing technology, issues and challenges, and importance of agriculture on food and nutrition and poverty alleviation.

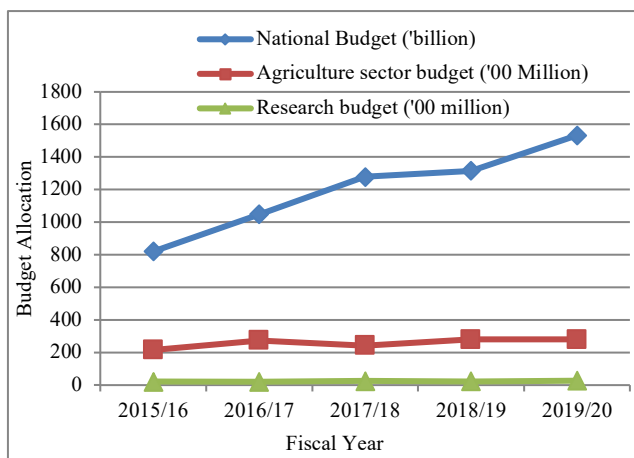


Figure 4. Trend of public investment in agricultural R&D (2015/16-2019/20)
Source: MoF (2019)

Production, Import and Export of Major Agricultural Commodities

The production status of major agricultural commodities shows an increasing trend. The total production of cereals increased from 8.6 million metric tons in 2015 to 10 million metric tons in 2017 with an annual increase of 5% (Figure 5). Similarly, the annual increase in production of vegetables is around 3%, fruits 3.77%, milk 4.2%, and meat 2.3% in the past 3 years.

The import trend of major cereals crop shows a drastic increment of 12.25% per annum

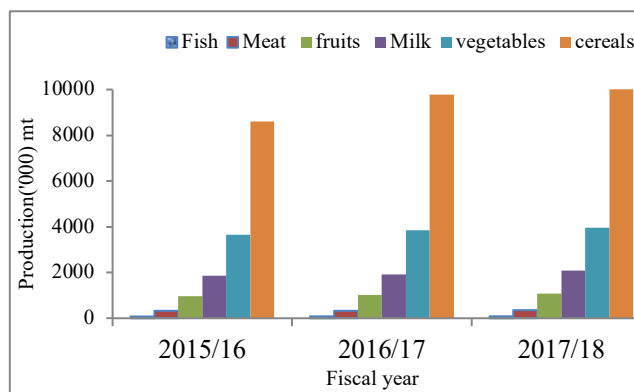


Figure 5. Production (Mt) of major agricultural commodities (2015/16-2018/19)
Source: MoALD (2019)

reaching around NRs 45.41 billion in 2017. Similarly, the import of vegetables, roots and tubers reached up to 23 billion with an annual increase of around 19% and the import of fruits and nuts reached up to 23.72 billion with an annual increase of 4.03% (Figure 6).

The export worth NRs 4.28 billions of large cardamom, NRs 3.2 billions of orthodox tea and 0.51 billions of ginger was recorded in 2018/19 (Figure 7). The total export of agriculture related products is around NRs 97 billion against NRs 1418 billions of import with a huge trade deficit around 1321 billion (DoC, 2019).

Thematic Area Wise Country Situation

The overall country situation based on 6 different thematic area as crops, horticulture, livestock, fisheries, natural resources management and agricultural policies are discussed as below.

Crops

Rice, maize and wheat are the major cereal crops grown in the country. Rice is the most important cereal crop contributing around 15.35% of AGDP and 33% total calorie requirement (MoALD, 2019). The area under these crops are more or less stagnant within past 10 years period (Figure 8) whereas the production have been

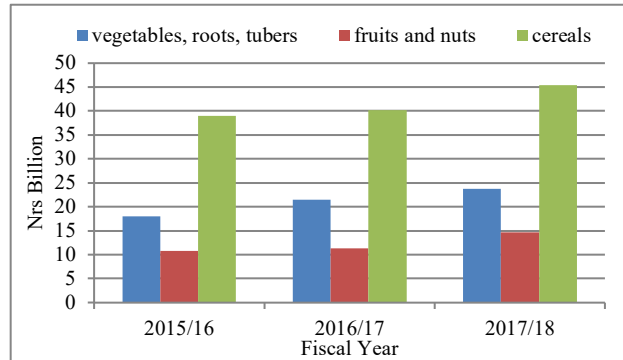


Figure 6. Import of major agricultural commodities (2015/16 -2017/18)

Source: MoALD (2019)

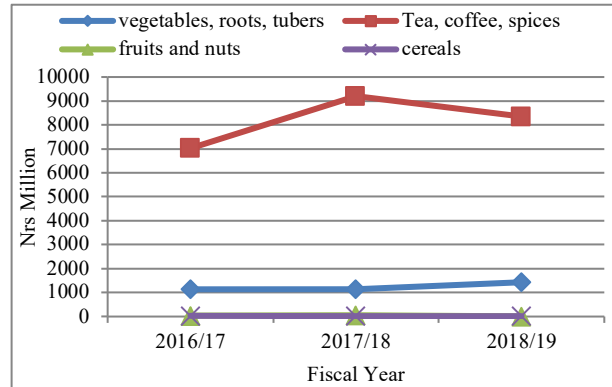


Figure 7. Export of major agricultural commodities (2015/16 -2017/18)

Source: MoALD (2019)

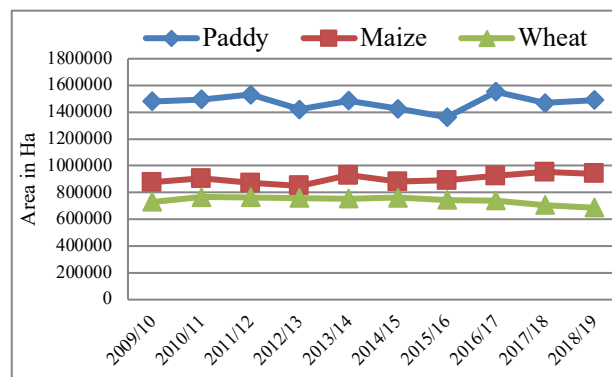


Figure 8. Trend of area covered by paddy, maize and wheat (2009/10-2018/19)

Source: MoALD (2019)

increased from around 4 million tons to 5.6 million tons with productivity from 2.72 Mt/ha to 3.76 Mt/ha. Rice production being very much interlinked with monsoon, the annual fluctuation in production is found very common. Similarly, the availability of quality fertilizer during transplantation also affects paddy production.

Area covered by paddy and maize increased by 0.7% and 7.6%, respectively, whereas area of wheat decreased by 6%. Area covered by paddy, maize and wheat was 1,481,289 ha, 875,660 ha and 73,113 ha, respectively in 2009/10 which changed to 1,491,744 ha, 942,079 ha and 686,557 ha, respectively in 2018/19 (Figure 8). Similarly, the production has also increased over the decade.

The production of paddy, maize and wheat were 4,023,823 Mt, 1,855,184 Mt and 1,556,539 Mt, respectively in 2009/10. The total production increased by 39%, 43% and 31% for paddy, maize and wheat, respectively reaching 5,610,011 Mt, 2,644,801 Mt and 2,036,706 Mt, respectively in 2018/19 (Figure 9). The yield of these crops has increased by 38%, 32%, and 39%, respectively reaching 3761 Mt/ha, 2807 Mt/ha and 2967 Mt/ha, respectively. Increase in irrigation facilities, use of improved and hybrid seeds, use of chemical fertilizers have contributed to the improvement in productivity.

On the research side, there are 123 varieties of rice out of which 63 rice varieties are released from research stations and 54 varieties registered to be suitable for cultivation in different domains. Similarly, for maize crop, 27 varieties have been released and 61 registered whereas 31 varieties have been released for wheat, 5 for millet, 6 for barley and 1 for buckwheat (Figure 10).

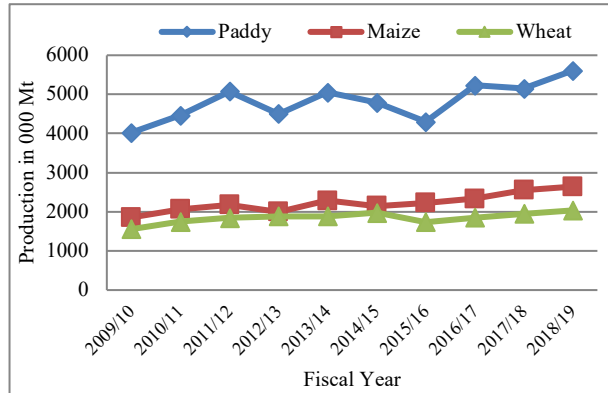


Figure 9. Trend of production of paddy, maize and wheat (2009/10 - 2018/19)

Source: MoALD (2019)

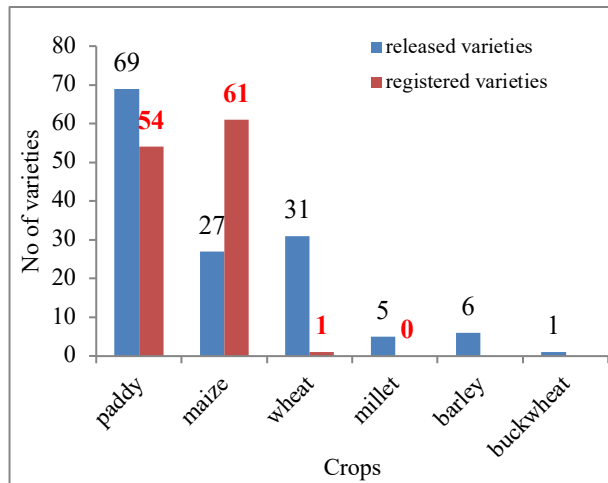


Figure 10. Released and registered varieties of major agricultural commodities

Source: AICC (2019)

Horticulture

Fruits: The country owns varied geographical and climatic conditions making it suitable for growing diverse biotypes of fruit species. Southern Terai regions are suitable for cultivation of tropical fruits while mid-hills and high-hills towards north are suitable for sub-tropical to warm and cold temperate fruit species. Total area covered by fruits is 4.79% of total cultivated area, out of which 57% are tropical, 26% area citrus and 17% are temperate (MoALD, 2019). Tropical fruits are grown in about 60% of total fruit growing area and production is nearly 65%. Citrus is grown in 22% of total fruit production area in the country. Among all citrus, mandarin occupies 65.3% of total citrus growing area and 67.2% of total citrus production. Temperate fruit share 15.5% of total fruit grown areas and production is 13% of total fruit production.

Productive area and production of fruits has increased over a decade. Productive area of fruits has increased by 67% from 70,722 ha in 2009/10 to 117,792 ha in 2018/19. Similarly, production has reached 1,153,227 Mt in 2018/19 from 706,972 Mt in 2009/10 (63% increased). However, productivity of fruits has slightly decreased over this period by 2% from 10 Mt/ha in 2009/10 to 9.79 Mt/ha in 2018/19 (Figure 11). Decreases in productivity are due to poor orchard management and disease pest especially in citrus fruits.

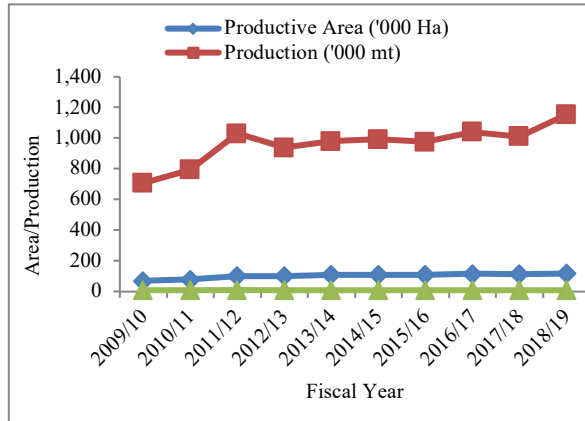


Figure 11. Area, production and productivity of fruits in Nepal

Source: MoALD (2019)

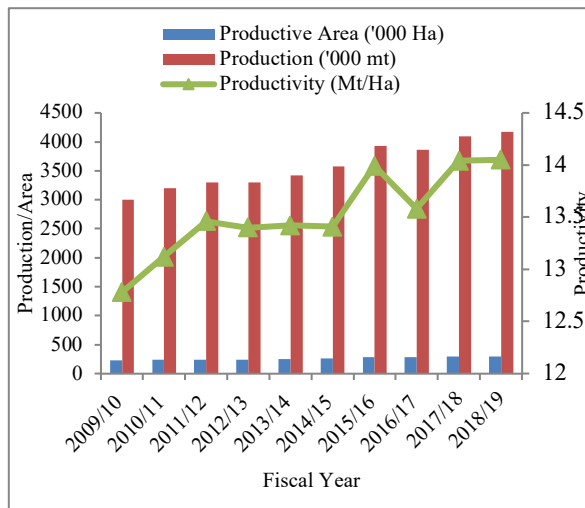


Figure 12. Area, production and productivity of vegetables in Nepal

Source: MoALD (2019)

Vegetables: Area, production and productivity of vegetables have increased over the decade. Area of vegetable has increased by 26% from 235,098 ha in 2009/10 to 297,191 ha in 2018/19 whereas the production has increased by about 39% from 3,003,782 Mt to 4,175,621 tons (Figure 12). Increment in production is more than increment in area of vegetables leading to the increase in productivity by 14.05% from 12.78 Mt/ha in 2009/10 to 14.05 Mt/ha in 2018/19 (MoALD, 2019). Increase in production is attributed by the favorable climatic condition, availability of seeds and fertilizers, improved management practices, mechanization and area expansion.

Livestock

Nepal has largely a smallholder livestock system where less numbers of livestock are raised by smallholder farmers. However, livestock sector contributes to human food security and nutrition, livelihood of farmers, employment and income generation, inputs for farm operation (such as draft and manure), industrial production, and rural transportation. In Nepal livestock and its products like milk, meat, and hides, contributes 11.5% of national GDP (CBS, 2011b). It is main source of household cash income especially in the hills and mountains. In the hills and mountains, mules, yaks, sheep and goats make an important contribution as pack animals.

The number of cattle increased from around 532,300 to 721,090 and total milk production of 1,700,073 ton to 2,085,000 tons within last 10 years (Table 1). The number of buffalo has increased by 17%, from 1,167,773 Mt in 2013/14 to 1,363,910 Mt in 2017/18 (MoALD, 2019). Similarly, milk production has increased by 23% from 1,700,073 Mt in 2013/14 to 2,085,000 Mt in 2017/18. Though the use of improved breeds and number of commercial farms are increasing but the productivity has not significantly improved. Hence, to increase the productivity by replacing unproductive breeds of buffalo by high yielding one is still a challenge in the livestock sector of Nepal. Also, poor nutrition and disease are the common stressor in livestock mortality and morbidity.

Table 1. Number of cattle, buffalo and milk production (2013/14 -2017/18)

Year	Number of Cattle	Number of Buffalo	Milk Production (Mt)
2013/14	532,300	1,167,773	1,700,073
2014/15	557,669	1,167,754	1,724,823
2015/16	639,590	1,214,295	1,853,885
2016/17	665,285	1,258,407	1,911,200
2017/18	721,090	1,363,910	2,085,000

Source: MoALD (2019)

There are number of local breeds with different special features. The major local breeds are: cattle (Aachami, Lulu, Khaila, Hill Cow, Terai cow, Siri), yak, buffalo (Lime, Parkotee, Gaddi), goat (Khari Goat, Sinhal, Changra) (AICC, 2019).

Fisheries

Fishpond area, production and productivity of fisheries have increased over the period. In 2009/10 fishpond area, production and productivity were 6,900 ha, 24,869 Mt and 3.6 Mt/ha, respectively. Over a decade, the cultivated area increased by 142%, production by 188% and productivity by 19%. In 2018/19, area, production and productivity of fisheries was 16,719 ha, 71,726 Mt and 4.29 Mt/ha, respectively. Trend of area covered by fishponds, production and productivity of fisheries over a decade.

Natural Resources Management

Nepal's national economy and people's livelihood largely depend on natural resources. However, in 1980s' the concept of sustainable use of natural resources was first incorporated in 5th Five Year Periodic Plan (1975/76 -1989/80). This plan highlighted the resource conservation through watershed management and land use control at the policy level. In the sixth plan (1980/81-1984/85) a number of policy measures for conservation and sustainable use of natural resources were incorporated. In the beginning of 1990s, the Government of Nepal (GoN) formulated its separate environmental policy for the protection and management of natural resources and its surroundings along with long term national plans focused on sustainable development and poverty alleviation.

Water Resources: Water resource is one of the most important natural resource of the country (WECS, 2019). Water resources are abundant throughout the country in the form of snow covers, rivers, springs, lakes, and groundwater. Glaciers, permafrost, and glacial lakes are main forms of water storage. There are about 3,252 glaciers with total coverage of 5,323 km² in Nepal. The surface water available about 225 billion m³ per annum out of which 15 billion m³ is in use. There are altogether 6,000 rivers (including rivulets and tributaries). The cumulative length of rivers is 45,000 km. Snow fed-types rivers such as the major rivers systems: the Koshi, Gandaki, Karnali and Mahakali originate from snow and glaciated regions in Himalayas and their flow regimes are mostly governed by the melting of snows and glaciers. As a result, flow in these rivers is perennial and sustain flow during the dry season. These rivers are reliable source of water and also provide potential opportunities for hydro-power generation and irrigation in the downstream. Nepal also has abundant ground water resources. The estimated renewable ground water potential of the country is estimated to be 12km³, which are the major source of domestic uses and irrigated agriculture in *Terai* regions.

Water Resources Act 1992 governs the management of water resources in Nepal through necessary and timely legal arrangements for the rational utilization, conservation, management and development of the available water resources in the form of surface water, underground water or in whatsoever form preventing environmental and other hazardous effects thereof and also for keeping water resources free from pollution.

Soil Resources: Nepal occupies only 0.1% of the total land of the world. Only 17% of total land is cultivable. Alluvial soil is found in river basin of *Terai* region. Different types of soils are available in the diverse geography, particularly in the hill, valley, mountain and terai. Degradation of agricultural land is a major problem affecting agricultural productivity and national food security. Topsoil loss has been reported as high as 87 tons per hectare per year on sloping terraces. It is estimated that 1.7 mm of topsoil is lost each year due to soil erosion and about 21,000 m³ of soil, equivalent to 64 Mt ha⁻¹, is being eroded annually in the Khajuri catchment of Siwalik Hills of Nepal only. Nepal is also facing serious problem of decline in soil fertility. Majority of the soil samples were found to be acidic (53%). Similarly, Soil organic matter range from low to medium and majority of the samples have low content of soil nitrogen, phosphorus and potash (Dawadi & Thapa, 2015). In this context the technologies to enhance soil fertility status should be developed and disseminated throughout the nation.

Agricultural Policies

Rational policies and institutional set up are required for supporting and facilitating investment in agriculture. Policies in inputs (fertilizer, seed), agribusiness promotion, mechanization, land use, trade, climate change and agro-biodiversity promotion have been developed. However, formulation and implementation of legislations and regulations favoring commercialization of agriculture e.g., Contract Farming Act, Land Leasing Act, Agriculture Land Use Act, Agribusiness Policy are lacking. Existing policies related to agricultural research and development are discussed in Table 2.

Table 2. Lists of some major policies on agriculture and their silent features

Major Policies	Features
National Seed Policy, 2000	<ul style="list-style-type: none"> ▪ Easy availability of required amount of high quality seeds of different crops. ▪ Encourage seed export by promoting production of high quality seeds. ▪ Make the seed business effective, taking into account the present international trade. ▪ Conserve and protect genetic characteristics specialty seeds and coordinate with concerned organization to protect intellectual rights.
National Tea Policy, 2000	<ul style="list-style-type: none"> ▪ Enhance qualitative and quantitative tea production through the participation of the private sector in tea plantation. ▪ Contribute to poverty alleviation by increasing income and employment opportunities. ▪ Help environment conservation through the expansion of tea plantation.

Major Policies	Features
National Fertilizer Policy, 2002	<ul style="list-style-type: none"> ▪ Reconfirming the government's firm adherence to liberating the fertilizer market. ▪ Ensuring the provision of policy and infrastructure management conditions for enhancing fertilizer consumption. ▪ Promoting integrated plant nutrient management for the efficient and balanced use of fertilizers.
National Coffee Policy, 2003	<ul style="list-style-type: none"> ▪ Promote export promotion and import substitution of coffee. ▪ Contribute to poverty alleviation through income generation and employment opportunities. ▪ Help environmental conservation through the expansion of income generation. ▪ Make coffee enterprises sustainable and attractive.
National Agricultural Policy, 2004	<ul style="list-style-type: none"> ▪ Contribute to food security and poverty alleviation by achieving high and sustainable economic growth through a commercial and competitive agricultural system. ▪ Increase agricultural production and productivity. ▪ Make agriculture competitive in regional and international markets. ▪ Conserve, promote, and use natural resource, the environment, and biodiversity sustainably.
Agribusiness Promotion Policy, 2005	<ul style="list-style-type: none"> ▪ Support market oriented and competitive agricultural production. ▪ Contribute to internal marketing and export promotion through the development of agro industries. ▪ Contribute to poverty alleviation through the commercialization of agriculture.
Agro Bio Diversity Policy, 2007	<ul style="list-style-type: none"> ▪ Strengthen food and nutrition security and develop agriculture appropriately through the conservation, maintenance and sustainable use of agro bio diversity. ▪ Protect and maintain farmers right to indigenous knowledge, skills, technologies and practices. ▪ Manage opportunities from and build an equitable distribution system for the benefits of using agricultural genetic resources and materials. ▪ Contribute to balance ecological promotion for long term agro bio diversity conservation.
Dairy Development Policy, 2007	<ul style="list-style-type: none"> ▪ Enhanced Dairy production and productivity in rural areas. ▪ Expand the transportation system for milk collection and milk processing industries by making the production of milk and milk products competitive. ▪ Substitution for imports through the diversification of milk products according to the feasibility of internal markets. ▪ Enhance the availability of milk and milk products for general public by improving their quality and regulations.

Major Policies	Features
Rangeland Policy, 2012	Policy aims to increase productivity by improving forage/grass productivity, to protect farmers' rights for pasturing livestock in community rangeland and forest, and to determine stocking density to minimize competition between grazing domestic and wild animals.
National Land Use Policy, 2012	The Policy aims to encourage optimal use of land for agriculture by classifying the country's land territory into seven land use categories- agricultural, forest, residential, commercial, public, industrial, and others. Further, it aims to increase agricultural productivity by systematizing land fragmentation and by adopting a land pooling system.
Climate Change Policy, 2011	Mitigating and adapting to the adverse impacts of climate change. Adopting a low carbon emissions socio-economic development path. Meeting the spirit of the country's national and international agreements related to climate change.

Source: ADB (2009) and Author's synthesis

Agriculture Development Strategy (ADS)

Agricultural Development Strategy (ADS) is a 20 years vision for agriculture development in Nepal (MoAD, 2015). It has envisaged driving economic growth and contributes to improved livelihoods and food and nutrition security through a self-reliant, sustainable, competitive, and inclusive agricultural sector. ADS is expected to accelerate agricultural growth through four strategic components related to commercialization, productivity, competitiveness and governance while promoting inclusiveness and sustainability (MoAD, 2015). ADS intend to develop private and cooperative sectors in this process and ensure connectivity to market infrastructure. The strategy has been formulated taking into account the need for economic transformation from the one primarily based on agriculture to one that derives most of its income from services and industry while also modernizing agriculture. This process will have profound implications for the Nepal to shape its food production and distribution systems, development of rural areas, increasing labor and land productivity, trade balance and management of natural resources in the context of increasingly more severe climate change events. In this context, it is worth emphasizing that the ADS considers the agriculture sector in its complexity and encompasses not only the production sectors (crops, livestock, fisheries, forestry) but also the processing sector, trade and other services (storage, transportation and logistics, finance, marketing, research and extension). The ADS envisages some prioritized national programs, which are referred to as "ADS Flagship Programs" (MoAD, 2015). The flagship programs of the ADS are:

i. Food and Nutrition Security Program (FANUSEP)

FANUSEP aims at improving food and nutrition security of the most disadvantaged groups. The commonality of the subprograms of FANUSEP is to target the poor, the

disadvantaged groups and the geographically disadvantaged areas. The program will promote interventions that improve productivity, livelihoods, and nutritional practices of targeted beneficiaries including pregnant and lactating women farmers (MoAD, 2015).

ii. Decentralized Science, Technology, and Education Program (DSTEP)

DSTEP aims at decentralizing the extension and research system while fostering coordination of research, extension, and education in order to enhance responsiveness of extension, research, and education institutions to farmers' and agro enterprises' needs. The decentralized extension system will include three main measures:

- Establishment of Community Agricultural Extension Service Centers (CAESC).
- Strengthening capacity of existing and planned Agriculture and Livestock Service Centers that will provide backstopping services to the CAESCs.
- Promoting a voucher system to empower farmers to access the best available agricultural input and extension service providers.

iii. Value Chain Development Program (VADEP)

VADEP aims to develop prioritized value chains through comprehensive and integrated measures along the value chain that results in strengthened value chain linkages, increased public-private partnership (PPP) investment and value added with sector impact and benefits to the poor. VADEP will have the following innovative features:

- Developing all the stages of the value chain, from seeds to final products, from production to processing, from market infrastructure to access to roads and connectivity, from postharvest technology to quality assurance and exports.
- Engage and promote associations of farmers, traders, processors, input providers and other value chain stakeholders in order to strengthen the linkages and ensure effective investment.
- Replication the VADEP model and make linkages throughout the country and achieve national impact.
- Work concerned stakeholders, department and value chain actors.

iv. Innovation and Agro Entrepreneurship Program (INAGEP)

This flagship aims to foster agricultural innovation and agro-entrepreneurship through the combination of tax incentives, agribusiness incubators, and matching grants. The main beneficiaries of this program will be private enterprises including micro, small and medium enterprises, cooperatives, and targeted groups including youth, women, and disadvantaged groups. The funds required for implementation of the INAGEP will be pooled into a fund that will be replenished through contribution of Government and Development partners.

Prime Minister Agriculture Modernization Project (PMAMP)

The introduction of Prime Minister Agriculture Modernization Project with concept of pockets, blocks, zones and super zones of different agricultural commodities as cereals, horticulture, fisheries, honey, mushroom etc. to ensure food security and create sustainable economic opportunities through agricultural industrialization which assist in overall economic development of country by integrating and mobilizing overall components of agriculture value chain. PMAMP aims to transform agriculture based to agriculture industry based economy through modern, commercial, sustainable and self reliant agriculture sector. The project has following objectives:

- To develop specialized agricultural areas for major agricultural commodities.
- To enhance the competitiveness of export oriented crops through value addition.
- To develop agriculture as a profitable enterprise and create employment opportunities in agriculture.
- To maintain functional coordination among the multi stakeholders for ensuring effective service delivery.

Project focuses on voluntarily agricultural land pooling, use of improved technology and quality infrastructure development, establishment and operation use of post-harvest systems, agro industrialization and output based facilitation. It introduces mechanization through custom hiring centers, inputs supply, creating awareness and promotion of value addition through entrepreneurship development, use of Information Communication Technology (ICT) in agriculture along with value chain approach and market linkages are other programs under the project to achieve accelerated growth in agriculture. Most importantly bridging the yield gaps through increase productivity and reducing cost of production along with value chain approach with market linkages would help in increasing profitability of farmers. The project has four components such as Pocket, Blocks, Zones and Super Zones as operating units for implementation of the project activities.

Challenges and Opportunities in Agricultural R&D

Nepalese agriculture continues to face challenges of decreasing size of farm holdings, labor migration leading to scarce and more costly agriculture labour, poor access to credit and investments, inadequate rural infrastructure, problems in retaining rural youth in agriculture, extreme events of climate change, increasing cost of production, investment in research, capacity and infrastructure development, management of effective distribution system of production inputs, adoption of resource efficient and labor saving advanced technology leading to improved productivity in agriculture.

Challenges in Agricultural R&D

i. Loss of agricultural land

One of the major emerging issues in the country is the loss of agricultural land. Huge loss of agricultural land has been experienced in major cities and market centers of Terai and Hills as a result of rapid urbanization and unplanned infrastructure development. Land degradation, depleting water resources, and environmental pollution are other reasons of loss of agricultural land. Population growth, rural poverty, and lack of alternative livelihood options have forced farmers to cultivate marginal lands, encroach forests, overgrazing of livestock, and loss of biomass resulting in continued land degradation. Soil erosion and landslides resulting in from inappropriate land uses are major causes for land degradation particularly in the Hills and Mountains.

ii. Shortage of agriculture labor

Agriculture sector is facing huge shortage of agriculture labor basically due to rapid out-migration. Around 25% of the households have at least one of their family members are migrated around 85% of which are from rural households. The number of out-migrated population is estimated to be 4 million which is almost one third of the working male population in the country (CBS, 2011a). Though labor outmigration has resulted in a large flow of remittances in Nepal, it caused a critical shortage of human labor in agriculture and rapid increase of feminization in agriculture. Labor shortage increased cost of production and increased fallow land.

iii. Low investment in agriculture

The public sector investment in agriculture is only around 2% of the national budget. Low investment in agriculture has affected agriculture research, education and extension resulting in poor technological development, poor human resources and low access of farmers to extension thereby appropriate technologies to meet the need of diverse clients is limited. The access of farmers to public agriculture extension is only around 15% basically due to low investment in agriculture research and extension. Furthermore, it has direct implication in rising production cost, low technological base, poor infrastructure, and increased input prices. Paudel (2016) argued that at least 5% of total national budget should be invested in agriculture to reduce trade deficit and create employment in rural areas.

iv. Climate change and its impact in agriculture

Nepal is highly vulnerable to climate change and its effects on temperature and precipitation at a faster rate than the global average. Millions of Nepalese are at risk from the impacts of climate change including reductions in agricultural production, food insecurity, strained water resources, loss of forests and biodiversity as well as damaged infrastructure. Warming of temperature and increasing rainfall uncertainty have brought

increasing incidence of climatic hazards such as drought, flood, landslide, cold-wind, hailstorm, which have serious effect on the agricultural production, food security and the people's livelihoods. However, agricultural development policies and programs lack clear road maps for mitigating and adapting climate change effects in agriculture.

v. Soil degradation and loss of agro-biodiversity

Injudicious use of chemical fertilizers and pesticides has increased environmental pollution (air, water, and soil pollution) leading to destruction of ecosystems and adverse effects onland and aquatic life. Furthermore a rapid erosion of agro-biodiversity is occurring due to use of hybrid varieties and haphazard use of agrochemicals. Over hundreds of traditional crop varieties and animal breeds are either disappearing or under risks of extinction with modernization and commercialization. Implementation of *Agro Biodiversity Policy- 2007* and *Pesticide Act (1991, amendment 2005)* needs to be in place for protection of biodiversity and judicious use of pesticides in food and agricultural products. Also incentives and support measures for the conservation and sustainable use of biodiversity needs to be triggered.

Opportunities in Agricultural R & D

i. Topography and climatic conditions

Nepal is blessed with diverse agro-climates suitable for growing many types of crops and raising animals. There are places of unique microenvironment in very short vertical distance. Such micro climatic variation favors comparative advantage of growing off season crops in the hills where there is high demand of such commodities in the plain and urban area. Main season in the hill becomes off season for the same crops in Terai and valley floor. Commodities grown in valley floor can be grown in the hills as off season. Because of comparative advantages of micro climate, vegetables, fruits, condiments and species grown in the hills of Nepal have now access to far flung market of Indian subcontinents including Bangladesh and Middle East as well. If such opportunities could be tapped, hill agriculture could provide employment and income generation for rural youth and reducing labor migration. Comparative advantages of hills and mountain where there is temporal and spatial variation in micro climate is a boon for year round fresh vegetable and flower production.

ii. Policies and programs for commercialization of agriculture

Many policies and programs are in place for agriculture commercialization and modernization with the investment from public and private sectors. Also, different donor funded projects are under implementation focusing on agriculture mechanization, infrastructure development and value chain development. Agricultural mechanization is also taking pace to address the labor shortage issue, reducing cost of production and enhancing efficiency in agricultural production. It also reduces women drudgery and

promotes diversification in agriculture. ADS envisage bringing modernization of agriculture by promoting profitable commercialization and governance of agriculture. Similarly, the PMAMP is focused on introduction of mechanization of agriculture

iii. Attraction of youth and economically active population in agriculture

Youths and economically active population, particularly returnees from Gulf countries are taking interest in agricultural commercialization. They have invested their saving and technical knowledge, which they acquired abroad. Most of them are actively engaged in the dissemination of technology and modern farming techniques to their neighbors. Technical knowledge and their experiences can be shared among other interested farmers and entrepreneurs and further momentum can be given to the process of agricultural commercialization and agri-business promotion. Some big corporate houses as Chaudary Group Nepal, Golcha Organization, Buddha Air Corporation Private Limited are investing in agriculture sector. Also, the involvement of some political leaders and celebrities have motivated other youths towards this sector.

iv. Organized farmers/ entrepreneurs and presence of commodity organization

In recent years with liberal economic policy, the role of private sectors and other non-state actors such as cooperatives, producer groups, community based organizations (CBOs), and non-governmental organizations (NGOs) are increasingly emerging as key providers of inputs, seeds, exotic varieties, and the technical services (Gauchan, 2003). The farmers and entrepreneurs are organized in different commodity specific groups, cooperatives, business organizations and social groups at the local level. There are also national level commodity associations primarily developed to serve their members. Commodity based organizations are also formed to provide various services to the local communities including agriculture. These organizations are not only promoting production but also supporting marketing and trade. The agricultural extension and marketing related services are provided to the community members and the farmers in a cost effective manner in collaboration and partnership with farmers groups and CBOs.

v. Globalization and trade liberalization

Nepal has adopted liberalized economic policy since 1980s, which was accelerated in 1990s. As a member of WTO, Nepal has wider opportunity for trade within the international arena. We have opportunity to enhance competitiveness and increase our trade volume basically in premium agricultural commodities as tea, cardamom, MAPs, and Vegetables. However, Nepal couldn't harvest from the membership of WTO due to inefficiency in production and less competitiveness of the products. Furthermore, to fulfill the SPS and TBT mechanisms human capacity and infrastructure support needs to be enhanced. Hence, in the post liberalization period, the trade openness in the agriculture sector has been found to be low with the share of only around share 3% (Chaudhary, 2011). Prioritizing competitive commodities and facilitating their production

with suitable policies as well as infrastructure supports could be beneficial to Nepal to harness the opportunities created by globalization and trade liberalization.

Recommendation of Priority Programs

1) Enhancing productivity of rice through technology exchange program (Crop)

Background and Justification

Rice is major staple crop in south Asia including Nepal. The increasing demand for high quality fine rice has created huge agriculture trade deficit in Nepal. The decrease in land area demands for varieties with higher productivity. Lack of resources, human capacity and infrastructures hinders research and hence development of new varieties and technologies takes longer time which before adoption, has to compete with another new varieties. As most of SAARC countries shares similar climatic conditions and topography, successful varieties in one country can be adopted to another easily through location specific adaptation trails in other countries and could be immediately recommended as a suitable variety in other countries. Hence, this project helps in location specific trials of successful rice varieties, seed production and distribution and with higher yield potential to other countries and thus helps in increasing production and ensuring food security throughout the region.

Components/ Activities

- Development/ exchange of high yielding/ hybrid crop varieties and intensive crop production practices/systems.
- Develop short duration and multi-stress (abiotic & biotic) tolerant field crop varieties.
- Strengthening R&D for climate smart agricultural technologies (variety, tillage & establishment method, water management, pest management, pre harvest & post-harvest techniques).

2) Establishment of SAARC seed bank and SAARC food bank (Crop)

Food security is a serious issue not only in Nepal but for the SAARC region as a whole. To combat the food security through seed security, establishment and operation of SAARC seed bank would be helpful for preservation and exchange of seeds within SAARC region. Similarly, the SAARC food Bank needs to be established especially during food shortage and emergencies.

3) Promoting agroforestry for sustainable and environmental friendly agricultural development (NRM)

Promote agroforestry approach for the sustainable and environmental friendly livelihoods of the rural farmers. Agroforestry could incorporate fodders, fruits, NTFPs,

herbs and shrubs. Community forestry need to be expanded for improving livelihoods through agroforestry approach.

4) Value Chain Development of vegetable crops focusing on enhanced market linkage (Horticulture)

Vegetable production is gaining pace in Nepal. More farmers are now engaged in commercial production of tomato, cabbage, cauliflower and other different vegetables. But the adjustment in production volume and production season poses serious threat in marketing of vegetables with reasonable price assurance. Sometimes, the farmers have to throw tomatoes in streets and sometimes plough cabbage in field. Also the supply of quality inputs including quality seeds poses hindrance in commercialization of vegetable crops. The share of producers in consumers' price is very low and middle men are enjoying much of consumers share. Similarly, collaborative efforts among the SAARC member countries might include:

- Varietal development to address stress tolerance and high yielding.
- Marketing linkage of smallholder farmers for fruits and vegetables.

5) Genetic improvement and conservation of indigenous livestock and poultry genetic resources (Livestock)

Diversity and genetic variability in SAARC region is a very precious resource for research in livestock breeding. Nepal also has vast pool of livestock genetic resources. The local breeds of Nepal are very hardy to disease pests, can thrive well in adverse climatic condition but are with low productivity. Thus harnessing the suitable potential of the local breeds could be done for improving productivity of livestock sector throughout SAARC region.

Components/ Activities

- Breed improvement through traditional & molecular approaches.
- Establishment of SAARC gene bank for economically important breeds/ strains of regional importance and sharing of genetic resources amongst SAARC Member States.
- Establishment of bank of vaccine & diagnostics for prioritized trans-boundary animal disease.

6) Value chain development of fresh water fishes focusing on enhanced market linkage (Fishery)

Nepal has huge potential for fresh water fishes. However, we are still depending upon the imported fish to a larger extent. Lack of efficient technologies for fishery production, processing and marketing is hindering the development of this sector. Exchange of

suitable cost effective technologies and easy access to market could accelerate the development of fishery industry in Nepal.

7) Facilitation of regional trade through improved policy environment (Agricultural Policy)

Access to market is a major hindrance for major exportable commodities in SAARC countries including Nepal. Commodities like ginger faces problem of non-tariff barriers as SPS and TBT. The inconsistency in policy measures of both importing and exporting partner countries poses serious threat in commodity production and export due to market uncertainties. Also the quality of the exportable commodities is a serious concern for importing countries. Hence, to fulfill the obligations, both human as well as infrastructural capacity needs to be strengthened. Also there exist different policies on agricultural trade among the SAARC member countries. Identifying the major trade policy gaps and reforms in the agricultural trade policy of the trading nations is an immediate issue to be addressed. Similarly, supports in development of infrastructure for production, grading, storage, packaging, laboratory testing, quarantine system needs to be improved along with the development of quality human resources. The policy review or formulation, policy harmonization among the SAARC countries and trade facilitation is crucial for enhancing trade in the region.

8) Agricultural policy needs to address the following issues along with associated programs (Agricultural Policy)

- Access to agricultural inputs including improved varieties of seeds, chemical fertilizers, soft credits, and insurance scheme to the farmers.
- Decent work, capacity building of agriculture labor, enhancing efficiency and productivity of labor, farmers, and traders.
- Capacity building through postgraduate program (PhD and Master).
- Conservation and promotion of underutilized indigenous nutritious crops for food and nutrition security.
- Strengthening food standards and safety mechanism for improving food and nutrition security.
- Develop agricultural enterprises, agribusiness promotion and value chain development.

9) Domestic marketing development and efficient distribution of agricultural products and foods linking with farmers (Agricultural Policy)

Farmers are constrained by inefficient marketing system in the country by not getting the reasonable price of their products because of lengthy marketing channel and lots of marketing agents involved. Studies revealed that some of the countries are applying

direct and farmers' cooperatives marketing system reducing such types of lengthy and complicated marketing channel. Indeed, direct marketing system helps to reduce the marketing margin, which contributes to increase the farmers' share and reduce the market price of the products. Therefore, SAC is suggested to organize programs that could gain knowledge and ideas among the SAARC countries.

10) Use of ICT tools for managing agriculture statistics and data is imperative for rational planning and policy formulation in the region (Cross-cuttings)

11) Mitigation of plant and animal trans-boundary disease and pest in the region (Cross-cuttings)

12) Climate change adaptation and mitigation in agriculture including crops, horticulture, livestock and fisheries (Cross-cuttings)

Climate change and its impact especially in agriculture is a serious issue not only in Nepal but along the SAARC region as well. The change in climate has also adverse effect in aquatic life. A wide variety of adaptive actions may be taken to face adverse effects of climate change on aquatic life. Before that, each country/region need to know, with some degree of confidence, what kind of changes in temperature, rainfall and other climatic factors its likely to face. This should be followed by necessary adaptation and coping-up mechanisms. Collaborative research activities among the member countries for development of fish breeds, rearing techniques and other suitable measures needs to be accelerated to cope up with the change in climate.

On-farm adjustments to climate change would require crop varieties suitable for late/early sowing, new cropping sequences, supply of seed and inputs on demand, water conservation, diversified production. All these call for investments. Climate change being a common challenge to all SAARC nations, more specifically to Himalayan countries as Nepal and islands like Maldives and Srilanka. The regional countries need to collaborate to promote strategies to mitigate the risks associated with climate change. Agricultural adaptation to climatic variation i.e. cereal crops, fruits, vegetable, livestock, fisheries production, and agro-forestry promotion is required. Climate smart agriculture and conservation agricultural practices are crucial for sustainable soil health and profitable crop productivity.

Conclusion

A broad range of institutions has involved in the agricultural sector within SAARC nations, including public sector, NGOs, private sector, and international organizations. Policy reforms have moved agriculture toward a more market-oriented system; the participatory approach has been increasingly adopted in the implementation of a variety of programs and institutions, including agricultural research and extension activities

have progressed more rapidly. Investment in agriculture is low but increasing in level and private sector and youth are attracted towards modern agriculture techniques and agro industry. However, there is still limited access to rural credit by farmers and agriculture in most cases is rain-fed due to lack of year-round irrigation facilities. Climate change is creating larger negative impact in agriculture sector of country and the size of the land holdings is gradually reducing which can make the production commercially unviable. Quality and food safety are emerging issues to be addressed by developing countries to compete in international market besides production volume for which a strong platform working for the mutual benefit of member countries needs to be formulated and work in harmony with each other. Also, minimum support price for farm produce through competitive market or government needs to be ensured. The situation demands alternate ways to bring in scale of operation by adopting contract farming and/or establishment of farmer producer organizations, either as companies/ cooperatives/ societies. Also attracting and retaining youth in agriculture can be addressed by encouraging agriculture as an enterprise. Involving agri-business companies in popularizing and facilitating farm mechanization, promoting Custom Hiring Centers, skilling Para technicians, facilitating maintenance support, demands strong collaboration between SAARC nations. Greater synergy and partnership efforts can meet the needs of all farmers. As, most of the farmers of SAARC countries shares common features and problems, development of regional programs and plans in close collaboration with all the members nations would be very helpful in effectively implementation of the programs and uplifting the situation of farmers of SAARC countries.

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Chapter 8

Agricultural Research and Development: Policy and Program Priorities in Pakistan

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Abstract

Pakistan is a country blessed with natural resources and enabling environment for agriculture. Of the total population (20.70 billion), almost two-thirds live in rural areas and majority of them depends on agriculture. The agriculture sector growth has exhibited an erratic pattern and declining contribution to the Gross Domestic Product (GDP) for the last decade. The livestock has always surpassed to other subsectors of the agriculture and contributes 60.5% to total agricultural output and 11.2% to GDP. The livestock, fishery and horticulture sub-sectors have enormous potential for value-added agriculture and off-farm industry development. The two-tier national agriculture research and development system exists at federal and provincial level that works through agriculture ministries, research institutes, research centres and agriculture universities. The national and international coordination and linkages are maintained at the federal level. While the agriculture policies are formulated at both national and sub-national levels that are governed by their defined policy and institutional frameworks. There is huge potential to grow and derive the inclusive growth through introducing and expediting the major reforms in agriculture sector. The focus of the agriculture policies and programs kept on changing over the time and achieved partial successes on account of mis-matched budget allocations, lack of monitoring mechanism and least integration. The off-farm sector of the rural economy is untapped that could be instrumental for inclusive growth and poverty reduction. A shift from supply-driven research to demand-driven research is deemed necessary for agriculture sector to get due share in the national and global economy. In collaboration with private sector, the crops and livestock insurance schemes are essential to protect the farmers from the vulnerabilities of agriculture to climate.

Keywords: Agricultural research, inclusive growth, off-farm, policy and program

Background

Geographic and Economic Outlook of Pakistan

Bordering the Arabian Sea in its south and China (523 km) in north, Pakistan shares longest eastern border (2,912 km) with India. While in the west, Afghanistan and Iran respectively share 2430 km and 909 km borders with Pakistan. Of the 20.74 billion population (GOP, 2017a), the major cohort (65%) resides in rural areas of the country. With an average annual growth rate of (2.4%), the population is almost in equal proportions with respect to males (50.83%) and females (49.17%). The country is blessed with diverse landscape, ranging from plains to deserts, hills, high mountains, forests, and plateaus – that spread from the southern coastal areas of Arabian Sea to northern mountains of Karakoram and arid high desert at 5,000 meters altitude. Stretched over 79.6 million hectares of geographical area, the rangelands and cultivated area in the country are 50.8 million hectares and 21.2 million hectares, respectively. With respect to vegetative cover, the crops are grown on 23.80 million hectares of land and the forest cover is on 4.21 million hectares – merely 5.89% of the total geographical area of the country. Having the best irrigation system in the region, the country's irrigated area constitutes 80% of the total cultivated area in Pakistan. Geologically, Pakistan overlaps both the Eurasian and Indian tectonic plates.

Marked and predicted slow GDP growth rate for the next couple of years, Pakistan has been struggling to sustain its economic growth for decades (Figure 1). Having achieved a sizable GDP growth of 5.8% during year 2019, the country could not maintain the pace of economic growth in year 2019 (GOP, 2019b) that declined abruptly to 3.5%. Compare to the regional economies, Pakistan's GDP growth has remained volatile leading to an erratic pattern that primarily stemmed from structural problems- like decline in investments (public and private), shortage of energy, consumption rather than investment led growth, and proneness to global financial and commodity crises.

Pakistan at 110th position on the Global Competitiveness Index (WEF, 2019), followed by Nepal (108th), Bangladesh (105th) and Sri Lanka (84th) and India (68th). Focus on economic growth without considering the elements of inclusiveness and sustainability could have serious consequences for the world in general and for the country itself in particular. However, Pakistan is now reining the fiscal and external imbalances (ADB, 2019a) through wide range of economic and structural reforms under the umbrella of Extended Fund Facility (EFF) of the International Monetary Fund (IMF).

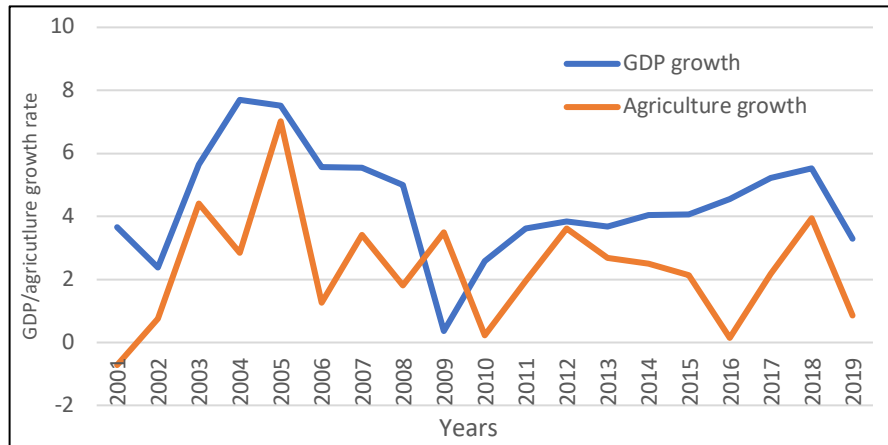


Figure 1. Pakistan's GDP and agriculture growth
Source: GOP (2019b)

Economic Outlook and Institutional Framework of Agriculture

Pakistan is bestowed with abundant natural resources and a climate that make it suitable for agriculture to flourish. Agriculture has been the backbone of the country since its independence in 1947, driving its growth and development. The agriculture sector contributed 40% of the GDP during the green revolution era in 1960s and 1970s. While lately, Pakistan's agriculture could not maintain that momentum of growth and rather became a support sector for the industry. That shift in focus to industry and services declined agriculture's share to 18.5% in GDP during the financial year 2019. The growth trend in agriculture remained erratic and declining (Figure 1). Average growth at 4-6% during green revolution period, the agriculture growth declined to 3.7% in 2000-2010, 2.8% between 2011-2014, 2.13% in 2015 and projected to be 0.85% in 2019 (Table 1).

Table 1. Agriculture and sub-sectors' growth percentage

Sector	2013	2015	2017	2019 (Projected)
Agriculture	2.68	2.13	2.18	0.85
Crops	1.53	0.16	1.22	-4.43
Important Crops	0.17	-1.62	2.60	-6.55
Other Crops	5.58	2.51	-2.51	1.95
Cotton Ginning	-2.90	7.24	5.58	-12.74
Livestock	3.45	3.99	2.99	4.00
Forestry	6.58	-12.45	-2.33	6.47
Fishing	0.65	5.75	1.23	0.79

Source: GOP (2019a)

The agriculture sector contributes 18.5% to GDP of Pakistan and employs 38.5% of the total labour force in the country (GOP, 2019a). The share of agriculture in GDP dropped from the last year share of 20.60%, predominantly because of underperformance of major crops on account of insufficient availability of water that led to reduction in area under crops and fertilizer intake. Consequently, the negative growth of -6.55% was recorded in the crop sub-sector during year 2019. The share of various sub-sectors of agriculture to GDP is; crops (6.14%), livestock (11.22 %), fisheries (0.39%), and forestry (0.39%). While major crops' contribution to valued added agriculture is 21.90%, minor crops 11.21%, livestock 60.5%, fisheries 2.1%, and forestry 2.1%. In terms of agriculture production, Pakistan is at 4th position in mango and cotton, at 5th in livestock and dates, at 7th in wheat and at 13th in rice production in the world. However, the agriculture has under-performed for the last one decade, primarily because of the stagnant productivity of almost all major crops as well as the area under major crops largely remained unchanged. Moreover, the effect of climate change has posed a serious challenge to Pakistan's agriculture, and has threatened country's water availability and food security.

Ministry of National Food Security and Research (MoNFSR) at federal level and the agriculture ministries at the provincial level provide policy and regulatory environment and funds for their subsidiary departments, institutes, centres, and universities for agricultural R&D. With the devolution of agriculture to the provinces in 2010, the MoNFSR was established at the federal level to coordinate with provincial ministries, provincial and federal research institutes, and to develop links and cooperation with the international research and development organizations. Pakistan Agricultural Research Council (PARC) is an apex organization that serves as a steering forum for policies formulation, research and development planning, and coordination. The research areas covered by the National Coordinated Research Programs (NCRPs) of the PARC include wheat, rice, maize, millet, sorghum, oilseeds, sugar crops, fodder crops, pulses, fruits, vegetables, potatoes, rangeland management, floriculture, breeding of small and large ruminants.

PARC is closely working with international organizations Consultative Group on International Agricultural Research (CGIAR) such as International Water Management Institute (IWMI), International Center for Agricultural Research in Dry Areas (ICARDA), International Wheat and Maize Improvement Center (CIMMYT), International Rice Research Institute (IRRI) and International Livestock Research Institute (LLRI), Asian Vegetable Research and Development Centre (AVRDC), Australian Centre for International Agricultural Research (ACIAR), Food and Agriculture Organization (FAO), Pacific Association of Agriculture Research Institutes (APAARI), etc.

Situation of Agricultural R&D in Pakistan

Crops Sector

More than 35 kind of crops are cultivated in Pakistan in two cropping seasons i.e. *Kharif* season and *Rabi* season. The sowing time of the “Kharif season” crops is April-till-June and the harvest time is October-December. Whereas almost opposite is the case for “Rabi season” crops as the sowing period is October-December and the harvest comes between April-May. The major Kharif season crops are maize, rice, sugarcane, bajra, moong and jawar. The predominantly grown crops in the Rabi season include wheat, lentil, gram, rapseed, mustard and tobacco. The important agricultural crops are wheat, rice, cotton and sugarcane - that respectively contribute 2.7%, 0.9%, 1.4% and 0.8% to the country’s GDP. The share of these important crops (wheat, rice, sugarcane maize and cotton) in the value addition of agriculture sector and GDP is 21.9% and 4.06%, respectively. The other crops contribute 11.21% in the value addition of agriculture sector and 2.08% in GDP (GOP, 2019a). The trend in area, production and yield of important crops is given in Figure 2.

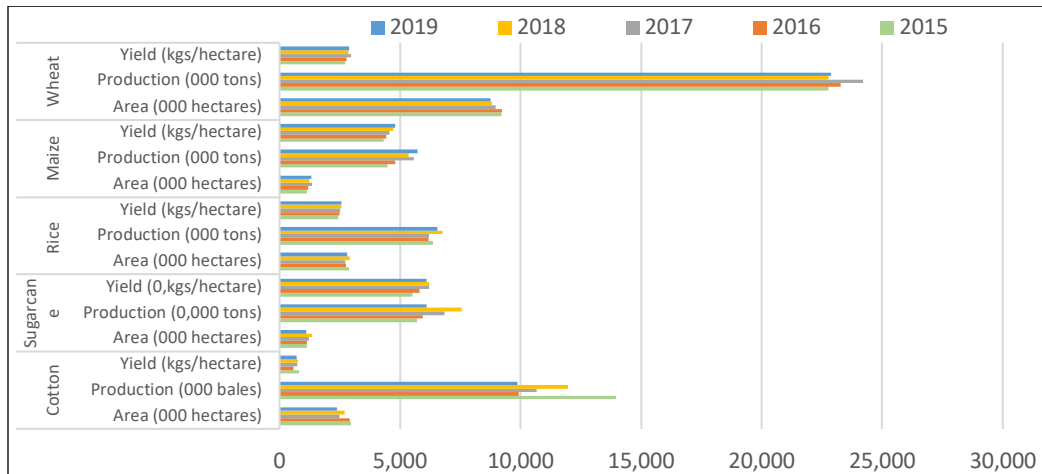


Figure 2. Area, production and yield of major crops
Source: GOP (2019)

Over the last five years, the yield of wheat, cotton and sugarcane depicted an erratic pattern, while that of rice and maize kept on growing with varied proportions (Figure 2). The main reasons for decline in the yield of cotton were unfavourable weather conditions and pest attacks. Moreover, low economic returns due to fluctuation in the international price of cotton and low purchase prices offered to the farmers by the sugar mills have resulted in decline of area allocation. Wheat production showed an increasing trend but there is also a slight shift of area to the competitive oilseed crops.

The crops’ production and productivity are predominantly hampered by environmental, agronomic, socioeconomic, institutional and technological constraints. The environmental threats are climate impacts, water lodging, soil fertility depletion, soil erosion and soil

salinity. The agronomic constraints chiefly stem from farmers’ incapability of acquiring required knowledge, capital, inputs, and market access. Resultantly, the farmers use traditional cultivation method, apply insufficient fertilizers at the critical time and more importantly use low quality cheap seed. The socioeconomic constraints include small/fragmented landholdings, illiteracy, poverty, inaccessibility to quality services and inputs.

The inequitable distribution of canal water, low water use efficiency, and inappropriate conjunctive use of canal and ground water are the issues that originate from lacking in the institutional arrangements for irrigation water management. Similarly, inadequate credit facilities for the farmers, ineffective agricultural education, research and extension services and inadequate institutional capacity for seed production are prominent institutional constraints that have adversely affected the growth of crops and agriculture in the country. Moreover, the least upscaling of existing technology and lack of awareness among the farmers about the use of modern technology and practices in agriculture are the technological constraints to crops’ productivity. Therefore, the existing yield gap between the average and potential offers a good opportunity to enhance the crops’ productivity. That could be achieved through improvement in agriculture research and extension systems, adoption of latest production and irrigation technology, use of improved inputs, proper reclamation and drainage, enhanced farmers’ access to credit and information through effective communication channels.

Horticulture

The production of horticultural crops in Pakistan is growing and the major share of that product is consumed in the domestic market. Of the total cropped area (23.80 million ha), the horticultural crops are grown on 1.48 million hectares that is almost 6.2%. Though subjected to annual variations, the overall area and production of horticultural crops in Pakistan have increased by 2.1% and 24.8%, respectively (GOP 2018a). Much encouraging is that yield of the horticultural crops has improved over the years (Figure 3).

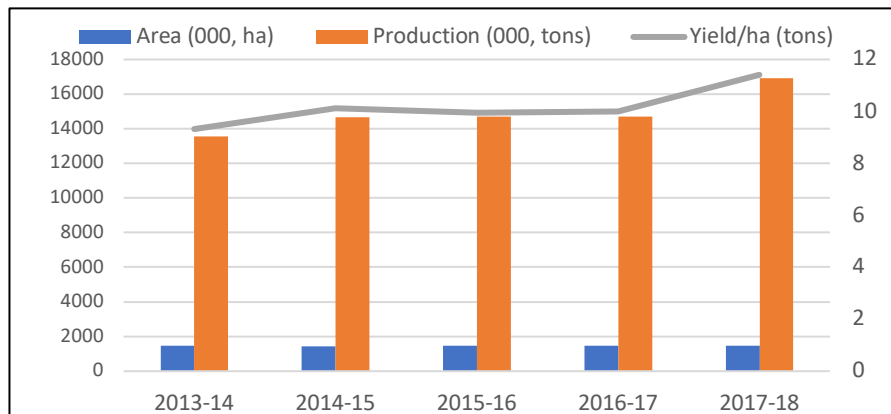


Figure 3. Area, production and yield of horticultural crops

Source: GOP (2018)

Vegetables

Vegetables constitute an integral component of the cropping pattern but the increasing pressure on food and cash crops has limited the area under vegetables to about 0.26 million hectares. More than 35 kinds of vegetables are grown in dry zone to the wet zone, low elevation to high elevation, rain fed to irrigated and low input to very high input systems. The summer and spring seasons' vegetables are tomato, chillies, brinjal, potato, cucumber, gourds and okra. During rainy season, gourds, cucumber, beans, okra and brinjal are common. The winter season is the most important for growing a wide variety of vegetables including, cauliflower, cabbage, lettuce, spinach, onion, potato, carrot, radish, turnip, coriander, fenugreek and peas. Though subjected to annual variations, the overall area and production of vegetables in Pakistan showed an increasing trend during the past five years. But per hectare yield of the vegetables remained almost stagnant during that period (Figure 4). Therefore, increase in overall production of the vegetables was primarily because of increase in area under vegetables to meet the demand of ever-increasing population of Pakistan.

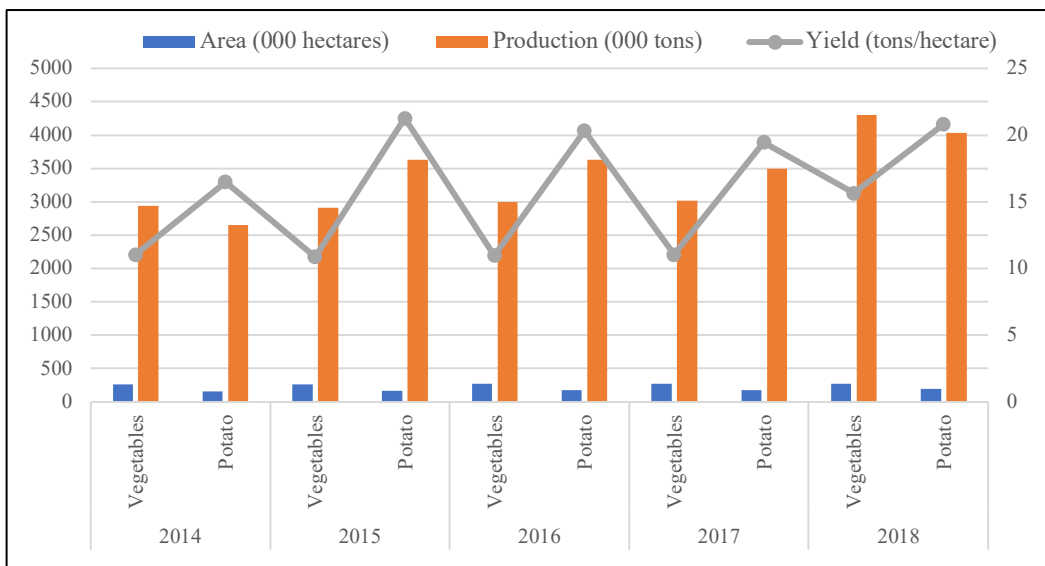


Figure 4. Area, production and yield of vegetables and potatoes

Source: GOP (2018)

Fruits and Condiments

The temperate, tropical and sub-tropical fruits and condiments¹ are grown on area of approximate 779,948 hectares with annual production of around 6,394,058 tons (GOP, 2018a). The province of Khyber Pakhtunkhwa and Northern Areas have great potential and

¹ Onion, Garlic, chillies, Coriander, Turmeric

scope for promotion of citrus fruits, peaches, plums, apricot, persimmon, apple, strawberry, guava etc. In Punjab citrus (Kino, oranges, etc.), mango, guava, while in Sindh, mango, banana, dates and papaya and in Baluchistan apple, grapes, dates, stone fruits (apricot, peach, plum, cherry, etc.) and pistachio can be targeted for international marketing by promoting processing industry for value addition and export. The area, production and yield of fruits shows the increased production of fruits over the years.

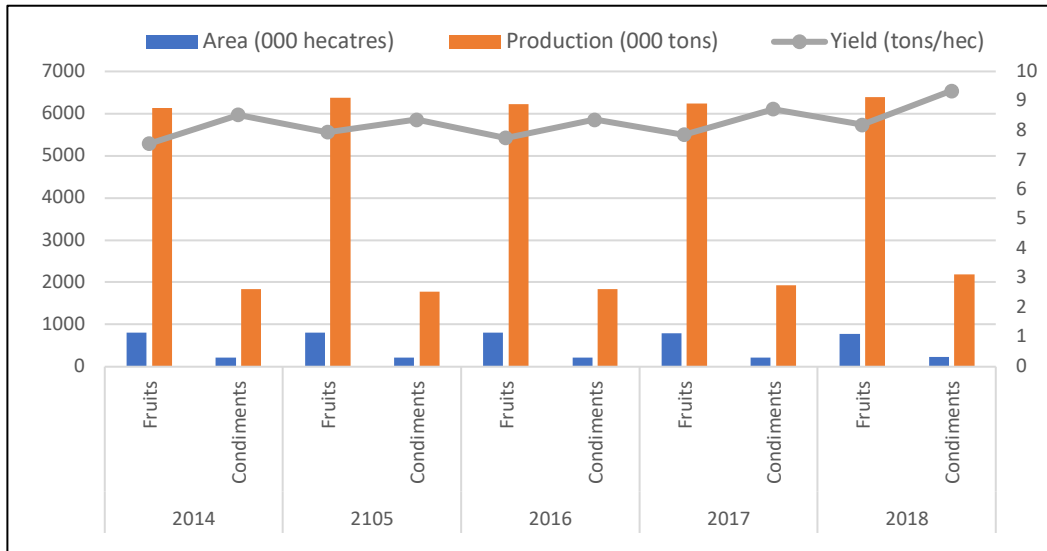


Figure 5. Area, production and yield of fruits and condiments

Source: GOP (2018)

Challenges and Opportunities in Horticulture

The farmers cannot realize the maximum benefits of horticultural products for not having proper knowledge of production practices, picking and packing. There is lack of specialized extension services to educate the farmers about post-harvest handling and management of their perishable produce. Therefore, the post-harvest losses of fruits and vegetables are about 20- 30% of the fresh produce due to mishandling in the supply chain. The structural change needed in the horticultural industry to make it compatible with the requirements of the global buyers and highly sophisticated market. The needed structural adjustments include value-chain integration, quality-control, certification mechanisms, private-led integrated growth and policy environment enabling public-private partnerships.

Being a labour- intensive sector, it provides on-farm employment to relatively a large rural population and also creates many off-farm livelihood opportunities in the area. The way forward is the reforms in institutional and market structures, technology change, innovations and entrepreneurship in the horticulture sector. The marketing system can be

improved by increase the number of markets, minimize the monopoly of powerful licensed dealers from public-sector run fruits and/or vegetables markets, determine fair-value of the marketing margins and commissions, ensure equitable access to market information, and improve infrastructure for transportation, display and storage. The China – Pakistan Economic Corridor (CPEC) is a great opportunity for this sector to flourish.

Livestock

Livestock sector is one of the fastest growing segments of agricultural economy in Pakistan. The sector constitutes 60.5% to total agricultural output and more than 11.2% contributes to overall GDP of the country. The value of livestock sector is greater than the combined value of major and minor crops in agriculture. The share of value-added livestock products along with live animals exceeds 3.1% of total foreign exchange earnings. More than 80 million families are engaged in livestock farming and earn around 30-40% of their livelihood from this sector. The livestock sector exhibited an annual growth (4%) larger than overall growth (0.85%) of agriculture (GOP, 2019b). Pakistan is ranked fourth amongst high milk producing countries, and buffaloes and cattle being major milk producing animals (approx. 97%). Beautiful blends of local and cross breeds of cattle, buffaloes, sheep and goats are being reared by rural farming communities from small to large scale. Inclusion of imported breeds has resulted in substantial increase in animal productivity. Commonly found cattle breeds in the country are Dajal, Cholistani, Achai, Red Sindhi, Bhagnari, Gibrali, Lohani, kankari, Sahiwal, Thari and Rojhan. Amongst these breeds, Red Sindhi, Sahiwali and Cholistani, having distinct features, are internationally well known.

Over the time, the estimated population of the livestock has increased, particularly of dairy animals. The evidence from the last three years’ data in Table 2 proves a greater positive change in the population of cattle (8%), followed by buffaloes (6%), goat (5%), assess (4%) and sheep (3%). With increase in the population of dairy animals, the production of milk increased by 6.6% over the base year 2017. Relatively more positive change was recorded in the production of cow-milk (7.7%) as compare to buffalo-milk (6.6%). The meat production has increased by 10.3% in the last three years and the major increase was recorded in the production of poultry meet (Table 3).

Table 2. Estimated livestock population in Pakistan (million Nos)

Years	Cattle	Buffalo	Sheep	Goat	Camels	Horses	Assess	Mules
2016-17	44.4	37.7	30.1	72.2	1.1	0.4	5.2	0.2
2017-18	46.1	38.8	30.5	74.1	1.1	0.4	5.3	0.2
2018-19	47.8	40.0	30.9	76.1	1.1	0.4	5.4	0.2
% Change	8	6	3	5	0	0	4	0

Source: GOP (2019b)

Table 3. Milk and meat production (,000 tons)

Species	2016-17	2017-18	2018-19	% Change
Milk (Gross Production)	50875	52517	54213	6.6
Cow	18273	18963	19678	7.7
Buffalo	30955	31875	32822	6.0
Sheep	35	36	36	2.6
Goat	808	830	853	5.5
Camel	803	813	824	2.6
Meat	3684	3866	4062	10.3
Beef	1891	1955	2020	6.8
Mutton	636	650	664	4.4
Poultry meat	1158	1262	1377	19.0

Source: GOP (2019a)

Constraints and Remedies on Livestock Sector

Speedy deterioration of natural rangelands in the country is leading to limit nutrients' abundant food supply to the livestock. Moreover, most of the farmers hesitate to switch to formulated balanced livestock feed; instead strictly adhere to conventional feeding pattern. Despite serious efforts at government end, majority of the smallholder livestock farmers has not access to adequate quality veterinary services. Though livestock regulatory measures encouraged imports of livestock breeds, vaccines, equipment and machinery; but still the sector lack in superior germplasm that enhance animal productivity.

There is lot of room for development in institutional structure and regulatory framework to protect the producers from ruthless behavior of market functionaries and middle men. There is need for establishing large scale breeding farms through corporate livestock farming to develop high yielding cattle and buffaloes. Quality, balanced and nutritious feed for both fattening and dairy animals is quite essential. As against crop segment of agriculture, the livestock farmers have no better access to credit and it constitutes only 11% of total agricultural credit extended to the farmers across the country. The government may use appropriate policy instruments, particularly on price, institutional, and technological change.

Fisheries

The Arabian Sea and plenty of inland waterways (rivers, lakes, dams and ponds), extended across the country, provide suitable climatic conditions for the aquaculture. The fish sector contributes nearly 0.4% to GDP and employs 0.39 million people directly (Patel et al., 2018). It contributes 2.1% to agriculture value-addition (GOP, 2019a) and more than 0.4 million people get off-farm employment in the ancillary industries of fishery sector. The marine waters' capture, inland capture and aquaculture are the common sources of fish

production in Pakistan. The estimated total production of fish is 6,3400 tons (GOP, 2019a) and the marine water's capture is 430,000 tons. Compare to the previous financial year, the fish production grew by 0.79%. Though fishery sector has a minimal contribution to GDP (0.39%) but it is a good source of livelihood for coastal inhabitants and the export earnings (US\$ 293.9) for the country, albeit only 23% of the total fish and fish products is exported. The major export of fish and fish products are to China, Malaysia, Thailand, Hong Kong, South Korea, Bangladesh, United Kingdom, Egypt, Middle East, Japan and Sri Lanka.

The fisheries R&D has been assigned to the provincial governments. Pakistan has no fishery research vessels, therefore, largely depends on foreign vessels that are not usually available. The country is emphasizing on maintaining quality control to enhance its exports to European Union (EU) countries. Various quality control laboratories (Microbiology, Hydrology, Chemistry, Biological and Biochemical laboratories) of the Marine Fisheries Department (MFD) are involved in chemical analysis and quality control of seafood. The Microbiology and Chemistry laboratories of MDF have got the status of accreditation under ISO/IEC-17025 from Norwegian Accreditation Body and Pakistan National Accreditation Council (PNAC). National Policy and Strategy for Fisheries and Aquaculture Development in Pakistan was formulated in 2007 by the then Ministry of Food Agriculture and Livestock (MINFAL). Then after devolution to provinces, *Sindh Fisheries and Aquaculture Development Strategy (2010-13)* was formulated for the propagation and growth of aquaculture in the province.

Constraints and Remedies in Fishery

Lack of planning and governance in the fishery sector are the major reasons for slow growth in the aquaculture industry. Use of outdated technologies, poor quality control mechanism and focus on low-grade products (fish meal) have hampered the post-harvest processing of fish in Pakistan. Speedy loss of mangroves along the coastal line could be a serious threat for the survival of offshore fisheries leading to reduced commercial activity and will minimize the livelihood opportunities for the inhabitants (Amjad et al., 2016). There is also very limited Aquatic Animal Health (AAH) surveillance despite the existence of Animal Quarantine Ordinance and requirement of health certificate for live aquatic animals. Heavy accumulation of the metals in the cultured fish from the agriculture and industrial sources are serious threat to freshwater aquifer (Chatta et al., 2016).

The maximum nutritious benefits for human health could be attained from the fish for being a rich source of essential nutrients, protein, and healthy fats (Work Bank, 2015). This is the best time for Pakistan to go for "**Blue Revolution**" to enhance cultured and captured fish production with prime focus on value addition for both domestic and foreign market. Additionally, the management practices to be focused on maintaining biodiversity, ensuring judicious use of scarce resources, and maximizing the economic and social benefits to build healthy and strong nation. (Patil et al., 2018). Innovative approaches that aim on helping the fishermen and support in the establishment of effective supply chain

could play important role in the natural resource management to save for the future generation (FAO, 2015). The country has to spend precious foreign exchange on the import of seed of shrimp and sea bass at costly price. The government and the private sector should come forward to invest in the untapped potential of fishery culture and save the precious foreign exchange of the country.

Natural Resource Management

Natural resource management brings together the water management, land use planning, biodiversity conservation, and the future sustainability of the industries like agriculture, mining, tourism, fisheries and forestry. Different countries have focused on conservation of different resources, depending on their scarcity, importance and vulnerability. Like wildlife management is the most prominent area of natural resource management that associate with ecotourism and rangeland management in USA. In Australia, water sharing and catchment area management is at the top priority in NRM. While Pakistan has prioritized conserving water and forestry for future generation of the country.

Geographic location of country makes agriculture and food system vulnerable. On the Global Climate Risk Index 2017, the country is ranked as 7th most affected country from natural calamities (Eckstein et al., 2018). With an estimated population of 227 million by 2025, Pakistan's current water availability of 1100 cubic meters per person, down from 5,000 cubic meters in 1951, classifies it as a "water-stress" country, that is headed toward becoming a "water-scarce" country if action is not taken urgently (GOP, 2014). The major threat to the natural resource is the climate change. The risks associated with the climate change are increased frequency and intensity of floods, prolonged droughts, melting of glaciers on Himalayan mountains, shift in disease vectors, and hurricanes. Similarly, there are growing risks of water scarcity for drinking, sanitation and agriculture. Decline in biodiversity is another threat to natural resources in Pakistan.

Water resource

A comprehensive "National Water Policy 2018 (GOP, 2018b) is approved by the Government of Pakistan, Ministry of Water Resources. The policy is comprehensive reviewing the past policies to address all the prevailing and foreseen challenges to water in Pakistan. The highest tier institutional structure for the governance of the policy is National Water Council (NWC) headed by the Prime minister of Pakistan, the Chief Ministers of all the provinces, relevant ministers and secretaries as members. The policy envisages the implementation of the water related provision in The *National Environment Policy (2005)* and *National Climate Change Policy (2012)* in letter and spirit. The policy also takes into account the establishment of the resilient irrigation/flood infrastructure as envisaged in the National Disaster Risk Reduction Policy approved in 2013 (GOP, 2013).

The 11th Five Year Plan (2013-18) focused on the adoption of modern technology in agricultural production-practices for sustainable management of natural resource-base,

particularly, the sustenance use of water and land resources of the country. Revamping of the whole agricultural research system to address through the provision of adequate capital, introducing incentive structure and putting in place the robust monitoring and evaluation system to track the progress and measure the impact of innovative research and technology on sustainable development of agriculture.

Microbial genetic resource

Of the genetic resource preservation, the microbial culture is the least-considered resource for management. The PARC initiated Microbial Genetic Resource Program (MGRP) with an aim of offering services for the preservation and supply of microorganisms. For the preservation, the program is using techniques that maintain purity, important traits and viability of the microorganisms. The main driver for establishing MGRP in PARC was the growing realization of the importance of microbes in agriculture, biotechnology and industrial applications. The PARC has also established an Institute for Microbial Culture Collection of Pakistan for the preservation of microbial bio-assets collection across the country. The institute collects many strains from various institutes for identification and preservation in National Culture Collection of Pakistan.

Agro-forestry

Agro-forestry has strong linkages with the sustainability of natural resources and agriculture. Currently, neither the MoNSR nor the Ministry of environment own this sector. Eventually, there is limited resources allocation for agro-forestry and almost non-existence of research, development and extension services. However, the 11th five-year plan proposed the constitution of a committee for systematic development of the agro-forestry through establishment of institutional structure at federal and provincial level, future outlook for preservation of natural resources, need for research and development, existing legislation and policy environment, economic value of the suitable species for different ecological zones, training and technology transfer and prospects of social forestry. The plan also encompasses the assessment of agro-forestry, promotion of community -based interventions, development of medicinal plants, and establishment of bamboo research institute to enhance bamboo production.

Challenges and Opportunities in Agricultural R&D

i. Integrated Policies and Programs

The agriculture research and planning, based on the endoscopic analysis of the agriculture system, could not yield the desired results. Rather, placing agriculture sector in the overall economic framework of the country and relating its issues and problems with the broader economic framework and the policy environment could lead to better strategize agriculture R&D in the country. Hence the integration of the policies and programs is essential to gain the path of growth trajectory.

ii. Climate Change

The South Asia in general, and Pakistan in Particular is under high risk of natural disasters like floods and earthquakes. To cope with such adversaries, there is need to integrate risk reduction measures into national development strategy and investment plans. More spending on the mitigation measures is better than on response and rehabilitation. Similarly, there is need of pooling risks through insurance and reinsurance (ADB, 2019b), particularly of crops and livestock. Unfortunately, no serious attempts have been made so far in Pakistan towards the insurance of the crops and livestock. In year 2012, the International Fund for Agricultural Development (IFAD) supported Pakistan Poverty Alleviation Fund (PPAF) to seek the potential for both crops and livestock insurance for small farmers through their established Community Organization (COs). But working in isolation of the agricultural research systems could not win the favour and ultimately could not come on ground. Therefore, this is the area that needs to be focused in Pakistan.

iii. Innovation and technology adoption

The technology has played greater role in the enhancement of agriculture productivity. But the countries should think about it in view of human capital investments and mitigation of unintended adverse impacts of the technology advancements. So, the technology governance has to be at par of the technological advancement and the countries should better balance technological integration and human capital investments. The state of the adoption of Information Communication Technology (ICT) in Pakistan is quite meagre. No evidence of serious effort made in the use of ICT in agriculture in Pakistan. Similarly, innovation capability, product market, skills, and institutions are the indicators wherein the country is far behind the competitiveness frontier – thus demanding immediate attention to play their potential role in productivity.

iv. Land-use-efficiency

Optimal utilization of the state-owned land has never been realized by the governments, rather the allotment of such precious land has always been made to gain the political motives. Hundreds of thousands of the acres of the state-owned land has either been allotted at a nominal price or have been occupied by the land mafias in the Pakistan. No serious attempt has been made to recover such land so as to rent out at market competitive price. In 2010, the then Punjab Government took an initiative of allotting state-owned 12.5 acres of irrigated-land or 25 acres of arid-land to each agricultural graduate for five years. But the land mafias, with complete support of the land revenue department, impeded to materialize such a productive program. Therefore, there is need to revive such kind of the programs to ensure the optimal utilization of state land, improve agriculture productivity and create employment for the agricultural graduates.

v. Agriculture extension services

An effective agricultural extension helps to reduce the yield-gap between the actual and potential through technology transfer and supporting the farmers to become good manager (Anderson & Feder, 2003). But the traditional model of extension services (trainings and field visits) is practiced in Pakistan. The steps towards the specialized knowledge and use of Information Communication Technology (ICT) and the deployment of women extension agents are still at nascent stage. The 11th five-year plan (2013-18) envisaged to equip the extension services with ICT and deployment of specialized staff to encourage the precision agriculture and high value crops such as vegetable, fruits and floriculture. Very few of the multinational companies (Engro, Syngenta, etc.) and big national companies (Rafhan) provide direct advisory services to the farmers but for limited and selected crops. By and large, the private sector stands no-where in agriculture extension services to the farming community. And very much concerning is that the processing industry and manufactures are completely out of the picture who have to convert commodities into products.

vi. Women role in agriculture

Whenever is realized the role of the women in agriculture, it has always been their on-farm engagement like rearing rural poultry and livestock, feeding and milking of animals, cutting grasses, plantation, etc. In the era of emerging technologies, the agriculture is to be realized as an industry – rather a mother industry- and the role of women as an entrepreneur, value-chain actor, supply chain agent, etc. Why only on-farm activities why not women in off-farm activities. The women's participation and role in agricultural activities varies across the countries and regions subject to social and cultural bindings (World Bank, 1994; FAO, 1999; Mohammed, 2002; Mwange, 2004). In most part of the world, women are reported to work more efficiently than men in raising and managing livestock (Ishani, 2004). While looking at women's specific activities, these particularly include milking animals, caring young calves and sick animals (Bekure et al, 1991). They usually perform livestock and poultry management as housework. Majority of the rural women remain engaged in fodder cutting, milking, collecting manures and making dung cakes (PARC, 2004). They work shoulder by shoulder with men from dawn to dusk in catering crops and livestock (Habib, 1996); and are equally efficient in performing assigned tasks (Ahmed & Hussain, 2004). Further, women are found relatively more devoted to their work than men (UNDP, 1997; FAO, 2001). Despite being complementing member and significant contributor of households' economic activities, the woman role in major household's decisions looks negligible in Pakistan. Their work as a part of house work have not been considered in to account.

vii. Agriculture inputs and output markets

The market mechanism should give equitable access to market, real time prices, and ensure quality transactions. Such market mechanism provides opportunity for the investment in value-added agriculture through processing of livestock and horticultural products. There is too much room for the development of agricultural market at the level to meet the emerging global needs. The market information should enable the show-casing of the national commodities and products to the global customers. Like, growth (of 8.8%) seen in the production of rice during year 2018, needs to explore export opportunities in China and the European Union (EU), as the later has banned the rice import from India on account of excessive spray of a fungicide (tricyclazole) on rice crop (GOP, 2018b). Similarly, potential opportunities for export of wheat could arise in Asia and Africa.

Review of Agricultural Policies and Programs

Agriculture Policies

The major policies related to agricultural research and development are National Commission on Agriculture- 1988, *The National Agriculture Policy- 1991*, Framework for Economic Growth- 2011, *National Food Security and Agriculture Policy- 2017*. These policies framework looked for inclusive growth through structural reforms, productivity enhancement, youth engagement, along with national food security. Over the years, these documents exhibit the shift in focus of agriculture policies. These emphasized on crops' yield, land reforms and governance. Recently, the focus has shifted to food security, inclusive growth, and bio-diversity. The performance of those policies remained mixed in meeting set objectives. For instance, the policies under five-year plan (1960-65) and Green Revolution promoted use of inputs and modern technology, markets' stabilization, infrastructure development for irrigation, research and extension, that remained effective to spur growth in the agriculture sector (average 4%). Whereas, the attempts made for land reforms in 1959, 1972 and 1977 could not limit the size of landholdings. The policies to regulate water remained successful in the earlier years but later on, could not deal with the persistent problems of inadequate storage, and low water productivity.

Pakistan adopted a long-term development strategy "*Pakistan Vision 2025*" in 2014 (GOP, 2014). The strategy envisages macroeconomic stability through inclusive growth and zero-hunger by the adoption of innovative technologies and cost-effective approaches to production. For the implementation of vision 2025, the MoNFSR developed a *National Food Security Policy 2017* (GOP, 2017b) to alleviate the food insecurity. Similarly, the *National Zero Hunger Action Plan (2012-17)* is a five-year plan to target 61 million people who are food insecure. To cope with the effects of climate change, the Government developed the "*Framework for the Implementation of Climate Change Policy (2014-2030)*" to create enabling environment for integrated and climate-compatible processes.

The developed strategies and policies in the past were very much elaborated and comprehensive but mismatched-budget allocations, lack of monitoring mechanism, and more importantly, no integration of agricultural policies with the overall policy framework of the country. It's time to shift the focus from major crops to high value crops, livestock and off-farm enterprises to meet the changing demand of the domestic and international market. A paradigm shift in agriculture is required to capture unique opportunities, created by CPEC, in terms of a big food market of China (imports over US\$ 500 billion every year) and access to central Asian states for value-added agricultural products.

Very well-defined investment priorities are to be set and major cuts should be made on the expenditures for procurement, storage and distribution of wheat and subsidies to the fertilizer industry to keep fertilizers price low. Divert funds towards the high value addition to agricultural products and promotion of efficient supply chains. A greater need is to develop institutional capacities, coordinate and intergrade policies at different level of government tiers. Similarly, the development of an appropriate water policy is required to ensure judicious use of scarce water resources, increasing water-use efficiency and introducing an efficient irrigation system.

Agriculture Programs

One of the intended outcomes of the United Nations Sustainable Development Framework for Pakistan, is "*Food Security and Sustainable Agriculture*" (United Nations, 2018). With an aim to "improve economic growth, agricultural development, and food security in Pakistan", the United States Agency for International Development (USAID) launched a \$30 million initiative named as "Agricultural Innovation Program" in year 2013 (USAID, 2013). The program was designed in a way to provide a platform for building partnerships between research and its allied services like knowledge generation, sharing and making use of it; development impact awareness raising and showcasing the returns from agricultural innovation. Therefore, the AIP program attempted to revitalize the contribution of science, technology and innovation to agriculture, strengthen the innovative capability of scientific communities and deepen the linkages with Pakistan's agricultural research community and the wider global community of agricultural research.

Punjab Agriculture Department (PAD) has included youth engagement (agriculture graduates and post graduates) under the agriculture policy framework through grants from Agriculture Innovation Fund. In order to establish institutional structure, the groups of agriculture graduates will be developed in district universities under the Higher Education Commission (HEC) Entrepreneurship Development Programs. They shall operate under university academics to give necessary skills and their clients, the small farmers to operate small business. The policy will be instrumental in establishing linkages between universities, private sectors and Extension Directorate.

Under the policy, the PAD has realized to shift from supply-driven to demand-driven research but lack in capacity of determining the opportunities. Therefore, highlighted the need for the establishment of technical structures to identify the priorities, determine the human and funds requirements and monitoring the progress. Punjab has taken a step forward towards the establishment of Commodities Research Board (CRB) through engaging experienced farmers, processors and exporters from the private sector.

Recommendation of Priority Programs

The paper sets out theme-wise priority areas, projects and programs that could provide supports for agricultural growth in Pakistan.

1) *Enhancing production of demand-driven crops in Pakistan (Crops)*

Background and Justification

Why do our policies and programs revolve around the promotion and propagation of traditional important crops? Why not shift to the ones that are in demand? Emerging connectivity opportunity through CPEC demand for change in crops' cultivation. Keeping in mind the potential accessible consumer markets in near future, an evidence-based modelling of area-allocation for potential crops along with complete facilitation environment in the shape of technology package, inputs and guaranteed prices are needed for agricultural and economic growth of the country.

Objectives

- Identify exportable crops and efficient technologies for production and processing.
- Effective supply-chain and/or value-chain actors and advocate government for creating enabling policy environment to promote agriculture processing and business industry.
- Revitalize the education and research extension services through specialized extension agents and experts.

Expected outputs

- Research priorities are aligned with the growth strategy of the country.
- Crops, having export and processing potential, are identified and cultivated.
- Technical support, extension services and technology packages are given to the farmers.
- Enabling policies are formulated to encourage the cultivation and production of selected crops.
- Value-chain and supply chain of the selected crops are built and functional.

2) Horticulture oriented off-farm industry and enterprises development (Horticulture)

Background and Justification

Whenever is talked about inclusive growth and poverty, the rural economy comes first. The agricultural production and On-farm labor have the major share (probably 90%) in the rural economy. But the allied off-farm opportunities haven't been recognized as an engine of growth for agricultural and rural economy. Having said that the improved production technologies contribute towards the agricultural growth but the outcome of that supply-side driver could be manifold in the rural economy with the development of off-farm industry and enterprises.

Objectives

- Explore potential for off-farm small industries in different agro-ecological zones.
- Identify and establish feasible supply-chains and markets for the products of off-farm industries within and outside the country.
- Effective M&E mechanism to progress tracking and information management for separate recording of off-farm contribution to rural economy and GDP.

Expected Outputs

- Identified and recorded the types and numbers of potential off-farm small industries segregated by climatic zones, administrative units, gender and business volumes.
- Initiated various types of off-farm enterprises and small-scale industries in the potential villages.
- Conducted the skills gap analysis of the rural labor force and market assessment of rural labor force for off-farm analysis.
- Trained and capacitated the rural labor force with the skills in demand, rural entrepreneurs with business development, and the investors initiation and management of their industry.

3) Livestock oriented off-farm industry and enterprises development (Livestock)

Background and Justification

The livestock sector boomed since the milk collection centers and chillers reached the farmers door-step in their villages. The families get attracted to sell their milk and get daily returns of their hard-work. But the full potential for off-farm small industry and enterprises is not realized by the formers and investors. The livestock oriented off-farm industry could be a Game-Changer for the rural economy in general for women in particular. This is almost unexplored area in the rural economy and no serious attempt has been made in the past.

Objectives

- Explore potential for Off-farm small industries and enterprises in different agro-ecological zones of the country.
- Identify and establish feasible supply-chains and markets for the products of off-farm industries within and outside the country.
- Effective M&E mechanism to progress tracking and information management for separate recording of off-farm contribution to rural economy and GDP.

Expected Outputs

- Identified and recorded the types and numbers of potential off-farm small industries segregated by climatic zones, administrative units, gender and business volumes.
- Initiated various types of off-farm enterprises and small-scale industries in the potential villages.
- Conducted the skills gap analysis of the rural labor force and market assessment of rural labor force for off-farm analysis.
- Capacitated the rural labor force with the skills and rural entrepreneurs with business development.

4) *Aquaculture development of trout and shrimp (Fisheries)*

Background and Justification

Due to larger dependence on marine fishery and least domestic consumption for fish, the real potential of aquaculture is not explored yet. With the likelihood of improved connectivity through CPEC, the culturing and farming of Trout and Shrimp fish at commercial scale could be a handy source of export earnings for the country. The current inland catch of trout fish from the northern hilly areas does not meet the domestic demand. Hence, the promotion of Trout and Shrimp is very essential for the economic growth and nutritious food for the nation.

Objectives

- Promote the culture and production of the Trout and Shrimp farming at commercial scale.
- Establish hatcheries, and multiplication and propagation farms at suitable places in the country.
- Awareness raising on benefits of fish consumption, fish farming and fishery business.

Expected outputs

- Established farms for culture and propagation of trout and shrimp farms.
- Private investment in fishery sector increased for the establishment of infrastructures, equipment, machinery, feed, seed, etc.

- Domestic production, consumption and exports increased to many folds.

5) *Fishery oriented off-farm industry and enterprises development (Fisheries)*

Background and Justification

The fishery sector has great potential to provide input for the establishment of off-farm industry and enterprises. Not only the marine culture has the potential for such opportunities, rather inland and aquaculture has great potential to support the small-scale industry. Till now, the potential of off-farm small industry and enterprises is not realized by the fishermen and investors. The fishery oriented off-farm industry could be instrumental for the rural economy, particularly the marginal segment of the society.

Objectives

- Explore potential for off-farm small industries and enterprises in marine, aquaculture, and inland fishery across the country.
- Identify and establish feasible supply-chains and markets for the products of off-farm industries within and outside the country.
- Effective M&E mechanism to progress tracking and information management for separate recording of off-farm contribution to rural economy and GDP.

Expected Outputs

- Identified and recorded the types and numbers of potential off-farm small industries segregated by fishery culture & catch, administrative units, gender and business volumes.
- Initiated various types of off-farm enterprises and small-scale industries at the potential sites.
- Conducted the skills gap analysis of the rural labor force and market assessment of rural labor force for off-farm analysis.
- Trained and capacitated the rural labor force with the skills in demand, rural entrepreneurs with business development, and the investors initiation and management of their industry.

6) *Restructuring and modernizing agricultural markets in Pakistan (Agricultural Policy)*

Background and Justification

The use of Information and Communication Technology (ICT) in marketing has provided an innovative interface to the producer, intermediaries and consumers for information, interactions and transactions. It has provided an easy access to information for all market-functionaries related to price, quality, certification, traceability, etc. Improving access to the agriculture markets and providing opportunity for show-casing the horticultural

products on the national and international marketing dash-board is very essential to promote country's growth. Therefore, there is need to restructure, capacitate and well-equip the existing agricultural markets in the country.

Objectives

- Provide equitable access to all for licensed dealer-ship of the public-run agricultural market and determine fair commissions.
- Explore public-private partnership for investment in infrastructure and market-control mechanism to make it more efficient and responsive to both producers and consumers.
- Integrate agricultural markets internally and internationally through ICT for improved competitiveness and exports.

Expected Outputs

- More markets are established, and infrastructure of existing and new markets is at par with the current requirement.
- The market facilitating functionaries are provided with required trainings and capacitated through provision of deficient resources.
- ICT-based dissemination of market information is in place and modern means of auctions are in practice.
- Inter and intra-markets integration as well as integration with value-chain actors established and in use.

7) *Weather-based agriculture insurance in Pakistan (Agricultural Policy)*

Background and Justification

The general insurance industry in Pakistan is still at nascent stage. Recently, the insurance culture is propagated in vehicles for being compulsory for the bank-leased vehicles. But the health insurance program of GOP has earned popularity across the country. Now is the time to work for agriculture (crops) insurance to safeguard the farmers. Though, the State Bank of Pakistan (SBP) has issued directives to the banks for ensuring insurance cover of agri-credit but that does not cover the small farmer who have no access to credit at all. Moreover, the changing climate conditions have further enhanced the uncertainty in crops' success.

Objectives

- Determine the marginal productivity of important crops with respect to weather parameters depending crop physiology.
- Seek support of Pakistan Space & Upper Atmosphere Research Commission (SUPARCO) for real time weather data and develop centralized system of weather tracking.

- Estimate the premium prices and the levels of triggers for insurance pay-offs.
- Advocate government for subsidy provision at the earlier stages of the projects and gradual withdrawal of subsidy.

Expected Outputs

- Agro-ecological zones-based marginal productivity of all main crops and cash crops are determined and in use for weather-based insurance modeling.
- Linkages are built with SUPARCO for data provision and integration with information system of the project.
- Subsidies are provided to the farmers for paying premium for at least three years.

Conclusion and Way Forward

The country has made significant progress in research and development of agricultural crops, however disparity exists in resources' allocation, policies and programs for various crops and sub-sectors. Setting research and development priorities, in accordance with the demand-side requirements and preferences, will require institutional and structural reforms in the agricultural research system to embed the inclusive and participative approach.

What's needed is the formulation of an appropriate agricultural strategy rather than going with the stereotyping in crops' cultivation and other sub-sectors. Therefore, the policy makers, researchers, food processing industrialists, seed companies and producers should come together to devise an agricultural strategy encompassing long-term and short-term plans that are very much aligned with the country-development-strategy. The failure of the policies and programs generally occurs due to mismatched-budget allocations, lack of monitoring mechanism, and integration. The concept of monitoring and evaluation (M&E) mechanism is almost non-existent in agricultural projects and programs. Therefore, M&E mechanism should be made compulsory for each agricultural project and program to gauge the extent of achievement of set outputs, outcomes and results.

A major change from supply-driven-research to demand-driven research is required to address the emerging and changing demands for agricultural commodities and products. It's time to shift the focus from major crops to high value crops, livestock and off-farm enterprises to meet the changing demand of the domestic and international market. The real potential in off-farm industry and enterprises have never been explored. By providing enabling environment, this hidden potential of the rural economy could not only be instrumental in economic growth but would lift the marginalized segment of the society from poverty.

Agriculture is the most volatile and vulnerable sector but the farmers engaged in agriculture sector are least protected in the country. Despite having least access to

agricultural credit, their crops and livestock are also not ensured. In collaboration with the national and international insurance companies, agriculture research institutes and SUPARCO, the ministry of national food security and research should take lead on the development of weather-based crops insurance schemes. Similarly, there should be an insurance scheme for the dairy and fattening animals. Moving forward, the country has a great opportunity of global-connectivity through CPEC; so making competitiveness of the agricultural products to compete with international market is crucial in Pakistan.

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Chapter 9

Agricultural Research and Development: Policy and Program Priorities Sri Lanka

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Abstract

Sri Lanka is an upper middle level income country having Gross Domestic Product (GDP) per capita income of US\$ 4,102 with a total population of 21.6 million. The agriculture sector has been significantly declining over decades and contributes 8% to the GDP in 2018. However, about 70% of the people still live in rural areas and they mainly depend on agriculture. The agriculture sector faces number of challenges including lower production and productivity, lack of quality of improved seeds, depleting land quality, increased cost of production, labour scarcity, less mechanization, weak value chain development and climatic resilience, and declining youth in agriculture, etc. The government policies for agriculture sector development envisage the expansion of export food products of the comparative and competitive advantageous agricultural products giving attention on cropping patterns which consume less water, fertilizer and agrochemicals. It also highlights the incorporation of climate resilience factors in enhancing production, modernization of agriculture through technological innovations, use of effective water management technologies to increase agriculture production and productivity. The agricultural policies are aligning with Sustainable Development Goals (SDGs) mainly ensure food and nutrition security of people substituting possible imports through increased production. Promotion of Good Agricultural Practices (GAP) and value addition for agriculture produce are aligned with self-sufficiency in rice and increase the contribution of other food crops, vegetable and fruit crop sub-sectors are also vital for achieving major agricultural objectives of the country.

Keywords: Good agriculture practices, agriculture modernization, value addition, Sri Lanka

Background

Sri Lanka is an island with a land area of 65,525 km² and located between 50 54' and 90 52' north latitude of the equator and 790 39' and 810 53' east longitude. The island has a

maximum length of about 435 km and maximum width is nearly 225 km. The climatic pattern of the country is determined by the monsoonal rainfall patterns in the surrounding oceans. Rainfall is monsoonal and convectional, and 55% of island rainfall comes from the monsoons. The mean annual rainfall ranges between 900 mm to 6,000 mm. The country is divided into three broad climatic zones; wet zone, dry zone and intermediate zone on the basis of rainfall and its distribution as well as on the elevation (Figure 1).

The mountains and the southwestern part of the country, known as the "wet zone," receive annual rainfall of 2,500 mm. Most of the southeast, east, and northern parts of the country comprise the "dry zone", which receives between 1,200 mm and 1,900 mm of rain annually covering two thirds of the country. Much of the rain in these areas falls from October to January; during the rest of the year the rainfall is limited.

Sri Lanka is an upper middle level income country with Gross Domestic Production (GDP) per capita income of US\$ 4,102 and a total population of 21.6 million in 2018. Due to the increasing population pressure, the land: man, ratio is declined. The economy grew at an annual average of 4.8% during the period 2012 to 2018. However, the economic growth rate was showing lower value during the period 2016-2018 compared to 2012-2015. This is due to adverse weather conditions affecting agriculture and slowing growth in manufacturing and services sectors (CBSL, 2018 a).

The country's main economic sources are tourism, tea export, textile industry, rice production and other agricultural related primary products. In addition to these economic sectors, overseas employment, especially in the Middle East, contributes substantially in foreign exchange earnings. In 2018, the services sector contributes 62%, industrial sector 29%, and the agriculture sector 8% to the GDP (CBLS, 2018b).

Situation of Agricultural R&D in Sri Lanka

The agriculture sector of the country produces mainly rice, coconut and grains largely for domestic consumption. The tea and rubber industry are mainly focused on exports rather than domestic use in the country. The contribution of this sector to Gross Domestic



Figure1. Climatic zones of Sri Lanka

Source: DOA (2018)

Products (GDP) was dropped from 8.5% in 2010 to 7.7% in 2017 due to adverse weather conditions and expansion of the service sector in the last few years (CBLS, 2018b).

Economically active population in agriculture sector and related fields is estimated to be 54%. The rural agrarian nature of the Sri Lankan economy is characterized by more than 70% of the people still living in rural areas and the main occupation of this group of people is agriculture. Agriculture is the mainstay of the rural economy that employs about 26.1% of total employed population in the country. About 60% of total agricultural production is directly rain-fed and tied down with the vagaries climatic conditions mainly floods and drought. Apart from natural hazards, agriculture has become non-profitable due to low productivity and high cost of production. As a result, youth in the rural areas migrate to the urban areas looking for better opportunities including employment and living standards. Hence it is important that agriculture be made more attractive and prestigious through making agriculture as a better source of income generation. The uses of novel technology in agriculture therefore is highly emphasized (SLCARP, 2018).

Land Use Pattern in Sri Lanka

The agricultural land comprises 54%, forest 31%, water bodies 7%, non-agriculture land 1% and other 7% of the total land in the country (3.5 million ha) (DOA, 2018). The agricultural land consists of home garden 41%; paddy 26%; coconut, tea and rubber 21%; and other crops 12%.

Agriculture Production

The major agricultural crops grown in Sri Lanka are paddy, maize, legumes, oil crop, condiments, vegetables and fruits. The area, production and productivity of some major crops are presented in Table 1.

Table 1. Area, production and productivity of agricultural crops (2018)

Crop	Area(ha)	Production (Mt)	Productivity (Mt/ha)
Paddy	1,040,900	3,929,800	3.78
Maize	70,895	270,041	3.81
Green chilli	13,553	79,003	5.83
Red onion	4,044	61,073	15.10
Ground nut	15,752	27,602	1.75
Potato	5,174	88,897	17.18
Tomato	6,712	101,404	15.11
Beans	7,344	83,966	11.43
Brinjal	10,834	129,212	11.93
Pine apple	5,543	34,651	6.25
Banana	45,487	72,010	1.58
Mango	28,440	493,529	17.35

Source: DOA (2018)

The government has been carried out agricultural R&D to enhance productivity, production and quality improvements of major exportable crops; namely Cinnamon, Pepper, Clove, Cardamom, Nutmeg, Coffee, Cocoa, Vanilla, Betel, Areca nut, Citronella and ginger. These exportable crops are contributed small share of agricultural export but these crops have higher demand in importing countries (Table 2).

Table 2. Cultivated areas and production of export agricultural crops (2017)

Crop	Area (Ha)	Production (Mt)
Cinnamon	32,985	22,341
Pepper	42,989	29,549
Clove	7,177	6,428
Cardamom	1,257	113
Coffee	6,580	3,009
Cocoa	1,987	471
Nutmeg	1,031	2,714
Betel	2,860	18,739
Areca nut	18,720	21,191
Citronella	1,413	42
Ginger	1,883	16,326
Turmeric	932	10,267

Source: MOA (2019)

Livestock Sector

The trend in farm animal populations of the country shows a decreasing over more than 30 years. DOA (2018) reported that the current national herd sizes of cattle, buffalo, goat, sheep, pig and chicken are 1.0, 0.28, 0.28, 0.01, 0.09 and 21.2 millions of animals, respectively. However, the population of all ruminant categories seemed to be relatively stable in recent years. The poultry population growth near to a 100% increase during the 2002-2017 (MOLRCD, 2011). The dairy and poultry sub-sectors experienced considerable expansion during the last ten years, milk production has almost doubled, and egg and chicken production are in increasing trend (Table 3).

Table 3. Livestock Production (2008 – 2017) in Sri Lanka

Products	2009	2011	2013	2015	2017
Cattle meat (mt)	3,513	3,321	3,356	3,488	3,270
Cattle Milk (million liters)	184	203	268	305	328
Buffaloes Milk (million liters)	49	55	64	69	61
Sheep & Goats Meat (mt)	63	63	65	51	43
Poultry Meat (1000 mt)	99	117	145	164	201
Eggs (million)	1,623	1,711	2,075	2,294	2,856

Source: CBLS (2018b) and DOAPH (2018)

Fisheries Sector

The fisheries resource base of Sri Lanka comprises of the exclusive economic zone (EEZ) of 517,000 km², the territorial sea of 21,500 km², internal waters of 1,500 km² and man-made reservoirs of 5,200 km². Aquaculture is practiced in bays, lagoons, reservoirs and certain lands located in reservoir areas. The current annual fish catch/production is 530,000 tones, of which some 15% are from aquaculture and inland fisheries. The sector also supports an industry that exports about 5% of catch/production, comprising tuna, shrimp, lobster, and crab (Table 4).

Table 4. Fish production, 2008 – 2017 ('000 Mt)

	2009	2011	2013	2015	2017
Coastal	180	222	268	269	260
Deep Sea	113	163	178	184	190
Inland	47	60	67	67	82
Total	340	445	513	520	531

Source: CBLS (2018b)

Current production from seasonal village tanks culture contributes only 1.2% to national inland freshwater fish production. However, due to its perceived potential, it has been identified as an activity, which can boost domestic freshwater fish production as well as enhance the livelihood of the rural poor. Other sectors of aquaculture, which have been identified, include finfish culture, seaweed culture and freshwater prawn culture for further developments. In the recent years, farming of high value fish species including ornamental fish for export is a promising industry.

Challenges and Opportunities in Agricultural R&D

Challenges in Agricultural R&D

Recently, the agricultural sector faces a number of problems and challenges including low productivity and production, low level of technological innovation, inadequate use of quality seeds and planting material, and diminishing land availability. Furthermore, increasing production cost, labour scarcity, deteriorating growing eco-system, weak value chain, inadequate credit flows, poor access to international markets, seasonal gluts and excess production, small scale product units, uncertain weather and unfavorable climate for optimal productivity are the major challenges in agriculture.

Sri Lanka's agricultural output per hectare or per agricultural worker is significantly lower than that of the neighboring Asian countries (Priya et al, 2012). Lower level of productivity for land and labour are the key issues for this unfavorable outcome. About 44% of the agricultural lands are sparsely used, which will have a huge potential for

development in the country. The scientific knowledge available in institutions is hardly linked to the extension services as researches are neither linked to nor does address the emerging issues in the agriculture sector. Although a large number of rural people are engaged in agriculture, they are not versed in modern scientific agricultural methods. As a result, inputs such as water, fertilizer and chemicals are either over used or inappropriately used.

The crops are also selected without considering the emerging needs in the markets. Shortages and the inconsistent supply of value-added products meeting the high global hygienic standards have acted as an impediment to global market access. Inadequate credit flows from formal banking institutions have impeded the smooth functioning of the agricultural investments. Shortage of quality improved seeds and planting material remain a major issue in increasing production and productivity. About 35% of the paddy seed requirement is provided by both private sector and government and the rest is fulfilled by the farmers’ self-seed production or by farmer to farmer sharing practices.

In order to address these issues, the government intends to introduce a series of measures and incentivize the policy measures in favor of farmers. Accordingly, the Government places high priority to modernize agricultural practices, promotion of GAP and improvement of productivity and competitiveness. The government makes special attention to promote GAP that assures health, quality and environmentally friendly products for the end consumers. This program benefited the farmers by increasing their income with a premium their products and minimizing the cost of product though optimal use of resources for sustainable farming concepts. The promotion of value-added product ensures the farmer income, minimizes the food wastage in glut period and assures a healthy society. A one stop shop, “*Helabojun*” (traditional slow food outlet) and training program have been implemented to promote value adding product among society and make additional income generation for the farm women (MOA, 2018).

SWOT Analysis

A SWOT analysis was conducted to identify strengths and weakness (internal factors) as well as opportunities and threats (external factors) in relation to agriculture sector. A result of this study is in Box 1.

Box 1. SWOT analysis of agriculture sector

<p>Strengths</p> <ul style="list-style-type: none"> ▪ Developed national policies in agricultural development. ▪ Developed well organizational structure for conducting agricultural R & D and policy recommendations. 	<p>Weaknesses</p> <ul style="list-style-type: none"> ▪ Obstacles for implementation of regular staff recruitments. ▪ Weak mechanism to retain experienced and qualified staff and brain drain.
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<ul style="list-style-type: none"> ▪ Qualified and experienced research, extension, training and supporting human resources. ▪ Developed research, education and extension culture and strong linkages with national and international institutes/agencies. ▪ Well-developed and regionally distributed infrastructure facilities with defined functions. ▪ Established collection and conservation system of germplasm. ▪ Network of information collection and management system. ▪ Good sources of seed and planting material. ▪ Well-developed mass media. 	<ul style="list-style-type: none"> ▪ Inadequate human resource development programme. ▪ Lack of proper monitoring and evaluation system for programs and staffs. ▪ Insensitivity in staff performance evaluation. ▪ Poor coordination and understanding among managers. ▪ Poor stakeholder linkages. ▪ Inadequate qualified extension staff at grass root level. ▪ Poor inter-institutional linkages.
<p>Opportunities</p> <ul style="list-style-type: none"> ▪ Improve food and nutritional security. ▪ Favorable natural resource base for agriculture. ▪ Support from national and international research and development agencies. ▪ Developed infrastructure facilities. ▪ Favorable market environment and potentials of agriculture products in export markets. ▪ Existence and growth of supporting institutions. 	<p>Threats</p> <ul style="list-style-type: none"> ▪ Inconsistent policies. ▪ Climate change and its adverse effects. ▪ Natural resource degradation. ▪ Macro-economic instability. ▪ Frequent global crisis in foods and economy. ▪ Low investment on research and development.

Source: Expert's consultation by Authors (2019)

Review of Agricultural Policies and Programs

The *National Agricultural Policy- 2007* highlights linkage with other sectors and sub-sectors and reflects the complex and cross cutting concerns and interactions that contribute for fostering agricultural development. The national agricultural policy is in compliance with the Sustainable Development Goals (SDG) in Sri Lanka, in particular with Goal 1 (No poverty) and Goal 2 (Ending hunger) and contributed to numerous other goals including Goal 5 (Gender equality), Goal 8 (Decent work and economic growth), Goal 12 (Responsible production and consumption) Goal 13 (Climate change), and Goal 15 (Life on land) (SLCARP, 2017a). The vision of national agriculture policy is to build a

nation with an agriculture sector of environmentally prudent, economically productive and nutritionally prolific. It focuses to assure food and nutritional security, ensures environmental sustainability and develops economic opportunity. The government of Sri Lanka considered following principles and values in formulating policies:

The principles and values are given below that are used for formulation agricultural policy and programs:

- Agricultural practices environmentally sound, nationally appropriate, socially acceptable, and economically viable.
- Safety aspects considered and integrated throughout the production cycle.
- Fair distribution of benefit to both producer (farmer, processor) as well as consumers.
- Sustainable consumption and production.
- Ecosystems stability ensured.
- Traditional knowledge and practices respected in the development of farming systems.
- Effective governance ensured through integration of agriculture, water and environmental components to the maximum possible extent.

National Agriculture Policy - 2007

The National Agriculture Policy- 2007 envisaged following nine core components:

i. Increased sustainable agricultural production and productivity

Ensuring enough production to sustainably meet increasing demand for nutritional food, welfare, livelihood of rural farmers and their income. Input management includes quality seed and planting material, appropriate and safety use of fertilizer and pesticides, productive use of land, efficient and sustainable use of water resources, adoption of good agricultural practices (crop zoning, planned agriculture and diversification), mechanization, plant protection, infrastructure and affordable renewable energy.

ii. Research, development and innovation

Research and Development (R&D) focuses on modernization of the agricultural sector, in the face of growing demand and environmental pressures. It is implemented using technology exchange, knowledge sharing, cooperation and partnerships (among state, private sector and universities, international cooperation and synergy with traditional knowledge systems).

iii. Food and nutritional security (FNS)

FNS intend to meet the demand of foods for increased population addressing the accessibility, affordability and malnutrition. Increasing and facilitating access to more healthy and nutritious food, home gardening and urban agriculture, integration with other sectors (livestock, fisheries etc.) social and behavior change communication (nutrition education and communication) monitoring food security and vulnerability, diversifying employment are major strategies for implementation of food and nutrition security policy.

iv. Food safety

It impels to ensure that food and agricultural product availability to the public that are environmentally friendly, healthy and nontoxic. Food safety is assured by the reduced use of agricultural chemicals, good agricultural practices and organic farming and low input agriculture.

v. Environment vulnerability and resilience

This policy statement promotes the environmentally friendly and resilient climate smart farming systems, soil conservation, disaster risk reduction, crop insurance, waste management and conserve the natural resources base in agriculture.

vi. Market development

Implementation of market development policy uses following key strategies that promotes flow of market information, reduce barriers to entry and exit from the market, protection and encouragement of small and medium enterprises and enforces regulatory framework for efficient market operations.

vii. Private sector involvement

This ensures increased living standards of the farming communities and increased contribution to the national economy, through transforming of small farm agriculture to an enterprise-based approach with increasing role for the private sector. Up-scaling Farmer Business School (FBS) approach, supply chain and value chain management, promoting post-harvest technologies to reduce waste and improve value-addition, strengthening Public-Private-Producer Partnerships, input supply and marketing of produce, promoting agro-based industries and employment, including mechanization and training of youth, promotion of Agro-Tourism based on our unique ecosystems, promoting planned agriculture for stable supply and prices and promote foreign direct investments in agriculture are some of the identified policies.

viii. Extension and empowerment of farmers

This ensures the promotion of an integrated effective extension system to enhance and rejuvenate the workforce in agriculture, specially supporting the positive role that youth

and women bring to agriculture by strengthening their capacities and facilitating access to production factors. Make effective extension system through integration of services and capacity development, modernize the agriculture education system to meet current and future demands, empowering and strengthening capacities of youth and women, and promoting the role of farmer's associations are key policy statements in the development of extension and empowerment of farmers.

ix. Information systems and communication

This policy ensures coordination between ministries and across different levels of government, researchers, business community, producers and consumers, policy makers and the concerned stakeholders. Promotion of e-based agriculture for better information management and dissemination, sharing market information and enhanced communication strategies are few measures in this policy.

National Policies Related to Agriculture

Box 2. Major agricultural policies in Sri Lanka

- | | |
|---|---|
| ▪ National Agricultural Policy (2007). | ▪ New Trade Policy (2017). |
| ▪ National Policy on Sustainable Consumption and Development (2018). | ▪ National Agricultural Research Policy and Strategy (2018-2017), (2018). |
| ▪ National Plantation Industry Policy Framework (2006). | ▪ National Program for Food Production (2016 – 2018), (2015). |
| ▪ National Livestock Policy (2006). | ▪ National Biosafety Policy (2004). |
| ▪ National Policy and Strategy on Cleaner Production for Agriculture Sector (2012). | ▪ National Access and Benefit Sharing Policy (2013). |
| ▪ National Land Use Policy (2007). | ▪ National Seed Policy (1996). |
| ▪ National Fisheries and Aquaculture Policy (2018). | ▪ Economic Vision (2015). |

National Legislations Related to Ministry of Agriculture

At present there are many Acts and rules that regulate various aspects of agriculture, plant protection and environment conservation. Department of Agriculture (DOA) have implemented five acts to protect the agriculture sector in the country ensuring the soil conservation, plant protection, the quality of seeds and regulation of using agrochemicals (SLCARP, 2017a). The Box 3 listed out the national legislations implemented and related to Ministry of Agriculture.

Box 3. National Legislations Related to Ministry of Agriculture

▪ Soil Conservation Act (1951) and amendment (1996).	▪ Promotion of Export Agriculture Act, (1992).
▪ Plant Protection Act (1999).	▪ Paddy Marketing Board Act (1971).
▪ Seed Act (2003).	▪ Agrarian Services Act (1979).
▪ Control of Pesticide Act (1980) and Amendments (1994).	▪ State Agricultural Corporation Act (1972).
▪ Agriculture and Agrarian Insurance Act (1999).	▪ Agrarian Research and Training Act (1972).
▪ Land Development Act (amendment) (1993).	▪ Fertilizer Act (1988).
▪ Agrarian development act (2000).	▪ Mahaweli Authority Act (1979).
▪ National Environmental Act (1980) and amendment (1988 and 2000).	▪ Sri Lanka Council of Agricultural Research Policy Act (1987).
▪ Freedom from Hunger Campaign Act (1973).	▪ Tree Felling Control Act (1951).

Recommendation of Priority Programs

Based on the aforementioned discussion, following programs are recommended in consultation with the Ministry of Agriculture and stakeholders.

1. Sustainable food security through increased rice production (Crops)

Background and Justification

The rice sector makes a significant contribution to the economy of Sri Lanka. About 10% of the crop sector contribution to the agricultural GDP is from the rice sector. Approximately 800,000 farm families, which is about 20% of the population, depend on rice cultivation for their livelihood. There are two cultivation seasons namely; Maha and Yala which are synonymous with two monsoons. Maha Season falls during “North- East monsoon” from September to March in the following year. Yala season is effective during the period from May to end of August. Nevertheless, even during Maha seas on all these lands are not entirely cultivated. About 85% of the land (620,000 ha) is cultivated in Maha and 50% (360,000 ha) in Yala. Therefore, the average annual area under rice is about 980,000 ha amounting to a low annual cropping intensity of 134%. During year 2018, 322,217 ha have been sown under major irrigation in Maha and 242,542 ha in Yala. The extent under minor irrigation declines from 148,600 ha in Maha to 84,900 ha in Yala. A similar decline from 196,300 ha to 46,400 ha is also seen in rain fed extents (CBLIS, 2018a).

During the last ten years, the national annual average yields have stagnated as 4.4 Mt/ha. Higher yields have been consistently recorded under major irrigation during Maha (5.3 Mt/ha) and Yala (5.2 Mt/ha), while yields under minor irrigation and rainfed cultivation are comparatively low. Average yields under minor irrigation are about 4.2 Mt/ha in

Maha and 3.9 Mt/ha in Yala. Under rainfed conditions the yields are only 3.6 Mt/ha and 3.3 Mt/ha in Maha and Yala, respectively. High yielding varieties developed by The DOA have contributed significantly to the increase in rice yields. Sri Lanka produces on the average about 2.9 million tons of rough rice per annum and out of 60% total production is comes from Maha. The annual production accounts for 95% of the national requirement. In 2018, the extent cultivated was above average and annual rough rice production amounted to 3.07 million tones.

Self – sufficiency in rice for sustainable food security, increasing domestic production to reduce imports and thereby save foreign exchange are the major national priorities. The basic challenge is to increase local production to ensure food security and to reduce wheat flour consumption at least by 20% within the next 5 years.

Objectives

- Achieve 100% level of self-sufficiency in rice.
- Increase productivity by promoting Good Agricultural Practices program.
- Promote value addition and improve mechanization.
- Sustainable management of natural (land and water) resources.

2. Increase the contribution of field crop sector to national economy (Crops)

Background and Justification

The Other Field Crops (OFCs) grown in Sri Lanka comprise four major commodity groups: (i) coarse grains (maize, finger millet and sorghum), (ii) condiments (chilli and onion), (iii) grain legumes (green gram, black gram, soybean, cowpea and pigeon pea) and (iv) oil crops (groundnut and sesame). According to 2018 statistics, extent under these crops is about 157,000 ha and this sector provides employment to about 580,000 farm families. In 2018, this sector contributed 3.8% (200 million US\$) to the national agricultural GDP.

Cash crops such as Chilli and onion produce relatively higher financial returns to farmers compared to rice. Maize and soybean are also widely used in the animal feed industry. Grain legumes are a cheap source of protein for the low-income groups. Finger millet, groundnut and sesame are consumed as different preparations. Resource poor farmers grow these crops for their own consumption and also to obtain some additional income. Current production levels of most OFCs are inadequate to meet domestic demands and hence large quantities have to be imported. In 2018, imports amounted to 119,087 Mt maize, 246,237 Mt big onion, 52,849 Mt chilli, 16,425 Mt green gram, 12,414 Mt black gram and 4,300 Mt groundnut. The per capita availability of maize, finger millet, green gram, soybean and groundnut is estimated to be 9.36, 0.4, 0.9, 0.39, and 1.30 kg/ year 2014 (CBLS, 2018b).

Demand for OFCs has gradually increased due to population increase and growth in the animal feed industry. However, extents under most OFCs and production have shown a

declining trend from about the mid 1980's. This is mainly due to unfavorable government policies on the production and marketing of these crops. Enhancing production of these crops is essential to save foreign exchange, ensure food security and generate employment particularly in the rural sector.

Objectives

- Develop technologies and supply of improved seed varieties at village level.
- Promote good agricultural practices program.
- Improve production, marketing and processing of selected OFCs through group farmer extension programs and strengthening farmer production societies.

3. Raise farmers' income and improve nutrition security through promoting vegetables and potato (Horticulture)

Background and Justification

Vegetable production in Sri Lanka is seasonal because of the bimodal rainfall pattern. Production figures of the past decade show an increasing trend in upcountry vegetables, while low country vegetable production has declined. In general, there is no significant change in vegetable growing extents. Vegetable production in Sri Lanka is dominated by about 40 species, which include root and tubers. The high nutritional value of vegetables makes them essential component in the daily diet. Potential for employment generation in this sector is also high, particularly in the value addition operations such as processing, packing and product development (SLCARP, 2017). The Medical Research Institute of Sri Lanka recommends a daily intake of at least 200g vegetables, but Sri Lankan consumes 94 gram/day. Hence, increasing vegetable production is a national priority.

Due to the high cost of production, Potato production is dropped from 100,955 Mt to 2,717 Mt during the period 1996-1999 in the country. However, with introducing the incentive trade policies, domestic production was increased to 73,000 Mt in 2017. At present, Sri Lanka imports about 150,000 Mt consumption potato annually and per-capita availability is about 8 kg/year. Availability of quality planting material and high cost are the major constraints in potato farming. DOA has initiated and popularized self seed production technologies for potato.

Objectives

- Adequate supply of seed and planting material of improved varieties and hybrids.
- Increase yield, improve quality of the products and minimize post-harvest losses.
- Stabilize price through year - round production, processing, value addition, marketing efficiency and export share.

4. Enhancing farmers' income and food security through fruit production (Horticulture)

Background and Justification

A wide range of tropical, sub-tropical and few temperate fruits can be grown in Sri Lanka. About 55 fruit species are found growing in the country of which about 25 species are grown on commercial scale. Development of the fruit crop sector is important because of the significant contribution it can make to increase the level of national income, generate new employment opportunities, increase farm income and enhance the nutrition and health of the people.

The total extent under fruit crops is estimated to be around 1,207,000 ha and in 2017, production was estimated about 110,000 Mt (CBLS, 2018a; CBLS, 2018b). These figures include only banana, lime, mango, orange, papaya, passion fruit and pineapple.

The potential for cultivating fruit crops for the domestic and export markets is high. A greater potential exists for the export of fruit juice and organic fruits. The country also imports large quantities of fruit and allied products annually, and has been steadily increased during the recent past. In 2017, the total imports were 50,000 Mt valued at US\$ 45 million, indicating the vast export potential of this sector.

The per capita consumption (PCC) of fruits in Sri Lanka is low compared to other countries in the Asian region. The per capita consumption ranges between 2.8 - 21.8kg fresh fruit per year (DCS, 2018), which is far behind Australia- 90-100 kg, Canada – 60 kg, Western Europe and USA – 50kg. Therefore, to meet domestic requirement and increasing export demand, fruit production need to be increased.

Objectives

- Development of productive, environmentally friendly sustainable and economically viable fruit production, harvesting and processing technologies.
- Disseminate improved technologies in collaboration with provincial extension system, other public and privets organizations, universities and NGOs.
- Reduce post-harvest losses and efficient value chain development.

5. Good Agricultural Practices and Pesticide residue monitoring for fruits and vegetables (Horticulture)

Background and Justification

Indiscriminate use of insecticides in Sri Lanka during the last few decades has created a situation, also resulted in detrimental effects to the environment and for the consumers of agricultural crop products. It does not only make resistance build up among pests but also accumulates these chemical residues in plants and plant products consumed by the people. The major problem under this scenario is that due to the ever-increasing high

prices the country has to spend more for the importation of insecticides. Indiscriminate use also creating very high cost of production resulting in high retail unit prices, where the average consumers finding it difficult to afford. Further, there are instances that our products in international markets, especially in European Union (EU) are being rejected due to the presence of high concentration of insecticide residues. The necessity of promoting island wide GAP programme is proposed for environment friendly agricultural biological pest and disease management strategy in Sri Lanka.

GAP protocols are developed to reduce the contaminated fresh produce due to heavy and indiscriminate use of pesticides and fertilizer and to meet the international standards which are expected in the export market to avoid rejection of consignments due the presence of pesticide residue and pests. Many rejections of exported fruit and vegetable consignments were experienced during the previous years due to exceeded levels of pesticide residues (MRLs) as well as the presence of harmful organisms which indicated a red light to the fruit and vegetable export industry. "SL-GAP" program was initiated and implemented by 'Agro- Enterprise Development and Information Centre' of Extension and Training Centre at the DOA in 2015. To provide a safe and healthy food, the existing GAP program including the Certification Division need to be developed complying to the ISO 17065 standards as an accredited certification body.

Objectives

- Assurance of quality and safe food supply for local consumers and promotion of exports of agricultural commodities through Good Agricultural practices.
- Monitoring the Pesticide residue program for ensuring safe foods.
- Enhancement of safe food production through GAP certification.

6. *Natural resource management*

Background and Justification

The biggest challenge of the 21st century is feeding of nearly 21 million people in the country without detrimental to planet earth under a changing climate and in the context of growing competition for land and natural resources. Specific issues include: rational utilization of arable lands and, available water sources, sustainable agricultural intensification to reduce the demand for land and reduce pressure on forest and other natural ecosystems, unavailability of healthy food. Further, Fauna and flora are increasingly threatened by agriculture expansion. The threat can increase from many avenues such as forest clearance, introduction of invasive and alien plant species and over use of chemicals, which destroy beneficial soil fauna (SLCARP, 2017b).

The fast growth of developments in Sri Lanka has led to resource degradation, with adverse impact on sustainability. The main source of environmental damage is associated with land degradation, particularly soil erosion on the steeply sloping lands of central

hills. At present, 44% of Sri Lankan agricultural lands are facing the problem of soil erosion due to malpractices of machineries and other improper land management. Low cost appropriate soil conservation methods need to innovate and introduce to reduce soil erosion.

Water is the least regulated natural resources in Sri Lanka. Water security implies accessibility of water for agriculture, food and for other utilities. Water security should also entail an equitable distribution of water for all stakeholders in the country to prevent social, political and civil unrest. In Sri Lanka, almost 96% of available water from the hydrological cycle is used up in agriculture and food production. Per capita water availability expected to decrease over time, water security should become a key element in national planning in Sri Lanka.

Natural resources management is vital for the economic development of the country. There are many challenges with regard to sustainable management of natural resources while maintaining a sustainable economic growth for long term. Main challenges include: continuous increase in demand of food due to population growth and life style changes, climate change and scarcity of resources such as water, soil fertility.

Sri Lankan government has taken step to optimize the use of land and water resource on agricultural productivity in a sustainable manner. Changes in land use pattern along with increasing population pressure, diminishing both the quality and quantity of land and water resources while climate change and its extreme situation are exerting additional pressure to them. These issues are leading to accelerate soil erosion, declining soil fertility, salinization and retardation of water availability for agriculture and deterioration of soil and water. Technology development targeting to judicious utilization, conservation natural resources, particularly land and water resources are vital tasks.

Objectives

- Soil conservation and watershed management, land suitability evaluation, agro metrology and climate change, geo-informatics and remote sensing, soil and water quality assessment and on-farm and off - farm water management.
- Ensure environmental and eco-system conservation.
- Increase yield using improved soil and water management.

7. *Agribusiness and agro enterprise development (Agricultural Policy)*

Justification and background

The importance of commercial agriculture and agribusinesses has been recognized by the DOA. In order to promote agribusiness sector, Agribusiness Enterprise Development and Information Service (AgEDIS) has developed and implemented several related programs. Each year, entrepreneurship development training programs are focused in 12 training

modules and undertaken to improve the knowledge and skills of youth and other stakeholders. The trainees were further assisted to start their own agribusinesses by directing them towards value addition and processing. Also, farmer groups have been formed centered for processing and pack house facilities have provided by the Department of Agriculture. The farmers are encouraged to cater demand driven requirements having dialogues with farmer groups, exporters and supermarkets. The required assistance is provided by providing pack houses, processing centers. Value addition through different processing techniques including dehydration is promoted. Market linkages are being provided by mobilizing entrepreneurial farmers as community group. For instance, promotion of “Hela Bojun” program for women entrepreneurs has been highly successful. Furthermore, commercial farming is promoted by AgEDIS through supporting entrepreneurs with available land over 10 acres who are willing to convert their lands into commercial farms and orchards. The lands were inspected for suitability by performing a site inspection coupled with soil and water tests. Also, technical assistance is provided with a complete business plan for the farm.

Objectives

- Increase the knowledge for model technology and marketing process among farming community.
- Increase farmers’ income through value chain development.
- Develop value added product for local market.
- Build agro enterprise oriented to export market.

8. *Agricultural marketing system development in Sri Lanka (Agricultural Policy)*

Background and Justification

Marketing of agricultural produce is a different task compared to other manufacturing goods, because of the perishability and seasonality of many of the produce. DOA intervention is led to the significant achievement in promotion Cavendish banana exports by providing pack houses. However, the assurance of continues production is considered as a critical point in the identified market. Exporting value added food are facilitating market promotions rather exporting traditional raw material. A greater potential is identified for value addition in fruit-based products. In order to promote this sector, private sector encouragements along with research collaboration is crucial.

Objectives

- Promote export market through value addition of quality standards products.
- Protect local industry and traditional farmers by trade regulations.
- Promote hi-tech agriculture with private sector partnership for smooth flow of value chains.

9. Enhancing agricultural trade in South Asia (Agricultural Policy)

Background and Justification

Sri Lanka has three brand tariff structures in which zero tariff rates applied for imports of essential goods and basic raw materials. For intermediate goods 15% tariff level is applied while for finished products 30% tariff is imposed. Although, Sri Lanka has granted preferential tariff rates under Indo- Sri Lanka Free Trade Agreement (ISFTA), Pakistan- Sri Lanka Free Trade Agreement (PSFTA), South Asian Free trade Agreement (SAFTA) and Asian-Pacific Trade Agreement (APTA) – formerly known as Bangkok Agreement, most of the agricultural products and livestock products are in the negative or sensitive list of these agreements in which there is no duty waiver on importation of these products.

Regional trade of agricultural products continues to expand rapidly with the emphasis on food and nutrition security. Trade affects four dimensions of food security; food availability, access, utilization and stability. However, geo-political and weather uncertainties as well as government responses essentially exacerbate the future of trade flows. Although, every country has its own trade policy, it is crucial to harmonize trade in the SAARC region. The countries restrict the regional trade by imposing trade barriers through tariff and non-tariff (TBT and SPS) barriers that could be one of the major reasons for suffering people from food shortage leading to hunger and malnutrition in the region. Therefore, harmonizing the trade policies, processes and practices is the urgent needs among the countries in the region.

Objectives

- Identify niche markets and potential export crops.
- Determine factors affecting regional trade.
- Reduce barriers to entry and exit firms in the market.
- Examine exportable products, analyze trade barriers and trade potentiality.

10. Strengthening farmers' cooperative and access of farmers to markets (Agricultural Policy)

Background and Justification

Promote efficiency in markets for inputs and agricultural products, minimizing waste and losses through the entire supply and value chain, encourage entrepreneurship and innovation, protecting farmer interests, especially for smallholders, and ensuring national food security. The national agricultural policy recognizes that the development of agricultural markets for Sri Lanka requires balancing the interests of smallholders, consumers and the nation as a whole, with the evolution of a vibrant and competitive environment for enterprise development through cooperatives to ensure sustainable

consumption and national food security. In order to enhance economics of scale in production and marketing of the smallholder farmers, cooperatives approach is crucial.

Objectives

- Development and strengthening farmer organization at village level.
- Promote efficiency of in markets for inputs and agricultural product by increasing economics of scale.
- Develop competitive environment for enterprise development through cooperatives to ensure sustainable food security.

11. Promote agriculture markets and effective flow of market information system (Agricultural Policy)

Background and Justification

Both government and the private sector can play key roles in the provision of market related information. Such information can be used for planning, monitoring, reducing risk. The flow of information in both directions along with value chains is a key feature of value chain development and the provision of freedom for an access to information boosts market efficiency overall. Transparency in markets helps to reduce rent-seeking behaviors and helps to improve product traceability. Market information flows benefit both producers and consumers.

Objectives

- Ensure the availability of market related information in the value chain development to the concerned stakeholders.
- Development of the transparency in markets.
- Operationalize regulations relating to standards and quality assurance to support market operations.
- Control monopolies and collusion between firms.

12. Food quality standardization, food safety and food security policy (Agricultural Policy)

Background and Justification

Food safety is a key concern of the National Nutrition Strategic Plan, which provides a platform for inter-sectoral cooperation to accelerate efforts to achieve optimum nutrition for every Sri Lankan. Safe water supplies are the subject of the National Policy on Drinking Water (SLCARP, 2018). The recognizes and enhances of the important, role of food safety regulations, testing and penalty systems for maintaining food safety in the interests of producer and consumer safety, for domestic produce, imports and exports. In addition, it is necessary to promote and to make compulsory in the long-run, prevention-based, food safety systems such as “Hazard Analysis and Critical Control Points” (HACCP).

The total cultivable land is 2.9 million ha, and 65% (1.9 million ha) is cultivated with agricultural crops. Majority of rural farmers are not interested in modern scientific way of doing agriculture. Improper use of water, fertilizer and agro-chemicals has led to degradation of natural resources. Such inefficiencies make agronomic practices and water management strategies already implemented, insufficient for achieving their potential yields.

Reduced use of agro chemicals: Promotes the transition to a more environment – friendly production, minimizing the use of pesticides in food production, and encouraging use of bio- pesticides and IPM with public and private sector participation are become important. Agro chemicals may be required to economically managed crop production. Such chemicals will be used only with authorization and after appropriate, rigorous scientific testing. The safety of the product, environmental impact and precautionary awareness of long-term effects need to be critically evaluated. The Ministry of Agriculture and the private sector share the responsibility for the education of farmers and extension officers on the handling and disposal of non – biodegradable wastes, especially for those associated with toxic substances.

Good Agricultural Practice (GAP): Hygiene standards of food are an integral factor along the supply chain. This hygiene commences at production point itself ensuring good agricultural practices that are followed by farmers. This includes the provision of infrastructure to ensure clean, potable water supplies, sewage and waste disposal systems and the use of certifiably clean materials in each step of the production process. Good Agricultural Practices are key to ensure safe, nutritious and high-quality products for national consumers as well as to increase access to international market opportunities. Many importers of food products, such as the European Union, have formal standards of quality that must be met at each stage. GAP underpins this export success helping to overcome technical barriers to trade and facilitating implementation of traceability for agricultural commodities.

Organic and low-input agriculture: Markets for organic, low input and natural agriculture products, typically those produced without the addition of (chemical) fertilizers or other manufactured nutrients are recent trends in crop cultivation. There is also a growing local demand for safe produce and for international markets where niche products will furnish Sri Lanka with important revenue and sustain agriculture broadly and in traditional areas. Hence, market research will be promoted to analysis future demand to explore price trends and to search for niche market opportunities (local and foreign)

Climate smart irrigated agriculture: Climate Smart Irrigated Agriculture with the aim to improve the productivity and climate resilience of small holder agriculture in selected hotspot areas in Sri Lanka through increased adaptation of climate-resilient agricultural practices and technologies, improved agriculture productivity, and increased access to markets in targeted smallholder farming communities.

13. Promote women and youth engagement in agriculture (Cross-cutting)

Background and Justification

Involvements of women in agriculture are directly related to improve nutritional security and social status of farm families through increasing women's contribution for agricultural development of the country in agriculture production as well as in services sector. Promotion of local food introduction programs for women at a better home environment, establishment and strengthen women's organization are important priorities in Sri Lanka. In addition, "Hela bojun" sale - promote local slow food program. The main objective is to popularize local food and generate additional income for women. It helps to make people healthy and uplift farm families from poverty through strengthen women in household.

Objectives

- Improve nutritional security and social status of farm families.
- Promote agro-based industries and employment, including mechanization and training of youth.
- Promote avenues for women entrepreneurs especially in Local food promotion.

14. Sustainable agriculture for food and nutrition security and poverty alleviation (Cross-cutting)

Background and Justification

Sri Lankan government develops a National Nutritional Policy aimed at improving the access to availability, utilization and stability of safe and nutritious foods. Further it is sufficient to meet the individual needs of all households and individuals ensuring sustainable consumption at all times. Nutritional security must begin with food and agriculture. Promote home gardening and urban agriculture to enhance household food and nutritional security and generation of farm income. Integration with other sub sectors including the plantation crop, fisheries, livestock production.

Moreover, nutrition sensitive food systems incorporating production processing marketing and consumption can contribute significantly to the eradication of all forms of malnutrition. The availability of adequate food at the national level does not necessarily ensure economic and physical access to food at the household level. The mean value of household income per month has been increased from Rs. 12,803 in 2002 to Rs. 62,237 in 2016. During the same period, the mean value of household expenditure on food items has been increased from Rs 5,848¹ to Rs 19,114. It indicates that there need to link of agricultural development with food and nutrition security and poverty alleviation.

¹ One US\$ equivalent to 180 LKR

Objective

- Increasing production and access to more healthy and nutritious foods.
- Promoting awareness programme for improving healthy diets for women, youth and school children.
- Monitoring food security and vulnerability assessments.
- Diversification of employment by promoting rural nonfarm opportunities including agro tourism and value adding for agricultural product.

Conclusion and Way Forward

Agricultural development policies and programs at the regional and national levels need to be tie-up with Sustainable Development Goals (SDGs). Self-sufficiency in rice for sustainable food security, increasing domestic production to reduce imports and thereby to save foreign exchange are the national priorities. The basic challenge is to increase local production to ensure food security by promoting Good Agricultural Practices and value addition programs.

The demand for Other Food Crop (OFCs) has gradually increased with the population increase and growth in the animal feed industry. Enhancing production of these crops is essential to save foreign exchange, ensure food security and generate employment particularly in the rural sector.

Increasing vegetable production is the national priority. The demand for vegetable is typically influenced by price, income and other factors such as size and education level of the population. Furthermore, increase of current fruit production levels is planned to meet domestic requirements and increasing export demand, cultivated extents, productivity and production based have to be expanded.

The domestic and global agricultural market is demanding the need and the necessity of the production of safe food free from hazardous chemicals and pesticide residues. The implementation of GAP at the on-farm production is considered to be the initial point of producing quality and safe food.

Agricultural modernization is seen as a timely need to boost agricultural production and productivity. This is essential in assuring food availability to combat with population increase. The use of novel technologies can uplift the old way of doing agriculture with a commercial orientation. This vision is to revitalize the declining significance of agriculture to an enterprise-based production unit targeting farm profit. In order to improve the food and nutritional security of Sri Lanka, policies and programs need to be aligned to address the issues in agriculture sector including food crops, livestock and Fisheries.

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Chapter 10

Agricultural Policy in South Asia: Pathways for 2020-30

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Abstract

The paper is organized in three cores areas namely the productivity of South Asian agriculture compared to the world, agricultural policies around agri-development themes, and priority programs in the region. The South Asian agriculture is faced with a task of modernizations to augment agri-foods and non-foods for its populations (1.82 billons, growing by 1.34%), and increases its agri-GVA per worker to US\$ 3,118 in the world from US\$ 1,595 in South Asia in 2018. The agricultural development policies and programs are considered around six themes: i) natural resources/ input management; ii) risk, uncertainty and insurance; iii) inclusive development; iv) marketing, agro-processing and trade; v) agrarian structure; and vi) economic policy and advocacy. It sums up changes in the growth of bio-physical resource for 1961-99 and 2000-19 periods, and their projections for 2030. Second, it suggests that agricultural (re) insurance in the region has huge gaps to cover by the public and private agencies. Third, the inclusive development index rank in three pillars: growth and development; inclusion; and intergenerational equity and sustainability. Fourth, the agricultural marketing, agro-processing and trade. Fifth, agrarian structures. Sixth, economic policy environment and advocacy emphasizes the fiscal expenditures, deregulation, privatization and foreign direct investment. The authorities in South Asia have targeted to increase the agricultural growth rate from 3.31% during 2010-18 to 4.86% during 2019-24. This paper puts forth the regional agri-development programs in five areas: i) value chain development in dairy, pulses, oilseeds, aromatic rice and herbs; ii) soil health and fertilizer/ input security; iii) market integrations, pricing and trade competitiveness; iv) policy and governance (research and development, education, extension and investment); and v) water resources development. The paper emphasizes a common framework for agricultural policy and programs for the region for consideration by the SAC, governments, and development agencies for bridging the productivity gap between South Asia and the world during 2020-2030.

Keywords: Agricultural policy, resource management, value chain, growth and development, trade and competitiveness

Population, Economy and Agriculture: An Overview

South Asia comprises of the SAARC countries (Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka), and Myanmar, Tibet Region of China, and Iran. This view of South Asia (SA) is based on the hydrological, geographic, agro-ecological system and a possible common market. The region is an agrarian society in terms of the majority populations' occupational patterns, share of agriculture in national income, and the state of agricultural technology. An overview of South Asia vis-a-vis the world in terms of the population, economy, agriculture, productivity and variability for 2000-18 is provided in Table 1. The population of South Area was 1.82 billion (23.9% of the world) in 2018. Agricultural production depends on the decisions of largely the small family farms, followed by the larger farm holdings, cooperatives, corporate agencies, and the state sectors (Lowder et al., 2014). The farm holdings carryout the agricultural production decisions for subsistence and commercial enterprises under particular nature of the markets for land, labor, capital, insurance, raw materials, agro-processing, technology and inputs, risk and uncertainties, trade and political economic priorities.

The region's arable land is 0.27 billion ha or 0.15 ha per capita (2016). The arable land decreased by 0.02% annually during 2000-18. Labor productivity is important issue for competitiveness in the world. The labor force employed in agriculture was about 0.30 billion (30.84% of the world) in the same year. Employment in agriculture tended to grow during 2000-18; there are some signs of transfer of labor away from agriculture to non-agri sectors in India (-) 0.30%, Bangladesh (-)0.43 % and Sri Lanka (-)1.64% annually. The share of agriculture in female employment was 59.5% in SA (world 27.6%) in 2018, which has declined by -0.84% annually during 1991-2018. The agri-GVA (Gross Value Added) per worker is much below the world average, which affects for competitiveness of agriculture in the international trade. Agri-GVA accounted for 15.9 % of the GDP, and the elasticity of GDP growth with respect to Agri-GVA growth has been 2.1 in SA for 2000-18. Thus for increasing the GDP growth rates from 6.3% during 2000-12 to a double-digit rate in the future, the agri-GVA growth rate must be increased from the present 3.0% to 4.75% in the region. The sources of growth in Agri-GDP may be accounted by its sub-sectors, which are discussed below under inclusive developments.

Table 1. Indicator of population, economy, agriculture and vulnerability (1961-2018)

Country	Population (2018, mn)	Population growth rates (2000-18) %/yr	GDP growth rate (2000-18) %/yr	Agri-GDP growth rate (2000-18) %/yr	Elasticity of GDP to Agri-GDP growth rate (2000-18)	Arable land (2016 mn ha)	Labor employed in agriculture (2018mn)	Agri-GDP in at 2010 K-Price (2018mn)	Agri-GVA per worker at 2010 K-Price of 2018, (US\$)	Labor productivity growth rate (2000-18) %/yr	CV of Agri-GDP growth rate (1961-2018)
Afghanistan	37.2	4.4	6.8	2.6	2.7	37.9	5.4	4,573	886.0	2.0	615.7
Bangladesh	161.4	1.5	6.1	4.1	1.5	9.2	27.5	24,773	950.2	4.4	143.3
Bhutan	0.8	1.5	7.2	2.7	2.7	0.5	0.2	324	1,594.4	-4.6	68.1
India	1,352.6	1.6	6.6	3.0	2.2	179.7	223.7	361,976	1,660.7	3.2	200.7
Maldives	0.5	4.7	5.6	1.6	3.6	0.01	0.02	163	7,791.5	-5.5	372.8
Nepal	28.1	1.0	4.3	3.2	1.3	4.1	11.4	6,495	587.9	2.0	121.5
Pakistan	212.2	2.7	4.4	2.7	1.6	36.8	30.8	48,231	1,645.2	-0.2	98.4
Sri Lanka	21.7	0.9	5.3	2.8	1.9	2.7	2.2	5,778	2,670.7	4.6	137.0
<i>South Asia</i>	<i>1,814.4</i>	<i>1.7</i>	<i>6.3</i>	<i>3.0</i>	<i>2.1</i>	<i>271.1</i>	<i>301.4</i>	<i>452,323</i>	<i>1,549.1</i>	<i>2.9</i>	<i>165.1</i>
Iran	81.8	1.4	3.7	3.7	1.0	46.0	4.8	42,313	10,015.9	-2.3	127.3
Myanmar	53.7	0.8	9.9	4.7	2.1	12.8	12.3	20,475	1,675.2	5.5	94.3
<i>World</i>	<i>7,594.3</i>	<i>1.3</i>	<i>2.9</i>	<i>2.7</i>	<i>1.1</i>	<i>4863.3</i>	<i>977.1</i>	<i>3,068,575</i>	<i>3,241.8</i>	<i>2.9</i>	<i>45.3</i>

Source: FAOSTAT (2019) and World Bank (2019)

Agricultural Policy by Themes

The agricultural development is taken as having six facets; namely, natural resources management, risk and uncertainty, inclusive development, marketing and trade integration, agrarian relations, and policy and advocacy.

Natural Resources/ Input Management

Natural resources such as arable land and soil fertility, fresh water and rainfalls, forests and biodiversity are very scarce relative to the population size and its growth rates in South Asia. The biophysical resources in the region indicate: i) Agricultural land have expanded to 57% of total area during 1961-2016 (world average 38%). The agricultural land has been declining in Afghanistan, Pakistan and Bangladesh because of converting it to the housing, infrastructures or has degraded. There is need to protect the land uses for agriculture and environments. ii) Renewable internal fresh water resources have declined from 2.3 to 1.2 m³/capita during 1961-99 and 2000-16 (1/5th of world average). In Southern Asia, Iran is exception where productivity of water is declining, and the whole region lags behind the world in increasing the productivity of water. The disparities in fresh water endowments among the countries are very high, and water has the trans-boundary riparian issues. The productivity of water is US\$ 2.0/m³ against the world average of US\$ 20.8 during 2000-18 (Table 2). iii) Forest area has dwindled from 36 to 34% of the land area between 1961-99 and 2000-17 in the region against world average of forest area as 30.9% in 2017 (Figure 1). The forests' rental value has decreased from 0.56 to 0.30% of the GDP in South Asia (World Bank, 2019). In deforestation, Myanmar and Nepal are moving in the same direction, which is worrying.

The arable land, water, forests and soil nutrients are interrelated and have implications for developing the sustainable agri-food systems. Based on studies of Gill (1995), Stevenson (2018), Scherr (2018), World Bank (2007) and Macours (2018), **the approaches to improve the NRM for agricultural production include:** i) Transition from the fine-cereal grains dominated, land-extensive and water-intensive production system to coarse grains, pulses, fruits, root crops, vegetables, upland farming system, livestock. These require less land, conserve water and depend less on energy for irrigation infrastructures; ii) Increase level of knowledge embodied in technology, skill levels, institutions, and policies for producing high value Agri-GDP from less land and water resource; iii) Apply better methods of measuring and monitoring the natural resource base such as participatory and community ownership in forestry and farmer-managed irrigation systems; iv) Apply the 'sets of nine': agro-forestry; alternative wetting and drying; conservation agriculture; drip irrigation horticulture; forest co-management; inter-cropping; integrated soil fertility management; rain water harvesting; and soil fertility based extension; and v) Others: Integrated watershed management; model forest and forest management; crop-livestock, forest-fish production, and value-chain processing;

green infrastructure and natural restoration; polyculture land use mosaics, under shade; reduce agro-chemical input requirements; domesticate more food and agro-industrial commodities; improve commercial traits on minor crops and breeds; link to farmer seed-sharing networks; integrate genetic, agronomic and NRM research; incorporate environmental and institutional topics into food production and food systems policy and market research; zero tillage; and irrigation management transfer.

Table 2. Water productivity (constant 2010 US\$ GDP/ M³) of total freshwater withdrawal

Country	1970-99 (US\$)	2000-16 (US\$)	Change (US\$)
Afghanistan	NA	NA	NA
Bangladesh	NA	2.9	2.9
Bhutan	NA	3.9	3.9
India	0.8	2.0	1.2
Maldives	NA	553.4	553.4
Nepal	NA	1.3	1.3
Pakistan	0.4	0.8	0.4
Sri Lanka	2.1	2.9	0.8
South Asia	0.7	2.0	1.2
China	1.5	9.8	8.3

Source: World Bank (2019)

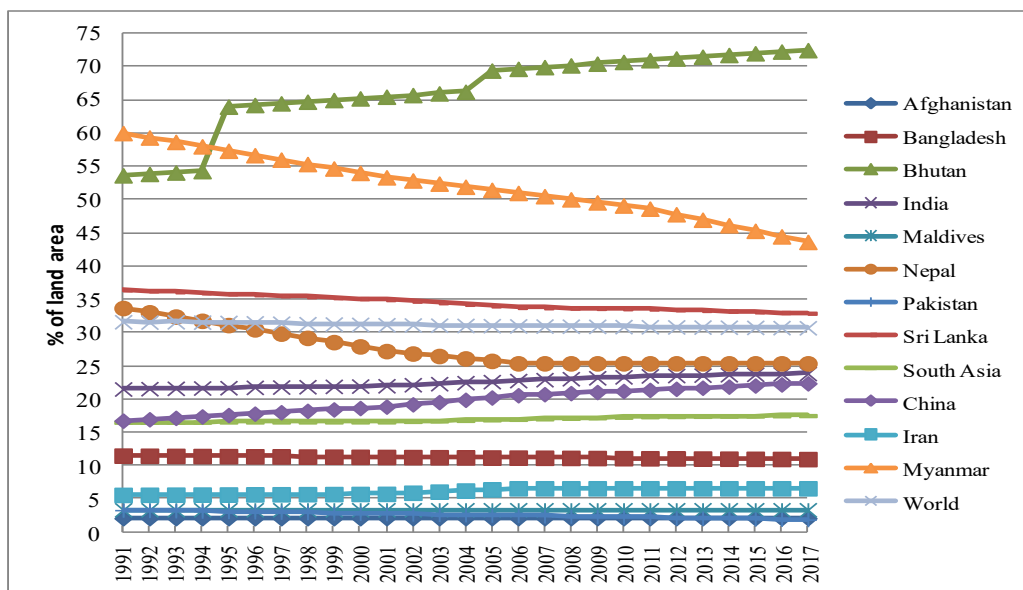


Figure 1. Forest area (% of land area)

Source: World Bank (2019)

Risk, Uncertainty and (Re-) Insurance

The farmers in developing countries often behave in a risk-averse manner in the absence of adequate insurance provisions. The risk and uncertainty to the farmers in agriculture arise from: i) Production or yield risk (rainfall, temperature, hails, frost, insect, pest, diseases); ii) Price or market risk (both inputs and outputs); iii) Institutional risks (government rules on safety, trade, environment, tax, credit, inputs and production); iv) Human or personnel risk (death, divorce, injury, disruptions); v) Financial risk (interest rates, cash flows, leverage or debt/ equity ratios); and vi) Asset risk (theft, fire, other losses) (Iturrioz, 2009; World Bank, 2009; Bairawa, 2013; Ullah et al., 2015a; 2016).

In managing the agricultural risks, **farmers use different strategies and tools such as:** i) Enterprise diversification (subject to resource, climatic conditions, market outlets, and others); ii) Vertical integration/coordination (subject to initiatives by producers and/or buyers in the supply chain); iii) Production contracts (subject to production management, resource provision, quality and compensation); iv) Marketing contracts (subject to prior agreements between producer and buyers on price, schedule and outlets); and v) Other ways to manage the risks (cultural practices, adjustments in inputs/outputs, excess machine capacity). Further, the climate change effects can be reduced through adopting improved technologies (high yielding and stress tolerance crop varieties); efficient information system along with early warning system; financial access to farmers; adopting climate smart agriculture (shrestha & Bokhtiar, 2019).

Selection of a combination of risk management strategies and instruments is one of the most fundamental and complex decisions a farmer has to make (Velandia et al., 2009; Ullah et al., 2016). The socio-economic and demographic factors such as the age, gender, education, owned-land and off-farm income signal the differences in risk attitudes, and are important factors in farmers' risk management decision-making (Sherrick et al., 2004; Cohen & Einav, 2007; Velandia et al., 2009; Tanaka et al., 2010; Gloede et al., 2011). For example, a higher proportion of owned land and/or greater farm size signal a larger capacity for bearing risk and a reduced need for risk management instruments. Use of and access to local knowledge and information is also essential for the interpretation of agricultural risk within a given area (World Bank, 2011). Historically, much of the information needed has come from research, extension and universities. However, more recently, many new innovative commercial information sources have emerged to serve agriculture.

A large number of risks prevalent at the farm level has severely restricted the farmers' access to credit for agricultural borrowings. This problem is compounded by the fact that the majority of farmers have very low levels of collateral (World Bank, 2011). Credit constraints coupled with aversion to risk and limited access to information sources are the main reasons why diffusion of new technologies has been slower than expected. Therefore, the developing countries need to develop the insurance and credit markets.

In analyzing the farmers' adoption of risk management tools, most studies have pursued the factors influencing the adoption of a single risk management tool for crop insurance or hedging. For example, the uses of the hedging with futures and options (Raju & Chand, 2008; Makus et al., 1990), on forward contracting/pricing for crop insurance (Sherrick et al., 2004). Other authors apply the multivariate and multinomial probit models to account for simultaneous adoption of multiple risks management tools and concluded that decisions to adopt multiple risk-coping tools simultaneously are often strongly correlated (Velandia et al., 2009; Ullah et al., 2015b; Kumar, 2018). The policy implications of studies on agricultural risk causes, nature and responses are: i) Transition of crop insurance scheme should be made to an actuarial regime supported by upfront subsidy in premium with insurers taking full responsibility for claims, save catastrophic claims; ii) Strengthening the weather insurance system through technological developments like electronic weather stations and remote sensing technology; iii) Contract farming should be popularized as an alternative risk management instrument; iv) Introduce farm income insurance scheme for protecting farmers' income comprehensively; and v) Introduce price stabilization fund and credit risk management fund to insulate formers from price volatility.

Agricultural insurance is a special line of property insurance applied to agricultural firms. The agri-insurance products and their market shares globally in 2014 are as follows: i) Crops/ multi-peril cropping index (74%); ii) Crops/ hail (16%); iii) Livestock (4%); iv) Pure breeds (3%); v) Aquaculture insurance (1%); vi) Silviculture (1%); and vii) Greenhouse (1%) (Atlas, 2018). Thus, about 90% of agricultural insurance is based on crops. In the various covers of agricultural insurance in terms of their product definitions/ measurements, reimbursements and availability indicates, Indian agriculture appears prominently in the crop yield/ index based insurance and other South Asian countries do not figure prominently. Other than India, the agri-insurance coverage by sectors is limited to a few subsectors, penetration in terms of volume is shallow and the insurance premium as percentage of Agri-GDP is low in all other countries.

The volume of agri-insurance is expected to grow with at a double-digit rate in South Asia. For example in India, the agri-insurance premium grew from US\$ 0.8 billion in 2015/16 to US\$ 4.0 billion in 2017/18 and is projected to reach US\$ 6.3 to 7.0 billion during 2022/23. During this time, the arable area covered by insurance is expected to increase from 35 to 50%. The growth in the agri-insurance is derived from three components; namely, increasing the coverage per farmer, increasing the number and types of crops insured, and increasing the share of insured farmers and cultivated land (Schanz & Zurich, 2018).

Only a selected group of about 20 reinsurance companies have been providing reinsurance capacity for agricultural risks in the world. Of them, only a few companies are able to provide terms and conditions for reinsurance treaties. In such cases, the

government needs to establish and administer the catastrophe funds. The role of reinsurers in agricultural reinsurance goes beyond providing reinsurance capacity as to cover the provision of advisory services such as: risk assessment, risk modeling, pricing, risk structuring, design of loss adjustment and operational manuals, risk rating and risk accumulation control software, and the wordings in insurance contracts.

Inclusive Growth and Development

The approach of World Economic Forum (WEF, 2018) for inclusive development index (IDI) 2018 is to rank countries on three pillars: i) Growth and development, ii) Inclusion, and iii) Intergenerational equity and sustainability. Growth and development includes GDP per capita, employment, labor productivity and healthy life expectancy; inclusion includes the median household income, poverty rate, income Gini and wealth Gini; and intergenerational equity and sustainability include the adjusted net savings, public debt as a share of GDP, dependency ratio, and carbon intensity of GDP. The WEF (2018) states that a new growth model that places people and living standards at the center of national economic policy and international economic integration is required to transform inclusive growth from aspiration into action in the Fourth Industrial Revolution. Such an effort to reshape the assumptions and priorities of the way modern market economies organize themselves to generate socioeconomic progress can only be realized with the engagement of all stakeholders.

The IDI rank of the South Asian countries for their agriculture is to be pursued in Table 3. The Agri-GDP comprises of some 25- subsectors/commodity groups such as the cereals, pulses and oil seeds, horticulture and plantations, livestock, forestry and fisheries. The agricultural policy must create conditions for parity in the growth and development of all these sub-sectors and products. The aspects of inclusion are about the resource endowments of different farmers, farming systems and opportunity of economic growth. In Table 3 last column, the indicative growth rate for 2030 is arrived by multiplying the past growth rate by 1.468 for all products; the is policy issue is about the differences priority to given to across the product groups, which affect diversification farming system, different agro-ecological regions, and different farm size classes.

Table 3. Output of agriculture, forestry and fisheries in Southern Asia (1961-2030)

Agricultural Outputs (selected items)	Production Ton (2017)	Share in physical volume (%)	Production in 2017 (kg/capita)	Growth rate 1961-99 (%/yr)	Growth rate 2000-17 (%/yr)	Growth rates change (%)	Indicative target for 2020-30 (%/yr (vi*1.468))
i	ii	iii	iv	v	vi	vii	viii
Cereals	448,688,567	21.34	239.49	2.86	1.85	-1.01	2.7
Coarse grains	63,459,832	3.02	33.87	1.54	3.45	1.92	5.1
Pulses	25,284,820	1.20	13.50	1.11	2.56	1.45	3.8
Oilseeds (oil equiv)#	13,748,853	0.65	7.34	2.85	3.18	0.33	4.7
Fruits	126,723,355	6.03	67.64	3.60	3.30	-0.30	4.8
Citrus	17,519,149	0.83	9.35	4.84	3.49	-1.35	5.1
Tubers	78,386,257	3.73	41.84	4.70	3.97	-0.73	5.8
Vegetables	157,643,936	7.50	84.14	3.84	3.49	-0.35	5.1
Nuts	1,924,779	0.09	1.03	4.89	4.47	-0.42	6.6
Fiber crops #	11,823,586	0.56	6.31	1.69	4.13	2.44	6.1
Sugar crops	401,039,090	19.07	214.06	3.41	0.71	-2.70	1.0
Onion and garlic	31,164,864	1.48	16.63	4.73	7.54	2.81	11.1
Ginger	1,449,875	0.07	0.77	6.23	8.27	2.04	12.1
Tobacco	1,032,849	0.05	0.55	2.50	1.94	-0.56	2.8
Tea	1881832	0.09	1.00	2.52	1.37	-1.14	2.0
Coffee, green	317,903	0.02	0.17	8.85	0.97	-7.88	1.4
Cocca beans	20,291	0.00	0.01	6.33	4.85	-1.48	7.1
Meat	15,610,530	0.74	8.33	3.02	3.38	0.36	5.0
Milk	234,986,287	11.18	125.43	3.59	4.11	0.52	6.0
Egg	7,346,422	0.35	3.92	6.20	5.61	-0.59	8.2
Skins & hides *	1,953,555	0.09	1.04	2.07	1.18	-0.89	1.7
Wools of sheep	20,207	0.00	0.01	3.18	0.09	-3.09	0.1
Fish	18,415,646	0.88	9.83	4.40	4.47	0.07	6.6
Fuel woods	383,745,323	18.25	204.83	1.53	0.37	-1.17	0.5
Log sows	58,305,168	2.77	31.12	3.32	1.03	-2.29	1.5
Total / Average	2,102,492,976	100.00		2.77	3.00	0.2	4.40

Source: FAOSTAT (2019); World Bank (2019)

Notes: Population 2017= 1,873.51 million (SAARC 1,792.85 million, and Iran 80.67mn); &, Forestry: Woods m³= 442,050,491, and m³/ capita = 236; *, #, refers to production in 2013, 2014; #, for total, growth rates refer to net-value of produce of agriculture, forestry and fisheries; Production of oilseeds (oil equiv), fibers are up to 2014, and production of skin, wool are up to 2013.

The present approach to agricultural development emphasizes transition from raw materials production to value-chain development (VCD). The methods for ranking the agricultural VCD to ensue the economic efficiency, social equity and environmental sustainability are proposed in Table 4. The recent thinking emphasizes inclusion of small holders in the VCDs (Dunn, 2014), value chain and nutrition (Gelli et al., 2015), and regional VCD. So, we propose distribution of weights (total 75 points) by criteria/sub-criteria to rank the VCD of commodities for developments.

Table 4. Methods of ranking for agricultural value chain development

Criteria	Weight	Sub-criteria (weight)	Weight
Poverty Reduction Potential.	18	Significant number of households involved in sector.	6
		Poverty incidence of target group in the sector	6
		Impact on disadvantaged area.	6
Growth potential.	12	Growth potential in next 5-10 years.	6
		Potential for target group (income/ employment).	6
Intervention potential/ feasibility.	15	Measurability of impact.	3
		Availability of scale agents with high leverage potential.	3
		Potential for crowding in (concentration) of market players.	3
		Current status of required infrastructure (road, storage, etc.).	3
		Feasibility with given resource and capacities.	3
Other cross-cutting priorities.	18	Consistency with government priorities	3
		Impact on balance of trade.	3
		Opportunities for inclusive development.	3
		Explicit opportunities for addressing gender inequality.	3
		Opportunities for positive impact on the environment.	3
		Geographical spread of sub-sector regionally/ nationally.	3
Agro-processing, value-addition and FDI.	12	Applicable for higher value addition by agro-processing.	7
		Applicable for foreign direct investment.	5
Total	75		75

Note: The ADS Nepal included 4 criteria (Sr nos 1-4) in column-1 with total of 63 full marks in the above table. We have added a 5th criterion to emphasize agro-processing industry and trade at the regional/ international levels.

The above researchers have studied the smallholders' inclusion, upgrading and benefits in the VCDs for dairy (Bangladesh), vegetables (India) and HVCs, traditional crops, horticulture, maize, fertilizer, inputs (other countries) to carryout inclusive market programming. First, for inclusive market development, they recommended as follows: i) Facilitate increases in the quality and type of information available to smallholders, which will match the educational, experience and resource levels of the target audience, and address information bottlenecks and facilitate the flow of market and technical information; ii) Develop and facilitate scale-appropriate agricultural technologies and input packages to increase productivity of smallholders per unit of land, and be well-matched to the smallholders' resource and risk profiles; iii) Make investments that benefit large number of smallholders (infrastructure, road, communication, power, transportation, cold chain storage systems, and regulatory environment) to reduce costs and improve profitability such as through ICT. The investment plans to benefit broad populations in rural areas should incorporate deliberate strategies to include women and girls; iv) Improve and standardize indicators for smallholder outreach under market facilitation projects, which distinguishes three types of participants: direct contact entrepreneurs, indirect contact entrepreneurs, and imitator entrepreneurs /firms; and v) Improve approaches for measuring impact on income under inclusive market systems projects helping to track how the income of participants changes over time.

A second issue is that approaches for measuring enterprise and household income should incorporate issues such as the household food security, household income diversification, intra-household resource allocations, and fungibility of capital. Finally, attention should be paid to measuring the full impacts of programs by incorporating benefits that accrue beyond the smallholders such as: the impacts on rural food and labor markets, multiplier effects from circulation of increase in expenditures on the local economy for consumption and for agricultural investment. The aspects of inclusion are not only about the economic growth of different classes of farmers, but it also deals with the incidence of poverty in rural areas, prevalence of under-nutrition of populations, nutrition status of women in reproductive age group (ages 15-49 years) and children (under 5-years) and the likes in relation to the GDP per capita (Figure 2). It may be noted that the indicators of social inclusions related to poverty in society, under-nutrition of population, anemia among women and stunting of children are strongly associated with the level of GDP per capita as proxy for income levels. But the trend-lines for each indicator have a very different relation with this economic variable. Why? Further the prevalence of over-nutrition and diet related disease has positive relation with the GDP per capita. How? These are issues of 'nutrition transition' (Popkin, 2017), and must be addressed to reduce the non-communicable diseases (diabetics, heart attack) to have good health of the populations.

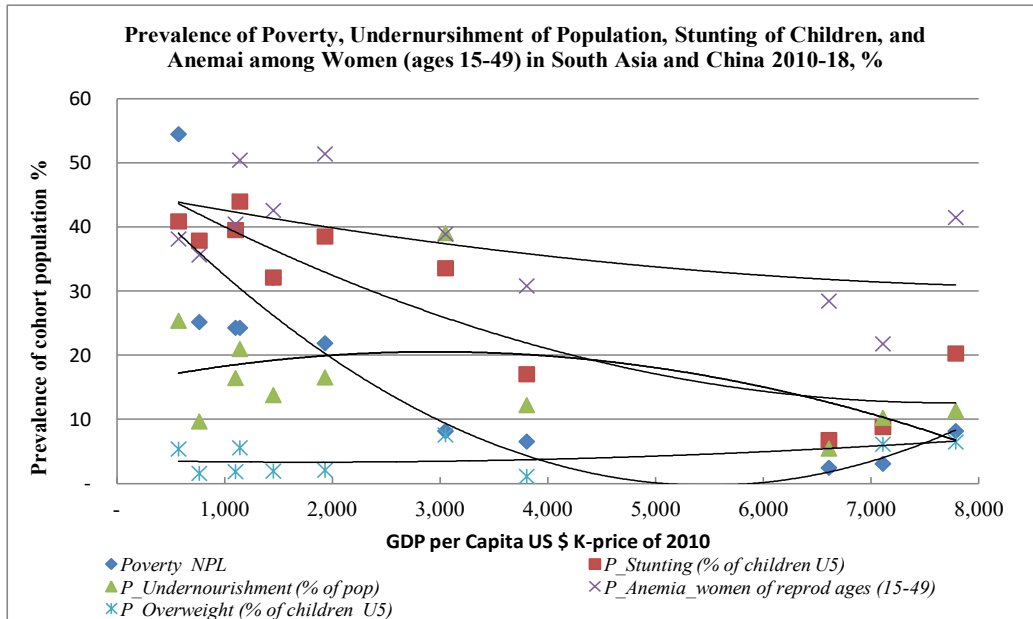


Figure 2. Prevalence of poverty, undernourishment, overweight, stunting and anemia

Source: World Bank (2019)

Note: Cross-country evidence from SAARC states, Iran, Myanmar and China. GDP per capita is average for 2016-18, and poverty and nutrition are latest available for 2010-18.

The inclusive development through the value-chain shows the interrelationships among the GDP per capita, nutrition and health at the family level (Gelli et al., 2015). There are three main channels for the value-chains to improve nutrition: i) through increased consumption of nutritious foods (a demand side pathway); ii) through increased incomes from value-chain transactions (a supply side pathway); and iii) through increased nutrition value-addition in the chain transactions. These pathways are interlinked and context specific. Issues for further research and programming are: i) Mechanisms, costs, and impacts of the interventions involved; ii) Ways to increase the demand for nutritious foods; iii) Ways to increase the supply of nutritious foods; iv) Methods to optimize flow of nutritious foods along the chain; v) Managing trade-offs; and vi) Equity and pro-poor considerations.

Marketing, Agro-Processing and Trade Integration

Agricultural marketing policies of a country, her trade integration with other countries in South Asia and rest of the world have increasing importance because of the farm production programs are supposed to be 'market-demand driven', specializations are based on 'comparative and competitive advantages', and trades are based on rules of the regional trade agreements (RTA), free trade agreements (FTA), and WTO- Agreement on

Agriculture (AoA). Some key instruments affecting international trade are the aggregate measures of support, tariffs, SPS/ Codex standards, currency exchange rates, and degree of connectivity and so on. The agricultural markets and trade are considered efficient if these can generate more marketed surplus from farm sector, increase the farmers' income, and promote specialization by country based on efficiency of resource use.

The marketed surplus of agriculture in most of the countries in South Asia is low. So the growth of agro-processing industry and the balance of trade are often negative. This applies more with the smaller economies in the mountains such as Bhutan, Nepal, and Afghanistan. India has been able to create more marketed surplus ratio (MSR) of agriculture. For India, the Ministry of Food Processing Industry (MoFPI) provides the estimates of marked surplus ratios for some 24 crops of which, our table has included only 8 crops for exposition of the issues. There is need to augment the MSR of agriculture so that it can support the growth of agro-proceeding industries because the region's share in the global food processing industry is very small at 4 percent.

Indian NITI Aayog and MoFPI have emphasized the agro-processing activities for economic development such as the capital formation, employment, innovations and value-added (Ghosh, 2014). Agricultural marketing needs to be conducted within a supportive policy, legal, institutional, macro-economic, infrastructural and bureaucratic environment. Inappropriate law can distort and reduce the efficiency of the market, increase the costs of doing business, and retard the development of a competitive private sector. Poor support institutions such as agricultural extension services of the Municipalities that operate markets inefficiently and inadequate export promotion bodies can be particularly damaging. Poor roads increase the cost of doing business, reduce payments to farmers and increase prices to consumers. Finally, corruption can increase the transaction costs for agencies in the marketing chain.

The agricultural marketing services (AMS) provide testing, support standardization and grading, and research and promotion programs. India has the long-established National Institute of Agricultural Marketing, Milk Marketing Board and the Egg Marketing Board. These are primarily research and policy organizations. But other agencies provide facilitating services for marketing channels like provision of infrastructure, market information and documentation support. Recent developments in marketing emphasizes on new marketing linkages between the agribusiness, large retailers and farmers. These are gradually being developed through contract farming, group marketing and other forms of collective action. Development partners are paying increasing attention to ways of promoting direct linkages between farmers and buyers within a value-chain context. More attention is now being paid to the development of regional markets and to structured trading systems to facilitate the above developments. The growth of supermarkets has a significant impact on marketing channels for horticulture, dairy and livestock products. Nevertheless, "spot" markets will continue to be important for

many years. Therefore, there are needs to improve the infrastructure such as for retail and wholesale markets.

The agricultural development in the region depends on trade of which, we have space for three aspects here. First, the directions of trade on agricultural goods among SAARC countries, China and the rest of world in 2017, shows that small economies (Afghanistan, Bhutan, Nepal) are dependent on SAARC for their total trade; nevertheless, their exports are precarious (Table 5). Even big economies (India and Pakistan) have negative balance when bigger economy (China) is accounted for. Trade balance of SAARC economy may improve if adjoining Iran and Myanmar are included in the regional common agricultural market. Secondly, the small agrarian economies that have more labor force dependant on agriculture, in fact are facing continuous growth in the deficit of trade in agricultural goods, for example the case of Nepal during 1961-2018 (Figure 3). Finally in the agricultural trade with the world, even the big economies are facing adverse barter terms of trade in agriculture, for example India and Pakistan (Figure 4 and 5). The region needs to act together to remedy this anomalies through proper policies in macro-economy, science and technology and agriculture.

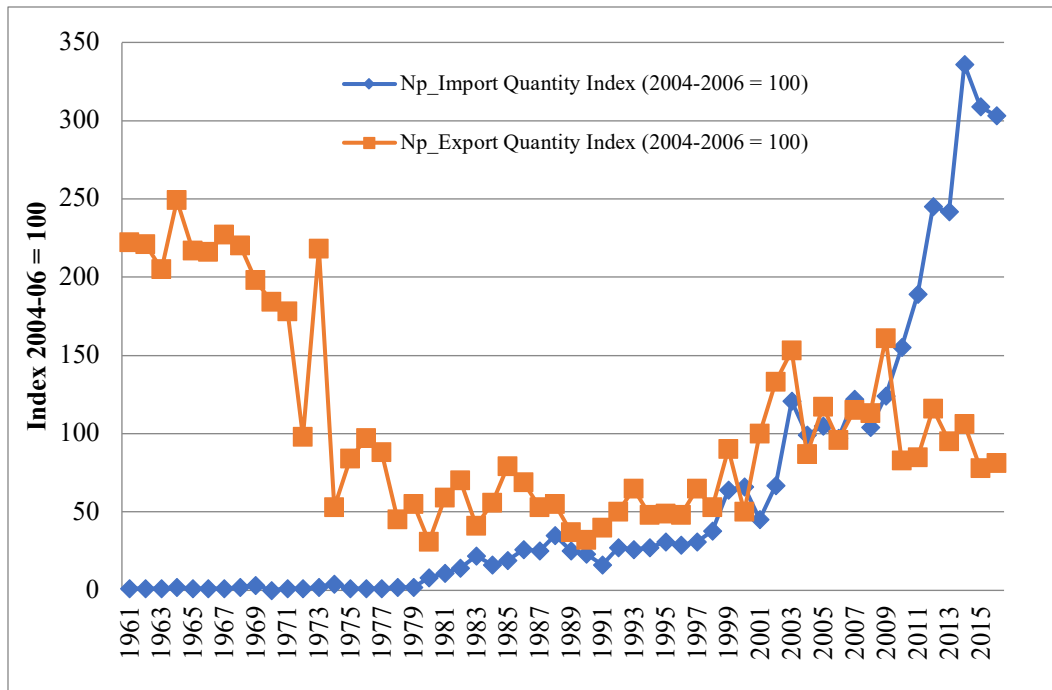


Figure 3. Nepal trade of agricultural goods

Source: FAOSTAT (2019)

Table 5. Directions of trade statistics of agricultural goods from South Asia 2017 (US\$ mn)

Country	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka	China	World	With SA %	With China %	With RoW %
Afghanistan	-	-	-	330.4	0.1	204.0	0.1	6.5	569.5	93.9	1.1	5.0
Bangladesh	-	-	-	35.0	18.3	71.6	43.2	80.3	942.8	17.8	8.5	73.7
Bhutan	-	-		241.7	8.3	0.1	-	0.2	275.1	90.9	0.1	9.0
India	85.6	976.6	44.6		652.3	137.5	404.7	571.2	27,119.1	8.5	2.1	89.4
Nepal	-	9.5	0.1	168.9		0.1	-	6.4	211.2	84.6	3.0	12.4
Pakistan	890.8	19.8	-	110.3	1.3		58.4	227.4	4,473.4	24.2	5.1	70.8
Sri Lanka	0.1	7.9	-	243.5	0.3	39.2		53.7	3,031.6	9.6	1.8	88.6
China	34.6	291.2	0.2	435.0	73.3	336.1	223.8		73,934.9	1.9	-	98.1
S Asia-China	1,011.1	1,305.0	44.9	1,564.8	753.9	788.6	730.2	945.7	110,557.6	5.6	0.9	93.5
World	1,776.7	7,662.1	51.4	18,243.2	1,779.9	6,900.7	2,790.8	115,520.5	1,532,581.7	2.6	7.5	89.9

Source: Thapa and Joshi (2019) & FAOSTAT (2019)

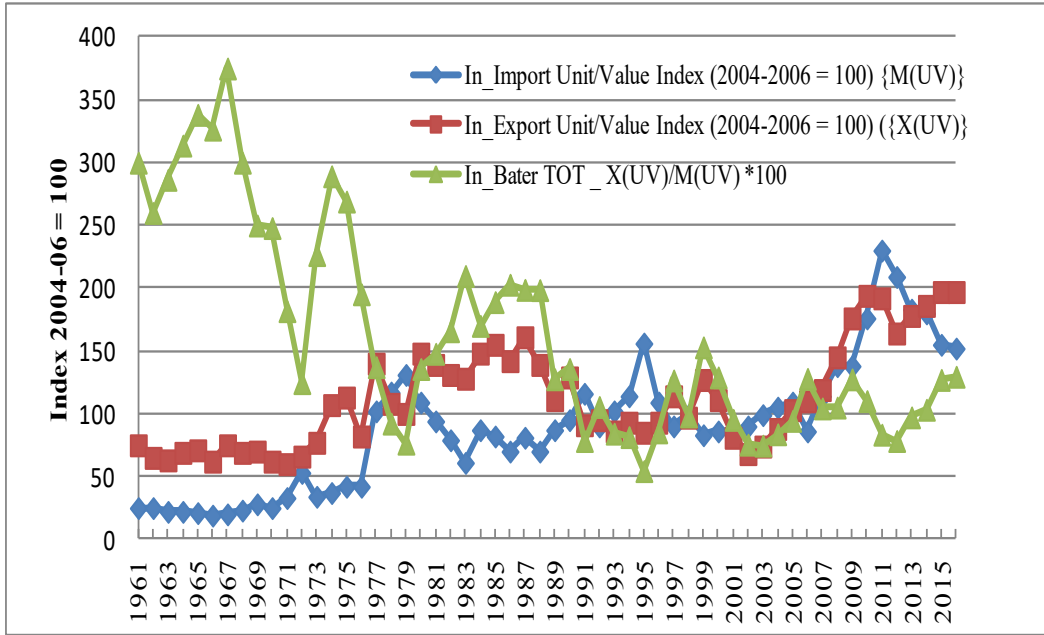


Figure 4. India Indices of unit value of imports, exports and barter terms of trade
Source: FAOSTAT (2019)

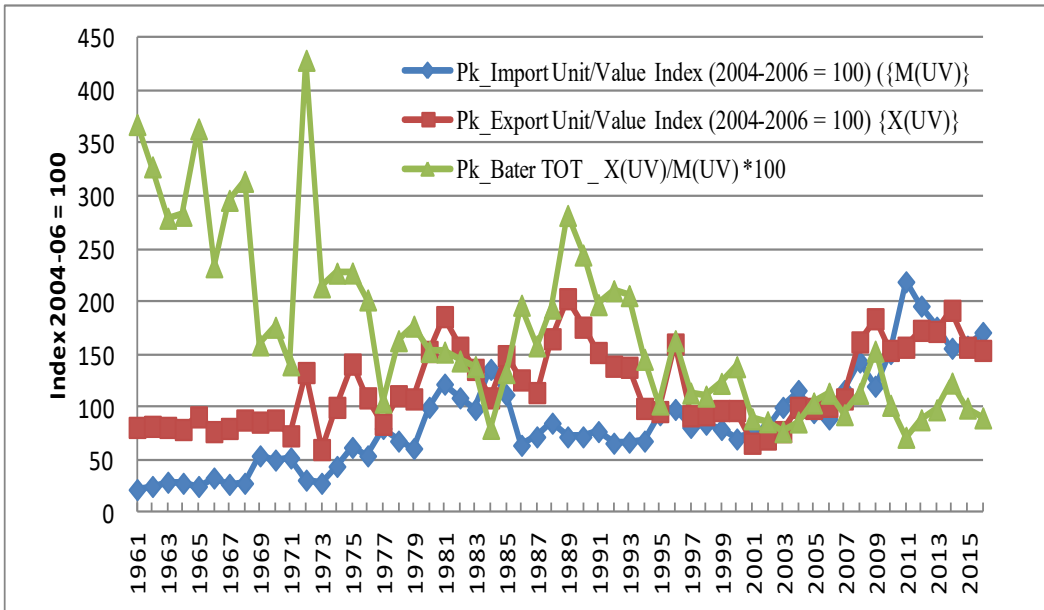


Figure 5. Pakistan indices of unit value of imports, exports, and barter terms of trade
Source: FAOSTAT (2019)

Agrarian Structures Modernizations

An example of how the agrarian relations matter for the agricultural development can be found in India's present concept of doubling the farmers' income. The targets expressed in terms of farmers' incomes emphasize aspects of the demographic indicators (birth, death, and migration), occupational patterns, industry structures, infrastructure, institutions, factor markets (wages, rents, interest, etc). The agrarian structures have to evolve to increase social capital for agricultural development.

The agrarian structures have a two-way relationship with agricultural development. The agrarian reforms broadly include land reform measures, credit measures, training, extension, land consolidations, etc. The World Bank (2007) evaluated the **agrarian reforms using five dimensions**: i) Stocks and market liberalization; ii) Land reform (including development of land markets); iii) Agro-processing and input supply channels; iv) Rural/ urban finance; and v) Market institutions. Cousins (2007) and Vishwanathan et al. (2012) emphasized that land reform is concerned with rights in land, and their character, strength and distribution. Thus, the agrarian reform is land reform plus a broader set of issues such as class character of the relations of production and distribution in farming and related enterprises. It shows how the relations connect to the wider class structure. Examples of other agrarian issues include tenure security for farm workers, labor tenants, farm dwellers and tenant peasants. Such concerns make these workers and tenants to have better prospects for receiving private-sector loans, infrastructure and support services, government support to forms of rural enterprise as complementary to agriculture, an increase of community participation in the government decisions in rural areas.

Some of the key indicators to assess the South Asia agrarian transformations in rural residences would include the human development indices (HDI) in rural areas, which depends on the average incomes, level of education and life expectancy; farm sizes and its distribution by sizes of holdings; agro-industry friendly infrastructures and institutions, employment and occupational structures, rates of capital formation, class-caste harmony and so on. The key point is that the rural incomes from both farm and non-farm sources need to rise rapidly and there should be environment to re-invest the savings to develop the rural economy.

Economic Policy, Institutions and Advocacy

Agricultural development also depends on broader issues of: i) Agricultural policy and the macro-economic framework; ii) Fiscal expenditure and subsidies; iii) Improving the incomes of the rural poor; iv) Gender and agricultural development; v) Selected issues in privatization; and vi) Principal aspects of legal framework (Norton, 2003). A stable macroeconomic environment favors investment in agricultural sector provided that the rates of return are sufficiently high. These returns depend on the trends in real

agricultural prices, i.e., agricultural prices relative to non-agricultural prices (i.e. barter terms of trade- ToT). The linkage between macro and sector levels via relative prices is powerful and is often the dominant one.

From the point of agriculture sector, the **principal instruments of macroeconomic policies are:** i) Exchange rate policy; ii) Trade policy; iii) Tariff policy; iv) Taxation policy; v) Fiscal expenditure policy; vi) Interest rate or monetary policy; and vii) Regulatory framework for finance and contractual relations. Of these, the first four are especially important in determining real prices of agricultural outputs. In this context, Dhokhalaya and Saprea (2013) studied the Gujarat agriculture and Indian agriculture and concluded about the hypothesis that favorable terms of trade for agriculture lead to a higher growth in agriculture and the whole economy. There was strong evidence for positive price elasticity of supply in agriculture and they almost ruled out the possibility of backward bending supply curve. Favorable ToT for agriculture were an additional factor for the high growth trajectory of Gujarat agriculture.

The public fiscal expenditure and subsidies are regarded as a principal instrument of agricultural policy. The capital and current account expenditures cover development finance, subsidies in explicit or implicit types, grants, economic rents, etc. The pressure to increase such outlays from the government budget have arisen in part from the desire to compensate the sector for unfavorable trends in real prices, which are due to downward trends in world markets prices, macroeconomic policy, subsidies by richer countries on production and exports. Kumar (2018) analyzed the contribution of total factor productivity (TFP) in agricultural growth of Bangladesh, India, Nepal, Pakistan, and Sri Lanka. They outlined policies towards food security under the sub-heads: i) Arresting deceleration in TFP; ii) Enhancing yield of major commodities; iii) Accent on empowering the small farmers; iv) Environment protection; and v) Strengthening of national agricultural research system; they suggested for further research in this area.

For improving the incomes of the rural poor, a central question is how to devise a set of policies to place the rural poor on a self-sustaining growth path. For the programs that address the symptoms of poverty (such as under nutrition and diseases), we need policy to diminish the *causes* of poverty, i.e., to enhance the earning-capacity of low income households. These may include better agriculture education, improved access to cultivable land, improved access to technology and better farmer training, improved access to production credit and insurance.

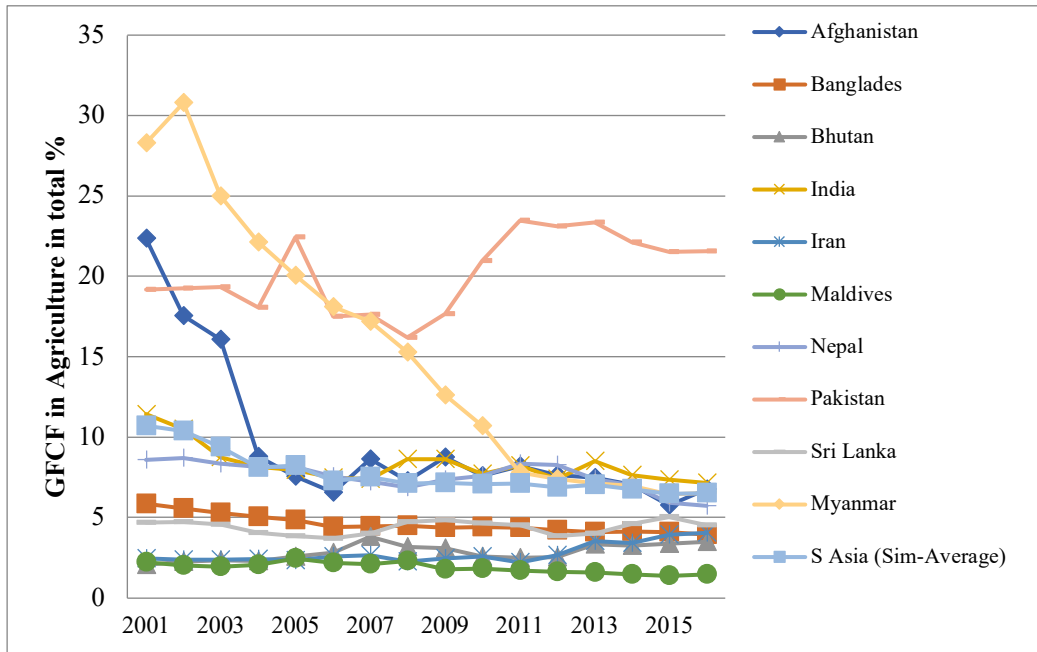


Figure 6. Gross fixed capital formation (agriculture, forestry and fishing) share of total (%)
Source: FAOSTAT (2019)

The economic distance between the small farmers and the institutions may reduce with agricultural policies are: i) Agricultural growth is more inclusive than industrial growth, and so select more pro-poor agriculture subsectors; ii) Targeted fiscal subsidies; iii) System of certification of deposits (crop liens) which small farmers can participate-in; iv) Creation of second- storey land fund, which can finance purchase of small farms, with a subsidy in the price to the buyer; v) Market assisted land reform(that is land fund); vi) Improvement of land rental markets; vii) Privatization of grain silos to enable small farmers alongside the larger farmers; viii) Development of viable rural financial system serving small-scale producers; ix) Investment in small-scale irrigation and formation of water users association for participatory management; x) Institutional reforms to improve respect for contracts so that no broker breaches it; and xi) Education and training programs oriented towards poor rural families and rural women. In addition, SAARC (2014) explained a long list of about 30-ways forward for poverty alleviation along with their program inputs, costs, financing, and institutional arrangements (Box 1). It is important that these best practices in poverty alleviation be related with the implementations of the SDGs 2015-2030 regionally and nationally.

Box 1. Ways forward in the best practices of poverty alleviation in South Asia

1. **Land management:** A comprehensive land management policy to ensure balance between different uses of land like crop production, rural roads and urban settlements, and the access to land to the poor farmers.
2. **On-farm water management:** Technical skills, farm level irrigation systems, water storage capacity, water management organization, farmer's knowledge on crop water requirements, and new technologies.
3. **Water harvesting/water management** techniques crucial for any farming activities.
4. **Climate action:** mitigation and adaptation strategies.
5. **Agricultural technology:** diversified and redirected toward cereal and non-cereal crops.
6. **Crop sector diversification:** to future consumer demands for individual foods.
7. **Commercial vegetable production and marketing:** support to the service provider organization. Integrated combination of hardware and software supports.
8. **HVC:** Investment on high-value agricultural products (poultry and dairy) and agro-processing.
9. **Community livestock development:** Adoption of a value-chain approach, river corridor based in low cost areas of production, school milk feeding program, wider adoption of forage.
10. **Social safety nets:** targeting via local level poverty maps to address fairness and transparency, and empower local community stakeholders.
11. **Targeted nutrition and health programs:** Age-specific complementary feeding and micronutrient supplements, community management of malnutrition, SUN, access to safe water/ sanitation, homestead food production, and use of fortified foods.
12. **Self-sustained sanitation program:** for the poorer sections, based on a participatory development.
13. **Essential healthcare services:** focused attention on capacity building/ utilization, and integration in the national program for service deliveries and HMIS.
14. **Energy:** renewable sources such as solar panels, wind turbines, biomass gasification, and biogas.
15. **Electricity:** networking with the central electricity grid.
16. **Micro-initiative funds:** MIF programs enterprises such as vegetable and horticulture production.
17. **Self-help groups:** capacity of SHGs in farmers' groups/cooperatives through trainings/study tours. Participation of women to fulfill their needs with their own capacity, institution building at cluster level.
18. **Rural self-employment training institute:** Ministry to collaborate with banks and state governments, to attract youth and facilitate enterprises, to include inputs on entrepreneurial development.
19. **Pro-poor employment generation:** Access to finance, infrastructural support, wider market, and production network.
20. **Model village development:** based on available natural and human resources; collectively implemented through the spirit of self-help, voluntarism, and cooperative approach.
21. **Training:** Partner organizations need to ensure long-term training support for participants.

- 22. **NGO/CBOs:** Training.
- 23. **Business development alliance:** Private sector partnerships with local entrepreneurs, consumer networks for selling locally produced products, linking participants with Business Development Service Center, and leverage government resources.
- 24. **Targeted groups:** Youth targeted directly, in addition to women.
- 25. **Home stay:** Publicity and improved access services. Product linkages/relationships with the hotels/lodges, tour operators, and *Adivasi* development.
- 26. **Poverty as a multi-dimensional problem:** Key areas (income, shelter, health and sanitation, food and nutrition, education, accessibility, entitlements, recognition), engage in a holistic approach.
- 27. **Urban planning:** Limited supply of basic amenities to city dwellers.
- 28. **Program monitoring and information management:** Capacity and information management systems for a better view of ongoing operations and performance.
- 29. **Governance:** Reflect participation of vulnerable/ marginalized to engage in local public institutions.

Policies on gender and agricultural development shows that the gender biases against women hinder agricultural development and reduce the nutritional status of rural households. Gender bias is manifest in agriculture through diminished access to land and credit, little attention to women's needs as producers and marketing agency by agricultural research and extension services, exclusion from most decision making regarding irrigation systems, lower access to agricultural inputs, and unequal inheritance. The deregulation, privatization and foreign direct investment (FDI) are important for increasing enterprise productivity and economic growth because of two reasons: i) Government budget outlays' agricultural orientation is very low, and ii) Private investment and FDI agency would bring more capital with skilled management and technology. In addition, there would appear to be a case for public expenditure and investment reform. Public investment in agriculture is in decline (Figure 7). It is recognized that public investment in infrastructure, services, and public goods such as roads and broadband connectivity also crowds-in the private investment. For this, the private sector needs government guidance and enabling support (Ferroni & Zhou, 2018).

Institutional basis provided by the legal support and judicial systems for agricultural development is essential. The FAOLEX is a comprehensive and up-to-date legislative and policy database. The legal support and judicial system underpins the commitments to honor the ownership and contractual obligation, forms of economic association such as the joint-stock or limited liability company, and cooperative form of association.

The nature of laws and judicial system have significant impacts on agriculture development. **Major laws affecting the legal and judicial systems in agriculture are:** i) Commercial code, labor codes, tax legislation, trade and commerce, intellectual property rights; and ii) Land tenure and tenancy system, farming rights, gender aspects of legislation; and agencies to surplus inputs (seed, water, fertilizer, pesticide use); iii)

Agricultural marketing, Agro-processing and rural industry; iv) Consumer protection legislation, anti-hoarding acts/essential commodities acts, food sovereignty; v) Finance: collateral, bank supervision on prudential norms, bankruptcy laws, insurance; and vi) Law enforcement agency (at governments at the central/ provincial/ municipal levels), and judiciary). The effectiveness of the agricultural laws and judicial provisions in South Asia may be approximated from the volume of FDI inflow in agriculture or food sectors, which appear to be very small till date (Figure 7). The available data suggest that FDI in South Asia increased annually by US\$ 0.87 million in agriculture, forestry and fishing, and by US\$1.13 million foods beverage and tobacco sectors during 1994-2012.

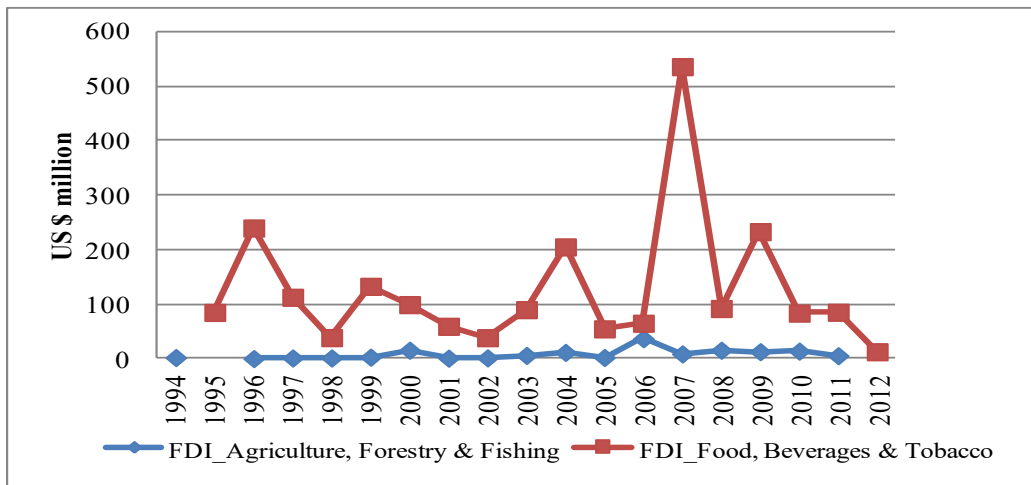


Figure 7. FDI inflows to agriculture and agro-industry in Southern Asia (US\$ mn)

Source: FAOSTAT (2015)

Challenges and Opportunities

The regional agriculture policy in South Asia may be inferred based on the mandates of the SAARC Agriculture Center (SAC), or its sub-region **BBIN (Bangladesh – Bhutan – India - Nepal)** or **Bay of Bengal Multilateral Scientific and Technical Cooperation (BIMSTEC)**, and the areas of agreements like **SAFTA, bilateral FTA or BIPA (Bilateral Investment Promotion Agreement)**. In reality, Southern Asia barley has a common agricultural policy, common agricultural market or common position in the international forums. In terms of government policy directives, the SAARC Agriculture Ministers' Decelerations, namely, the Thimphu Declaration 2019, Dhaka Deceleration 2016 provide are examples of recent policy directions. This section sum up the agricultural development policy challenges and issues for the region through the assimilation of national policies.

The Indian NITI Aayog (2018) has visualized the agrarian economy developments through the linkages of agriculture - manufacturing - service sector industries, and has formulated the agricultural development mission in terms of **doubling the farmers' income during 2016-23 through:** i) Modernizing agriculture; ii) Policy and governance; and iii) Value-chain and infrastructure. The principal constraints in the modernization of agriculture are as follows: use of outdated and inappropriate technology is the main reason behind low productivity of crops and livestock; affordability is a significant constraint on technology adoption particularly by the small and marginal farmers; several bottlenecks are hampering on-farm adoption of technology developed in public sector; agricultural research is constrained by resource inadequacy, regulations and intellectual property rights (IPR); multiple private and public sources supplying different information to farmers create confusion; a huge gap exists between the demand for and supply of skills in agriculture, which hinders diversification, adoption of precision agriculture and on-farm post-harvest value addition; the region has not caught up to the rest of world in terms of technology such as efficient irrigation, market intelligence, skills in extension, modernizing trade and commerce and like; viii) absence of adequate capital for production and marketing; and low scale of farming or business has constrained the adoption of improved practices in the input and output market.

So for modernizing agriculture, the opportunities/ ways forward are to **improve the productivity and efficiency through:** i) Increase area under irrigation, investment subsidy for micro-irrigation, and sustainable water use in agriculture; ii) Increase adoption of hybrid and improved seeds, and increase variety replacement ratio (VRR), strengthen seed testing facilities, and uniform national procedure for seed licensing; iii) Efficient fertilizer usage, and reorient fertilizer subsidy policy, and subsidies on liquid fertilizers; iv) Regulate pesticide use; and v) Custom hiring centers. Similarly **strengthening extension system through:** i) synergy between Agriculture Technology Management Agency and Krishi Vigyan Kendras (KVKs); ii) Public Private Partnership in KVKs; and iii) Market led extension, value-added extension, and district level skill mapping; and iv) Replication of dealer training program in the (state) agricultural universities.

Finally, diversification or promotion of high value commodities (HVCs) are to be done through: encourage diversification to HVCs (incentives); establish regional production belts; use of hybrid technology in vegetables, rootstocks for production of fruits, and smart horticulture; strengthen markets for organic products and convert agricultural waste for re-use and re-cycle; For livestock, breed indigenous cattle with exotic breeds, and promote and develop bull mother farm (white revolution); village level procurement systems; and convergence of schemes in fisheries sector, and capacity building for fish breeders and farmers (blue revolution). To push forward the above pathways, additional opportunity comes from the agricultural research councils, universities, commodity boards, food safety laws among others.

The **policy and governance aspects** for raising farmers' income emphasize the need to shift focus from agriculture to agribusiness, and is constrained by factors such as: i) Fragmented land holdings, ii) Low price realization, iii) Non-farm employment which is limited especially in manufacturing, iv) Agricultural credit scarcity especially for tenant farmers, and v) Agricultural trade especially uncertainty in regional trading regime.

To overcome these difficulties in agricultural policy and governance aspects, the opportunities/ ways forward have been as follows: i) Marketing reforms such as *Model Agricultural Produce and Livestock Marketing Act (APLM) 2017* in India, and e-trading in the national agricultural marketing (e-NAM) platforms; ii) Amending the Essential Commodities Act to balance the interests of farmers and consumers; iii) Stable export policy; iv) Price realization via Agricultural Tribunals, minimum reserve price (MRP), and auctions in *mandis* by creating competitive, stable and unified national market; v) Contract farming such as the (draft) *Model Contract Farming Act 2018*; vi) Land aggregation such as *Model Agriculture Land Leasing Act 2016*, digitization of land records such as geo-tagging and agnostic land registration to make land leasing effective, promoting farmer producer organizations alongside cooperatives; vii) R&D focusing on precision agriculture, increasing allocation research from 0.3 to 1.0% of Agri-GDP, creating a knowledge-hub to disseminate best practices (like KVKs), developing models of integrated farming across the farming value-chains and the likes; viii) Innovations like zero-budget natural farming, herbal inputs to improve soil quality and make plants more pest resistant, organic farming techniques, and ix) For the non-farm income (which contributes 2/3rd in the farmers' income), one needs to shifting farmers to agro-business and farm-related skills to make up the supply gaps, incubation of agripreneurs for achieving greater value-addition through agro-processing and propagation of modern extension services and trading of agri-inputs and agri-foods.

Lastly the **value chain and rural infrastructure (VC&RI)** aspects (such as public irrigation and power, farm machinery hub, rural markets, warehouses, cold-chains, processing facilities, e-NAMs, one needs to emphasize export logistics to create agro-industry, and make higher earnings. The main constrains in VC&RI are: i) low investment by public and private agencies and slow and uncertain implementation; ii) Inability to acquire land for market yards; iii) Existing marketing infrastructure suffering from finances, manpower and proper facilities, and the government's sub-market yards limited to government procurement but do not provide opportunities for open auction; iv) Poor maintenance of rural roads and their sub-optimal linkages with local and feeder roads; v) Lack of separate feeders to supply electricity to the agriculture and domestic uses, and vi) Lack of agriculture best practices and mechanisms with regards to traceability from producers to consumers, and to meet the quality standards for exports.

The opportunities available to address constraints in VC&RI come from: Markets and value chain; Rural roads, electricity and mechanization; and Export enablers. For the

markets and value-chains aspects, the ways forward and opportunities have been as follows: i) Infrastructure status for agriculture value-chains which means that full-fledged infrastructures may be deemed for the warehousing, pack-houses, ripening chambers, and cold storages, and that the fiscal benefits be availed for them at village levels also; ii) Village level procurement centers, which would serve farmers closer to the farm-gates; iii) Linking production to processing at local levels; iv) Food processing to create agripreneurs for greater value additions; v) Rural markets where agro/food processors could establish backward integration to secure/ source their raw materials; vi) Upgrade wholesale markets, upgrading warehouses with pledge financing facility, and creation of block-level resource centers; vii) Convergence/ synergy in line ministries (agriculture, food processing, and commerce) for developing the effective procurement linkages, processing facilities, retail chains, export activity and viability-gap-funding; and viii) Strengthen transport (railway/ truck freight operations) through temperature-controlled containers and loading/unloading facilities to reduce post-harvest losses and connect land-locked states to export markets.

For the rural roads, electricity and mechanization aspects, the ways forward/ opportunity have been as follows: i) Maintenance of rural roads through the women SHGs; ii) Revisiting criteria for identification of rural habitats for road connectivity to be more inclusive; iii) Incentivize electricity feeder separation for domestic and agricultural uses; and iv) Incentivize private investment in farm implements for the small farm hubs, and big farm hubs.

Lastly the export enablers are important both nationally and internationally, and the **strategies for export promotion are:** i) Develop export-oriented clusters with common infrastructure facilities, end-to-end cold chain system along with processing facilities; ii) Testing laboratories essential for health certificates for exports, and support to private agency/ agricultural universities for international accreditation; iii) Augment cargo handling facilities at the airports/ dry ports for exports, green channel clearance especially for channel for perishable produce in airports handling cargo; and iv) Regulatory frameworks to combat rejections in export markets (regarding uses of pesticides, growth hormones, and antibiotics) and for marine produce need to be developed, and ensure traceability mechanism through promotion of farmer producer organizations, contract farming and export-based clusters.

In Pakistan, the Constitution Article (18th Amendment) puts agriculture as a subject of Provinces who in turn have Departments of Agriculture. The Central Government has Ministry of National Food Security and Research, but national agricultural policy is nonexistent. The 12th Plan (2019-23) growth target of agriculture is 3.6% for GDP growth rate of 5.8%; its text on agricultural policy is not available. Pakistan's 11th FYP 2013-18 has agricultural policy and institution around 6-themes.

First, the Agriculture Policy Institute (API) is to be created by transforming the Agricultural Prices Commission for tackling the post-food crises situation through the requisite analytical and prescriptive underpinnings. API would be an autonomous institution with its Board of Governors of experts (economists, agri-economists and experts), private sector (farmers, agro-industry, financial institutions, exporters) and different ministries (GoP, 2016).

Second, the availability of agricultural statistics and database management issues (e.g. land use, cropping pattern, source of irrigation, crop-cutting) are to be improved through with piloting to collect and revalidate crop reporting by satellite imaging and remote sensing. There is need to develop reports on changes in agriculture productivity, profitability and competitiveness, domestic resource cost of products, consumption and utilization of agro products, food security and terms of trade indices, agriculture prices and parity, etc.

Third, the decline in agricultural terms of trade since 1990 with consequent depressions in investment in agriculture is to be addressed by strengthening the capacity for judicious formulation of the agricultural price policies.

Fourth a policy on biotechnology is to be firmed up with roadmap to accelerate R&D activities towards: i) Immediate legislation of the Seed Act (amendment) and Plant Breeder Right Bill; ii) Upgrading the research on biotechnology at par with the major agricultural economies through international collaboration with CGIAR institutions and multinationals; iii) Third-party evaluation of existing biotechnology institutions; iv) Implementation of the National Biosafety Guidelines and Rules; and v) Establishing a National Biosafety Committee leading to formation of National Biotechnology Regulatory Authority to take care of all the IPR, biosafety, biosecurity and related bioethical issues.

Fifth the coordination among federal governments for development and research functions is to be improved such that the agriculture development activities primarily fall in the domain of provincial governments. And the national agency are to deal with the policy and regulatory matters such as food and fiber security, international trade, trans-boundary issues (such as introduction of new varieties, flow of agri-goods and services, pests and diseases, and R&D), innovative high-tech projects, quarantine, SPS measures and compliance with the WTO regulations. Lastly, the corporate agriculture is to be revitalizing to overcome the limitation of the small land owners by setting up land development corporations; this agency will have majority equity of the poor and professional managers for its operations.

Raja (2018) stressed that Pakistan should target for agricultural growth rate of at least 5% annually to ensure GDP growth of 8% in order to absorb the new entrants to the labor market. The author outlined for Pakistan's agricultural policy as follows: i) Formulation of a national land use policy by suitably amending the industrial zoning and urban

planning policies to save the arable land going under brick and mortar; ii) Concentrate on agrarian reforms to transform entire socio-economy of the rural areas, to increase the productivity of farm and nonfarm operations, to reduce poverty levels, and to improving the quality of life of people living in the villages; iii) Add a new article to the Constitution to make the 'Right to Food' a fundamental right of every citizen within a reasonable time frame. Central government should formulate a comprehensive food security policy in consultation with all the provinces, and help the provinces to develop their own food security policies and strategies, to formulate investment plans, to enhance capacity of agricultural departments, and capacity building of district governments; iv) Link food security program with social safety-nets. Improve it through sound management, transparency and additional funding to increase its outreach; v) Strive to improve the farm productivity by developing on commercial lines and integrate the small farmers with the commercialization of agriculture, make economical landholding, access to finance, access to market. Integrate small farmers in the value-chain through four different means, namely, cooperative farming, contract farming, commercial farming and corporate farming, and to various parts of the large-scale supply chain; vi) Put great emphasis on agricultural mechanization, innovation and technology dissemination. vii) Promote matching between the agro-ecological zones and the crops sown through specialization across agro-ecological zones; and viii) Improve management and more equitable distribution of water, which accounts for 25% of productivity of any crop. Formulate a long-term strategy to increase the water availability, reduce its losses and use it more efficiently.

The Pakistan's 12th FYP 2018-23 plan has targeted agricultural growth rate of 3.4 % to make the country a net-food exporter with strategies such as: i) Agriculture diversification and value-addition; ii) Import substitution; iii) Reforming/ modernizing agriculture produce markets; iv) Harvest opportunities under the China-Pakistan Economic Corridor; and v) Taking SPS measures and quality compliance.

In Sri Lanka, the '*Overarching Agriculture Policy (draft) 2019 has 10-themes areas*: i) Reserving Natural Resources; ii) Land Use Planning, Land Administration and Land Degradation; iii) Agriculture Water Management; iv) Climate Change; v) Food Security; vi) Border (trade) Measures; vii) Effective Governance; viii) Development Subsidies for Value Chain Actors; ix) Production Support and Service Delivery; and x) Strengthening Education-research-extension.

Nepal's *Agriculture Policy- 2004* needs to be updated in view of: i) Agreements with WTO in 2004; ii) Agricultural Development Strategy 2016-2035; iii) Climate Change Policy revision (2075); iv) The Constitution of Nepal (2016) that has coded a federal 3-tier governments (Centre, Province, Municipality) with agriculture in concurrent list; v) SDG 2030 Agenda. The agricultural development policy constraints and opportunities by country are helpful for inferring the South Asia region's agricultural growth targets in the next section.

Review of Policies, Gaps and Programs

The SAARC agriculture grew by 3.31% annually during 2010-18 where the growth performance varied from a negative (-) 1.2 % in Maldives (apparently due to Tsunami factors) to a highest of 5.1% Afghanistan, which may be associated with the post-war recovery efforts. Against this performance of agriculture in the past decade, the agricultural growth target proposed by the SAARC countries to about 4.86 % for 2019-24. This target is arrived from the SAARC countries' targets in their plan documents (Table 6). The SAARC agencies will need to scale-up the agricultural growth rate by some 46% for the 2019-24 periods. The upward increase in the agricultural growth targets is particularly due to higher expectations in India and Nepal.

On various aspects of agricultural production/ supply functions, the issues about constraints, opportunities and ways forward are also discussed in the preceding sections. So there is need for dynamic market models (demand, supply functions), regional market creation and expansions. In this way, the SAC may choose from among several programs to develop specific plan of actions at latter stage.

Table 6. Agricultural growth performance and targets in SAARC area

Country	Agri-GVA growth rate (2010-18)	Targets for Future		References, source of data on targets
		Reference period	Agri-GVA growth target (%/yr)	
Afghanistan	5.06	NA	-NA	Earlier period 2010-18
Bangladesh	4.27	NA	3.34	7 th FYP 2016-20
Bhutan	2.13	2018-23	3.01	12 th FYP 2018-23
India(*)	3.35	2016-23	5.22	Chand (2017) {US\$ 1,505 to 3,420}.
Maldives	(1.22)	NA	NA	Historical 1997-2018
Nepal	3.11	2016-35	5.4	15 th Plan 2019/20-23/24, ADS 2015-35
Pakistan	2.69	2013-18	3.60	12 th FYP 2018-23
Sri Lanka	4.20	2016-25	NA	Vision 2025; Overarching Agril Policy
SAARC (#)	3.31	NA	4.86	

Note:*, India: doubling farmers' income underpins agricultural growth rate as 5.22%; it is weight-adjusted sums of: i) crop sector productivity 2.19%, ii) livestock value-added 1.35%, iii) Cropping intensity 0.7%, and iv) Crop diversification 1.0%.

#, To compute pooled growth rate for SA, the figures for Afghanistan, Maldives and Sri Lanka are as per past period (shown in the table). The weights for average are ratios of agri-GVA three-year average ending 2018.

Prioritized Areas under Agricultural Policy

Considered below are a range of about 22 programs to prioritize the highest scoring programs. The scores are subjective for maximum of 10 points. These scores are based on the author's individual perceptions about their importance to contribute in the Agri-GDP, innovations and institutions. We suggest that the SAC and other stakeholders to apply the value-chain ranking methods (as in Table 4).

Table 7. Suggested major policies, programs and projects with scores (max 10)

Policy Agenda	Proposal Program as per the Agricultural Policy	Score
Sustainable delivering framework for piloting and scaling-up of sustainable agri-technology.	Align the farmer producers with investors in agro-processing (domestic or FDI) and super markets in commodity production (may use contract law).	5
Agricultural policy and research gaps.	Collaborations with NARC system on developing GM/GE type oil seeds and pulses crops.	8
Investment policy on agricultural R&D.	Intensification of SUN movements in agriculture to nutrition pathways.	5
Access to agricultural inputs, particularly chemical fertilizers	Ganges basin collaboration in hybrid seeds of aromatic fine rice.	8
Agriculture labor market.	Productivity improvement, ensure minimum wages; empower women.	7
Production economics and agribusiness promotion.	Fertilizer industry/ input security in joint venture among the small states/ companies.	8
Value-chain development in agribusiness.	Pasmina goat VCD in Hindu Kush – Himalayas.	6
Strengthening to implement food standards and safety policies.	SAARC Food Standards for intra-regional trade, and common approach to Codex and OIE; System for HACCP assurances.	7
Agriculture and food marketing system.	Enlarging MSP/ MRP to more commodities for the price gaps due to fair price less market price, federally.	9
Regional trade in agriculture (formal & informal).	Fostering the SAARC Agri-Trade and strengthening complementarities.	9
Non-Tariff Barriers (NTBs to agricultural trade.	Establishment of common laboratory for norms of quarantine, and issue of certificates for exports and imports of goods.	7
Capacity building through post-graduate programs.	Association of SA's Agri-Varsities for HRD in priority industry (PhD, Master, faculty exchange, brain storming sessions, publications).	8
Resource use efficiency.	Water conservation and productivity enhancement in upland/lowland by shifting to legumes, fruits/herbs.	7
Custom hiring services.	R&D on small farm mechanizations.	6
Issues of agriculture with income and poverty.	Localization of recommended dietary allowances and Food-Based Dietary Guidelines by country/ province.	5

Policy Agenda	Proposal Program as per the Agricultural Policy	Score
Access to food and nutrition.	Common property development through social mobilizations, enhance production, proper distribution.	7
Livelihoods.	Off-farm, post-harvest project activity developments.	6
Youth and women.	Model villages, agro-tourism start-ups; Improvement of rural/agri-infrastructure under the leadership of women; Women empowerment/ inclusive development through cooperatives.	7
Agriculture and climate change.	On-farm renewable energy supply, and diesel substitution; System to compensating to farmers for industrial effluent pollution of land water.	6
Mitigation of plant and animal trans-boundary diseases and pests.	Support for Bio-security and Strengthening Trans-Border Safety with emphasis on Dairy and Citrus.	8
Risk and uncertainty.	Establishment of Agri. Insurance Re-financing Fund for SA.	8
ICT for agri-statistics, data management, and knowledge management.	GIS and GPS services to the farmer, and insurance.	7

Recommendation of Priority Programs for Agricultural Policy

Among the above-proposed thematic areas, agricultural sub-sectors/commodities and VCD alliances, we propose a set of few programs on products, institutions and markets on the basis of their priority. The following five programs are thus proposed here for implementation on a trans-boundary basis in South Asia during 2020-30. These programs appear somewhat generic at the outset but it can lead to specific projects at the sub-regional levels. The generic programs are: value chain development in high value foods (dairy, pulses, oilseeds, aromatic rice and herbs) program; soil health and fertilizer/input security for all states and farmers program; market integrations, pricing and trade competitiveness enhancement; policy and governance: R&D, education, extension and investment; and water resources development and trading program.

1) *Efficient value-chain development alliance (dairy, pulses, oilseeds, aromatic rice, herbs)*

Background and Justification

South Asia needs agro-industrial products that can earn good incomes for the farmers or agriprenuers, are nutritious, have export markets, contributes in the VCD's environmental and social aspects, and provides connectivity among countries. From such perspectives, the priority goes to five group of products, namely, dairy, pulses, oilseeds, fine and aromatic rice and herbs.

Dairy: South Asia especially India is the largest dairy producers in the world and has established brands in the export markets. India may help get her adjoining neighbors like

Nepal, Bhutan, and Bangladesh etc for the dairy regional VCD alliance. Dairy products have various segments from fresh milk to utility transformation such as the butter, cheeses, chunk lets. Dairy products are high-value low-volume products, which are traded internationally. The income elasticity for consumption of this product is high. On the production/supply, the importance of dairy for social inclusion, gender empowerment, organic agriculture and nutrition status of the population can hardly be over emphasized. There are several gaps in dairy cattle development and dairy technology.

Pulses and Oilseeds: Both the oil seeds and pulses are very important foods in the diets, and their demand is increasing. These products are internationally traded. Supply of pulses, beans and oil seeds is very low in the Sothern Asia (Figure 8a). Productivity of the oil seeds, pulses and beans has hardly increased during recent decades in the region (Figure 8b). More so the oilseeds, pulses and beans are important from the social inclusion, water requirement efficiency, land uses and soil health and ecology, nutrition of human as well as animals. Hence a regionally coordinated program is needed to improve the pulses/beans and oilseeds. The program may cover functions like breeding, GM/ GE/bio-tech interventions in the area of seeds, processing and trade (e.g., import-substitution and export-promotion). Governments have invested less in such products and must be overcome as well.

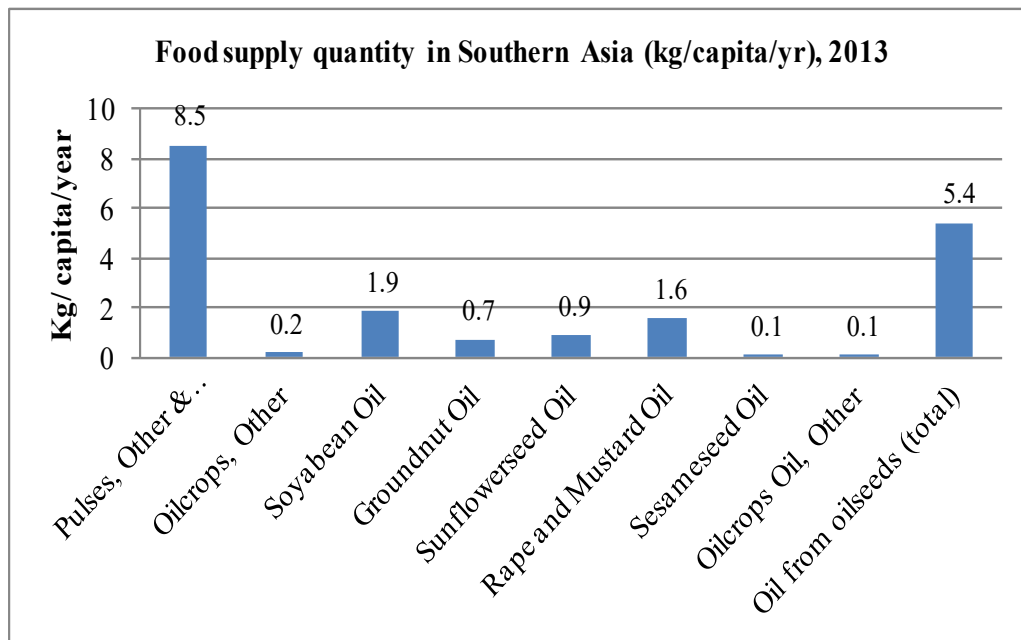


Figure 8a. Food supply quantity in Southern Asia (1961-2015)

Source: FAOSTAT (2019)

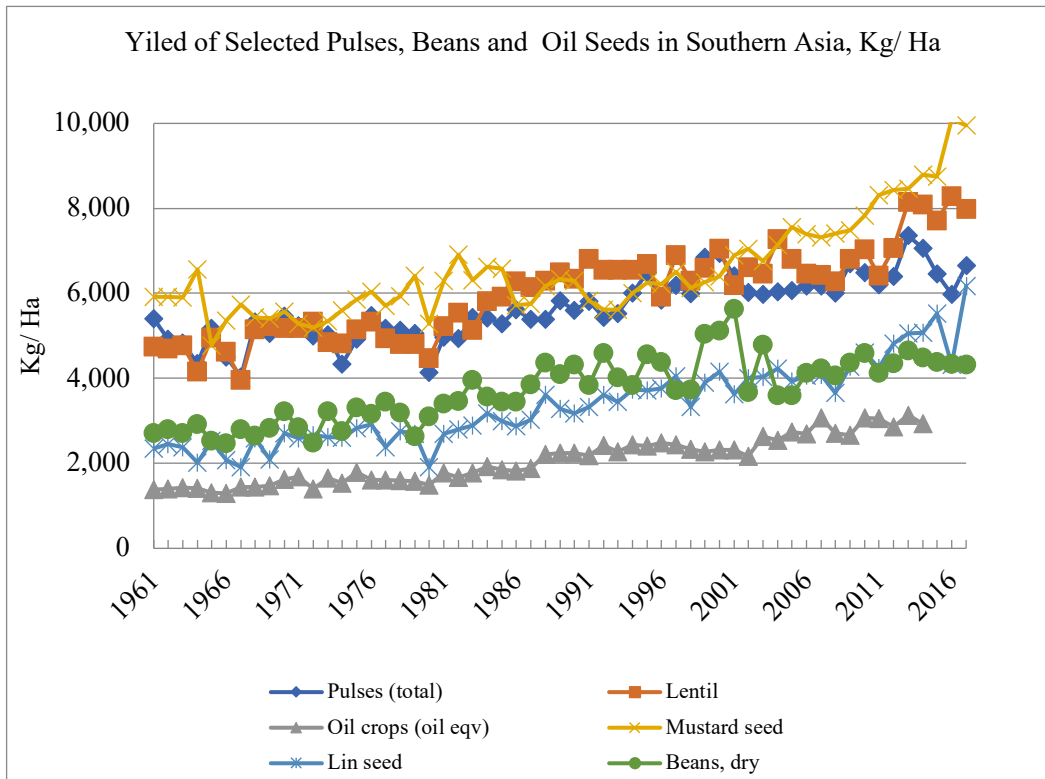


Figure 8b. Yields of selected pulse, beans and oil seeds in Southern Asia (1961-2015)

Source: FAOSTAT (2019)

Fine and aromatic rice: Demand for fine and aromatic rice such as *basmati*, *kasturi*, *kalanamak*, *jadhan* and others has been increasing in the region and international markets. SA is native to various kinds of fine aromatic rice varieties, but there is lack of documentation of various genotypes in the SA region. Statistics on the yield/production of fine aromatic paddy and other traditional/ indigenous rice varieties are very scanty and irregular. In general, the productivity of paddy (kg/ha) in the region has marginally improved during 2000- 17 (Figure 9). The yields of rice in South Asia are much less than the yield in East Asia. So, collective efforts are needed to improve the competitiveness of SA in the international markets for rice. India has developed the hybrid varieties of basmati rice, and can disseminate it throughout the Indus-Ganga plains and other niche agro-ecologies. Thus a program of regional VCD alliance in basmati rice and other sister genomes can help South Asia develop several industries with competitiveness in the rice markets of the world.

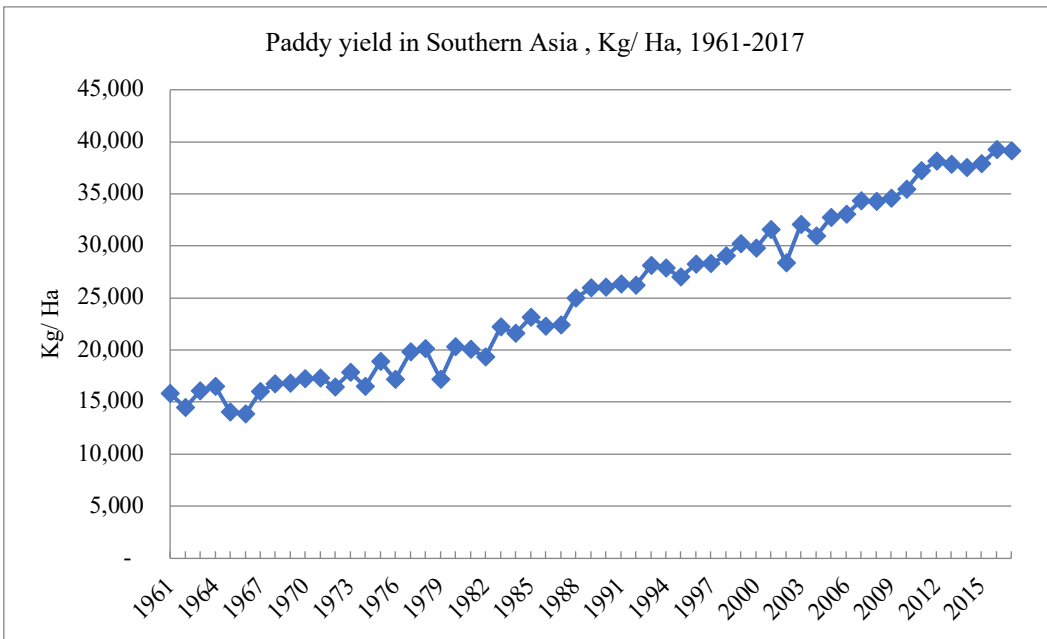
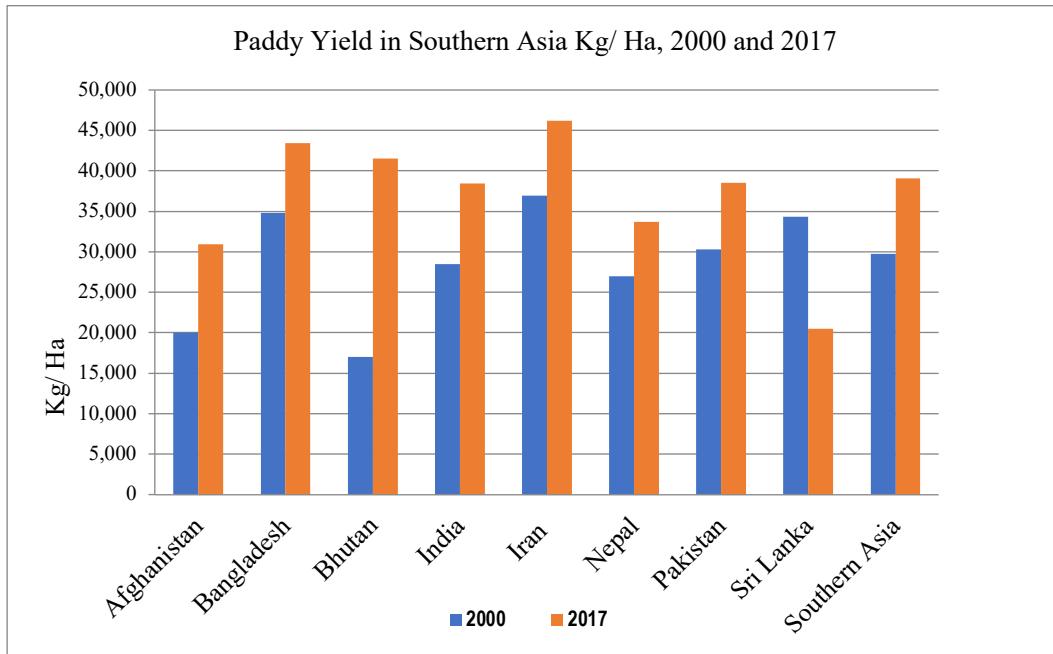


Figure 9. Paddy Yield/ ha by country 2010 and 2017 and trend of paddy yield 1961-2015

Source: FAOSTAT (2019)

Medicinal herbs: Medicinal herbs are in growing demand throughout the world and such herbs from the Himalayan region to Sri Lanka have special appeal to the customers. As with Yoga, the Ayurveda is a gift from South Asia to the global community both for medicine and nutrition. Promotion of medicinal herbs helps to develop the status of people in the central Indian uplands and Himalayan regions. Herbs have favorable impact in the natural resource management and climate actions.

Objectives

The program vision on 'value-chain development alliance (dairy, pulses, oilseeds, aromatic rice, herbs)' at the regional level during 2020-30 are conceived as follows: i) Dairy VCD alliance in the Dhaka–Thimphu–Kolkatta–Kathmandu quadrangle (and subsequently in Delhi-Islamabad-Kabul corridor) for inclusive and gender-empowering development with the sector's self-sufficiency and exports, and nutrition of the populations; ii) VCD in oilseeds, pulses and beans based on eco-friendly farming system with improved diets of protein and fatty acids, self-sufficiency and exports; iii) VCD in fine and aromatic rice and similar niche products with collective security of seeds, productions and coordinated exports of high quality products in the world market and higher income for the actors; and iv) VCD in medicinal and aromatic plant (MAPS) products consistent with resources growth in upland and mountain ecosystem with high incomes for VCD actors, optimum nutrition and medicine, and export earnings.

The program objectives are: i) Coordinate R & D for development of improved breeds of dairy, and seeds of pulses, oil seeds, pulses, aromatic rice and herbs, and set standards their of; ii) Harmonize among the participating countries to implement the commodity production programs ensuring traceability etc.; iii) Decide on the common post-harvest handling, processing, storage, branding-yardsticks, and the configuration of facilities their of; and iv) Carryout trading in the region and internationally for collective benefits.

Components/ Activities

The program targets are to increase the annual growth rates of HVCs against the base of 2000-18 by at least 46.8% (indicative for revision up/down) for the 2020-30 periods as follows: i) Dairy sector products growth rates increased from 4.1 % in the past to 6.0%; ii) Oilseeds products growth rates increased from 3.32 in the past to 4.7%; iii) Pulses products growth rates increased from 2.6% in the past to 3.8%; iv) Fine/aromatic rice products growth rates increased from 1.9 % in the past to 2.7%; and v) MAP (or spices) products growth rates increased accordingly. The project components are as follows: i) Natural resource and agro-biodiversity assessment; ii) Technology and innovations for value chain development and alliances, and IPRs; iii) Common bench marking: aggregate measures of support, quality, safety, and HACCP; and iv) Trading policy, program and market sharing.

2) Ensure fertilizer security to the smallholder farmers

Background and Justification

The South Asian farmers in mountainous countries (Afghanistan, Bhutan, Nepal) are in need of secure access to agricultural inputs like mineral fertilizers such that there can be food security. Further, all farmers throughout the region are in need of bio-fertilizers. With the intensification of agricultural production, the macro-nutrients (NPK: nitrogen, phosphorus and potash), micro-nutrients and trace elements need to be continuously replenished in the soils. The small/ marginal farmers depend on more of marginal lands, their natural resource base for production need further assistance.

The governments/ markets in the mountainous states are unable to supply required fertilizers to the peasants as shown by their lower rates of fertilizer uses. They also have disproportionate applications of various NPK and other plant nutrients and thus make the soils reaction acidic. For example in India, the applied proportion of NPK seems to be as 7.5:2.8:1.0, whereas the NITI Aayog recommendation is 4:2:1. Sometimes the price distortions such as excess subsidy for urea have led to over uses of NPK which has fiscal burden and biological magnification. The size of fertilizer industry in SA is about 35 million tones under the supply-constrained scenario and may grow to 50 million tones. Small economies need to collaborate with larger economies to develop fertilizer companies such as through the PPP arrangements. The SAC may work with the chambers of commerce and industries and financing agencies to develop the agri-inputs/ fertilizer security for all countries, and all farmers at reasonable prices for sustainable growth of agri-food systems.

Objectives

The program vision for soil health (organic matter, nutrients, reaction and biotic activities improved in all farming systems and fertilizer/input security for all states and farmers realized with cooperative self-reliance. The program objectives are: i) Assess the soil health in terms of nutrients, organic matter, reaction and other parameters in terms of suitability for proposed farming systems; ii) Carryout input market modeling, and projections of input demand-supply gaps, and viable ways to fulfill the nutrient demand; iii) Prepare a regional plan to supply fertilizers and other inputs and their pricing and cross-border transport arrangements; and iv) Prepare modalities for financing, rates of returns, and risk mitigations.

Components/ Activities

Farming systems maintain their soil organic matter at certain level. The program components are as follows: i) Assessment of supplies of raw materials and power for fertilizer and other inputs among the participating countries; ii) Preparation of formula for fertilizer and other inputs in terms of their constituents, and assessment of technology

for manufacturing/ production; iii) Agreements on factory location, management, trading and cross-border transports; and iv) Management plans for institutions, HDR, and insurance.

3) Market integrations, pricing and trade competitiveness

Background and Justification

The reasons behind why the farmers in SAARC region have lower wellbeing, agricultural production is below potentials, and agricultural supply response has low elasticity have got to do with the market inefficiency, unfavorable terms of trade in prices, and budget constraints with the government. This can be overcome through change from minimum support price (MSP) to minimum reserve price (MRP), integration of agricultural markets across the countries, common policy for agricultural marketing, and SAARC market expansion neighbors: Myanmar, Tibet/China, Iran and so on.

Firstly, the producer price indices for cereals in South Asia are very divergent which indicates the lack of market integration across the countries, but we expect these prices to converge to 'one price' as per the law of market. Further few countries (India, Pakistan) have implemented the MSP as 'fair' price to the farmers for limited number of commodities (paddy and wheat). Its fiscal costs are quite high because the government pays the total amount of MSP. One option is to devise a system that the support prices need to cover the difference between the desired price and actual market price, and expand such system of MRP to more commodities. In this way, markets can find more efficient solutions to deliver foods, governments can cover more people with lesser budgets, and farmers can benefit from more open and competitive market structures.

Secondly, the SAARC countries are faced with low growth or even decline in indices of the unit-value of exports; but the indices of unit value of imports are rising much faster, that is, worsening barter terms of trade with the rest of world. So the Southern Asian countries need to cooperate to develop their agricultural pricing policies, and utilize the economies of the scale to get better prices per unit of the exports. They can act together in reforming the agri-food market connectivity, market prices, parity of export/ imports etc. SAC may push to develop the common agricultural markets in SAARC, which requires symmetry among the countries in trade balance on agri-foods and raw materials.

Objectives

The vision of market-trade program is integrated/ common agricultural markets (inputs and outputs) nationally and regionally that are efficient, and pricing and trading system ensuring best welfare for the producers and consumers. The program objectives are as follows: i) Estimate the minimum reserve prices (MRP) that the farmers would need to be guaranteed for sale of their products, and recommend the government to finance the viability price gap (i.e., market price - MRP); and commodities to be covered under the

MRP; ii) Implement provisions of agricultural (re-) insurance in case of disasters with the MRP-commodities; iii) Implement system of electronic national agricultural market (e-NAM) and other efficient markets, including futures trading; iv) Propose systems for electronic regional agricultural market (e-RAM); and v) Design cross-border trading rules consistent with the WTO, SAFTA, BIPA and likes for smooth functioning of the agricultural marketing and trading in the region, and with rest of world.

Components/ Activities

The targets of market-trade integration program are as follows: i) Agricultural market surplus ratios reaching at least xx% by country; ii) Modern agro-/food processing industry share reaching xx% of the agricultural raw material produces; iii) Farmer/producers share reaching at least xx% in the consumers prices/ spending; and iv) Countries in the region have at least zero-trade balance in the region, and trade balance at least as xx % of their agric-GDP in trades with non-SAARC countries

The components of market-trade integration program are: i) Market and fiancé analysis for cost, price and rates of returns (actual and normative) of commodities and brands; ii) Agricultural market facilities, software and management systems by country and region; iii) Financial system architecture; and iv) Trading facilities and rules.

4) Policy and governance for R&D, education, extension and investment

Background and Justification

In the countries with federal structure of the government (India, Pakistan, Nepal etc), agriculture belong to the central, provincial or municipal governments in varying ways. This affects mobilization of the agricultural agencies and programs for desired results. State investment in agricultural R&D is required up to the optimum level. There are also issues of patenting the innovations, dealing with the multinational agri-tech companies, financing of education in agriculture and allied fields.

The agricultural science and technology indicators (ASTI) for South Asia suggested huge gap to be covered. The full time equivalent (FTE) researchers range between about 5- 15 per lakh farmers in India and Pakistan; it is declining in Nepal. More number of FTE are needed to address the "current climate of population growth, climate change, and shifting diets, it is vital to be able to track the funding, functioning, and impact of agricultural research in order to improve efficiency, promote evidence-based decision making, and demonstrate impact".

When the agricultural universities are in hundreds, there are also issues of coordination in standards and enforcements in education, research and technology. The agricultural extension services have been the responsibility of government, but private sector participation is also increasing. There may be possibility of involving market agents in extension for reaching the farmers. The experiences across countries on policy for

governance of agricultural development agencies and markets are different, and so is the government capacity to streamline these agencies in the markets. So SAC need to further develop regional platform to improve the agricultural policy and governance. Association of Agricultural Universities can be very helpful in producing the scientists in South Asia and neighboring areas, and to promote research, extension and education. South Asia has over hundred universities in different areas of agriculture (crops, horticulture, livestock/ veterinary, forestry, food/dairy technology, fisheries and so on). An association of such universities can set priorities by disciplines or industry.

Objectives

The vision of program of agricultural governance is enhanced social capital, efficient institutions and modernized farm holdings/ value-chain actors at par excellence advanced economies. Its objectives are: i) South Asia platform of CGIAR system; ii) Develop SAARC level and Hindu Kush Himalayan association of agricultural and allied universities; and iii) Contribute to human resource and agricultural technology.

Components/ Activities

The targets agricultural governance program are: i) Under the aegis of CGIAR system, a regional platform of NARCs formed and has biannual conferences; ii) South Asia Association of Agricultural Universities formed and to have biannual brain storming sessions and recommendations; iii) Collaborative research programs number reaching to at least to xx% of to total research programs in the region; iv) Allocation of resources to agricultural R&D by country reached to at least xx% of Agri-GDP; and v) The IKP documentation reaches xx numbers, innovations reaches xx numbers, and region's IPRs reaches xx numbers.

The components agricultural governance program are: i) Assessment of lessons from status of agriculture and agro-industry according to the structures of governments; ii) Communication coordination systems (structures, mandates, and rules) among agricultural /agro industrial institutions in public and private sectors; iii) Regional platforms of agricultural research councils, and of agricultural universities; and iv) Public investment policies on agricultural institutions.

5) Improving the water resource use efficiency and water trading for food security

Background and Justification

Water is the most limiting constraint in agricultural production and agro-processing industry. Huge areas remain to be irrigated. Meanwhile, the productivity of water in South Asia is only 1/5th of the productivity in the world, and has been behind the world in the dynamics of productivity of water. It has been necessary to revisit the farming system for more efficient uses of water in producing the foods and industrial crops.

Water availability is highly seasonal over the year. Summer monsoon is associated largely with floods and some draughts as well. There is a huge scope to do water harvesting as well as water storage for its uses during the lean months and years. Winter monsoons and snow falls are limited and are becoming erratic over the years. The agri-food production systems in the winter need more seriously to be revisited for increasing the productivity of waters.

The water market for agriculture within a country or community has been developing slowly and needs to be further explored. Many countries have inter-state water conflicts and tribunals to allocate the water. This region has many trans-boundary rivers and riparian disputes. Applications of *the Helsinki Rules 1966* remain to be effective in the region, or the rules are disputed. Some countries have a tendency to do a free riding of common property or exercise monopoly/ monopsony powers. Consequently, water storages projects for national and international uses must be promoted. This requires the need to recognize creation of regional market for water in the region for smooth development of agri-foods and raw materials.

Objectives

The vision of collaborative water management program is water resources management systems consistent with the climate actions, inter-state cooperative and most productive fashions, especially in the trans-boundary watersheds. The program objectives are: i) Develop water security plan for agriculture and agro-industry the region; ii) Design systems for increasing the productivity of water agri-food systems; and iii) Develop norms for investment in consumptive uses of water, its pricing and its trading between countries.

Components/ Activities

The targets of collaborative water management program are: i) Water use efficient farming systems or technologies adopted by farmers reaches to xx % of major farming practices; ii) Ground water recharge rate and abstraction rates balanced; iii) In the major trans-boundary rivers, collaborative efforts for storage of flood season rain-off reaches to xx billion cubic meters for its multipurpose uses; and iv) Arrangements put in place to do trading of water for agricultural and industrial uses the market.

The components of collaborative water management program are: i) Farming system and cropping patterns adjustments for water efficiency; ii) Water harvesting programs; iii) Water storage and trading programs; and iv) Policy, legislations, agreements and institutions for trans-boundary water resource development and trading.

Conclusion and Ways Forward

The paper South Asian agriculture policy 2020-30 sought to develop priority programs in/ for the Southern Asia, particularly the SAARC Agriculture Center (SAC) area. The South Asian agriculture/agro-industry is faced with a task of innovations and modernizing with an aim to supply for the growing demands for the food security of its countries, food sovereignty and nutrition of their populations; generating traded surplus with the rest of world, and conserve and grow natural resources. This requires more efforts to increase the competitiveness, innovations and factor price adjustments.

The paper **built agricultural development themes** as Natural resources/ input management; Risk, uncertainty and (re-) insurance; Inclusive development; Marketing, agro-processing industry and trade; Agrarian relation modernizations; and Macro-/political economic policy and institutions. It sums up trend of bio-physical resource in SAARC states for 1961-99 and 2000-19 sub-periods, and the projections for 2030. In particular, we consider the agricultural resources such as land, water, forests, and fertilizers and so on in relation to the rise of the population and state of know-how to manage the resources. **Second**, the slow pace of modernization of agriculture is attributed partly to the farmers' risk averting behavior, and inadequate support of public agency to improve the business environment. The life and general insurance among the agrarian population need to be steeped up in coverage and depth, and more work from the public and private agencies is needed to increase the (re-)insurance business. It suggests that that agricultural insurance and reinsurance business can be done by pooling the efforts of the public and private agencies together.

Third, the inclusive development index rank nations/societies in three pillars: growth and development, inclusion, and intergenerational equity and sustainability. This has important implications for both agricultural productivity and farmers' welfare. The IDI is also about the support of state to develop different farmers' resource endowments and production plans. Product composition of agriculture in terms of per capita availability and rates of growth are examined for 25-subsector: The growth of these commodity groups are worked out for the 1961-99 and 2000-18 sub-periods, which collate with the GATT-era and WTO-era. The paper proposes a methodology for the regional VCD ranking through their vertical and horizontal integrations. The impact of GDP per capita on nutrition are examined for the indicators of poverty, under-nourishment of population, optimum nutrition of children, and anemia in women in reproductive age group. **Fourth**, the agricultural marketing, agro-processing industry and trade are important because of the 'market demand-driven' approach, marketed surplus ratios, consumers' awareness to HACCP-ISO standards, and export-demands. The paper urges to further improve this marketed surplus ratio of agriculture with remunerative prices to them, and grater share in the spending of the final consumers. We emphasize

development of integrated agricultural market among the countries and in the region through the PPP approaches.

The **fifth** theme on modernization of agrarian relations deals with the wellbeing of farmers, capacity of agencies and motivation for enterprises. **Lastly**, the macro-political economic policy and institutions deals with aspects such as place of food and agriculture in the statutory documents, government levels and ministries. It also covered how the agricultural development policy is conditioned by the macroeconomic environment; public fiscal expenditure and subsidies; improvements in the incomes of rural poor; gender and agricultural development; deregulation, privatization and FDI. The agricultural orientation of the state investment both public and private agencies) is low and declining. These under-investments in agriculture are matters of serious concern. Also to be found are very comprehensive list of 'best practices for poverty alleviation and SDG fulfillments' in South Asia.

The FAOStat and WDI indicators indicate that agriculture in the Southern Asia grew by 3.0% annually during 2000-18. The agricultural plans of the SAARC member states imply a target of agricultural growth rate of about 4.86% during the next decade. The paper puts forth **specific priority program clustered in 5-areas for consideration** by the SAC: i) Value chain development in high value foods (dairy, pulses, oilseeds, aromatic rice and herbs) program, ii) Soil health and fertilizer/input security (for all states and farmers) program, iii) Market integrations, pricing and trade competitiveness enhancement program, iv) Policy and governance: R&D, education, extension and investment program, and v) Collaborative water resources development and trading program. The justifications, vision, objectives, targets and components for these programs are provided. It emphasizes a common framework for agricultural policy and programs for the region. SAC with such policy and programs may contribute to develop agriculture in Southern Asia, bridge the competitiveness gap with the world agriculture.

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Chapter 11

Resource Allocation for Agricultural Research in South Asia: Trends, Challenges, and Policy Implications

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Abstract

Quantitative evidence presented in this report demonstrates that total public agricultural research and development (R&D) spending in South Asia has risen considerably since 2000. This trend was largely driven by India, which has the highest investment levels and strongest human resource capacity in agricultural research South Asia by far (in terms of absolute size, average qualification levels of researchers, and the scientific outputs they produce). Compared with India, agricultural R&D faces greater challenges in the four other South Asian countries for which data were available (Bangladesh, Nepal, Pakistan, and Sri Lanka). Underinvestment in agricultural R&D in these countries is considerable, and agricultural research staff is significantly less-qualified than in India, the combined result of prolonged recruitment freezes, losses of highly qualified senior staff, limited training opportunities, and an aging population of researchers. In addition, political instability in some countries has either delayed or complicated much needed institutional and policy reforms. The scientific competence of South Asia's agricultural R&D agencies is high, particularly in India, but as in many developing regions of the world, stronger linkages are needed to connect agricultural research agencies and their staff with the end users of their research to improve the relevance, effectiveness, and efficiency of research outputs. Further efforts to strengthen sub-regional linkages are also needed in order to better utilize limited resources and reduce wasteful duplication. In addition, good governance is key to promoting the effectiveness and efficiency of research, and ongoing policy and institutional reform will be needed to further strengthen agricultural R&D and innovation in South Asia.

Keywords: Resource allocation, agricultural research, policy, South Asia

Background

South Asia has made remarkable progress toward economic growth and poverty reduction since the turn of the millennium; nevertheless, the sub-region is still home to nearly half the world's poor and malnourished people. Poverty and malnutrition in the

sub-region are not only widespread, but also increasingly concentrated in lagging rural areas, where roughly three-quarters of South Asia's poor people reside. The vast majority of the rural poor depend on the production of rainfed crops, livestock, forestry, and informal (often migratory) employment for their livelihoods.

To provide a pathway out of poverty for the sub-continent's rural poor and to tackle the widening rural-urban income gap, a revival of the agricultural sector is urgently needed. The World Bank predicts that the population of South Asia will reach 2.3 billion people by the year 2050, up from 1.8 billion today (World Bank, 2019). In order to feed these 500 million extra people and to address other pressing challenges—including adaptation to climate change and rising and volatile food prices—it is crucial that agricultural productivity in the sub-region be increased without delay.

A persuasive body of empirical evidence has demonstrated that agricultural research and development (R&D) has been a major contributor to agricultural innovation, productivity increases, and poverty reduction around the globe over the past six decades. From the 1960s through the 1980s, the so-called Green Revolution allowed significant increases in agricultural production in South Asia through the implementation of research-based agricultural methods and new technologies. These had a tremendously positive impact on food security and rural incomes; more recently, however, the impact of the Green Revolution has begun to level off. Further, the challenges that South Asia's rural population face remain daunting. Land and water have become increasingly scarce in some parts of the subcontinent as these resources have been diverted to nonagricultural activities, while misguided government policies together with climate change and rising fuel prices have added to the woes. All over the subcontinent, the call for a reinvigoration of the agricultural sector has intensified in recent years. Effective and well-targeted agricultural R&D plays a key role in this regard.

Despite the well-documented evidence that the payoffs to agricultural research are considerable, most South Asian countries continue to underinvest in agricultural R&D. Given the substantial time lag between investing in research and reaping its rewards—which is typically decades, not just years—agricultural R&D requires a long-term commitment in terms of sufficient levels of sustained funding and well-staffed research agencies. Quantitative data are essential for agricultural R&D stakeholders to be able to analyze trends in agricultural R&D investments and capacity; identify gaps; set future investment priorities; and better coordinate agricultural R&D across institutes, regions, and commodities. R&D indicators are also an indispensable tool when assessing the contribution of agricultural R&D to agricultural output and productivity growth and to economic growth more generally. This paper analyzes agricultural R&D indicators for five South Asian countries (hereafter referred to as South Asia): Bangladesh, India, Nepal, Pakistan, and Sri Lanka. It presents trends and challenges with regard to

agricultural R&D investments and human resource capacity throughout the sub-region, and provides policy recommendations for ways to address some of these challenges.

The analysis in this report is based on detailed data collected by the International Food Policy Research Institute's (IFPRI's) Agricultural Science and Technology Indicators (ASTI) program.¹ Since 2000, ASTI has periodically surveyed 500+ agricultural research agencies in the sub-region from the government, higher education, and nonprofit sector. The data in this report are presented in a highly aggregated fashion, but can be broken down by specific agency, sector, or commodity for more in-depth analysis upon request.² Unfortunately, ASTI has never implemented surveys in Afghanistan, Bhutan, and the Maldives. These countries are therefore excluded from the analysis. The most recent year for which data are available for Bangladesh, Nepal, and Sri Lanka is 2016. India's most recent data are for 2014 and Pakistan's for 2012.

Institutional Setup of Agricultural Research in South Asia

The landscape of South Asian agricultural R&D is highly complex, comprising a large number of governments, higher education, nonprofit, private sector, and international research agencies. The data presented in this report include only public national agricultural R&D. Staff and spending data for private-sector companies and international agricultural R&D agencies operating in the sub-region, such as the centers of the Consultative Group on International Agricultural Research (CGIAR), have been excluded. Over the past three decades, the institutional structure of public agricultural R&D in South Asia has remained largely unchanged. While there have been ongoing internal reorganizations, none of the countries has undertaken fundamental restructuring of its research system, as was common practice throughout the 1960 and 1970s. Despite differences in size and structure, the organization and coordination of national agricultural R&D systems bear some similarities across the five countries: all have national agricultural research councils that coordinate agricultural R&D, set priorities, and administer competitive grant schemes, although their roles and scope of authority vary and in some cases are undergoing change. The specifics relating to each country are discussed in turn below.

India has by far the largest agricultural R&D system in the sub-region in terms of staff, expenditures, and number of agencies. The Indian Council for Agricultural Research (ICAR) directly oversees 97 agencies, including 4 "deemed" universities, 45 research institutes, 17 national research centers, 6 national bureaus, and 25 project directorates. The research institutes and national research centers under ICAR primarily focus on research; the project directorates are responsible for the coordination of research

¹ For more information on ASTI, its methodology, and its findings, please consult <http://www.asti.cgiar.org>.

² The data exclude private-sector expenditures in agricultural R&D and spending by international organization, such as those by CGIAR institutes.

conducted by different agencies, including the state agricultural universities (SAUs); while the national bureaus primarily focus on natural resource conservation. The research conducted by ICAR's institutes covers a broad range of areas, including crops, livestock, fisheries, natural resources, agricultural engineering, policy, and management. ICAR institutes vary considerably in size, the largest by far being the Indian Agricultural Research Institute (IARI), followed by the Indian Veterinary Research Institute (IVRI), both of which, together with the National Dairy Research Institute (NDRI) and the Central Institute for Fisheries and Education (CIFE), are classified as "deemed" universities. Researchers from some of the other ICAR institutes serve as faculty staff to nearby SAUs, which are mandated to perform state-specific research and education; were created following on the U.S. land grant system; and comprise multiple faculties focusing on key areas like crops, horticulture, animal science, fisheries, and so on. Many SAUs attract students from across Asia at both the undergraduate and postgraduate levels. The country's largest SAUs include Chaudhary Charan Singh Haryana Agricultural University (HAU), Punjab Agricultural University (PAU), Acharya N. G. Ranga Agricultural University (ANGRAU), and Tamil Nadu Agricultural University (TNAU). A number of other government and higher education agencies are involved in agricultural R&D in India, but their collective shares of total public agricultural R&D remains small. Notably, the Indian Council of Forestry Research and Education (ICFRE) undertakes forestry research related to climate change, biodiversity, desertification, and sustainable management (Stads et al., 2016).

In **Pakistan**, the main agricultural R&D agency is the Pakistan Agricultural Research Council (PARC), whose broad mandate is the coordination of research among federal, provincial, and higher education agencies. PARC oversees a number of federal government research agencies located across the country. One of the largest is the National Agricultural Research Center (NARC), which in turn oversees a number of its own research institutes. Aside from PARC/NARC, 18 other federal government agencies conduct agriculture-related R&D under various ministries. Despite the size and large number of institutes at the federal level, agricultural R&D also falls within the domain of Pakistan's provincial governments. With the devolution of agriculture to the provinces in 2010, provincial research systems have gained a clearer mandate in R&D. A key challenge, however, will be to ensure an equitable division of resources and capacities both between the federal agencies and the provinces, as well as among the provinces themselves, given that half of the provincial-level R&D staff are currently located in Punjab Province, a major wheat-growing area. Efforts are underway to strengthen PARC and improve its relevance and effectiveness under the government's new configurations and economic growth priorities. Similar processes are being pursued in light of the government's plans to devolve public universities to the provinces. The role of Pakistan's universities in agricultural R&D has become increasingly important in recent years. Student enrollments in agricultural faculties have more than doubled since 2003, and

agricultural scientist have also followed a steep upward trend. The University of Agriculture, Faisalabad is Pakistan's largest agricultural university (Stads et al., 2015).

In **Bangladesh**, the activities of 10 different crop, livestock, forestry, and fisheries research institutes are coordinated by the Bangladesh Agricultural Research Council (BARC). The largest of these institutes are the Bangladesh Agricultural Research Institute (BARI), focusing on a wide range of crops, and the Bangladesh Rice Research Institute (BRRI). The fact that the BARC-affiliated institutes fall under five different ministries has complicated and limited the overall coordinating role of the BARC Secretariat. Outside of the BARC-affiliated institutes, 10 other government agencies and 32 higher education agencies conduct agricultural R&D in Bangladesh. The higher education agencies also follow the national research priorities set by BARC. Bangladesh Agricultural University (BAU), in particular, has strong research capacity and its number of research projects has been on the rise in recent years (Stads & Gao, 2019).

In **Sri Lanka**, the Sri Lanka Council for Agricultural Research Policy (SLCARP) exercises a high degree of central authority over agricultural research by overseeing and coordinating the activities of all 13 government and 7 higher education agencies involved in agricultural R&D. The bulk of the country's agricultural R&D is carried out by the government sector. Aside from the Department of Agriculture (which oversees institutes involved in rice, horticultural, and food crops research), public R&D is conducted by a number of R&D institutes specializing in plantation crops, as well as institutes focusing on livestock, fisheries, forestry, postharvest activities. The University of Peradeniya is the country's largest agricultural university (Stads & Thi Pham, 2019).

The vast majority of agricultural R&D in **Nepal** is carried out by the Nepal Agricultural Research Council (NARC), which assists the national government in formulating agricultural policies and conducts research related to crops, livestock, aquaculture, natural resources, postharvest, climate change, agro-economics and marketing. The Agriculture and Forestry University (AFU) and Tribhuvan University (TU) are the major universities engaged in agricultural R&D. Unlike other countries in the sub-region, nongovernmental organizations (NGOs), such as Local Initiatives for Biodiversity, Research and Development (LI-BIRD), play an increasingly important role in agricultural R&D in Nepal (Stads, et al., 2019).

The institutional composition of public agricultural R&D in South Asia has remained relatively unchanged since the mid-1990s. Government agencies represented about two-thirds of agricultural R&D capacity in the sub-region, while the higher education sector accounted for roughly one-third, and the nonprofit sector for less than 1% (Figure 1). These sub-regional shares mask major cross-country differences. While the government sectors in Bangladesh, Nepal, Pakistan, and Sri Lanka employ the majority of these countries' agricultural researchers, in India the higher education sector dominates in terms of R&D staff numbers: in 2014, universities (mostly SAUs) accounted for 61% of

Indian agricultural R&D capacity. Nepal is the only country in the sub-region where the nonprofit sector plays a significant role in agricultural R&D, representing 7% of the country’s agricultural research capacity in 2016.

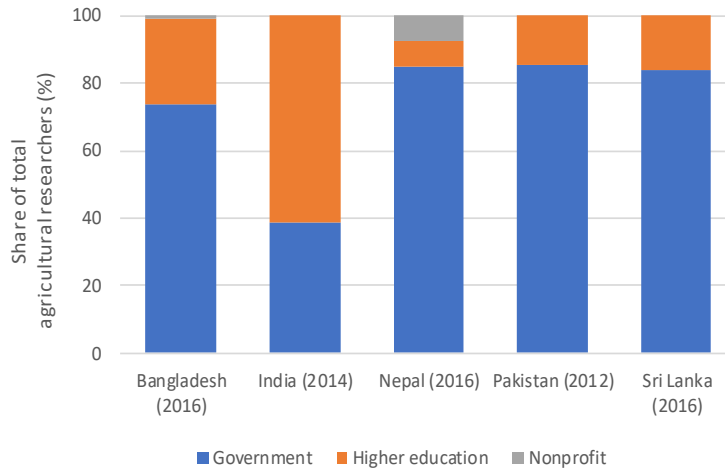


Figure 1. Institutional distribution of public agricultural research staff

Source: ASTI Survey Data (various years)

Long-Term Trends in Agricultural Research Investment and Capacity

Agricultural Research Spending

Total public agricultural research spending in South Asia increased from 2.5 billion to 4.1 billion dollars (in 2011 PPP prices) during 2000–2012, an increase of 66% (Table 1).³⁴ This growth was almost entirely driven by **India**, the sub-region’s largest country. ICAR’s expenditures accelerated in 2009 due to a nationwide pay rise for civil servants, which drove up ICAR’s salary costs. In 2011, India’s universities adopted the same pay structure as ICAR, explaining the increase in higher education spending that year. Another nationwide civil servant salary increase took place in 2017, which must have certainly driven up the cost of national agricultural R&D once again. In contrast, the amount that Indian research agencies spent on research programs, infrastructure, and equipment has remained fairly constant over time. The budgets of some state agricultural universities have fallen in recent years, but the World Bank loan-funded National Higher Agricultural Education Project is set to reverse this trend.

³ At present, the preferred method for calculating the relative size of economies or other economic data, such as agricultural research spending, is purchasing power parity (PPP) conversion. PPP exchange rates measure the relative purchasing power of currencies for a wide range of goods and services, converting current GDP prices of individual countries into a common currency.

⁴ These amounts include salary costs, operating and program costs, as well as capital investments.

Table 1. Agricultural research spending, 2000–2016

Countries	2000	2006	2012	2014	2016
	<i>(million 2011 PPP dollars)</i>				
Bangladesh	200.4	198.0	252.4	269.0	287.9
India	1,904.0	2,318.3	3,397.8	3,298.4	na
Nepal	39.2	28.2	53.3	75.1	81.9
Pakistan	235.6	295.6	332.5	na	na
Sri Lanka	104.5	92.0	78.2	89.2	112.4

Source: ASTI Survey Data (various years)

Note: na denotes that data are unavailable.

Although the rapid increase in Indian agricultural R&D spending in recent years overshadows the trends occurring in the subcontinent’s smaller countries, an examination of relative shifts in investment levels over time reveals some interesting cross-country and cross-institutional differences and challenges. In **Bangladesh**, agricultural R&D spending has shown an upward, albeit erratic trend since the mid-1990s. Before the turn of the millennium, increased government contributions and project-related funds derived from the World Bank loan–funded Agricultural Research Management Project (ARMP) led to a rapid increase in the country’s agricultural research spending levels. The completion of this project caused public expenditures on agricultural R&D to fall by more than one-third during 2000–03, but expenditures quickly recovered in subsequent years.

Agricultural R&D spending in **Nepal** is characterized by severe year-to-year fluctuations, largely linked to the influx of donor funding. The completion of World Bank loan–financed Agricultural Research and Extension Project (AREP), which ran from 1998 to 2002, led to a sharp decline in agricultural R&D investment levels. Spending rebounded somewhat after the 2006 signing of the Comprehensive Peace Accord due to increased government support for public agricultural R&D, but the launch of the Agriculture Development Strategy (ADS) and the Prime Minister Agriculture Modernization Project (PMAMP) were the main drivers behind the more recent increase in the country’s agricultural research expenditures.

In **Sri Lanka**, total agricultural research spending rose by more than 40% (in inflation-adjusted terms) during 2013–2016, after being more or less stagnant during the previous decade. The nationwide pay rise for public sector employees in 2015 was an important factor behind this increase. Operating and program costs as well as capital investment also rose considerably in 2016, largely driven by the Coconut Research Institute and the Department of Agriculture’s Fruit Research and Development Institute.

Growth in **Pakistan**’s agricultural research spending has been modest but erratic since 2000. Close to 80% of total expenditures by federal and provincial government agencies, on average, is spent on salary-related costs. The cost of actual research programs is to a large extent funded through the Agricultural Research Endowment Fund (managed by

PARC and funded through the sale of wheat donated by the United States government), the government-funded Research for Agricultural Development Program, the US-funded Agricultural Innovation Program for Pakistan, the Australia Pakistan Agriculture Sector Linkages Program, and various other donors.

Intensity of Agricultural Research Spending

Analyzing absolute levels of research expenditures explains only so much. Another way of comparing the commitment to public agricultural R&D investments across countries is to measure total public agricultural R&D spending as a percentage of agricultural gross domestic product (AgGDP). This relative measure goes beyond absolute agricultural R&D spending levels to indicate the intensity of investments. On average, South Asia invested around US\$ 0.35– US\$ 0.40 in agricultural research for every US\$ 100 of agricultural output (Figure 2), which is low given the high levels of poverty and malnutrition and low agricultural productivity in the sub-region—all in the context of adverse climate change impacts. South Asian agricultural research intensity ratios are also well below the 1% target recommended by the United Nations (United Nations, 2011). Although Sri Lanka’s research intensity ratio has shown considerable volatility over time, it has been consistently higher than ratios in Bangladesh, India, Nepal, and Pakistan. Nonetheless, intensity ratios of all South Asian countries are well below the global average (0.77% of global AgGDP). High-income countries invest 2.7% of their AgGDP in agricultural research, on average. China invests around 0.6%, Malaysia around 0.9%, and Brazil around 1.8%. It should be noted, that when comparing intensity ratios across countries, broader agricultural and economic contexts need to be taken into account as well.

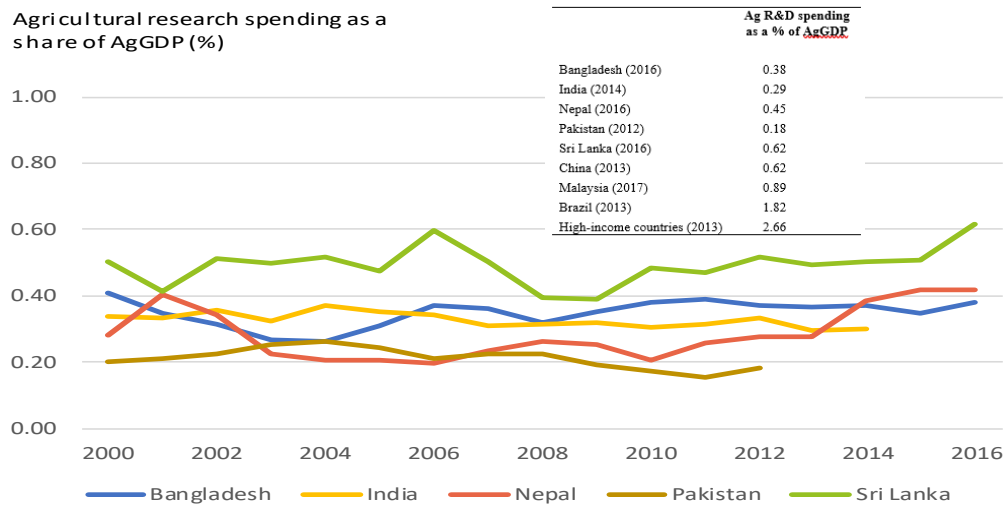


Figure 2. Agricultural research intensity ratios, 2000–2016
Source: ASTI Survey Data (various years)

Agricultural Research Staff

Roughly 20,000 full-time equivalent (FTE) agricultural researchers are active in South Asia.⁵ On average, agricultural researcher numbers in India have hovered around 12,000–13,000 FTEs (Table 2). During 2000–2009, levels markedly decreased at ICAR and the universities in response to years of stagnating recruitment. The number of agricultural researchers has begun to rise again in more recent years, largely due to the establishment of a number of specialized universities focusing on animal science, together with an intensification of recruitment efforts by ICAR agencies. With 3,678 FTEs in 2012 agricultural researchers, Pakistan has the second-highest agricultural R&D capacity in the sub-region, followed by Bangladesh (2,269 FTEs in 2016), Sri Lanka (648 FTEs in 2016), and Nepal (520 FTEs in 2016). It is important to note that the definition of what constitutes a researcher in South Asia differs both across countries and among institutes within countries, making it difficult to draw meaningful cross-country comparisons of human resource capacity. In India, for example, an entry-level researcher at ICAR or the SAUs requires at least MSc degree, whereas researchers at the agricultural research councils in the other four countries only require a BSc degree. Moreover, a large number of PhD-qualified researchers in India are employed as technicians rather than as researchers at ICAR, so it is important to include these staff members in any assessment of overall agricultural research capacity.

Table 2. Agricultural researchers in SAARC countries

Agricultural Researchers	Bangladesh (2016)	India (2014)	Nepal (2016)	Pakistan (2012)	Sri Lanka (2016)
Agricultural researchers (FTEs)	2,268.6	12,746.6	519.7	3,678.3	648
Share of researchers with PhD degrees	37%	73%	12%	21%	29%
Share of female researchers	22%	18%	19%	12%	52%

Source: ASTI Survey Data (various years)

Agricultural Research Focus

Governments and agricultural research agencies across South Asia are limited in their choice of options of how to allocate scarce resources. It is important that they allocate sufficient resources to the right types of research and on the right commodities for agricultural R&D to have lasting effects on productivity growth and poverty reduction.

⁵ ASTI calculates its human resource and financial data in full-time equivalents or FTEs. This method takes into account the proportion of time researchers spend on research compared with other nonresearch activities. University employees, for example, spend the bulk of their time on teaching, administration, and student supervision rather than on research. As a result, four faculty members estimated to spend 25% of their time on research would individually represent 0.25 FTEs and collectively be counted as 1.0 FTE.

Table 3. Distribution of agricultural researchers by commodity area

Commodities	Bangladesh (2016)	India (2014)	Nepal (2016)	Pakistan (2012)	Sri Lanka (2016)
<i>Share of total agricultural researchers (%)</i>					
Cereals	18.1	14.0	17.6	22.0	9.2
Roots and tubers	4.4	2.4	1.9	2.8	3.7
Pulses	4.8	5.6	6.0	5.2	4.1
Oil-bearing crops	3.8	6.5	0.8	2.9	7.5
Horticultural crops	9.2	12.8	13.9	12.7	10.5
Other crops	12.3	11.6	4.4	10.2	26.9
Livestock	11.1	16.0	16.9	17.3	4.5
Forestry	3.4	3.9	4.9	2.7	0.7
Fisheries	8.7	4.8	13.9	3.2	8.3
Natural resources	6.5	2.1	2.7	8.3	4.6
Socioeconomics	3.1	5.0	1.7	3.4	8.6
Other	14.8	15.4	15.2	9.3	11.4
Total	100.0	100.0	100.0	100.0	100.0

Source: ASTI Survey Data (various years)

Notes: Other crops include mostly fiber crops (cotton, jute) and plantation crops (tea, rubber). The category "Other" includes non-commodity areas, such as on-farm postharvest research, agricultural engineering, pastures and forages, and food and nutrition science.

ASTI collected detailed information on the allocation of FTE researchers across commodity areas. More than half of all FTE researchers in the 5-country sample conducted crop research, whereas 15% undertook livestock research (Table 3). Fisheries and forestry research accounted for 5 and 4%, respectively. These aggregated figures reveal some important cross-country differences. For example, Pakistan's research agenda is heavily orientated towards cereal crops. In Pakistan, 22% of agricultural researchers conducted research on cereals in 2012. In contrast, just 9% of agricultural researchers in Sri Lanka conducted research on cereals in 2016. In Sri Lanka, plantation crops (tea, rubber, coconut, sugarcane) are the most researched crops.

A closer look at thematic research areas of agricultural researchers in India reveals some interesting differences between ICAR and the higher education sector (Table 4). ICAR's research focuses on issues of national importance, whereas university research mandates target state-level priorities. Compared with the universities, research undertaken at ICAR generally has better funding, as well as better research infrastructure and equipment. ICAR researchers spend relatively more of their time on basic science, germplasm conservation, socioeconomic research, and emerging areas (such as biotechnology and

nanotechnology). University research, on the other hand, tends to be more applied. The emergence of state veterinary universities is reflected in the substantial focus on livestock health by universities. Forestry research falls under Indian Council of Forestry Research and Education (ICFRE) and hence does not feature prominently on either ICAR's or the universities' research agendas.

Table 4. Focus of agricultural researchers at ICAR and in higher education by thematic area, 2014

Thematic area	ICAR	Higher education
	Share of FTE researchers (%)	
Crop genetic improvement	14.9	11.7
Crop production (agronomy, fertilizer)	10.6	11.0
Crop protection	9.7	8.8
Other crop-related themes	1.5	1.3
Genetic improvement of livestock	2.7	5.2
Livestock health	3.8	13.1
Livestock management	1.5	7.6
Pastures, forages, and animal nutrition	2.4	5.5
Other livestock-related themes	2.2	2.9
Fisheries-related themes	4.7	9.5
Soil	1.6	2.5
Water	1.3	2.9
Agricultural engineering	2.2	1.2
Biodiversity, germplasm conservation	7.0	1.7
Farming systems	2.2	2.1
Food safety	1.5	1.2
Emerging areas (biotechnology, nanotechnology)	5.5	2.4
Onfarm postharvest research	6.0	2.5
Socioeconomic and policy research	13.0	4.3
Other themes	5.8	2.6
Total	100.0	100.0

Source: ASTI Survey Data (various years)

Challenges in Agricultural Research

The data in the section above give a concise overview of the status and direction of agricultural research capacity and investment in South Asia. ASTI collected a lot more detailed and disaggregated information that goes beyond the scope of this paper,

including institute-level data on agricultural research staff by degree, gender, age, and discipline; financial data by cost category and funding source; research focus data; and data on research outputs (peer-reviewed publications and varietal release). Based on a thorough analysis of the data presented above, as well as these additional ASTI indicators, a number of important challenges facing South Asian agricultural research systems emerged. These challenges are briefly described below. The severity of each of these challenges differs from one country to the next, given the different size and scope of sub-region's agricultural research and policy environment in which they operate.

i. Severe underinvestment in agricultural research

As the agricultural research intensity ratios presented above indicate, South Asia is underinvesting in agricultural research. South Asian governments have a critical responsibility when it comes to providing sufficient and sustained agricultural R&D funding and for creating a more enabling environment within which agricultural innovation can prosper. Given the substantial time lag between investing in research and reaping its rewards—which usually takes decades, not just years—agricultural research requires a long-term commitment of sufficient and sustained funding. In reality, these long research cycles rarely coincide with short-term election cycles, shifting political agendas, and changes in government budget allocations—all of which have major implications for agricultural research. Decision-makers have limited incentive to support long-term investment in agricultural research because extracting political credit for doing so is difficult. Agricultural research directly competes with other important public investment areas, including education, health, and infrastructure, the impacts of which are more rapidly visible than those of research.

It is hard to quantify the exact level of underinvestment. Conventional recommendations of agricultural research intensity levels, such as the 1% of AgGDP investment target recommended by the United Nations, assume that national investments should be proportional to the size of the agricultural sector. In reality, a country's capacity to invest in agricultural research depends on a range of variables, including the size of the economy, a country's income level, the level of diversification of agricultural production, and the availability of relevant technology spillovers from other countries. In efforts to address these nuances, ASTI developed a multi-factored indicator of research intensity that comprises a range of weighted criteria (Nin Pratt, 2016). Under this approach, countries with the same mix of inputs are expected to require similar minimum levels of research investment, and investment below that level can be interpreted as an indicator that the country is potentially underinvesting based on its particular input mix.⁶

⁶ A major difficulty in building this indicator is to define the weights necessary to aggregate the individual indicators into a single measure of R&D intensity. These weights should reflect the importance that the five determinants of R&D have as constraints of R&D investment in each country. Data envelopment analysis (DEA) approach was used to obtain a multifactored research and development (R&D) intensity measure. A

ASTI's weighted indicator of research intensity demonstrates that all 5 South Asian countries are indeed underinvesting in agricultural research (Figure 3). Underinvestment is most severe in Sri Lanka, Bangladesh, and Pakistan. These countries should be able to at least double their agricultural research spending. India stands out from the other South Asian countries in that its actual agricultural research investment is in fact very close to potential. The analysis also reveals that a 1-percent investment target is unrealistic for 4 of the 5 countries. Only Sri Lanka is capable of investing more, based on the structural characteristics of its economy and agricultural sector. An agricultural research investment target of 1.73% of AgGDP is thought to be realistic and attainable for Sri Lanka. To have met this target in 2016, the country would need to have invested 15.4 billion Sri Lankan rupees, instead of the 5.5 billion it actually invested (both in current prices). In other words, the gap between actual investment in agricultural research and estimated attainable agricultural research investment was nearly 10 billion rupees in 2016 alone. Even though the 2016 investment gap is lower than in the 1980–2010 period, it remains very high, raising questions as to what Sri Lanka's agricultural productivity could have looked like today had these investments been made in the past (Nin Pratt, 2016).

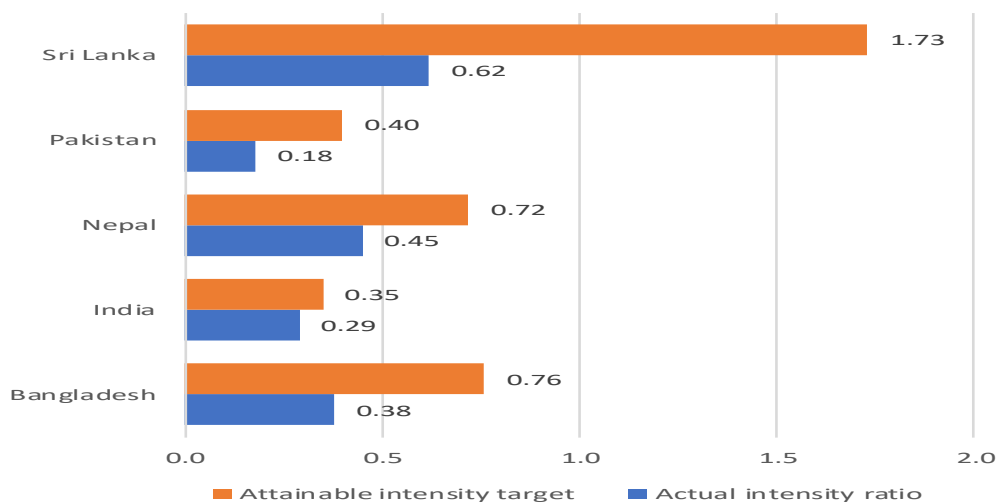


Figure 3. Actual agricultural research spending and attainable investment targets

Sources: ASTI Survey Data and Nin Pratt (2016)

ii. Relatively limited funding for non-salary research costs

As mentioned before, recent increases in agricultural research spending were largely driven by rising salary costs of agricultural research staff, rather than costs supporting

well-known feature of DEA is that it looks for endogenous weights that maximize the overall score for each decision-making unit given a set of other observations, yielding the most favorable country-specific weights.

actual research programs and infrastructure upgrades. Salary costs account for 75–80% of total expenditures by Pakistan’s federal and provincial government agencies and India’s ICAR institutes. No formula can determine the optimal allocation of agricultural R&D costs across salaries, operating and program costs, and capital investments: this breakdown depends on numerous factors, including country size, agroecological diversity, research mandates, and the composition of staffing. That said, when salary-related expenditures consume 80% of a country’s total agricultural research budget, a clear imbalance exists, such that too few resources remain to support the costs of operating viable research programs. Pakistan certainly has insufficient support for the day-to-day operation of research programs, which undoubtedly affects the quality and quantity of research outputs in this country. Taking salary costs out of the equation, Pakistan invests just 0.04% of its AgGDP on actual agricultural research activities and the costs of running and upgrading research centers, which is clearly insufficient.

iii. Limited diversification of R&D funding sources

Governments are by far the dominant source of funding for the sub-region’s research institutes, though donors and development banks play an important role in funding research in Bangladesh, Nepal, and Pakistan as well. The private sector is currently the least developed source of sustainable financing for public-sector agricultural R&D in the sub-region, which is a missed opportunity given the severe level of underinvestment. On a positive note, an increasing share of Indian agricultural research is funded with revenues generated through the sale of goods and services. The management of intellectual property and commercialization of technologies and other innovations have gained momentum at ICAR, and were integral to the National Agricultural Innovation Project (NAIP). However, Indian universities have been much slower in pursuing this revenue stream through the provision of fee-based research and consultancies and the sale of seed and plant material. In Pakistan, all internally generated resources through the sale of goods and services are channeled back to the national Treasury, which creates a disincentive for agricultural R&D agencies to pursue this revenue stream.

iv. Aging pool of researchers, particularly at the PhD level

Long-term public-sector recruitment restrictions have left institutes in Bangladesh, Nepal, Pakistan, and Sri Lanka with an aging pool of agricultural researchers, many of whom are set retire within the next decade. In Nepal, as of 2016, more than 70% of NARC’s PhD-qualified researchers and 60% of AFU’s agricultural researchers were in their 50s. In Sri Lanka, nearly two-thirds of the researchers at the government research agencies with PhD degrees are older than 50, whereas in Bangladesh, nearly 60% of PhD-qualified researchers at Bangladesh Agricultural Research Institute (BARI) and about half of those at the other Bangladesh Agricultural Research Council (BARC)-affiliated institutes are in their fifties. On average, researchers with MSc and BSc degrees were considerably younger, as were university-based scientists. Given that the mandatory civil

servant retirement age is 57 in Sri Lanka, 59 in Bangladesh, and 60 in Nepal, the bulk of PhD-qualified researchers are set to retire in the coming years. Recent figures for Pakistan are unavailable, but 2012 data indicate that the situation is similar there. In India, the distribution of researchers by age bracket is much more balanced.

v. Lack a critical mass of highly qualified researchers in certain key disciplines

A minimal number of PhD-qualified researchers is generally considered fundamental to the conception, execution, and management of high-quality research and to communicating its results to policymakers, donors, and other stakeholders at national and regional levels. Despite the overall growth in the total number of PhD-qualified agricultural researchers in South Asia over time, the smaller countries in the region have yet to achieve a critical mass. In Nepal, for instance, just 12% of agricultural researchers hold PhD degrees. NARC lacks a critical mass of PhD-qualified researchers in a number of key areas, including plant breeding, plant pathology, agronomy, soil science, and veterinary science. Given its aging pool of researchers, capacity gaps are only expected to increase in the coming years. Similarly, in Sri Lanka, as of 2016, more than 40% of the officially approved positions for scientists at the government research institutions were vacant. Pakistan severely lacks horticultural breeders, entomologists, plant pathologists, and virologists.

vi. Poor incentive structures for researchers resulting in staff turnover and unfilled vacancies

In Bangladesh, Nepal, and Sri Lanka, many government agricultural research agencies are challenged in their ability to compete with universities and the private sector when it comes to recruiting, retaining, and motivating well-qualified researchers. Low salaries, limited opportunities for promotion and training, and a lack of performance-based incentives constitute key impediments to staff motivation. These factors have also caused many younger researchers to seek more attractive opportunities both in-country and abroad. In Bangladesh, for example, more than 300 highly qualified researchers left for better remunerated opportunities elsewhere during 2000–2012. The country's civil service system of promotions restricts researchers' opportunities for career advancement. In Nepal, another major disincentive to a career in agricultural R&D is the fact that a PhD qualification has no impact on salary levels. In Pakistan, large differences in salaries, training opportunities, and performance-based incentives between federal and provincial research institutes make the provincial agencies less attractive as employers. Better incentive structures are needed to retain capacity over time.

vii. Female researchers severely underrepresented

Female researchers offer unique insights, perspectives, and skills that can help research institutions more effectively address the specific challenges of farmers in South Asia, the majority of whom are female. Furthermore, attracting women into agricultural research

would be a highly beneficial strategy for addressing the aforementioned low researcher capacity in many countries. Despite increases in the shares of female researchers over time in most countries, female participation in agricultural R&D in South Asia remains very low. In Pakistan, just 12% of all agricultural researchers are female. In India, women represent 18%, in Nepal 19%, and in Bangladesh 22%. Moreover, female scientists are far less likely to hold PhD degrees than their male colleagues, so these countries still have a long way to go in increasing female participation in agricultural R&D and hence integrating gender perspectives into the formulation of related policies. Interestingly, Sri Lanka stands out from the other countries in the sub-region in that the majority (52%) of its agricultural researchers are female. However, comparatively few Sri Lankan women hold managerial positions.

viii. Research not always focused on priority commodities

In some countries, major incongruences exist between the crops that generate the highest shares of gross value of national crop production and the crops that are researched the most, raising questions as to the allocation of scarce research resources. Rice, for instance, accounts for 28% of India's total value of crop production, but only 11% of India's crop researchers conduct rice research (Figure 4). Wheat, cotton, and vegetables appear to be under-researched in India based on their crop values as well. In contrast, a disproportionately large share of Indian researchers' time is dedicated to pulses following numerous recent nationwide initiatives promoting pulses. In Sri Lanka, rice and coconut appear to be under-researched based on their production values, while relatively more resources are allocated to plantation crops like tea, rubber, and sugarcane than the production values of these crops alone would warrant. In Pakistan, cotton, sugar, and rice appear to be under-researched.

In all countries, a balanced research portfolio that allocates sufficient resources to food, plantation, and export commodities is of vital importance to address the multitude of challenges the agricultural sector is facing, including stagnating productivity, high regional disparities in malnutrition, and underperforming sectors that need to become more efficient, innovative, and globally competitive.

The concept of congruency analysis can be useful in assessing the distribution of research efforts across commodities, but it is not an allocative rule. Research effort might be appropriately disproportionately allocated to a product with modest current value but projected high growth in demand. In addition, multiple objectives for agricultural development might channel research efforts toward a product with lesser weight in sectoral value added but particular relevance for, for example, nutrition or job creation. Finally, congruence analysis does not take spillovers across national borders into account. Not every country needs to invest in every commodity if barriers to moving new technologies across national boundaries are low. It is therefore important to view research support in a sub-regional context and strengthening regional linkages.

Congruence analysis therefore is not in itself a sufficient tool for allocation of research funds, but it offers important insight into the current distribution of capacity and resources, highlights where regional alliances should be strengthened, and can be combined with analysis of foresight and general equilibrium models.

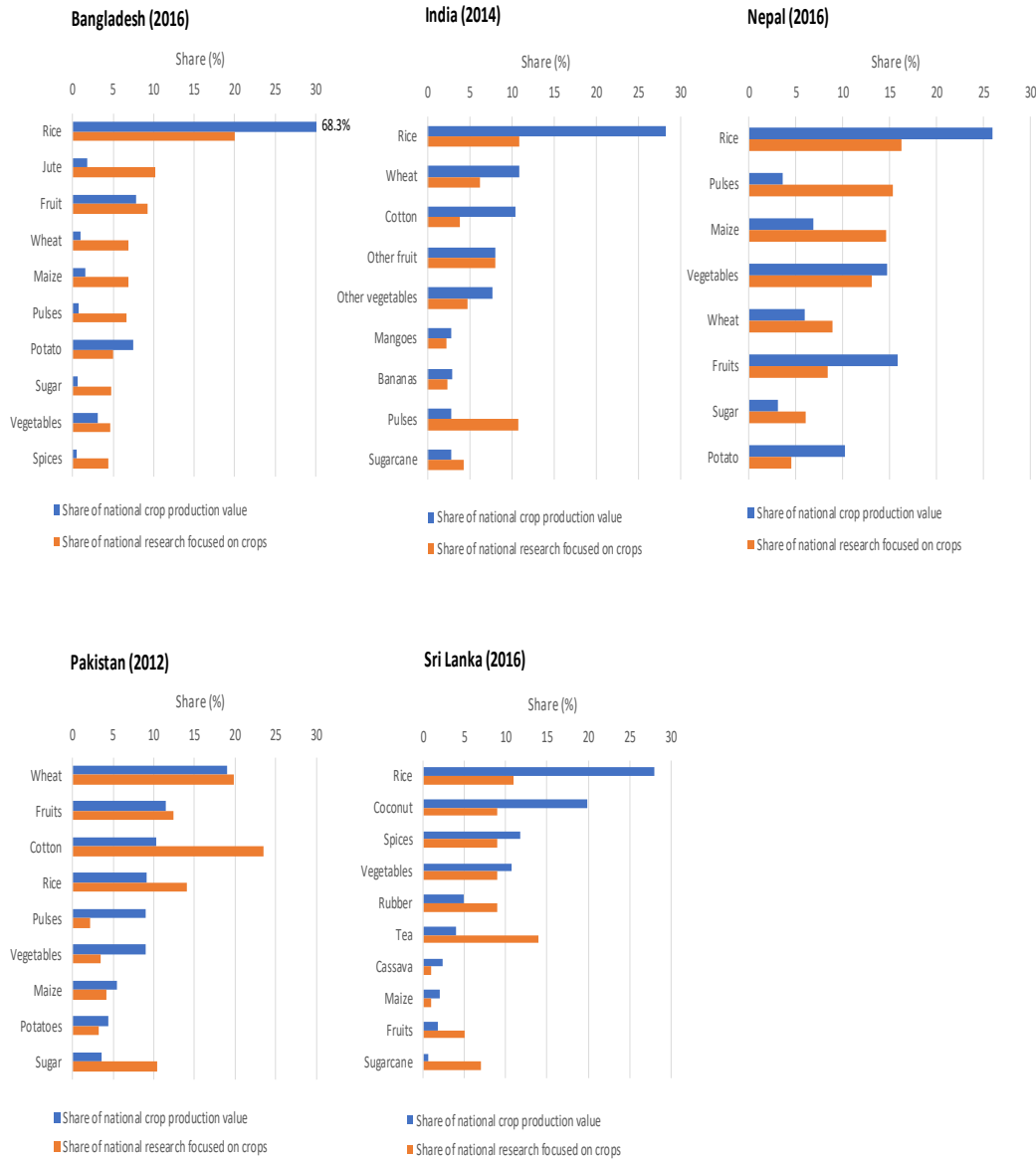


Figure 4. Congruence between agricultural research and production value
Sources: ASTI (various years) and FAOSTAT (<http://faostat.fao.org>)

ix. Low scientific output of research institutes

By international standards, average numbers of publications per agricultural researcher are relatively low in South Asia. On average, each ICAR researcher publishes 1.8 peer-reviewed articles per year. The scientific output per FTE researcher within the higher education sector was slightly higher (2.1 per year). Sri Lankan agricultural researchers published just 0.55 peer-reviewed publication per scientist per year, and the ratios in the other countries are comparable. On a positive note, however, the number of peer-reviewed publications per researcher has risen over time.

x. Institutional and governance challenges

The institutional setup of agricultural research in South Asia gives rise to numerous challenges and inefficiencies. In Pakistan, for instance, the complex structure of agricultural research and extension at district, provincial, and federal levels complicates the coordination of research and the dissemination of its outputs; it also triggers costly duplication of effort. There is little evidence to suggest that provincial agricultural research systems have been significantly strengthened since they were restructured following a major amendment to the constitution in 2010, which devolved agricultural sector responsibilities to the provinces. The majority of donor funding continues to be channeled to Islamabad, with very little reaching provincial agencies. In Sri Lanka, ministerial fragmentation (between the Ministry of Agriculture and the Ministry of Plantation Industries) complicates decision making on agriculture-related matters, including agricultural research. Similarly, in Bangladesh, BARC's mandate of coordinating the country's agricultural research is severely constrained by the fact that research institutes are administered by different ministries and under different legislation and regulations, and that BARC has no authority in allocating its funding despite being responsible for reviewing the institutes' research programs and budgets each year. While the 2012 BARC Act conferred the council with greater authority to approve research programs and recommend budget allocations to supervising ministries, BARC still lacks the autonomy to allocate funding based on designated research priorities and the quality and quantity of results and outputs. Such autonomy is needed to enhance the efficiency and effectiveness of Bangladesh's agricultural research.

xi. Ineffective extension systems

ASTI undertook long-term projections of the impact of historical agricultural research investment on agricultural output and productivity in South Asia, and of the impact of increased investment on future productivity growth. It found that political unrest (such as in Nepal and Sri Lanka), ineffective institutions, and an underachieving agricultural extension system have been important underlying factors limiting the long-term impact of agricultural research on agricultural productivity.

Historically, agricultural R&D planning in South Asia has operated from the top down, and linkages between agricultural R&D agencies and extension or advisory services have generally been weak. The need to improve linkages between agricultural R&D agencies and other organizations is widely recognized across the subcontinent, however. India's National Agricultural Innovation Project (NAIP) and Bangladesh's National Agricultural Technology Program (NATP) both have large components devoted to developing research consortia with civil society and private partners.

Problems often cited in association with public agricultural extension systems include insufficient funding, an inadequate number of extension workers, lack of extension worker qualifications and skills, lack of focus on farmers' needs, poor information and communications technology infrastructure and capacity, and dilution of impact due to thin coverage. Another problem is the fact that several different ministries are directly involved in assisting farmers with limited cooperation and coordination. The absence of a functional and active participation in extension priority setting of local government is problematic too. Agricultural research does not operate in isolation. The drivers of agricultural transformation are multidimensional and interrelated. A more holistic approach to agricultural innovation, comprising research, extension, education, and policy is vital, as are an effective institutional framework, governing mechanisms, and political environment that stimulate interaction between these players.

Policy Implications

i. Governments must address underinvestment in agricultural R&D and take the necessary policy steps to diversify funding sources

ASTI evidence does not indicate significant improvement in the relative intensity of agricultural research investment (agricultural R&D spending as a share of AgGDP) in South Asia over time (see Figure 1). Despite various national initiatives to promote stronger investment in agriculture (including agricultural research), agricultural R&D spending in most South Asian countries is still far below the levels required to sustain their agricultural sectors' needs. Countries that have increased their expenditures substantially, such as Bangladesh and India, have directed most of the funds toward (much-needed) salary increases, rather than actual research programs. National governments urgently need to address underinvestment in agricultural R&D and ensure the full disbursement of approved budgets. They must provide stable and sustainable levels of funding to secure a strategic program of effective research activities that yields increased agricultural productivity.

Rather than relying too much on donor contributions and development bank loans to fund critical areas of research, governments need to determine their own long-term national priorities and design relevant, focused, and coherent agricultural R&D programs. Donor and development bank funding needs to be closely aligned with

national priorities, and donor programs should synergistically complement these priorities. Mitigating the effects of any single donor's abrupt change in aid disbursement (the main driver of funding volatility in Bangladesh, Nepal, and Pakistan) is crucial, highlighting the need for greater funding diversification—for example, through the sale of goods and services, or by attracting complementary investment from private sector.

The private sector is currently the least developed source of sustainable financing for agricultural R&D in South Asia (its funding potential remains largely untapped in most countries). Cultivating private funding requires that national governments provide a more enabling policy environment through tax incentives, protection of intellectual property rights, and regulatory reforms to encourage the spill-in of foreign technology. In some countries, policy reform is needed to stimulate the diversification of funding sources, including funding by regional or local governments, and the private sector.

ii. Governments must invest in training and capacity building and remove status and salary discrepancies between government- and university-based researchers

Few research institutes in South Asia have autonomous status in setting their own financial, human resource, or operating policies, which limits their ability to diversify their funding sources, offer competitive salaries and working conditions, and generally maximize efficiency levels. Growing concern exists regarding the lack of human resource capacity in agricultural R&D to respond effectively to the challenges that agriculture in South Asia is facing. In all countries except India, long-term recruitment restrictions have resulted in a situation where the majority of PhD-qualified researchers are set to retire by 2025.

In order to address the most immediate capacity challenges, in 2017, the Sri Lankan government agreed to fund 300 million Sri Lankan rupees annually (in current prices) for capacity strengthening and MSc and PhD training of agricultural researchers over the 2018–2022 period. As part of this program, a total of 41 candidates (21 women and 20 men) from the government research institutions commenced postgraduate training in 2018 and 2019 in the Philippines, Malaysia, and Thailand, with more to follow in the coming years. In addition, a number of Sri Lankan researchers are pursuing PhD training at Indian universities as part of the Memorandum of Agreement between ICAR and SLCARP. In Bangladesh, a large number of scientists are currently pursuing PhD training, both in-country and overseas, as part of the National Agricultural Technology Program (NATP: 2009–2024), funded through loans from the World Bank and IFAD. Similarly, a few Nepalese agronomists are currently being trained overseas. However, training opportunities in other disciplines, including horticulture, livestock, and fisheries are rare for Nepalese scientists.

This large-scale training of young South Asian agricultural scientists to the PhD level after years of neglect is a positive development of course. However, it is important that

countries develop more systematic human resource strategies going forward, incorporating existing and anticipated skills gaps and training needs, rather than retroactively responding to large-scale losses of qualified researchers to retirement or greener pastures. The successful implementation of such human resource strategies will require both political and financial support, and not just from foreign donors. In addition, national governments must expand their investments in agricultural higher education to allow universities to increase the number and size of their MSc and PhD programs—or establish such programs in countries where MSc and PhD programs are still lacking—and to improve the curricula of existing programs. This includes the establishment and expansion of various regional capacity-building initiatives, so that smaller countries can benefit from the expertise of larger countries.

In addition to degree-level training, research institutes should involve present and past tenured researchers in mentoring their younger colleagues. In some countries, this may involve increasing the official retirement age of researchers or instituting some form of flexible working arrangements for retired researchers. Developing incentives to create a more conducive work environment for agricultural researchers is crucial. In a large number of countries, significant discrepancies exist in the remuneration, working conditions, and incentives offered to researchers at government agencies compared with their university-based colleagues (or in the case of Pakistan between federal and provincial institutes). These inequities need to be removed or overcome to enable the government R&D agencies to attract, motivate, and retain well-qualified researchers.

In India, four ICAR institutes have so-called deemed university status, which is an accreditation that allows them to award degrees. In Nepal, a proposal is currently under preparation to grant NARC deemed university status based on the Indian model. Such status, if adopted, would provide certain senior researchers with a (part-time) teaching mandate to enable the Council to more quickly and effectively strengthen its capacity. This would enhance junior researchers' access to higher degrees and contribute to staff retention, but it would require an official amendment to the NARC Act (1991). This could be a model to be considered by other countries as well.

iii. Governments must develop and enforce ambitious long-term national agricultural innovation policy agendas

Although most countries have numerous official agricultural and food security policies in place, many of them are not rigorously pursued or enforced, so the impact of some of these policies remains limited. Moreover, some countries lack a clear sense of direction in the area of agricultural innovation, dispersing coordination across too many ministries or governance levels, leading to duplication of activities or even competition. Consequently, a critical area needing urgent attention is the development of strong, national agricultural research and innovation policy agendas, together with the necessary expertise to support these agendas long term.

It is essential that governments strengthen the institutional, financial, and infrastructural foundations of agricultural R&D agencies so they can more effectively address farm productivity challenges. Strengthening the planning capacity at the research program level is crucial to the overall effectiveness of R&D agencies. Many agricultural R&D agencies currently lack efficient administration systems and practices needed to more effectively monitor progress and inform strategic decision making.

Governments will also need to provide the necessary policy environment to stimulate cooperation among the country's agricultural R&D agencies in order to maximize synergies and efficiencies in the use of the scarce resources available to universities and government agencies. Channeling a larger share of research funding through competitive mechanisms may enhance cooperation and make research more demand-driven.

In addition, governments must take action to ensure that improved varieties and technologies released by agricultural R&D agencies are disseminated to and adopted by farmers. This involves strengthening extension agencies and actively promoting cooperation between research and extension. The establishment of a central body, such as MANAGE in India, that develops the necessary regulatory framework, management systems, and personnel to integrate and optimize national and provincial level extension strategies may be a useful model for other countries to be considered.

iv. Governments must strengthen research linkages in-country and at the sub-regional level

Further integration of R&D at the sub-regional level is indispensable too. Cross-country collaboration is cost-effective because countries can more rapidly capture technology spillovers across geographic boundaries and reduce research duplication. India has a sophisticated national agricultural research system that produces technologies and methods applicable to other countries in the sub-region. Nonetheless, collaborative research across countries on issues of sub-regional significance is still relatively limited, and initiatives that build and enhance linkages need to be further strengthened in order to maximize possible synergies. More support is needed for regional bodies, networks, and mechanisms that can help effectively define, implement, and fund a regional research agenda targeting issues of common interest. Both the Asia Pacific Association of Agricultural Research Institutions (APAARI) and the SAARC Agriculture Centre (SAC) have key roles to play when it comes to promoting spillovers of technical and institutional innovations throughout the subregion and sharing knowledge and experiences across countries.

Conclusion

New quantitative evidence presented in this report demonstrates that total public agricultural R&D spending in South Asia has increased considerably since the turn of the

millennium. This trend was largely driven by India, which has the highest investment levels and strongest human resource capacity in agricultural research in South Asia by far (both in terms of size and qualification levels). Other aspects that set India apart from its neighbors are the comparatively important role of its private sector in agricultural R&D, and the sweeping NAIP-stimulated agricultural R&D reform process, which is exploring new forms of consortia-based partnerships involving farmers and private enterprises to increase the relevance and efficiency of research. Overall, Indian agricultural research is relatively well-funded, although the budgets of some state agricultural universities have fallen in recent years.

Compared with India, agricultural R&D in the other South Asian countries faces greater challenges. These countries are characterized by severe underinvestment in agricultural research and their investment levels have shown large year-to-year fluctuations, in many instances due to the instability of donor funding. Agricultural research staff in these countries is also significantly less-qualified than in India, the combined result of prolonged recruitment freezes, losses of highly qualified senior staff, limited training opportunities, and an aging pool of researchers. In addition, political instability in some countries has either delayed or complicated much-needed institutional and policy reforms. Various policy initiatives have been or are in the process of being implemented to address institutional inefficiencies, strengthen research capacity, and make research more responsive to end user needs. However, more ambitious policy measures are needed to tackle the subregion's severe underinvestment in agricultural research, to ensure that research institutions stay adequately staffed into the future, and to strengthen research linkages both in-country and at the sub-regional level.

Recommendation: Institutionalizing ASTI in South Asia and Embedding its Evidence in National and Regional Policy Programs

Eleven years of Bill and Melinda Gates Foundation (BMGF) funding has enabled ASTI to update and expand its set of agricultural research and development indicators in South Asia, automate its systems of data collection and reporting, develop a number of interactive data dissemination tools, foster partnerships with key stakeholders, expand the initiative's analytical component, and enhance its outreach for increased impact on the ground. ASTI's data and analyses have been extensively used by governments, donors, and international organizations to identify key capacity gaps or areas of underinvestment, guide agricultural research investment and policy decisions, and demonstrate the returns to investments in agricultural research. Without ASTI, information and analysis of agricultural research investment and capacity in the subregion would be completely lacking, and comparative analyses across countries, and over time would not be possible. It is important, however, that datasets are more frequently updated and expanded to other countries in the region.

BMGF funding to ASTI is drawing to a close this year. In formulating its future strategy, ASTI recognizes that its long-term sustainability and impact ultimately depend on countries taking ownership of their national data, and that more focus is needed on effective data analyses and creative outreach activities to ensure that targeted messages are incorporated into national and regional decision-making processes. For these reasons, ASTI is focused on creating a multi-stakeholder platform that will support (i) sustainable national level data collection; (ii) demand-driven collaborative data analyses and research; and (iii) a diverse set of delivery mechanisms to inform policy.

ASTI has already successfully devolved the functions of data collection, processing, and provision in Southeast Asia and the Pacific, by entering into a strategic partnership with APAARI. IFPRI and APAARI are keen to follow a similar approach in South Asia and are actively exploring funding opportunities. The main objective would be to build a solid foundation for the long-term monitoring and analysis of agricultural research investment, capacity, and outputs and to enhance knowledge on the inputs, performance, and outcomes of agricultural research systems in all countries in the region. IFPRI's role would evolve to focus on coordination, quality control, training, and support; maintaining the international database; and producing regional and international syntheses and analyses.

Ideally, ASTI would be strategically positioned in SAARC Agriculture Center's 2020–2030 strategic framework in order to ensure optimal uptake and impact. There will be a critical role for SAARC in disseminating ASTI evidence to policy makers and other key stakeholders in the region, and in ensuring that the evidence gets embedded in national and regional agricultural policy decision making processes.

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Chapter 12

Crops Research and Development in South Asia: Challenges and Opportunities for 2020-2030

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Abstract

Crop agriculture significantly contributed to food security in South Asia. However, food security inequalities within South Asia, rampant nutritional insecurity, much behind several countries in Global Hunger Index and ever increasing population challenge progress in crop agriculture to cope up with food and nutritional requirement by 2030. Status of major crops/ crop groups (rice, wheat, maize, millets, pulses, oilseeds and cotton) productivity during the past five years in different countries of South Asia is reviewed. Major challenges facing crop agriculture are: i) Climate change and variability; ii) Cutting edge technologies for crop improvement; iii) Farm diversity and crop diversification; iv) Access to quality seed; and v) Emerging pest concerns including safe transboundary exchange of germplasm and seed. Opportunities to face these challenges have also been highlighted. Policy gaps to enhance crop production and profitability have been identified relevant to the region. Value chain implementation through identification of crop corridors, attract youth and women to agriculture, use of modern technologies like blockcha in, artificial intelligence in crop value chain to be encouraged. Recommendations and major programs to address these challenges suggested include i) Huge investments for convert raw germplasm into inbreds and parental lines; ii) Effective use of genomic resources by developing critical capacities and infrastructure; iii) Public, private and community participatory projects for development of appropriate seed systems for quality seed access; and iv) Policy advocacy on promotion of biotechnology, cropping diversification, phyto-sanitation policy, seed without borders, retaining and empowering youth and women in agriculture towards achieving Sustainable Development Goals.

Keywords: Crops, policy, productivity, seed systems, South Asia

Background

In South Asia, more than 70% of the population live in rural areas. Small holders dominate the region accounting to 96% having 0.5 ha of average land size in Bangladesh, 93% of total holdings in Nepal are operated by small farmers with an average size of 0.8 ha, Sri Lanka's average size of holding is 0.8 ha; average farm size in Bhutan is less than 1.0 ha, 81% of holdings in India are less than 2 ha with an average size of 1.4 ha and Pakistan's average landholding is 3.0 ha and 58% of them have less than 2.0 ha. Thus small farmers need a special focus in South Asia for agricultural research and development. Food insecurity and undernutrition that prevailed in South Asia at 20% in 2003-2005 was significantly reduced to the level of 15% by 2015. Cereal production for food and feed increased considerably in the region. Diets have improved in quality and quantity with consumption of less cereals, more livestock products and in some areas increased fruit and vegetables. However, food and nutritional security were much better in the neighboring regions of East Asia and South East Asia. In spite of reducing food insecurity in the region, improper distribution and low purchasing power also, kept South Asian countries at a very low level in Global Hunger Index (GHI, 2019) (102-India, 94-Pakistan, 88-Bangladesh, 73-Nepal and 66-Sri Lanka) among 119 countries (GHI, 2019). Child wasting and stunting rates are very high for India at 20.8% and 37.9%, respectively. Wide range of variations also occurs within South Asia and for instance 33% of Afghanistan facing high level of food insecurity. Major challenge is eradication of food and nutritional insecurity even after increased population of 2.2 billion by 2050. Nutritional deficiencies particularly of iron, vitamin A and iodine are rampant in this region. In addition anaemia prevalence is alarming ranging from 40 to 60% in all the countries except Sri Lanka (FAO, 2018).

Rice, wheat and maize among cereals, pearl millet among millets, rapeseed-mustard, soybean and groundnut among oilseeds and pigeonpea and chickpea among pulses and cotton among fiber crops contribute significantly to crop agriculture production in the region. In spite of significant progress in crop agriculture, wide disparity exists within the region. Several challenges crippled growth rate of crop productivity leading to stagnation or even negative growth. It is alarming at this rate to cope with the ever increasing population demand for food and nutritional security and economic security from farm income. An attempt has been made in this thematic paper to review the state of crop productivity, identify challenges and opportunities for sustainable agriculture in the context of research, development and enabling policy environment. Appropriate recommendations have been put forth and priority projects suggested for South Asia for the coming decade (2020 to 2030).

Status of Crop Productivity in South Asia

The data on cropped area and productivity is mainly sourced from UN Food and Agriculture Organization (FAO, 2019a). In order to study the pattern of change, both for

productivity and cropped area, data of 2012 is taken as base and compared with the average of the next five years (2013 to 2017) for which data is available. Thus in South Asia, large cultivated area (million ha) is used for rice (>60), wheat (>43), maize (>12), sorghum (>6), millets (>10), pulses (>16), oilseeds (>35) and cotton (>14) production, leaving insignificant cultivable area for other crop diversity. The productivity pattern for the major crops in South Asia is reviewed below.

Rice

Rice is mainly cultivated (million ha) in India (43.72), Bangladesh (11.29), Pakistan (2.81), Nepal (1.45), and Sri Lanka (0.95). Rice is cultivated in small areas in Afghanistan and Maldives. Rice in India alone cultivated in as many as 11 different ecosystems ranging from relatively risk-free irrigated ecosystem to rain-fed upland direct seeded very early ecosystem. The potential rice yield is at 15-16 Mt/ha and attainable yield in risk free irrigated ecosystem is 10 Mt/ha (Muralidharan et al., 2019). In South Asia the rice productivity ranged from 3.28 to 4.51 Mt/ha (Figure. 1) with yield gap ranging from 5.49 to 6.72 Mt/ha even in the most favorable ecosystem. Productivity enhancement over the past five years was noticed in Bangladesh (2%) and Pakistan (4%). However, in India where the rice is cultivated in large area (>43.7 million ha), productivity entered in to negative phase (-0.2%). Sri Lanka with about one million hectares of rice, registered a negative change of productivity (-9.1%) over the past five years. Nepal also registered negative change in productivity (0.7%) cultivating over 1.5 million ha. Rice cultivated area in Bhutan is about 20,000 ha and it is also cultivated in small area in Maldives. Intensive rice breeding research based on plant type did not lead to substantial genetic gains in productivity. The largest genebank in the region housed in National Bureau of Plant Genetic Resources, New Delhi, India has over 109,000 accessions of rice. Intensive breeding efforts in India led to release of over 1329 varieties for cultivation during the past five decades. Improvement of plant type alone is not sufficient to enhance the production and productivity. Converting genetic gain obtained through breeding research in to production also largely depend on environmental conditions, appropriate agricultural public policies including economic incentives for adoption of recommended package of practices (Muralidharan et al., 2019). More than 1,09,000 accessions of rice in Indian national genebank are available. Improved genotypes from over 1,23,000 accessions from International Rice Research Institute (IRRI) are also available.

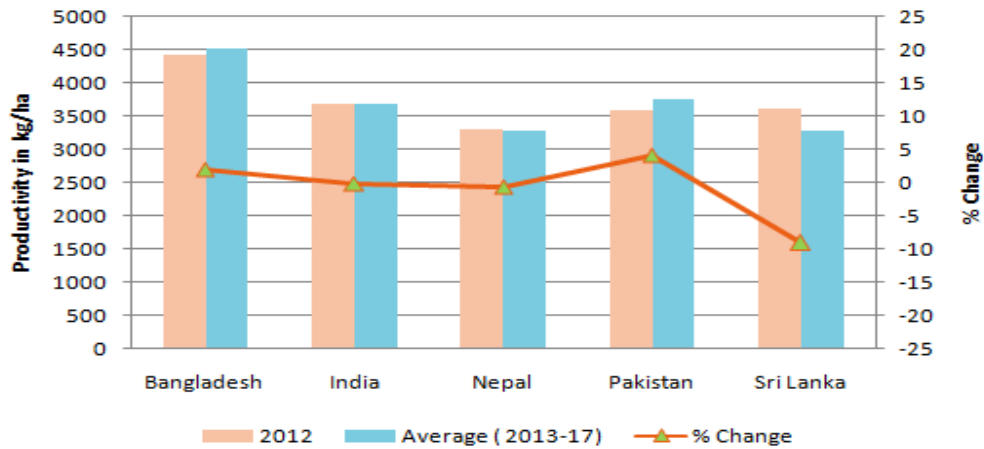


Figure 1. Rice productivity trend in major growing countries

Source: FAO (2019a)

Wheat

Major wheat growing countries in South Asia are India (30.5 million ha), Pakistan (9.1 million ha) and Afghanistan (2.4 million ha) followed by Nepal (0.7 million ha) and Bangladesh (0.4 million ha). India with over 100 million tons of annual wheat production has become self-sufficient and turned as potential exporter. Afghanistan has annual shortage of one million tons of wheat grain with lowest productivity (2.1 Mt/ha) in the region. India registered the highest productivity (3 Mt/ha) with the largest wheat area in the region. Pakistan with little over 9 million ha area increased the productivity to about 3.9% over the past five years.

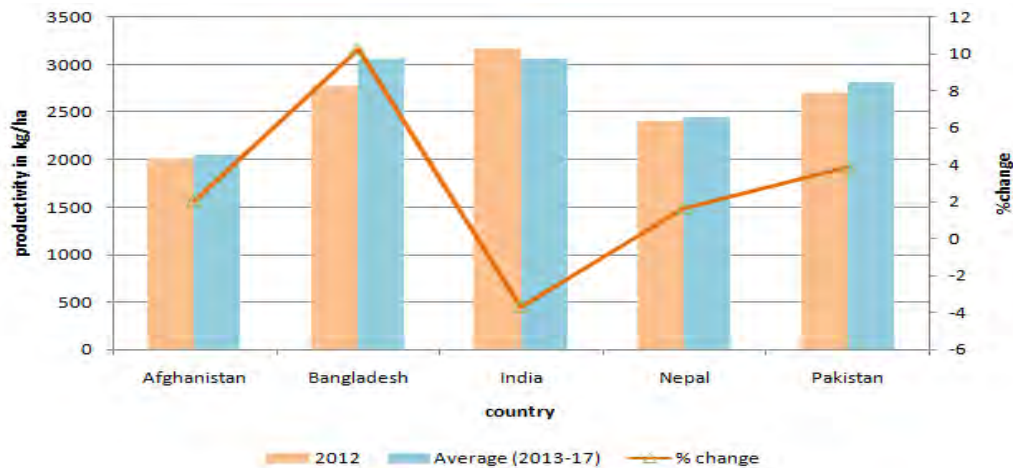


Figure 2. Wheat productivity trend in major growing countries

Source: FAO (2019a)

Bangladesh with 0.4 million ha registered the highest (10%) increase in productivity over a period of five years. India, in spite of touching the mark of 100 million tons production, the productivity over a period of five years decreased by 3.7% (Figure 2).

Indian national genebank has over 33,000 wheat accessions available for its crop improvement efforts. Further International Maize and Wheat Improvement Center (CIMMYT) has over 1,54,000 wheat accessions. India notified release of over 448 varieties of which 378 belong to bread wheat. A variety HD 2967 covered over 10 million ha in India is an example of combining leaf rust resistant genes, yield & quality through breeding efforts exploiting minor genes to withstand disease pressure and led to stabilized yields. Interstate variations in wheat productivity are conspicuous ranging from as low as 1.4 Mt/ha in Maharashtra to 4.3 Mt/ha in Punjab.

Maize

India is the largest grower of maize in the region with 9.3 million ha with 2.7 Mt/ha productivity. Pakistan registered a productivity level of 4.4 Mt/ha over an area of 1.22 million ha. However, highest productivity (7.1 Mt/ha) is seen in Bangladesh with an area of 0.32 million ha only. Yield potential of Bt hybrid maize is about 12 Mt/ha; USA has the highest productivity of 10 Mt/ha, Argentina and Ukraine also reap double the Indian maize productivity, of course with half the maize growing areas compare to India.

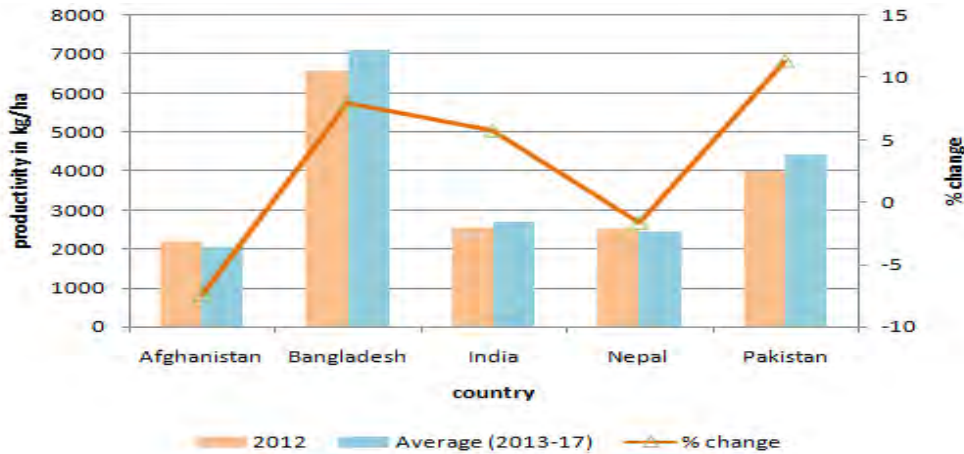


Figure 3. Maize productivity trend in major growing countries

Source: FAO (2019a)

Nepal with an area of 0.89 million ha has productivity of 2.5 Mt/ha and Afghanistan has productivity of 2 Mt/ha (Figure 3) with an area of 0.14 million ha only. With changing dietary habits in the region, India need about 45 million tons of maize by 2022 with more than 49% being used as poultry feed and 12% as animal feed. Only 15% of maize area in India is irrigated. Maize cultivation saves 90% of water and 70% of power, if it replaces

rice. The level of essential amino acids in Quality Protein Maize (QPM) is double that of conventional varieties has potential to change the nutritional security. Single cross hybrid maize technology is a success story in increasing productivity. Several public bred maize hybrids (>130) released in India in addition to private sector. Single cross hybrids of QPM and baby corn are also released. Technology adoption and increasing hybrid area are the key drivers to enhance maize production. Improved germplasm from CIMMYT developed from over 28,000 accessions and over 11,000 accessions from Indian national genebank are available for maize improvement.

Millets

Sorghum and pearl millet are major components of millets or coarse cereals or Nutri-Cereals that include finger millet and other minor millets (foxtail and kodo millets). India is the major millet growing country with 5.93 million ha of sorghum and 9.18 million ha of other millets including pearl millet. In spite of dramatic reduction in area of sorghum cultivation, India is still the largest grower of sorghum with productivity of 0.8 Mt/ha. Largely, oilseeds and pulses replaced sorghum in India. Pakistan has 0.24 million ha with productivity of 0.6 Mt/ha. Hybrid technology in sorghum revolutionized productivity worldwide including India. Sorghum is a potential bio-fuel crop. More than 35,000 accessions in International Crops Research Institute for the Semi-arid Tropics (ICRISAT) genebank and about 26,000 accessions in Indian national genebank are accessible for sorghum improvement.

India is also major millet (other than sorghum) growing country with 9.18 million ha with 1.2 Mt/ha productivity followed by Pakistan (0.48 million ha and 0.64 Mt/ha) and Nepal (0.27 million ha and 1.1 Mt/ha) (Figure 4). Among the minor millets, finger millet is major crop. Millet area and production of other countries in the region are extremely small. In the recent past, owing to the importance of nutritional value of these nutri-cereals are promoted through Government Schemes in India. Millet germplasm

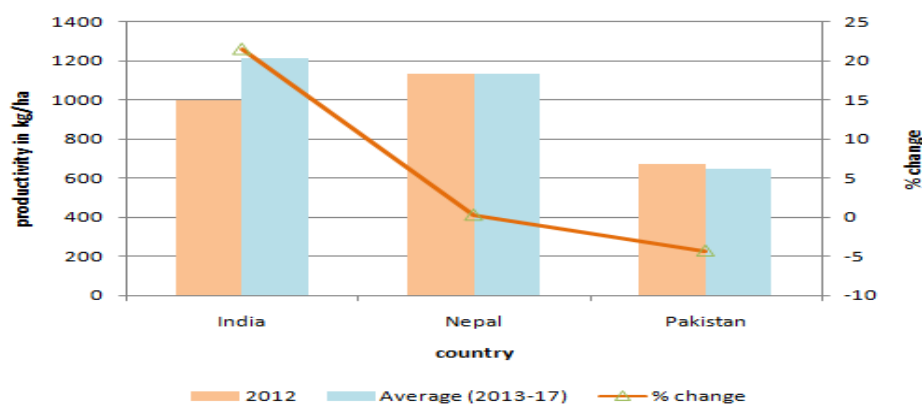


Figure 4. Millets productivity trend in major growing countries

Source: FAO (2019a)

to the extent of 59,000 accessions is available in Indian national genebank and about 33,000 accessions sourced from different parts of the world are available with ICRISAT genebank.

Pulses

Pigeonpea and chickpea are two major pulses in the region. However, in India additionally black gram (urd bean), green gram (mung bean) and lentil also significantly contribute to pulse basket. As per FAO (2019) statistics, pulses included lablab or hyacinth bean (*Dolichos* spp.); jack or sword bean (*Canavalia* spp.); winged bean (*Psophocarpus tetragonolobus*); guar bean (*Cyamopsis tetragonoloba*); velvet bean (*Stizolobium* spp.); yam bean (*Pachyrrhizus erosus*); and *Vigna* spp. Most of which are treated as vegetables under horticultural crops.

India is the major pulse growing country (15.29 million ha and 0.7 Mt/ha) followed by Pakistan (1.13 million ha and 0.6 Mt/ha), Bangladesh (0.12 million ha and 1 Mt/ha), Afghanistan (0.09 million ha and 0.7 Mt/ha) and Nepal (0.08 million ha and 1 Mt/ha) (Figure 5). Pulses production in India, was the highest in 2017-18, a record 25.23 million tons from over 29 million ha. Major contributors were black gram, pigeonpea and green gram in rainy season and chickpea and lentil in post-rainy season. Pulse production was given high importance due to their protein value, in India 50% of funds were allocated to this group under National Food Security Mission. Indian national genebank has over 66,000 accessions for legumes including pulses. In ICRISAT genebank about 50,000 accessions of pulses mostly chickpea, pigeonpea, groundnut and their wild relatives are available.

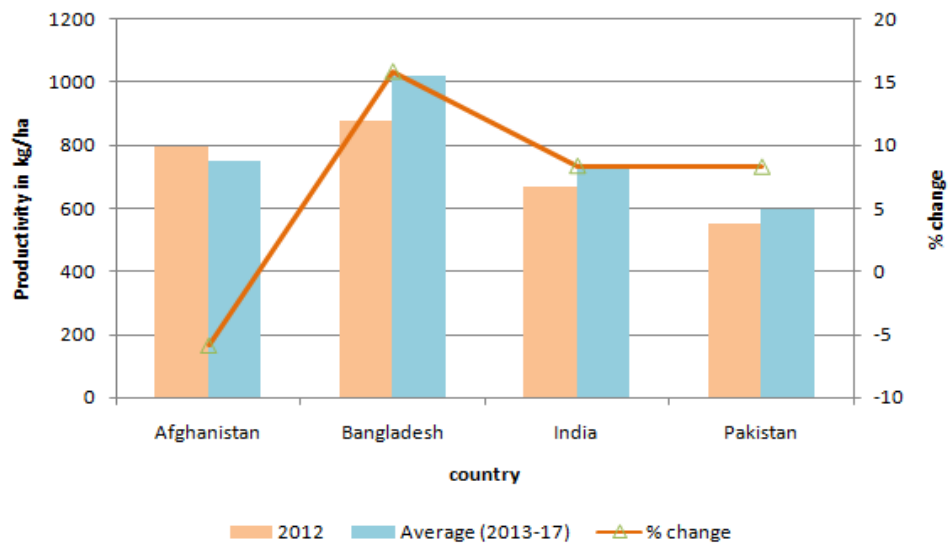


Figure 5. Major pulses (pigeonpea and chickpea) productivity trends

Source: FAO (2019a)

Oilseeds

Edible oil production in the region is deficient with imports ranging from 50 to 90% meet the national demand by different countries in the region. Soybean, rapeseed-mustard and groundnut are major edible oil crops grown in the region. Other minor edible oil crops are sesame, sunflower, safflower and niger. Castor and linseed are important non-edible oil crops. Other source of edible oil is cotton seed oil. Palm oil from oil palm fruits is imported mainly from Indonesia and Malaysia. India is the largest oilseeds grower in the region (22.60 million ha and 1.2 Mt/ha), followed by Bangladesh (0.4 million ha and 1.5 Mt/ha), Pakistan (0.32 million ha and 0.8 Mt/ha) and Nepal (0.19 million ha and 1.1 Mt/ha) (Figure 6).

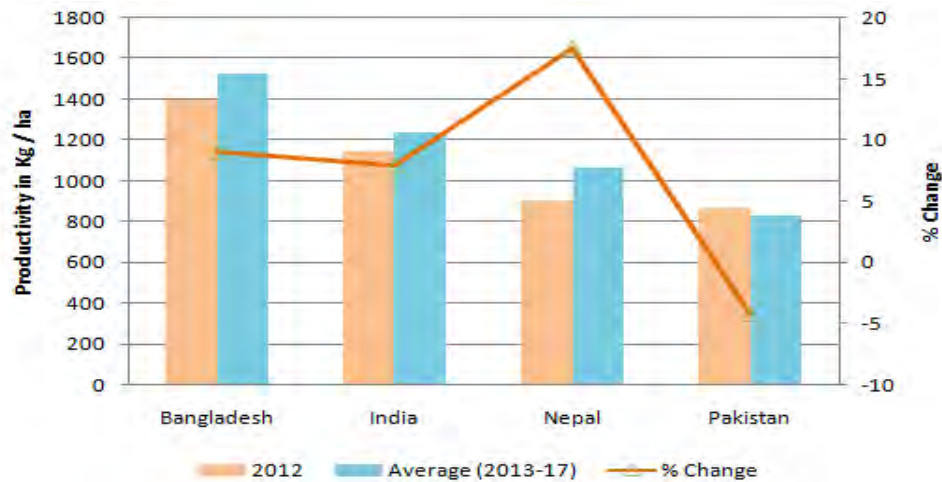


Figure 6. Major oilseeds productivity trends in major growing countries

Source: FAO (2019a)

Cotton

Cotton area tremendously increased in India and Pakistan after access to private industry Bt cotton seed varieties. The Genetically modified (GM) technology was readily accepted for cotton as it was a non-food crop. Bt cotton cultivation reduced the pesticide consumption considerably. However, policy environment was not fast enough to approve new additions of genes for pests and weed management. Debate on accepting Bt technology was misinterpreted and generic resistance to biotechnology was set in slowing down the use of new technologies for agriculture growth in countries like India and Pakistan. However, Bangladesh with small area under cultivation (0.03 million ha) moved ahead and welcomed the Bt Brinjal for cultivation. Afghanistan also has small similar area (0.03 million ha). Afghanistan productivity is 0.39 Mt/ha probably being non Bt varieties cultivation, while it is 0.67 Mt/ha in Bangladesh. Large area came under Bt cotton

cultivation in India (about 11 million ha) ensuring assured income to large number of small farmers under rain-fed conditions. The average productivity is 0.53 Mt/ha In India in comparison to Pakistan with productivity of 0.68 Mt/ha (Figure 7) in 2.79 million ha (WTO, 2019). Policy in the region shall catch up with technological advancements to pass on the benefit to the small farmers in the region.

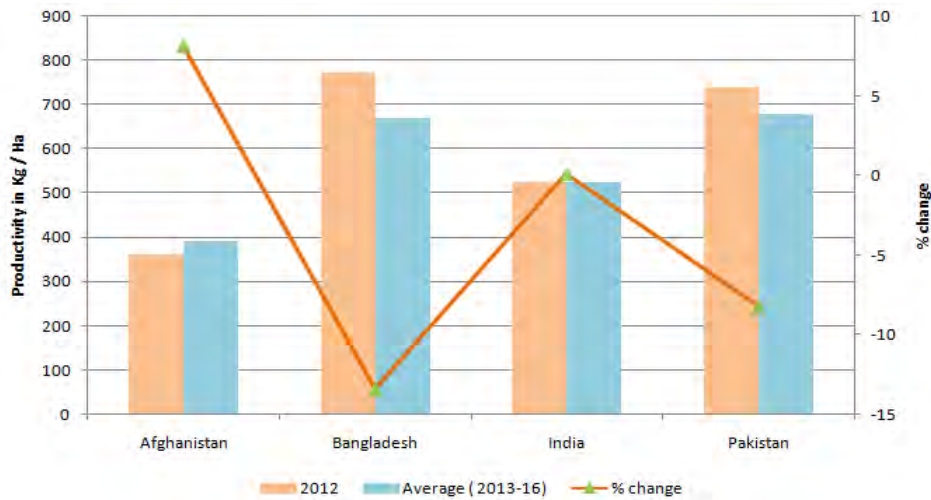


Figure 7. Cotton lint productivity trends in major growing countries

Source: WTO (2019)

Challenges and Opportunities in Crop Sector

Major challenges for crop sector are climate change and variability, cutting edge technologies in crop improvement, farm diversity and crop diversification, access to quality seed and emerging pest concerns are discussed below along with opportunities.

Climate Change and Variability

Climate change and variability are a reality largely with adverse effects on crop production and they are likely to remain key challenges (floods, droughts and heat events) for the next few decades unless serious attention is paid to mitigation and adaptation to stabilize the yield gains. Largest emission of Greenhouse gas (GHGs), mainly from enteric fermentation from the digestive systems of ruminants and other animals as well as from the application of synthetic fertilizers to the soil and for rice cultivation is recorded in South Asia. Rice is cultivated to the extent of 60.4 million ha there by contributing to GHGs. Intergovernmental Panel on Climate Change has projected 0.5-1.2°C rise in temperature by 2020 and by 0.88-3.16°C by 2050. Average yield of all crops is reduced by 8% by 2050s in South Asia. Food production and farm income are adversely affected due to climate variability that has potential to cause 60% yield variability (Aryal et al., 2019).

Climate change influences the start and length of growing seasons, the duration and magnitude of heat and water stress in agricultural production systems. Global warming reduced wheat yield by 5.2% from 1981 to 2009 despite adaptation (Gupta et al., 2017). Rain-fed maize yields are projected to lose by 3.3-6.4% in 2030 and 5.2-12.2% by 2050 and corresponding losses for irrigated maize are 3-8% and 5-14%, if the current varieties are cultivated. Major part of Indo-Gangetic Plains, the food basket of South Asia would become inappropriate for wheat cultivation. The average total economic losses are projected to be 9.4% for Bangladesh, 6.6% for Bhutan, 8.7% for India, 12.6% for the Maldives, 9.9% for Nepal, and 6.5% for Sri Lanka. Since agriculture provides livelihood to over 70% of the people, employs almost 60% of the labor force, and contributes 22% of the regional gross domestic product (GDP) in South Asia (Wang et al., 2017). Climate change owing to increase in temperature are projected to have adverse effects on major food crops in South Asia (Table 1). Thus climate change and variation is a major challenge for crop production in South Asia.

Table 1. Projected influence of temperature change on wheat, rice and maize production in South Asia

Country	Temp change	Wheat	Rice	Maize
India	<2 °C	(-) 5.20%	(-) 8.20%	(-) 10 to 30% under 350 ppm CO ₂
	<2 °C		(+) 8.40%	(-) 10 to 30% under 350 ppm CO ₂
	>3 °C			(-) 10 to 30% under 350 ppm CO ₂
Bangladesh	<3 °C	(-) 60%	(-) 2.6 to 13.5%	
	>3 °C	(-) 60%	(-) 0.11 to 28.7%	
Nepal	4 °C	(+) 18.4% due to CO ₂ fertilization and 8.6% with increase in temp	(-) 1.8% in terrain (+) 5.3% in Hilly area (+) 33.3% in mountain area	(-) 26.4% in terrain (-) 9.3% in hills
Pakistan	<3 °C	(-) 5 to 7% ;		
	>3 °C	Yield decrease in arid, semiarid and sub-humid zones, but increases in humid zone		
Sri Lanka	≤1°C		(-) 6%	

Note: (-) : decrease ; (+) : increase

Source: Aryal et al. (2019)

Cutting Edge Technologies in Crop Improvement

In spite of huge improvement in crop productivity 4.5 fold in the region from 1961 to 2014 (FAO, 2018) new challenges during the past decade are yield stagnation in major crops; lack of considerable attention on crop designing on nutritional (minerals, vitamins, protein) and quality parameters of released varieties for cultivation; under investments on developing climate resilient varieties of major food crops; improvement of under-utilized crops and lack of penetration and upscaling of new science tools for crop improvement in South Asia such as hybrid technology including haplotype based breeding, molecular breeding, synthesized and assembling genomes, editing genes, rewriting genomes, and speed breeding etc. Though there are success stories in Marker Assisted Breeding (MAB), they are limited to few crops and there is enormous scope for expansion in other crops.

Hybrid rice potential is well demonstrated in the region with its potential of enhanced yields to the extent of 20% over conventional varieties. Release and promotion of public hybrids slowed down considerably and the entire private industry focused on few selected niches only for seed production and promotion of hybrid rice for a variety of reasons. Indian wheat program for instance recorded an annual genetic gain of 1% per annum, which stagnated since release of the variety PB 343 (GOI, 2019). Exploitation of minor genes in resistance breeding is rather limited and only an isolated instance of developing HD 2967 is from India. Minor millets particularly finger millet, traditional pulses and sesame among oilseeds deserve more research investment for exploitation of hybrid and genome technologies. Research investment in developing water and nutrient use efficient varieties in major crops is a challenge. Organic and traditional agriculture is gaining popularity in certain areas of the region due to adverse effects of fertilizers and pesticides, and there is immediate need for improving soil and plant health towards sustainable agriculture. However, there are hardly any efforts on validating natural agriculture or improving traditional seeds or landraces for use in identified ecosystems.

Several opportunities now exist with new science tools empowering crop improvement and supporting crop breeding. MAB and minor genes exploitation are opportunities to develop new varieties across the region as they are not genetically modified crop varieties, hence acceptability shall be more even in countries such as Nepal and Bhutan. Tremendous opportunities are available with advanced technologies and genomic resources unfolded in the current era. Genetically modified varieties of cotton have been accepted in India and Pakistan and impacted positively several millions of farmers. However, stiff resistance against the policy of adapting Bt cotton varieties developed to the level that it blocked the extension of these technologies to food crops in India. Bangladesh proactively accepted GM technologies and Bt brinjal, the first GM food crop is now cultivated. The advancing scientific knowledge about the environmental and food safety of GM crops and the safety implications of new breeding technique require adequate adjustments in the biosafety approval system. Paradox on GM policy in the region needs to be addressed as GM corn,

soybean and canola products are permitted for import and consumed based on the safety data. However, their cultivation has not been able to get through the biosafety regulatory system. Recently, APAARI reviewed scoping of partnerships in biotechnology including policy status in the region, which will serve as a guide for further action to promote biotechnology in South Asia (Tyagi et al., 2018a). Hence a clear policy on GM food crops needs to be in place in the region to harness the latest GM technologies to eradicate hunger and under nutrition.

Farm Diversity and Crop Diversification

The first ever “State of the World’s Biodiversity for Food and Agriculture” report released by FAO in 2019 indicated that of the 3,82,000 species of vascular plants, little over 6,000 have been cultivated for food and of these less than 200 species had significant production levels globally. Nine crops namely sugarcane, maize, rice, wheat, potatoes, soybeans, oil palm fruit, sugar beet and cassava account for over 66% of all crop production by weight (Jayan, 2019). South Asia is no exception for this trend of reduced crop diversity.

Crop agriculture mainly focused to address food security in the region. However, due to promotion of few crops, mono cropping and cultivation of improved varieties and hybrids left behind several nutritionally rich crops and landraces disappeared from cultivation in the region. Consequently, nutritional insecurity and under nutrition have become rampant in South Asia. Several nutritionally rich crops such as millets, pseudo cereals and grain legumes and several other plant species called Neglected Under-utilized Species or Under-utilized Crops which have potential to address nutritional disorders, health and well-being have become uneconomical for cultivation. Fortunately, the region has several hundreds of plant species that can be groomed as future crops. Crop diversification in identified niches to address the Sustainable Development Goals (SDGs) of ending hunger, poverty alleviation, and for good health and well-being, sustainable production and consumption, climate change and sustainable use of ecosystems, governments need to accord adequate attention, priority and funding for its development and mainstreaming.

Excellent crop and intra crop diversity is available from national and international genebanks to enhance the farm diversity. In the process of crop diversification, an FAO study alerted continued rapid expansion of biofuel production up to 2050 would lead to higher number of undernourished pre-school children by about 1.7 million in South Asia. Therefore, policies promoting the use of food-based biofuels need to be reconsidered with the aim of reducing the competition between food and fuel for scarce resources (FAO, 2019b). Neglected/ under-utilized crops, suitable for sustainable agriculture need policy and seed system support to enhance farm diversity (Tyagi et al., 2018b). Enabling environment for utilization of diversity and a policy on cropping pattern is need.

Access to Quality Seed

Access to quality seed is one of the primary factors for crop production. In South Asia, farm saved seed use is between 60 to 80% depending on the sub-region. Quality seed or certified seed is accessible to only to 30-40% of the farmers. Access to quality seed for every farmer in South Asia remains a distant dream in spite of key initiatives of SAC on “SAARC Seed Bank” and “Seed Without Borders” unless issues of safe transboundary movement of seed are ensured and potential seed hubs are identified and executed in the region. There is a need to review the Seed Bank initiative to make it more effective to provide quality seed access to the farmers in the region. “SAARC Food Bank” is another major initiative facing challenges of defining food emergency situation, distribution of food from the bank, maintenance of food stocks and ensuring quality of the reserves, derestriction of trade in food grains, dispute settlement mechanism and enhancing institutional tie-ups (Manoj, 2015).

Proper linkages need to be developed among private seed industry, public research institutions including universities and government seed departments for developing new hybrids and facilitating quality hybrid seed access to the farmers. Establishing technological parks or research parks bringing all the stockholders at one place shall be examined with leadership from the universities, research institutes and government departments for the public good.

Emerging Pest Concerns

Phytosanitary capacities, invasion of exotic pests and emerging pests due to changing climate in addition to narrow genetic base of cultivars, lack of crop diversification etc. are key challenges in South Asia. Other challenges are overuse of pesticides often causing concern for human and animal health in addition to adversely affecting environment quality, soil versus plant health and their interaction is often neglected, losses due to pests and economics of their management is not documented rationally, Integrated Pest Management package of practices are too heavy to be adapted, dynamic and reliable local pest databases are lacking and backward linkages for knowledge management are weak.

Regional approach for phytosanitation is lacking in South Asia. Institutional structure and implementation mechanisms are needed for biosecuring the region. The pests not yet reported in South Asia with probable source region in parentheses are: Mexican cotton boll weevil (America); Rice yellow mottle virus (Africa); Maize streak virus (Africa, America); and Groundnut scab (Brazil).

Fall Armyworm (FAW), *Spodoptera frugiperda* is native to tropical and subtropical regions of the Americas. It was first detected in Central and Western Africa in early 2016. First report of occurrence of fall armyworm in India is in sugarcane from Tamil Nadu in 2019 and later reported from several other states. In the larva stage, the insect causes damage to

crops, feeding on more than 80 plant species. FAW primarily affects maize, but also rice and sorghum as well as cotton and some vegetables. The moth can fly up to 100 km per night and the female moth can lay up to 1,000 eggs in her lifetime and is a serious threat to crop agriculture in South Asia. Another pest challenge for South Asia is Maize lethal necrosis (MLN) disease. MLN is first reported in USA in 1976 as corn lethal necrosis and spread to several countries in Africa. It is caused by two viruses and is transmitted by insect vectors. Seed transmission is possible and hence all precautionary measures for its spread to South Asia need attention.

Table 2. Profile of pests highlighting variability or races reported in India

Category	Name	Variability
Viruses	<i>Rice tungro bacilliform virus</i>	Four variables isolated from South Asia
	<i>Rice tungro spherical virus</i>	Indian isolate is different from South East Asian isolates
	<i>Cotton leaf curl virus</i>	Severe damage in Pakistan & limited distribution in India
	<i>Groundnut bud necrosis virus</i>	With a wide host range
Fungi/ Bacteria	Cereal rusts (<i>Puccinia triticina</i>)	Whose spores are air-borne of which a number of virulent pathotypes are known
	Rice blast (<i>Pyricularia oryzae</i>)	High degree of variability reported
	<i>Ralstonia solanacearum</i>	Race 2 is not known in India
	<i>Xanthomonas campestris</i> spv <i>malvacearum</i>	Most virulent pathovar in Africa – XcmN is not known in India
Insects	Whitefly (<i>Bemisia tabaci</i>)	Attacks >600 host species ;16 biotypes known
	Brown plant hopper (<i>Nilaparvata lugens</i>)	Biotypes from India differ from those in other Asian countries
	Rice gall midge (<i>Orseolia oryzae</i>)	Six biotypes known from India

Pine wood nematode is reported from Nepal and Bhutan and *phloem necrosis virus* in tea is reported from Sri Lanka while other countries within South Asia are free from these pests. Often the host range and virulence changes after invasion in new areas and pests are likely more aggressive. Profile of some important pests in India is provided in Table 2, and such information is often lacking within South Asia.

Establishment of export facilitation centres, research on phytosanitation policy including salvaging treatments focusing on safe transboundary movement of seed enabling 'Seed without Borders' policy and rapid response teams backed by research to deal with invasive exotic pests are required to protect the region and enhance safe trade.

Policy Gaps to Enhance Crop Production and Profitability

In order to eradicate hunger and malnutrition, agricultural policies in South Asian countries need to change and also the existing favorable policies need to be implemented effectively. Institutional mechanisms and enabling policies are essential to scale up climate change adaptation in agriculture. Navigating and negotiating policy agendas requires an understanding of the competing incentives and interests of the various actors involved, including the private sector and civil society. A better understanding of governance can facilitate such negotiations, helping to identify opportunities, resolve trade-offs and strengthen nutrition-relevant pathways and outcomes (Gillespie et al., 2019). South Asian countries are committed and signed up international agreements. The National Mission for Green India aims to preserve forests and maintain ecological balance. National Mission on Strategic Knowledge for Climate Change primarily aimed at supporting research on climate change in academics by establishing universities and disciplines in institutions and enhance private sector initiatives to develop adaptation and mitigation technologies. Nepal also developed a Local Adaptation Plan of Action which contributes to bridging the gap between macro policies like National Adaptation Plan of Action and local realities. Climate resilience and poverty alleviation are some of the priorities of these adaptation programs. Pakistan launched the first national climate change policy in 2012. Despite having different levels of policy for climate change adaptation, there is no clear linkage between national-level and local-level adaptation plans in Pakistan. However, there is a need for effective cropping pattern policy in South Asia backed by cropping systems research in the region to tackle emerging issues of climate variation, extreme events and rise in temperature.

Several science tools are now available for crop improvement supporting conventional plant breeding. Nepal and Bhutan on one side keeping away from genomic technologies, Bangladesh on the other side accepting the technologies. However the member countries in the region need to revise the policies suitable to their conditions but moving towards ending hunger and malnutrition. These policy gaps need to be addressed with the highest priority for food, feed and environment safety, failing which SDGs cannot be achieved.

Seed without borders with safety is possible only when potential germplasm is exchanged safely for crop improvement. Data development for every sample need to be generated for every step from collection, post collection testing, conservation, evaluation, regeneration, post regeneration testing, utilization, re-export testing and post export testing supported by filed inspections and post-harvest testing. It is not only data generation, but access to such data on exchange will facilitate safe exchange - a kind of Green Pass for seed or germplasm transboundary movement. Development of framework for such a Green Pass will facilitate safe movement of gemplasm and seed without borders. In order to turn Green Pass concept in to a real policy, institutional framework and research investments are needed.

Value chain implementation through identification of crop corridors by mapping the existing process and facilitating value addition within the region of production would bring economic security to the producers. Blockchain concept was effectively implemented in safe production of export oriented grapes in India. This concept needs to be explored for major agricultural crops such as rice, wheat and maize. Youth and women are moving away from agriculture due to various reasons. Government should encourage through policy motivating, attracting and retaining youth in agriculture. Such programs and policies are being worked out in India and need to be replicated and effectively implemented in other countries of the region as well. Farmer Producer Organizations (FPOs) for making agriculture marketing viable needs to be encouraged and incentivized.

General Recommendation

- Huge investments are needed to convert raw germplasm in to inbreds and parental lines for crop improvement using molecular and conventional tools through multi-location field evaluation based on present day trait needs to tackle changing climate, emerging pests, nutritional and quality needs.
- Critical capacities and infrastructure needs to be developed in the region to effectively use genomic resources in the fields of pre-breeding, exploitation of minor genes for climate and pest resilience and developing inbreds for water and nutrient use efficiency, haplotype based breeding and speed breeding.
- Public, Private and Community Participatory project for development of crop varieties and hybrids needed for sustainable agriculture and facilitating development of appropriate seed systems for quality seed access to farmers with defined role for each sector need to be developed.
- Policy advocacy on promotion of biotechnology in the region based on the country needs and policies, cropping pattern/ crop diversification policy, phyto-sanitation policy towards achieving seed without borders in the region, motivating, attracting, retaining and empowering youth and women in agriculture, market facilitation through incentivisation of FPOs and any other policy area to promote crop agriculture in achieving SDGs.

Recommendation of Priority Programs for Crops

1) Capacities to enhance germplasm and landrace utilization for sustainable agriculture development through latest breeding approaches

Focused crops and countries

Wheat: Afghanistan, Pakistan, Nepal and Bhutan

Rice: Sri Lanka, Maldives, Pakistan, Nepal and Bhutan

Maize: Afghanistan, Nepal, Bhutan, Bangladesh

Pulses: Afghanistan, India, Bangladesh, Nepal and Pakistan

Oilseeds: India, Pakistan, Nepal, Bangladesh, Sri Lanka

Millet: Nepal, India, Pakistan, Bangladesh

Objectives

- Identify a germplasm panel for each country and focus crop considering challenges and available evaluation data.
- Build practical capacities of developing inbreds with high General Combining Ability in focus crops, exposure to haplotype based breeding and speed breeding.
- Develop marker sets relevant to traits of interest to each country and crop.
- Develop capacities of hybridisation including haplotype approach.

Components/ Activities

- Consultation process to prioritize crops, countries and traits to develop capacities.
- Consultation process to finalize the germplasm panel for each crop based on the above priorities.
- Organize brief trainings for theoretical capacities followed by season long training with mentors.
- Facilitate access to germplasm panels from national and international genebanks and identified research institutes to identified trainees.
- Monitoring by global experts on development of inbreds and parental lines for midcourse corrections if any.
- Facilitate sharing of developed parental lines and inbreds across the region.

Resource Partners: Consultative Group on International Agricultural Research (CGIAR) centers - IRRI, CIMMYT, ICRISAT; SAARC members - India, Bangladesh and Pakistan; Global crop experts.

2) *Strengthening public research and capacity development on gene editing for climate resilience, high yield and quality parameters in crops*

Objectives

- Strengthen public research and promote partnerships with private industry in crop improvement particularly in the latest technologies such as gene editing.
- Provide options to the farmers of improved varieties through gene editing from public funded research institutes and universities.

Components/ Activities

- SAARC facilitation of interface between public and private industry in the long term interest of promoting technical collaborations in gene editing projects for public good
- Identify collaborators having considerable infrastructure with few additions to make them functional gene editing laboratories.

Resource Partners: CGIAR centers - IRRI, CIMMYT, ICRISAT; and global private seed industry.

3) *Development of appropriate seed systems to enhance quality seed access in the region*

Objectives

- Explore establishment of Technology or Seed Parks involving all stakeholder including Farmer Producing Organizations (initial support from the respective Governments and enabling them self reliant within 3 to 5 year period).
- Study the current seed models and identify inefficiencies and develop models suitable to country needs (Requirements of Nepal and Bhutan could be completely different from India or Pakistan).
- Facilitation and initial assessment of seed system model in each country.
- Establishment local seed banks with the help of national governments.

Components/ Activities

- A critical study of Study of seed systems prevailing in SAARC region.
- Explore establishment of Technology/ Research Parks in countries that are ready to support.
- Explore to include community seed banks and model seed villages.
- Developing reports with the help of global experts on relevant seed systems for each country.

Resource Partners: Community Seed banks from India and Nepal; State Government Seed Departments from different countries; Pingtung Agricultural Biotechnology Park, Taiwan; Research Park of Iowa State University, USA; and Dutch Seed Sector, The Netherlands Experiences; Asia Pacific Seed Association and Global Seed experts.

4) *Development of phyto-sanitation framework for exchange of germplasm and trade facilitation of 'Seed without Borders'*

Objectives

- Study of existing legislations and phytosanitary framework and role of different ministries (Agriculture, Environment, Science and Technology, Commerce, Health etc.) in exchange of genetic resources and seed trade.

- Identify key challenges for implementing trade facilitation for safe movement of 'Seed without Borders'.
- Develop safe framework with nodal institutional support for Phyto-sanitation policy based on Green Pass concept.

Components/ Activities

- Engage global experts (Convention on Biological Diversity, WTO, International Plant Protection Convention) to study the existing systems in SAARC countries for safe transboundary movement of germplasm and seed.
- Facilitate consultation process with concerned ministries of governments contributing germplasm/ seed and receiving countries after identification of crops and accessions or varieties.
- Engage a global expert to develop a framework for Phyto-sanitation policy in the lines of Green Pass concept and validate the framework with few model transfers and assess the risks and rewards associated.

Resource Partners: CGIAR centers - IRRI, CIMMYT, ICRISAT; and global experts.

5) Policy Advocacy for promotion of biotechnology

Objectives

- Identify technologies relevant to the two sub regions in line with the country needs.
- Submit a report to the governments for consideration of policy implementations.

Components/ Activities

- Consultation with all the member countries to narrow down the policy gaps to reap the benefits of science and technology for agricultural development with specific response to biotechnology needs.

Possible Areas for Implementation: focus in two distinct sub regions: i) Afghanistan, Nepal and Bhutan, ii) Bangladesh, India, Pakistan and Sri Lanka.

Resource Partners: CGIAR centers - IRRI, CYMMIT, ICRISAT, International Food Policy Research Institute; and global experts.

Conclusion and Way Forward

Crop productivity in South Asia significantly increased compared to 1960's contributing to significant reductions in food insecurity. Ever increasing population, nutritional insecurity and undernourishment are key challenges to sustain and enhance safe and responsible crop production to meet the growing demand. Application of new science tools is essential to cope with this stupendous task of meeting food grain production by 2030 and 2050. Conventional breeding alone considering the country's sensitivities and needs, capacity and critical infrastructure development are key drivers to bring about this

change. Enabling policy is very important to achieve target crop production. Developing appropriate seed systems involving public, private and community participation to facilitate quality seed access to farmers and developing phyto-sanitation policy to enable 'Seed without Borders' in the region based on Green Pass concept is required. Policy advocacy for each country in different areas of agricultural policy needs to be developed through consultation process.

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Chapter 13

**Horticultural Research and Development in SAARC Region
Towards 2030**

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Abstract

Horticulture is an important component of agricultural economy for the member countries of the South Asian Association for Regional Cooperation (SAARC). It contributes to food and nutrition security, income diversification for smallholder farmers, job opportunities along the value chain, and an increase in foreign exchange. Nevertheless, the horticulture sector in South Asia faces various challenges: i) inadequate production and supply of nutrient-dense fruit and vegetables to meet daily micronutrient requirement of the people, especially for children of age under five years and women of reproductive age; ii) low productivity of horticultural products due to the use of low-yielding varieties, prevalence of pests and diseases, limited knowledge and skills in crop management, and unavailability of basic input materials; iii) climate change that brings out emerging invasive pests and infectious plant diseases, and abiotic stresses imposed on horticultural crops, thus aggravate already low productivity; iv) food safety concerns of marketed fruit and vegetables arising from overuse of pesticides, improper growing environment, and mishandling of horticultural products; v) post-harvest losses and waste of inherently perishable horticultural products due to factors such as improper handling, and inadequate facilities for storage, transport, and processing; and vi) inadequate marketing linkage and value chain development. To address these challenges for the next decade, we propose a series of research and development (R&D) programs that could be jointly implemented within the SAARC community in association with international and regional agricultural research organizations. The SAARC Agricultural Centre (SAC) is in best placed to facilitate implementation of the proposed research and development programs through the establishment of public and private sector partnerships, and leverage funding.

Keywords: South Asia, horticulture, research, development, collaboration

Background

Horticulture is a branch of agriculture concerned with high value fruit and vegetable crops that are used by people as part of their daily diet, with spices as a way to add flavor and increase appetite, with herbs for health purposes, and ornamental plants used for aesthetic functions that improve living quality. Horticulture is considered as distinct from the production of field crops such as cereals, starchy root crops, plantation crops, and oil seeds, which often are grown under a monocrop system with their products processed and traded in large quantities. Horticulture is usually labor intensive, making use of relatively small land areas and with high economic returns per unit area. Horticulture production supports agribusiness, creating new economic and entrepreneurial opportunities. Horticulture production diversifies and generates farm income, usually to a greater degree than other agricultural products.

Horticultural products are diverse, and play an important role in modern society and economies. Fresh edible horticultural products are nutrient dense foods that contribute to healthy diets of both rural and urban populations. Horticultural products also form the basis of a wide array of processed or partially processed products. An innovative private sector reinvents traditional plant species or preparations as innovative products using fresh fruit and vegetables in convenience foods and components of ready meals to meet the modern busy lifestyles of urban communities. Ornamental plants have high cultural value for humans as indoor and garden decorations in daily life and special events, settings for leisure activity and through urban greenery as an important part of the quality of life.

For low and middle-income countries, horticulture can contribute to food and nutrition security, and create income diversification for smallholder farmers, job opportunities, especially for women and youth along supply systems from seed to retail with value addition in between. As a whole, the horticulture sector may represent a 'picture of the future' for agriculture because it is a sector which is less restricted by measures such as subsidies and tariffs, but sees an increasing demand for higher standards due to health, safety, and broader quality concerns. Thus the sector encompasses the major challenges that South Asian agriculture faces in a world of increasing incomes, tougher delivery schedules, less restrictive conventional trade barriers, and more demanding product standards.

Regional Situation in Horticulture Sector

Agroecosystem

South Asia covers a variety of mountains, plateaus, dry regions, intervening structural basins, and island and archipelago, and has extremely diverse agro-climatic conditions due to major differences in altitude and rainfall as well as in slope characteristics. The

humid and moist sub-humid agro-ecological zones, which benefit from seasonal monsoon rains and more than 180 growing days per annum, are located in Bangladesh and around the northeastern, eastern and southern fringes of India, and cover the central, west and south of Sri Lanka. With large areas of alluvial soils and a high proportion of the land under intensive rice cultivation, these areas support a particularly dense population. The dry sub-humid areas, characterized by 120 to 180 growing days each year, cover most of the Deccan Plateau in Central India. The northwest of India, most of Pakistan and Afghanistan are semiarid or arid with less than 120 growing days. This area also features large year-to-year variations in the rainfall, frequently causing severe floods/droughts over large areas. The hilly areas, which include the foothills and valleys of Nepal, Bhutan, and northern India, are characterized with the terraced cultivation with 120 to 170 growing days. Maldives with a chain of islands is warm and humid but constrained by the poor quality soil for year-round production of crops.

The average size of farm holdings in South Asia varies from less than 0.6 hectare in Bangladesh to 3.1 hectares in Pakistan (Anik et al., 2017); the average farm size of most other South Asian countries remains less than one hectare. Furthermore, less than 50% of cultivated area is under irrigation.

Horticulture

The diversity of agro-ecological conditions and climates across South Asia provides an ideal environment not only for cultivation of a wide range of horticultural crops but also a vast potential for inter-regional trade and industry. The member countries of SAARC have also abundant availability of indigenous fruit, vegetables, flowers and herbs many of which are known for their therapeutic/medicinal and nutritive value and excellent flavor and color. The demand for such produce is likely to increase in the international market both in fresh and processed form. Nevertheless, uneven development or contrasting situations in the horticulture sector is apparent in South Asia, both within and between countries, partly due to the huge diversity of soil types, water availability, climate, and socioeconomic factors.

The region grows a diversity of indigenous and global horticultural crops (Akter & Azad, 2014). The total productions of fruit and vegetables in South Asia have been estimated at 127 and 158 million tons grown in 10.3 and 10.5 million hectares, respectively, in 2017 (FAOSTAT, 2019), in which India accounts for about 73% and 81% for fruit and vegetables, respectively (Figure 1). The export value of South Asian fruit and vegetables reached 60 billion US\$ in 2016 (FAOSTAT, 2019), in which India accounted for 55%. India stands second in the world production of fruit and vegetables after China. The total value of horticultural crops (fruit, vegetables, spices and ornamental plants) reached Rs. 344,900 crore in 2012 (GoI, 2017), which is about 16% of the value of output in India's agriculture. Fruit and vegetables account for nearly 90% of the total horticulture

production. On the other hand, as an archipelago country, agriculture in Maldives, plays a much more limited role in the country's economy, constrained by the limited availability of cultivable land and the shortage of domestic labor.

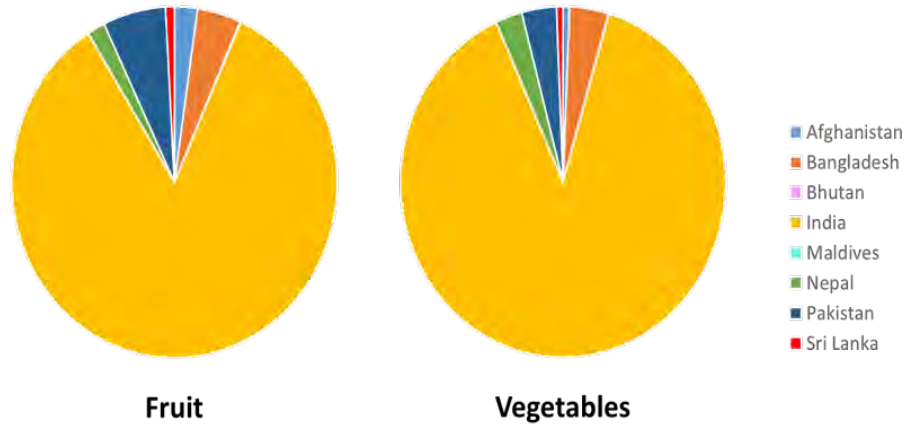


Figure 1. Proportion of fruit and vegetable production in South Asian countries

Source: FAOSTAT (2019)

Most of South Asian countries for the past decade, maintained positive growth in production of fruit and vegetables (Chhogyel & Kumar, 2018; FAO, 2018; Jha et al., 2019; Nabi & Bagalkoti, 2017; Pandey et al., 2017; Perera, 2013; Thapa & Dhimal, 2017; Yousufi, 2016) indicating the increasing role that horticultural crops play in enhancing farmer incomes, alleviating poverty and improving quality of diet. The total population in the region is expected to grow to 2.2 billion people by 2030 (Population Pyramids, 2019). This scenario, accompanied with rising per capita income and increasing urbanization (with 50% of the region's population lives in urban areas) will certainly lead to an increase in demand for fruit, herbs, spices and vegetables.

Bangladesh and Pakistan have the highest import-export ratios of fruit and vegetables (FAOSTAT, 2019), 18 and 20 times of import over export, respectively, implying that fruit and vegetable productions in these two countries lag far behind the domestic demand. Bangladesh has consistent production and area increases over the past 20 years, whereas Pakistan tends to have production and area decrease in the same period. Horticultural crops (fruit and vegetables) in South Asian countries range from 1% to 11% of total cultivated areas (Table 1) with Pakistan having the smallest share.

Table 1. Percent of areas under fruit and vegetables out of total cultivated areas in respective South Asian countries

Country	Fruit	Vegetables
Afghanistan	6.3	6.7
Bangladesh	5.7	6.8
Bhutan	10.4	10.1
India	3.9	4.6
Maldives	-	-
Nepal	8.1	11.3
Pakistan	3.8	1.9
Sri Lanka	7.9	3.3

Source: FAOSTAT (2019) & GoA (2016)

In South Asia, short-season vegetables and flowers are usually incorporated in the rice farming system, rice-wheat farming system, rain-fed mixed farming system, highland mixed farming system, and peri-urban and urban based farming system; whereas fruit trees and ornamental plants are grown in the scattered tree crop farming system. Spices are grown as intercrops with fruit and vegetable crops. However, there are also a few large plantations of mono-cropped spices like black pepper and cardamom.

Challenges and Opportunities in Horticulture Sector

Nutrition Security

South Asia has enjoyed sustained economic growth in the past decade, which will continue with Asian Development Bank’s forecast for 7.2% economic growth in 2019. Ironically, nevertheless, the region suffers from extreme poverty, undernourishment, and the deterioration of its natural resources. It houses more than 27% of the world’s poor earning less than US\$ 1.90 per day, primarily rural, young, and working in agriculture (CGD, 2019). The region has the highest Global Hunger Index score of 30.5, indicating serious levels of hunger (GHI, 2018). And undernourishment is widespread, especially among women and children. Nearly 15% of the population is undernourished. Bewilderingly, 33% of children aged under five are stunting and 15% wasting, and 49% of women of reproductive age are affected by iron-deficiency anemia (GNP, 2018).

Fruit and vegetables are nutrient dense and rich sources of minerals, vitamins, edible fiber, and functional phytochemicals. The regular consumption of a variety of fruit and vegetables is essential for a well-balanced diet. A number of international bodies (i.e., WCRF & AICR, 1997; WHO, 2003) advocate an increase in intake of fruit and vegetables to 400-500 gram per day (excluding potatoes and other starchy root crops). Furthermore, to avoid non-communicable diseases, Afshin et al. (2019) recommended optimal daily

consumption levels of 250 gram of fruit and 360 gram of vegetables, respectively, per person. Unfortunately, the per capita consumption of fruit and vegetables in South Asia remains low (Micha et al., 2015), i.e. 280 gram daily for India (Mukherjee et al., 2016) and only 100 gram daily for Pakistan (Hameed et al., 2016). All South Asian countries had less than 50% of their adolescents consuming ≥ 400 g of fruit and vegetables daily (Darfour-Oduro et al., 2018). Only 2.1% of the population in Nepal (Vaidya et al., 2013) and 1.0% in Pakistan (Hall et al., 2009) consumed fruit and vegetables at the WHO-recommended level. While global in scale, the prevalence of micronutrient (vitamins and minerals) deficiencies, also known as hidden hunger, is particularly high in South Asia despite recent successes in health care (Harding et al., 2018). In this connection, Hidden Hunger Index has been developed and employed as a ranked index of countries affected by the severity of micronutrient deficiency. Ruel-Bergeron et al. (2015) reported that South Asian countries were ranked in top half of 149 countries with high Hidden Hunger Index. Among eight South Asian countries, India has the highest score of Hidden Hunger Index (Table 2).

Table 2. Hidden hunger index scores (HHI) by country in South Asia

Country	Ranking (Out of 149 countries)	HHI	Prevalence (%)		
			Stunting	Anemia due to iron deficiency	Serum retinal <0.7 $\mu\text{mol/L}$
Afghanistan	12	47.7	59.3	19.0	64.5
Bangladesh	52	29.3	43.0	23.5	21.7
Bhutan	42	33.3	37.5	40.3	22.0
India	6	48.3	47.9	34.7	62.0
Maldives	50	30.0	31.9	48.9	9.4
Nepal	34	35.3	49.3	24.2	32.3
Pakistan	63	26.7	42.0	25.5	12.5
Sri Lanka	75	22.3	19.2	12.6	35.3

Source: Ruel-Bergeron et al. (2015)

Dizon & Herforth (2018) reported that low intake of nutrient-dense fruit and vegetables in South Asia is largely attributed to seasonal fluctuations in prices. Fruit and vegetables are more seasonally and spatially variable than those of energy-dense, low-micronutrient cereals and legumes. Moreover, fruit and vegetables tend to be highly perishable, thus they generally have a shorter shelf life for storage and transportation than cereals and grain legumes. And there are personal factors such as likes and dislikes of certain fruit and vegetables because of their sensory tastes, and social and cultural norms that deter the intake of these nutritious foods (Kehoe et al., 2019).

To address the issue of low consumption of fruit and vegetables, strategies need to be multidisciplinary and coordinated, and should comprise a balance of components to stimulate growth in both demand for and supply of fruit and vegetables. Besides increasing availability, accessibility, affordability and sustainability of fruit and vegetables for the consumers, messages about fruit and vegetable consumption need to be integrated into food-based dietary guidelines, to be country specific and culturally relevant, and coordinated with other messages about healthy diets. South Asian countries could also learn from various campaigns initiated in high income countries for promoting consumption of fruit and vegetables such as “Five A Day for Better Health” and “Fruits & Veggies – More Matters” in the USA, “Go for 2 & 5” and “Eat Brighter Live Lighter” in Australia, “6 a Day” in Denmark, “5 + A Day” in New Zealand, etc. Innovative communication campaigns at consumer level could include web campaigns inviting children to get involved with healthy eating; mobile/internet/video-games; toys/cartoon character or play-way based activities; field days for fruit and vegetables; and catering of hygienic fruit in public gatherings and schools.

On a different perspective, a growing body of evidence has emerged in the past decade that suggest an increased consumption of healthy plant-based foods (e.g., fruit, vegetables and legumes) might be associated with lower emission of greenhouse gases and thus might be more environmentally sustainable (Tilman & Clark, 2014).

Productivity

There are significant differences in yields of fruit and vegetables per unit land area among South Asian countries. India stands out as a country with the highest average yields for fruit and vegetables per unit land area in South Asia, at 13.1 and 15.0 Mt/ha, respectively (Table 3). Nevertheless, average yields of fruit and vegetables for South Asia as a whole are 71 and 50% of Northeast Asia. There are environmental and technological factors that potentially contribute to this gap. Night temperatures in tropical and sub-tropical South Asia are usually high, therefore respiratory losses are also expected to be high, thus resulting lower yield. On the other hand, a single growing season in temperate Northeast Asia is usually long; therefore photosynthetic products (biomass) are also expected to be high, thus resulting in higher yields. Moreover, high temperatures and humidity in the tropical and sub-tropical South Asia likely to increase the prevalence of phytopathogens (e.g. bacteria, fungi, nematodes, viruses, viroids, etc.), pests (e.g. insects, mites, vertebrate pests, etc.), and weeds that affect not only productivity but also quality of horticultural crops.

Table 3. Average yields (Mt/ha) of fruit and vegetables in South Asian countries (2017)

Country	Fruit	Vegetables
Afghanistan	8.5	9.6
Bangladesh	9.7	9.5
Bhutan	6.2	5.2
India	13.1	15.0
Maldives	9.5	1.7
Nepal	9.4	13.3
Pakistan	12.2	12.2
Sri Lanka	5.6	12.6
South Asia	12.3	14.8
Northeast Asia ¹	17.4	29.5
World	13.3	18.8

Source: FAOSTAT (2019)

¹Includes Japan, South Korea and Taiwan

There are also technological and policy factors that contribute to low productivity of horticultural crops in South Asia. Horticulture has been neglected by public sector, which places emphasis on staple crops. Smallholder farmers remain ill-informed on changes in cultivation practices. As a result, out-of-date farming practices and unavailability of quality inputs are the rule for the horticulture sector, except for some pockets with major private sector investment – high-tech horticulture is, therefore, possible. But these are out of reach for smallholder farmers (Quddus, 2009). As a result, productivity levels are low, prices are high, and fluctuate widely across the year.

In South Asia, more than 95% of the agriculturally suitable land is already under cultivation. Hence, there is hardly any scope for horizontal expansion of land for producing more horticultural crops. But to meet with burgeoning demand for quantity and quality of diverse horticultural products, besides shifting portions of cultivated land for horticultural crops, increasing productivity and profitability per unit land area is the only way. Towards this, there is a need for continuous technology innovation in developing improved varieties for resistance to diseases and pests, tolerance to drought, flooding and heat; improved varieties with short duration and producing good yields under stress conditions; integrated pest management (IPM) including bio-control agents for safer marketed products and environment; integrated soil fertility management; protected cultivation for all seasons; supply system of quality planting materials; improved water use efficiency; organic agriculture; precision management of fruit tree orchards; etc. Furthermore, smallholder farmers will have to acquire a high level of skill and knowledge to fully adopt these new technologies.

Climate Change

South Asian countries have been identified as some of the most affected countries by global climate change, although their contribution to greenhouse gas emissions has been shown to be low (World Bank, 2013). The impact of climate change can already be seen in the greater variability of the monsoon, increased frequency of tropical cyclones, and faster melting of the Himalayan glaciers. In the region, Bangladesh is one of the most climate-vulnerable and disaster-prone countries because of its geographic location, a flat and low-lying deltaic floodplain, as well as its exposure to various hydro meteorological hazards. Salinity intrusion is affecting agricultural production and is also becoming more intense and frequent. As a result, agricultural gross domestic product over 2005-2050 is projected to decrease 3.1% annually (USAID, 2015).

Much of the agriculture in South Asia is rain fed, so there is a fundamental dependence on rains that come seasonally. The probability of lower crop yields can thus increase with climate change. Crop yields in the region are predicted to decrease in the absence of increased resilience to cope with climate risk between 7 and 10% in the near future (TAAS, 2017). Climate changes have already caused distinctive reduction in production of fruit and vegetables in South Asia (Malhotra, 2017). Thus, smallholders in the horticulture sector are the most vulnerable, as their ability to bear risk is extremely low.

Many fruit and vegetable crops proven to be relatively sensitive to climate changes (Backlund et al., 2008), which raises the prospect of reduced fruit and vegetable availability in the future with contingent public health concerns. **Climate changes have shown to impact on:** i) the suitability and adaptability of prevailing varieties as temperatures change, together with changes in the optimum growing periods and locations for horticultural crops; ii) the re-distribution of current pests, diseases and weeds, and an increased threat of new intrusions; iii) downgrading product quality; iv) increased input costs for chemical fertilizers and pesticides; v) increased risk of spread and proliferation of soil borne diseases, e.g., bacterial wilt in solanaceous crops, as a result of intense rainfall events coupled with high temperatures; vi) increased risk of soil erosion and leaching effects of nutrients and pesticides from extreme rainfall events; and vii) increased irrigation demand especially during dry periods.

Besides, as many fruit and vegetable species rely on pollinators, a complete loss of pollinators because of climate change has been predicted to reduce global fruit supply by 23%, vegetables by 16% and nuts and seeds by 22% with major adverse effects on health (Smith et al., 2015). High temperatures may also indirectly affect fruit and vegetables yields due to decreased labor productivity of farmers. Many fruit and vegetable crops require high labor inputs, especially for planting and harvesting and hence climate change induced heat stress may disproportionately affect the horticulture sector.

To address climate change challenges as well as for economic growth and development of the horticulture sector, investment in research and development must be increased to develop site-specific adaptation/mitigation strategies. This may include the development of climate-resilient varieties; low-cost protected cultivation technologies; multiple cropping systems; smallholder farmer-friendly decision-making technologies; etc. And there are climate resilient agriculture technologies and practices, which enhance productivity as well as adaptation and/or mitigation and present opportunities for scaling up. For this profile, they include:

- Adoption of adaptive crop calendar.
- Use of crop species and varieties that are resistant/tolerant to diseases, pests, and drought, flooding, high temperature, salinity, etc. keeping in view the nature of crop, its sensitivity level and the agro-ecological region.
- Use of quality seeds and planting materials, and improved water use efficiency.
- Site-specific nutrient management.
- Protected cultivation to reduce impacts of extreme weather elements for year-round production.
- Multiple cropping to reduce impacts of climate change, mulching with crop residues and plastic mulches to conserve soil moisture and suppress weeds.
- Integrated pest management including use of bio-control agents and monitoring of emerging diseases and pests.
- Intercropping of vegetables in fruit orchard to suppress weeds and improve productivity.
- Raised bed cultivation to overcome flooding.
- Sustainable land, soil management, and organic farming.

Nonetheless, given the scale of climate change impacts, stand-alone measures for the horticulture sector to adapt to them will not suffice. Resilience needs also to be mainstreamed and embedded into policies and programs such as material subsidies or crop insurance across scales of governance.

Food Safety

Most consumers pay attention to the appearance of fresh produce offered in markets and this means that farmers resort to indiscriminate and excessive use of pesticides to limit economic risks. As a result, food safety issue arises and becomes a particular concern for fruit and vegetable consumers in South Asia. We have conducted a literature survey on food safety concerns related to vegetables in South Asia. Insecticides classified by WHO (2009) as extremely hazardous (Ia) organophosphates i.e. methyl parathion and parathion, and highly hazardous (Ib) organophosphates i.e. dichlorvos, monocrotophos

and triazophos are still used in vegetable production in Bangladesh, India and Nepal; and highly hazardous carbamate (Ib) i.e. carbofuran used in Bangladesh and Pakistan; and their residues detected in marketed produces. On an average, vegetables in India were applied 10 to 15 times of pesticides, resulted in a total of 2 to 5 kg/ha (Kodandaram et al., 2013; Pujeri et al., 2016). Without personal protective equipment and proper application of pesticides, they likely will cause occupational hazards. Besides, pesticide residues contained therein can have both acute and chronic health effects, depending on their type, quantity, function, ways in which a person is exposed (such as eating or direct contact with the skin), and duration of exposure.

In view of the above, governments need to introduce policies that facilitate removal of ineffective or highly dangerous pesticides from the market, and encouragement of the bio-control industry, training of farmers or farm operators on safe use of pesticides and IPM. It is encouraging that many Asian countries are embracing biocontrol measures and speeding up legislation.

Apart from pesticides, high concentrations of non-essential highly toxic heavy metals (As, Cd, Cr, Pb) and pathogenic microorganisms (*Escherichia coli*, *Klebsiella* spp., *Listeria* spp., *Pseudomonas* spp., *Salmonella* spp., *Shigella* spp., and *Staphylococcus aureus*) were found in numerous vegetables grown and marketed in the region (Kuo et al., unpublished results).

Food safety should be taken as an element of food security. Health hazards can arise along any part of the food chain, thus food safety risks need to be reduced by preventing contamination throughout the food production, processing, storage, and distribution chain. Unfortunately, food safety programs on fruit and vegetables in South Asia generally lack some of the critical elements including: identification of the nature and extent of national food safety problems; understanding of the consequences of contaminated food on the population's health status; and, awareness of the urgency for the need to investigate and do research. There is a sound need of cost-effective methods for identifying specific food safety problems of fruit and vegetables, and their impact on the society, and a comprehensive and integrated multidisciplinary approach to food safety. Sharing information, education, and advice among stakeholders across the region are essential to enable food safety programs that reduce the incidence of food-related hazards from producing and consuming fruit and vegetables.

Post-Harvest Losses

Post-harvest losses are typically large for horticultural crops in South Asia. Losses have been estimated from 30 to 50%, varying from crop to crop and country to country (Bhattarai, 2018; Faqeerzada et al., 2018). These substantial losses and the resulting waste usually are caused by: poor practices in both the production stage as well as the postharvest stage with a lack of proper technique for prolonging the shelf life; inadequate

information and skills in harvesting and postharvest handling; smallholder farmers' limited financial resources for adopting improved postharvest management techniques; lack of appropriate and low-cost infrastructures; high transportation costs; poor access of farmers to markets and integration of marketing channels; weakly developed processing sector; non-utilization of horticultural waste; inadequate investment in R&D; and disappointing policy support. Furthermore, a number of causes of postharvest losses could be exacerbated by high temperatures, greater rainfall variability, and more frequent extreme weather events due to climate change.

These postharvest losses have several adverse impacts on farmer's income, consumer prices and nutritional quality of fruit and vegetables. They represent the decrease in the mass, nutritional value and/or quality attributes of nutrient-dense fruit and vegetables intended for human consumption (FAO, 2011). Moreover, prices of seasonal horticultural crops fluctuate greatly and during the period of maximum availability the prices are not remunerative to the farmer. At other times these horticultural commodities are so highly priced that the ordinary consumers find them beyond their purchasing power. Another problem is that fruit and vegetables are not uniformly available and some areas suffer from inadequate supply even when there is a glut in other parts. At present there is a considerable gap between the gross production and net availability of fruits and vegetables due to heavy postharvest losses. For example, despite India being as the world's second largest producer of fruit and vegetables, there still exists huge gap between per capita demand and supply of fruit and vegetables due to enormous waste during post-harvest storage and handling caused by improper bagging without crating, lack of temperature controlled vehicles, unavailability of cold chain facilities in various parts of country for preserving the produce (Raise & Sheoran, 2015), along with a miniscule 2% of the horticultural produce being processed into value-added products (Sachdeva et al., 2013).

There is a need for horticultural products that have good shelf life both before and after retail in order to maintain nutritional and sensory qualities, and to minimize waste. It is essential that traits related to postharvest behavior are taken into consideration from the early steps of new crop design as well as pre-harvest production management. Although not exclusive to horticultural food products, this area is of particular importance for fresh fruit and vegetables. For ornamentals, this is also highly important, and has distinct challenges from food products.

In order to reduce postharvest losses of perishable horticultural crops, cost-effective technologies for storage, processing and transportation have to be developed and adopted. Several post-harvest diseases and pests can be avoided with appropriate pre-harvest treatment. Such recommendations need to be popularized among growers to reduce losses and improve quality. In order to reduce post-harvest losses, there is urgent need to develop and implement appropriate harvesting methods. The maturity indices in

most of the horticultural crops are either not available or not followed by the farmers resulting in harvesting of these crops at varied maturity levels, thereby, a large quantity of produce has to be rejected while sorting and grading due to under or over maturity/ripening.

For smallholder farmers in South Asia, the development and adoption of improved low-cost containers, low or zero energy cool storage, field packing systems, shade covers, and small cold rooms are all practical. Furthermore, simple food processing such as drying, and the canning of sauces and jams are helpful methods for improving the availability outside the growing season of nutrient-dense fruit and vegetables by transforming highly perishable produces into stable, transportable, and storable foods.

On the other hand, to address the increasing demand from urban-based consumers and export markets for high quality horticultural products, there is a clear need for a more holistic, harmonized, and integrated approach when dealing with postharvest losses in the overall context of supply chain. Postharvest innovations such as cooling systems, ethylene controlling technologies, sustainable packaging, IT in postharvest management, vibration and moisture sensors, Coolbot technology, etc. with the context of supply chain, can have a very large impact on the prevention, reduction as well as possible recapture of value in postharvest losses (De Corato, 2019).

The investments in research and scaling of postharvest horticultural technology can have a major impact on reducing post-harvest losses and increasing availability and accessibility of fruit and vegetables, ultimately, improvement in the incomes with the use of existing production techniques without increasing productivity. The future research and extension activities must be toward the maintaining quality especially shelf life, sensory taste, nutritional content, and most important of all, food safety of marketed horticultural products (avoiding pesticide residues, heavy metal contamination, and microbial contamination).

Marketing and Value Chain

Marketing of horticultural products in South Asia includes a number of marketing channels involving the traditional as well as modern marketing networks. For the traditional marketing system, which is the mainstay of the horticulture sector in the region, most horticultural products from the smallholder farmers make it to markets via informal or formal pathways that are dominated by small traders, with relatively little coordination. This entire traditional supply chain is largely supply driven and laden with various constraints and challenges (Negi & Anand, 2015; Rais & Sheoran, 2015; Mallawaarachch & Ahmad, 2018). Except direct transactions between farmers and consumers, the constraints to market horticultural products in either rural markets or urban markets include fragmented connectivity to the market, poor handling, high cost of packaging materials, lack of sorting and grading system, inadequate cold chain

infrastructures, poor transportation conditions, dependency on a number of intermediaries, lack of access to market information, limited value addition processing, etc., which result in substantial postharvest losses of horticultural products. And this leads to poor price returns for the farmers on one end, and exorbitant prices paid by the consumers on the other end. Recognizing the challenges that affect the traditional marketing system of horticultural products, it is crucial for the government to further intervene. Such **important interventions** can come in the form of:

- Increasing public investment in supply chain infrastructures such as cold storage facilities, and transportation facilities and logistics.
- Making rural credit and micro finance easily accessible to the smallholder farmers.
- Encouraging clustering of smallholder farmers into farmers' associations or cooperatives that are equipped with marketing information management and entrepreneurial management skills to enhance economies of scale (Trebbin & Hassler, 2012).
- Establishing purchasing/assembly centers that handle sorting, grading and packing in rural or peri-urban areas, and terminal wholesale and semi-wholesale markets within or near major cities.
- Initiating one-village (or one peri-urban zone)-one-product to increase competitiveness of the product.
- Meeting consumer demand for safety, convenience, quality and nutrition.

The emergence of supermarkets, store chains and export companies over the last decade or so in South Asia has profoundly influenced fresh fruit and vegetable marketing system, and the trend is expected to continue into the foreseeable future because of rising per capita incomes, urbanization, trade liberalization, technological advances and changing lifestyles (Abeysekera & Abeysekera, 2006; Trebbin, 2014; Naik & Suresh, 2018). They employ the strategies of modern marketing systems, which are more direct than traditional marketing systems. The marketing chains are usually well coordinated, and are driven by consumer demand. They are further characterized by centralized produce procurement systems, systematic storage and distribution systems, specialized suppliers who may be farmer groups, contracted farmers or wholesalers, produce quality standards, and the use of advanced information/communication systems. They may affect the traditional marketing systems especially for smallholder farmers and suppliers with little capital and other resources; however, The Economist 2014 reported that supermarkets, which handle fresh fruit and vegetables are struggling to win customers from India's traditional retailing.

Relevant Policies, Laws and Programs

Afghanistan

The major national agricultural policies and strategies are the *National Agriculture Development Framework (NADF)- 2009*, and *National Comprehensive Agriculture Development Priority Program (NCADPP)- 2016* (GoA, 2016). One of NADF's four programmatic pillars is increasing production and productivity of crops. And NCADPP's strategic priority for horticulture value chain put in place the following **affirmative action measures**: expansion of the horticulture land-base (horizontal increase); increase productivity per hectare (vertical increase); develop promising value chains; infrastructure and market development; embrace standardization; support the private sector; develop the nursery industry; and expand the area under protected agriculture.

The World Bank's review (2014) considered that the horticulture sector is one the three most promising opportunities as "first movers" of national agricultural policies and strategies for quicker results. And to restore the agricultural sector's productive capacity from the negative effects of more than 20 years of conflicts, the World Bank has provided grant of US\$ 114.60 million for the National Horticulture and Livestock Productivity Project (NHLP) from 2013 to 2020. Increasing horticulture productions and technical assistance support are two of the three components that the project supports. NHLP's horticulture extension activities concentrate on linking rural farm producers with markets by promoting improved production practices through the gradual development of farmer-centric service delivery, and have created about 10,000 full-time jobs. In this connection, the horticulture sector's output has more than doubled in the past decade (Leao et al., 2018).

During the period 2006-2015 the Perennial Horticulture Development Project (PHDP), funded by the EC-EuropeAid Program, has been supporting the Ministry of Agriculture, Irrigation and Livestock of Afghanistan through a process of collection and selection of local fruit varieties in order to improve the private nursery system, as well as perennial horticulture. The PHDP contributed in capacity building at technical and institutional level, fostering the establishment of nursery sector associations, providing expertise and developing the Afghanistan National Nursery Growers Organization (ANNGO) and the apex Afghanistan National Horticulture Development Organization (ANHDO), mainly concerned with value chains (Masini & Giordani, 2016).

In addition, the Asian Development Bank has committed a grant of US\$ 75 million to support the Project of Horticulture Value Chain Development Sector from 2019 to 2024. The project will help strengthen the horticulture value chain by: i) improving the processing efficiency and marketing capacity of domestic agro-business enterprises; ii) modernizing crop production through better planting material, trellising, modern greenhouses, and on-farm facilities; and iii) contributing to the national effort in

establishing internationally recognized brands of horticultural produce. It will increase value addition for horticultural commodities produced in 11 provinces in the central, southern, and eastern parts of the country. As such, the project will contribute to increasing the supply of fresh and processed fruit and vegetables, and expanding exports of high-value fruit, vegetables, and nuts in which the country has a comparative advantage.

Bangladesh

In 2015, the Government of Bangladesh has adopted the *Seventh Five Year Plan (2016-2020)*, which focuses on developing the crop sub-sector to raise rural income and generate employment opportunities for poor rural people. The development vision of the plan aims at ensuring food and nutritional security, sustainable intensification and diversification of climate resilient agricultural production with increased commercialization and livelihood improvement through technological innovations and use, and linking farming community with markets, both national and international. Attaining crop diversification is considered crucial for increasing productivity, for ensuring human nutritional security, maintaining soil health and increasing cropping intensity, employment and the income of farmers. Furthermore, the *National Agricultural Policy (2013)* aims at promoting diversification by increasing space and production of fruit, vegetables, spices, and other crops under the Crop Diversification Programme, which will gradually be extended. In 2016, a national technical committee was created to guide the overall development of the Second National Plan of Action for Nutrition (2016-2025). The plan stresses on increasing vegetable and fruit production and productivity at national and household levels through integrated horticulture development. The effectiveness of these policies and programs to accelerating diversification towards more nutrient-rich fruit and vegetables requires investment in further research and development among others. In this regard, the Netherlands-Bangladesh Business Platform (Nyenrode Business Universiteit, 2014) reported that: i) prices of fruit and vegetables will rise, as it is not possible to increase the production at the same speed as demand due to limitation of land, limited use of modern technology and managerial capacities; ii) investing to reduce post-harvest losses in fruit and vegetables would mean a lot for the development of the supply chain; and iii) protected horticulture would be a feasible means to overcome heat, drought, heavy rainfall, and salinity problems in safe production of horticultural crops.

Apart from the aforementioned, various acts, bills and policies were enacted in the country that dictate the country's agricultural development and have implications on horticulture. They are: i) *Seed Rules- 1998*; ii) *National Integrated Pest Management Policy- 2002*; iii) *Fertilizer Management (Amendment) Act- 2009*; iv) *Pesticide (Amendment) Act- 2009*; and v) *Bangladesh Safe Food Act- 2013*.

Bhutan

The country is located in an ecologically risky area high in the Himalayan mountain range, with diverse ecosystems. And the agriculture sector is dominated by smallholder subsistence farmers, who scatter in the majority of the arable land. Food production is a challenge and the impacts of climate change are likely to add to the burdens of farming (Chhogyel & Kumar, 2018). The country has already been experiencing some impacts of climate change, such as crop loss to unusual outbreaks of diseases and pests, erratic rainfalls, windstorms, hail storms, droughts, flash floods and landslides.

The Horticulture Division of Department of Agriculture under the Ministry of Agriculture and Forests has set the long term objective of optimizing the contribution of the horticulture industry to the welfare of present and future generation of farmers and consumers with emphasis on improved cash income, food security, higher nutritional standards and export earnings; and the short-term objective of improving the existing management practices and to increase production and quality of those horticultural commodities with a comparative advantage in a sustainable manner in all production environments through interdisciplinary research, extension and marketing.

The expected outputs related to horticulture sector of the *12th Five Year Plan 2018-2023* (DoA, 2019) include:

- Increased vegetable production towards 100% self-sufficiency by the end of the 12th Five Year Plan.
- Sustainable citrus production with rejuvenated orchards and at high elevation sites.
- Collection, conservation, production, processing and marketing of medicinal and aromatic plants, and spices.
- Enhanced production and marketing of both cultivated and wild mushrooms.
- Increased commercial production of fruit, nuts and ornamental plants.
- Established repositories for horticultural crop germplasm.

Program activities include research, piloting and scaling of improved varieties, production technologies, plant protection, soil management, protected cultivation, production of planting materials, mechanization, and organic farming,

The Integrated Horticulture Promotion Project in the West Central Region (2016-2021) with financial and technical supports from the Japan International Cooperation Agency aims at promoting horticulture through improving and strengthening research, development and extension system, and ultimately increase the production of horticulture in West-Central region. Expected outputs are: i) appropriate technologies for horticulture farming; and ii) production systems for vegetable seeds and fruit planting materials, involving private sector; and iii) capacity building on horticulture farming, production of planting materials, and research and extension (IHPP-JICA, 2017).

Both the Commercial Agriculture and Resilient Livelihoods Enhancement Programme (2015-2022) funded by the International Fund for Agricultural Development, and the Food Security and Agriculture Productivity Project (2017-2022) financed by the Global Agriculture and Food Security Program have research and scaling activities related to horticulture. They include: i) climate-smart production of vegetables for improved food security and nutrition; ii) increased production of spices, vegetables and citrus through area expansion, increased cropping intensity, and elevated yield level; iii) development and production of climate resilient vegetable seeds; iv) reducing post-harvest losses of fruit and vegetables; v) strengthening nutrition sensitive value chains of selected fruit and vegetables; vi) support of community-driven vegetable market infrastructure; vii) strengthened linkages to domestic and export markets; and viii) capacity building.

India

The country has emerged as world's second largest producer of fruit and vegetables contributing to 10% and 14%, respectively of the total world production (FAOSTAT, 2019). The share of horticulture sector in value of agriculture output and the total exports of agricultural commodities stands at 34% (Bhat, 2017), and 37% (Jha et al., 2019), respectively. All of these indicate the significance of horticulture sector in India. However, the country still bears the brunt of food insecurity and nutrition insecurity. India was ranked 103 out of a total of 119 countries by the Global Hunger Index with a score of 31.1 indicating the country suffers from a level of hunger that is serious (GHI, 2019). Moreover, the country was ranked top eighth out of a total of 149 countries by Hidden Hunger Index (HHI) with a HHI of 48.3 (Ruel-Bergeron et al., 2015). This is very much related to the comprehensive challenges of production and supply of horticultural crops that the country is facing, for the reason horticultural crops play an important role by contributing adequate vitamins, minerals, edible fibers and other health-promoting phytochemicals. These challenges include persistent problem of low productivity because of the larger number of small and marginal farmers, tumultuous weather, seasonal cyclones, occasional drought, demographic pressure, industrialization, supply chain, and unprecedented use of pesticides, and migration of rural masses to urban areas for their livelihood (Bhat, 2017; Neeraj et al., 2017; Negi & Anand, 2015). Beside the dynamic production problems, limited availability of fruit and vegetables because of underdeveloped infrastructure support like cold storages, markets, roads, transportation facilities, etc.; volatile marketing conditions; and inadequate technologies for value addition and processing to minimize the post-harvest loss are the other challenging issues facing horticulture.

There is need to prioritize the development of research, technological up-gradation, infrastructure for transportation and marketing as thrust areas for future development of the horticulture sector in India (Jha et al., 2019). Towards this, the Government of India (GoI) has launched several schemes for the holistic development of horticulture sector.

The main step taken by GoI was the introduction of the *Mission for Integrated Development of Horticulture (MIDH)* to provide a thrust to the development of horticulture sector covering fruit, vegetables, root and tuber crops, mushrooms, spices, flowers, aromatic plants, coconut, cashew, cocoa and bamboo. It is a centrally sponsored scheme with cost sharing with the states. The main objectives of MIDH are: i) to promote holistic growth of horticulture sector through area based regionally differentiated strategies, which includes research, technology promotion, extension, post-harvest management, processing and marketing, in consonance with comparative advantage of each state/region and its diverse agro-climatic features; ii) to encourage aggregation of farmers into farmer groups to bring economy of scale and scope; iii) to enhance horticulture production, improve nutritional security and income support to farm households; iv) to improve productivity by way of improved varieties, quality planting materials, and improved water use efficiency; and v) to support skill development and create employment generation opportunities for rural youth in horticulture value chain from farm to retail. To achieve the abovementioned objectives, MIDH adopts the following strategies and activities:

- Adopt an end-to-end holistic approach to assure appropriate returns to producers.
- Technology development for production, post-harvest management and processing with special focus on cold chain infrastructure for extending the shelf life of perishables.
- Enhance productivity and quality through diversification with high-value crops, protected cultivation, precision farming, and area increase of fruit orchards.
- Improve post-harvest management, value addition and marketing infrastructure.
- Encourage public-private partnership at all levels.
- Support farmer/producer organizations to link with financial institutions.
- Capacity-building and human resource development at all levels.
- Provide financial assistance and subsidies for production of seeds and planting materials, protected cultivation, precision farming, and cold storage and market infrastructure.

Moreover, the National Horticulture Board develops and promotes horticulture, subsidies investment in cold storage facilities, and operates a market information service. Other than the aforementioned, various acts, bills and policies were enacted in the country that dictate the country's agricultural development and have implications on horticulture. They are: i) *National Seeds Policy- 2002*; ii) *Seeds Bill- 2004*; iii) *Pesticide Management Bill*, which may come in effect from December 2019; and iv) *Food Safety and Standards Act - 2006*.

OECD (2018) report suggests a series of reforms including horticulture sector which, if implemented, would help India improve food security for its vast population, advance

the quality of life of its millions of smallholders, overcome severe resource and climate pressures, while generating sustainable productivity growth and creating a modern, efficient and resilient agro-food system that can contribute to inclusive growth and jobs throughout the economy.

Maldives

Although the country is balancing its food requirements, staple crops, fruit, vegetables and other food items are entirely or largely imported. At present, agricultural production is mainly carried out at subsistence level with horticultural crops such as leafy vegetables, chili, watermelon, coconut, papaya, banana and a variety of root crops. One of activities under FAO's *Maldives Country Programming Framework 2013-2017* was to promote home gardening of fruit and vegetables for family consumption to improve nutritional status of communities, especially for vulnerable groups of children, women and elderly.

In cooperation with FAO, the Government of Maldives has adopted the *Agriculture Development Master Plan (2006-2020)*. The plan focuses on implementing policies that: i) improve food security, nutrition, incomes and employment opportunities; ii) foster gradual commercialization of the agriculture sector through increased production; iii) increase the capacity to generate appropriate technologies and improve farmers' and entrepreneurs' access to them; iv) develop market infrastructure that is supported by functional marketing networks and a market information system; v) provide adequate institutional support; vi) support human resource development; and vii) promote partnerships among the public, private and NGO sectors.

Nepal

In 2013, the Ministry of Agricultural Development has published the *Food and Nutrition Security Plan of Action* (GoN, 2013). The plan has outlined horticulture as one of the nine program components. The main objective of this particular component is to increase the availability of diverse and nutritious food at household level for domestic consumption as well as marketing, and hence improve household nutrition status. The component is expected to improve household nutrition and income through the production of fruit and vegetables throughout the year.

In 2014, GoN (2014) has also approved the *Agriculture Development Strategy 2015-2035* (ADS), which is an overarching policy adopted by the government to achieve food sufficiency, sustainability, competitiveness, and inclusion. It addresses food and nutrition security of the most disadvantaged rural populations, including pregnant and lactating women. ADS has foreseen good potential in vegetables, fruit, beverages, dairy and meat for import substitution through sufficient production. Also ADS has prioritized high-value vegetables as one of five priority value chain development programs through

extensive and integrated steps that benefit the poor by enhanced investment of producer farmers, cooperatives, public and private sectors with regional impact. Through the U.S. Government's Feed the Future initiative, the *Global Food Security Strategy Country Plan for Nepal*, high-value vegetable value chain is also included under an integrated farming systems approach. Moreover, the United Nations Development Programme is supporting the "value chain development of fruit and vegetables in Nepal," from 2018 to 2022. The goal is to improve incomes of smallholder farmers through value chain development of vegetables and fruit in Provinces 3 and 4.

ADB (2012) reported that the agriculture policy in Nepal encompasses sufficiently the concerns of horticulture sub-sector, but the key concern is the serious and effective implementation of horticulture related clauses. This implies that the organizational structure of horticulture or the investment or the working modalities of the sub-sector have many deficiencies. In this regard, Thapa & Dhimal (2017) recommended that the following areas should be addressed in the future: i) niche fruit, flowers and spice production in larger areas; ii) development of hybrid varieties of horticultural crops especially vegetables; iii) establishment of processing units for ginger, areca nut and large cardamom; iv) establishment of storage facilities for year-round supply and price stabilization of horticultural crops; v) capacity enhancement for horticulturists and extension workers; vi) single door policy for foreign aid and investment; vii) crop insurance policy for commercial farmers; and viii) sanitary and phyto-sanitary measures for exportable commodities. Furthermore, Atreya et al. (2019) estimated that by employing precision and protected horticulture can increase productivity by 3-5 folds over open field condition.

Pakistan

A variety of fruit, vegetables and spices constitute the horticulture sector. Citrus, mangoes, dates and apples dominate fruit production at the national level. Large-scale farmers are involved in the production of mangoes and kinnows (mandarins), often for export, and a large number of smallholders maintain small orchards that contribute to household income. Also, a large number of smallholder farmers are involved in vegetable production due to short production cycles and regular contribution to household income. Major vegetables and spices include potato, onion, tomato, chili, garlic, leafy varieties, and root crops.

Government of Pakistan has given high priority for achieving food security and nutrition for its population through important policy initiatives, which include concept development of National Zero Hunger Program, food security assessment survey, the recent commitment of the Government for Sustainable Development Goals, particularly to the SDG- 1 and SDG- 2 about poverty and zero hunger challenges. A comprehensive

National Food Security Policy (NFSP)-2017 was prepared to document all these initiatives (GoP, 2017). NFSP measures for the horticulture sector include:

- Introduction of high value fruit crops like olive, pistachio, almond, kiwi, grapes and dates for a range of agro-ecological zones, and up-scaling of fruit plant certification program.
- Development of modern seed industry that includes production of hybrid vegetable seeds, and disease-free fruit planting materials.
- Capacity building for processing, value addition and marketing of fruit and vegetables in terms of human resources, facilities and infrastructures.
- Assuring food safety of fruit and vegetables that entails scaling of IPM and safe use of pesticides to the farmers, production of bio-control agents, analyses and monitoring of pesticide residues, and compliance of national and international food safety regulations.
- Support for fruit and vegetables across the supply chain, including quality assurance, sorting, grading, packing, and product traceability.

Fayaz et al. (2014) advocated that devising food policy for the development of food markets in terms of market segmentation and quality improvements has to be undertaken in response to the positive demand for quality products. Furthermore, Mallawaarachchi & Ahmad (2018) suggested that efforts to modernize food value chain requires greater emphasis on improving entrepreneurial orientation at the growers' end. Regarding food safety of fruit and vegetables, a bill for National Food Safety, and Animal and Plant Health Regulatory Authority has been approved, which will improve the implementation of food safety standards articulated in NFSP (GoP, 2017). Moreover, *Pakistan Horticulture Vision 2030*, initiated by the private sector, deals with the major issues the horticulture sector is facing, including climate change, water management, lack of sectoral knowledge, skill development, adoption of modern technology, and, most importantly, absence of research and development. By effectively implementing roadmap in the vision, it is expected that the export revenue of fruit and vegetables can be enhanced to US\$ 3.5 billion in five years, and US\$ 6.0 billion within 10 years

Sri Lanka

There are several challenges the agriculture sector is facing in the country. They include aspects such as: meeting food and nutrition security of the people; sustainability of the system due to competition, globalization and climate change; technological challenges; and managing soil and environment toxicity and degradation due to the non-discriminate use of agrichemicals and soil erosion. Vegetable production, in particular, suffers from unfavorable weather elements, over use of agro-chemicals, lack of improved varieties, lack of seed production capacity, high pest and disease attacks, high cost of technical inputs and land fragmentation (Weerakkody, 2004). To address these

challenges, the National Agricultural Policy for Food and Export Agricultural Crops and Floriculture 2007 has been updated to strive for food safety that entails organic agriculture/natural agriculture, good agricultural practices, plant protection, safe use of agricultural chemicals, and white revolution (i.e. protected cultivation). Furthermore, Sri Lanka Council for Agricultural Research Policy (CARP) has formulated the National Agriculture Research Policy and Strategy (NARPS) 2018-2027 (CARP, 2017). For the horticulture sub-sector, the NARPS pursues the following strategic plans on fruit, vegetables, and floriculture.

On fruit crops, the strategy is to increase the national fruit supply to ensure increased fruit consumption. This is to be achieved through identification and introduction of diverse native and exotic fruit crops, which could be grown year round under different agro-ecological conditions, and through use of technically sound, economically viable, environmental friendly and socially acceptable technologies. Moreover, identification and linking to value chains are pursued so as to promote production of quality and safe value added fruit products for consumption in local and foreign markets, meeting acceptable standards.

On vegetable crops, focus in on developing high-yielding, demand-driven and climate resilient varieties and quality seeds. Improved varieties are to be adaptable to mechanization and having high degree of tolerance to biotic and abiotic stresses, with quality (high nutritive value, sensory and long shelf life), and suitable to open field and protected cultivation environments for year round production. Technically sound, economically viable and environmental friendly technologies for diverse cultivation environments will be developed to enhance production and to ensure food safety. Moreover, appropriate action will be taken to minimize price fluctuations by enhancing availability of value-added products while reducing post-harvest losses, towards increasing consumption from 100-130 g/day/capita to 200 g/day/capita.

On floriculture, varietal improvement, and development of technologies and innovations for value addition, labor-saving production and quality improvement are to enhance productivity and profitability of floriculture. Local, niche and export markets are to be expanded so as to generate higher incomes for the farmers.

Cross-cutting research areas include plant genetic resources, quarantine services, seed certification, organic agriculture, farm mechanization, food waste management, and capacity building. Sri Lanka is particularly vulnerable to climate-related natural disasters such as floods and drought. To address these issues, the World Bank has provided a US\$ 125 million credit for the Climate Smart Irrigated Agriculture Project from 2019 to 2024 to improve the resilience and productivity of agriculture for more than 470,000 smallholder farmers in six provinces.

Aside from the above, various acts, bills and policies were enacted in the country that dictate the country's agricultural development and have implications on horticulture. They are: i) *Seed Act- 1992*; ii) *Plant Protection Act- 1999*; iii) *Fertilizer Act- 1988*; iv) *Freedom from Hunger Campaign Act- 1973*; v) *Agrarian Research and Training Act- 1972*; and vi) *Control of Pesticides Act- 1980*.

Recommendation of Priority Programs for Horticulture Sector

From the above described, it is apparent that there are common challenges for the development of horticulture section as well as similar efforts have been taken to overcome these challenges among SAARC member countries. And it would be beneficial to all the SAARC member countries concerned to explore certain areas of collaboration. In this connection, we propose that specific future research and development initiatives by SAARC Agricultural Centre (SAC) should address the evolving knowledge and innovation demand of horticulture to reflect the multifaceted societal benefits represented by horticultural crops, products and the related sectors. In addition to identifying research priorities, it is important that researchers, industry and policy makers in the region work closely together using a multi-actor approach along the entire value chain to develop strategies for maximizing the economic and societal benefits from horticulture towards 2030. Approaches could include:

- Establish Operational Groups, Working Groups or Task Forces at regional level that involve those researchers engaged in specific problem areas to support knowledge exchange and encourage collaboration.
- Identify where technology platforms can make a contribution to identification and solving strategies of problems common in the region addressed by research and development in horticulture.
- Better coordinated horticultural research initiatives across SAARC member countries to address the particularly challenging interdisciplinary research and development environment of the horticulture sector.
- Develop regional networks with stakeholders from all sections of the supply chain to understand where plant science can best add value and solve specific challenges. Ultimately, stakeholder groups at national and regional level need to improve collaboration and directed interaction with research policy makers to ensure that the importance and potential of horticulture is understood and promoted, and that horticulture is better integrated into future SAC programs.
- Develop concept notes on priority research and development areas for collaboration with international and regional agricultural research organizations, e.g., WorldVeg, the Asia-Pacific Association of Agricultural Research Institutions (APAARI), CAB International (CABI), the International Centre for Integrated Mountain Development (ICIMOD), Crops For the Future (CFF), etc. as well as private sector partners that

engage in horticulture research and development, and for resource mobilization with regional and international donors, both public and private.

Specific collaborative research and development program areas for SAC to facilitate in the region could include some of the following priority areas in stepwise forward action in the next decade:

- 1) National and regional horticulture development strategies (development, follow-up, cross-learning, monitoring, tool to guide investments from public and private sector for infrastructure and market development, research and extension investments).
 - a. National Horticulture Development Teams formed / strengthened to develop the strategy and monitor implementation – yearly meetings to compare notes between countries and cross-learning.
 - b. Facilitating cross regional trade of horticultural products.
 - c. Measure of success: i) increased investment levels by public and private sector in the horticulture sector; ii) greater consumer demands for domestically and regionally produced horticultural products; and iii) increased export value of domestically and regionally produced horticultural products.
- 2) Fruit and vegetables for health initiative
 - a. Promoting diversified and sustainable production and consumption of indigenous and global fruit and vegetables.
 - b. Promoting scientific advancement and “know-how” in production, distribution, and consumption of indigenous and global fruit and vegetables for health benefits.
 - c. Measure of success: i) increased levels of promotion practices; ii) greater public awareness on the health value of fruit and vegetables; and iii) enhanced intake levels of fruit and vegetables.
- 3) Diverse genetic resource base to support the breeding of climate resilient horticultural crop varieties
 - a. Collection and conservation of genetic resources of horticultural plants to prevent erosion of the genetic base for future crop improvement.
 - b. Screening of genetic resources of horticultural products for desirable traits, e.g., pest and disease resistance; tolerance to high temperature, drought, salinity and waterlogging; and nutritional components.
 - c. Using modern high throughput methods for genetic and phenotypic characterization to enable the exploitation of the valuable diversity in form and properties captured within the collection of genetic resources.

- d. Development of pre-breeding materials incorporating novel desirable traits to facilitate prompt uptake by the seed sector.
 - e. Measure of success: i) increased utilization of pre-breeding materials for climate adaptation and improved nutrient contents; and ii) increased area and rate of return of planting with improved varieties.
- 4) Planting materials of horticultural species including underutilized and traditional horticultural crops to enhance diversity of sources of nutrients for maintain good health, and incomes.
- a. Provision of planting materials (seeds and propagules) with high health status.
 - b. Horticulture planting material testing using common protocols.
 - c. Policies to get seed tested, new materials distributed, acceptance of testing schemes across SAARC.
 - d. Measure of success: introduction of new materials, increase in diversity for nutrient sources and incomes, greater quality and pest and disease resistance, etc.
- 5) Integrated cropping systems from farm to consumer for production with minimal resource inputs and waste, and to ensure food safety
- a. Maintaining healthy and sustainable soil systems and efficient use of water and fertilizers.
 - b. Crop management and intervention for enhancing productivity, and predicting maturity and harvesting regimes to minimize waste in the production phase.
 - c. Expand protected cultivation of both fruit and vegetables to increase availability of fruit and vegetables in off-season and stabilize price fluctuation.
 - d. Developing intelligent production automation with the aim of facilitating an efficient use of labor.
 - e. Develop methodologies, standardization, regulatory system and certification of Good Agricultural Practices (GAP) as well as traceability that will be agreed by SAARC member countries.
 - f. Measure of success: increased productivity per unit land area, enhanced rate of return, increased trust of GAP across SAARC and beyond, and stable marketing of healthy and safe fruit and vegetables.
- 6) Sustainable horticulture pest and disease management including bio-pesticides and biocontrol
- a. Objective: reduce crop losses and reliance on chemical pesticides, and increase food safety of marketed horticultural products.

- b. Technological: testing of improved IPM technology, and managing multiple cropping (biodiversity) systems to prevent invasive pests and emerging infectious diseases through agro-ecological approaches.
 - c. Policy: better control of introduction, banning, removal of obsolete pesticides, introduction of bio-pesticides, common policies and approaches across SAARC.
 - d. Measure of success: i) reduced losses of horticultural crops in the production system; and ii) enhanced levels of food safety of marketed horticultural products.
- 7) Monitoring and management of climate-related transboundary pests and diseases
- a. Monitoring of invasive insect pests, e.g. *Tutaabsoluta*, *Spodopterafrugiperda*, and emerging infectious plant diseases, e.g., viroids.
 - b. Establish early warning systems of invasive insect pests and emerging infectious plant diseases.
 - c. Measure of success: i) heightened regional collaboration surveillance, information sharing and early warning; and ii) reduced impacts of transboundary pests and diseases.
- 8) Processing and value addition technology of horticultural crops
- a. Improve postharvest performance for horticultural products that have good shelf life both before and after retailing in order to ensure nutritional and sensory qualities and to minimize waste.
 - b. Develop new products such as semi-processed and health-related edible horticultural products for new domestic and international markets.
 - c. Develop microenterprises for local processing to reduce waste.
 - d. Measure of success: i) reduced levels of postharvest loss and waste; ii) increased income generation and employment from the value chain of horticultural crops.
- 9) Marketing of quality and safe horticultural products in the urban setting
- a. Develop protocols for grading, cleaning, sorting, packaging, bulking, preliminary safety testing, and primary processing for purchasing/assembly centers to create greater availability and affordability of quality and safe horticultural products.
 - b. Create demands for quality and safe horticultural products from the targeted consumers through education and promotion.
 - c. Establish business network for retailing quality and safe horticultural products by forming producers' groups, and linking these groups with retailers, consumers' groups, traders, processing companies, supermarkets, and exporters.

- d. Government support of appropriate market infrastructures, reliable market information systems, and value chain coordination and improvement.
 - e. Measure of success: i) enhanced availability of quality of locally-produced quality and safe horticultural products; and ii) greater demand and longer consumer lifetime for quality and safe horticultural products.
- 10) Capacity building and knowledge management
- a. Conduct short-term in-service training programs, training of the trainers, and long-term degree training on the above improved technologies and systems.
 - b. Create information sharing system and processes in the region.
 - c. Establish web-based horticulture knowledge bank.
 - d. Measure of success: i) progress made in the above nine areas; ii) linkages between data, information and knowledge management; and iii) extent of acceptance of new knowledge and technologies.

Conclusion and Way Forward

The challenges to leverage the horticulture sector for improving food and nutrition security, food safety, economic development and sustainable agro-environment under changing climatic conditions in the SAARC region for the next decade are immense. Even though certain policy issues that affect the development of the horticulture sector fall outside the mandate of research and development, effective research collaborations and networks on commonly targeted areas will be desirable underpinnings for the sector to thrive in dynamic regional and global markets and ever-changing consumer demands. And this calls for partnership among research institutions in the SAARC member countries, international agricultural research centers, advanced laboratories, private sector and other strategic partners to pull together resource and expertise.

Acknowledgement

The authors would like to acknowledge the support of long-term strategic donors to the World Vegetable Center: Taiwan (Republic of China), UK Aid from the UK government, United States Agency for International Development (USAID), Australian Centre for International Agricultural Research (ACIAR), Germany, Thailand, Philippines, Korea, and Japan. Also we would like to thank Aniruddha Hom Roy, S.M. Monowar Hossain, Lakey, Gasith Mohamed, Arulappu George Chandra Babu, and Narsreen Sultana for their valuable comments and suggestions.

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Chapter 14

Livestock Research and Development in South Asia

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Abstract

Livestock and poultry sectors are important component of agriculture production in all the SAARC countries. The region has a large diversified population of well adapted animal genetic resources, which are surviving on poor quality feed and fodder resources. Their production and productivity of livestock resources is very low, which adversely affect the overall food and nutritional security as well as economic viability in the region. However, these animal genetic resources are resilient to climatic changes for which South Asian countries are more vulnerable. There is a need to undertake certain programs related to regional coordination, capacity building of livestock keepers, professional trainings along with quick adoption of modern technologies. Existing policies related to trade and transfer of animals and their products in the region also need to be reviewed and improved. Better opportunities for breeding, feeding and health management of animal genetic resources will not only ensure higher profits from this sector but also help in decreasing poverty, hunger and malnutrition of millions of citizens of SAARC countries.

Keywords: Livestock, policy and programs, capacity building, South Asia

Background

Human population of South Asia is likely to be more than 2 billion by 2030, which will be nearly 22% of the world's human population. Food security and Nutritional security will be a serious challenge in the area. Agriculture is most important sector not only for food and nutritional security but also for livelihood security of a large rural population (more than 50%), who are directly or indirectly dependent on agriculture. Since time immemorial, livestock sector has been an integral part of agriculture in the South Asia and presently contributing about one fourth of the total value of output received from agriculture. This sector has the potential to achieve major sustainable goals related to poverty, hunger and good health. SAARC region has good number of well adapted farm animal breeds of various species of livestock and poultry. Most superior buffalo breeds of the world like Murrah, Nili Ravi and Jaffarabadi have been originated from SAARC countries. World's most relevant cattle milch breed like Sahiwal, Red Sindhi, Tharparkar and draft cattle breeds like Nagori, Khillar, Hallikar and Kangyam have also been

originated from South Asia. However, many of these breeds specially the draft breeds produce low amount of milk and are losing ground in view of mechanization of agriculture and reduced utility of these breeds. In the need and greed of more milk, the milch cattle breeds of South Asia are facing stiffer competition with exotic dairy cattle breeds like HF and Jersey. Therefore, large populations of indigenous cattle breeds of SAARC region need to be genetically improved for higher milk production. Small ruminants' diversity in the SAARC region is reflected in terms of 79 goat and 67 sheep breed. These breeds also need genetic improvement for faster growth rate, higher body weight and lower feed conversion ratio. Poultry is also a very fast growing sector in the South Asia and therefore, needs attention for developing the strains for higher egg production, body weight, lower Feed Conversion Ratio (FCR) and mortality.

Healthy livestock products suitable human health is only possible from healthy livestock. Situation on health management is also not satisfactory and some of the trans-boundary diseases like FMD and Avian Influenza have created problems time and again in the recent past. Further, several zoonotic diseases have also challenged to the human health in the region. Therefore, sound health of the livestock is also mandatory in view of the human health of the people and export potential of the livestock products. More productive and healthy livestock needs balanced feeding. There is shortage of green fodder and concentrates which is presently available in the SAARC nations. With growing productivity of animals, this problem is likely to be further intensified. Therefore, the gap of feed and fodder availability needs to be addressed with regional cooperation and planning of SAARC countries; so as to exploit full production potential from genetically improved livestock and poultry.

Regional Situation in Livestock Sector

The share of livestock sector in the national agricultural GDP of Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka is 50, 13, 24.11, 24.5, 27, 55.4 and 8.1%, respectively (SAARC, 2014). The livestock wealth available in SAARC nations (in million) has been summarized in Table 1.

Table 1. Livestock population (million) of major livestock and poultry species

Species	Afghanistan	Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Cattle	5.24	23.20	0.34	190.9	7.24	36.91	1.24
Buffalo	--	1.44	0.01	108.7	5.13	32.69	0.41
Sheep	13.82	1.89	0.01	135.17	0.81	28.42	0.01
Goat	7.31	55.00	0.04	65.07	9.51	63.15	0.38
Pig	--	--	0.03	10.29	1.14	--	0.09
Chicken	13.21	242.87	0.60	692.65	45.17	380.00	14.04
Duck	--	45.70		23.54	0.38	3.70	0.01

Source: FAO (2017)

A larger number of ruminant population of cattle is predominantly found in India, Pakistan and Bangladesh where low input-low output dairy production system is essential part of agriculture. Buffalo genetic resources have also been in demand in these areas primarily because of high fat milk and cheaper source of meat. This large ruminant population has contributed to good level of milk production in India and Pakistan where per capita availability of milk is quite satisfactory. Except for Bhutan and Sri Lanka, small ruminants contribute significantly to meet production, although goat meat is popular in Nepal also. As expected, pig production is limited to India, Sri Lanka, Nepal and Bhutan. Backyard poultry production system is the lifeline for millions of rural families in all SAARC countries except Afghanistan. There are certain pockets in rural areas of India and Bangladesh where duck is also a popular bird.

Table 2. Production of milk, meat, and eggs in the SAARC countries (2017)

Livestock	Afghanistan	Bangladesh	Bhutan	India	Pakistan	Nepal	Sri Lanka
Milk (Mt)	1.90	1.978	0.190	176.06	44.26	2.036	0.410
Meat (Mt)	0.282	0.674	0.698	7.12	3.663	0.383	0.219
Egg (Million No.)	4880	14933	116.71	88137	17294	1352.3	2073.83

Source: FAO (2017)

Health management of livestock and poultry is limited to urban areas of the region. Vaccination programme in rural areas has suffered not only due to lack of their availability but also because of poor maintenance of cold chain. This has led to food safety concerns pertinent to foods of animal origin related to Salmonella, parasite infections, antibiotic residues, Listeria, Campylobacter, Staphylococcus, and Clostridium etc. Sound surveillance information on the occurrence of diseases across the territories is a missing link in health management of livestock and poultry population of this region.

Further, new global trade regimes pose serious challenge and many opportunities to small milk producers of South Asian countries. These countries must enhance their competitive economic advantages in dairy and poultry products both in terms of quality and cost. In

view of these factors, there is a need to improve all aspects of animal husbandry including breeding, feeding, health management so as to get desirable production and productivity from livestock sector, which will provide adequate food and nutritional securities besides supporting employment the youth and empowerment of women.

All the SAARC Countries are putting their sincere efforts for increasing the livestock production and productivity to cater the needs and aspirations of Food and nutrition to the present generation and also in view of fast growing human population in the region. There is a need to genetically exploit the livestock population of high genetic merit along with nutritional as well as health management to achieve the goals of food and nutritional security. Therefore, it is imperative to develop regional coordination and co-operation between the SAARC Nations for improving livestock for food and agriculture.

Challenges and Opportunities in Livestock Sector

SAARC region is characterized by rich diversity and large genetic variability among livestock and poultry populations. This germplasm is well adapted to hot and humid climate as well as to major tropical diseases and can survive even on coarse and poor quality feed and fodder resources. However, this region encountered many challenges and a few opportunities which need to be addressed.

Challenges in Livestock Sector

- Improvement in productivity of regional livestock by using conventional as well as molecular breeding programs.
- Sharing of superior quality genetic material, vaccines and diagnostics in the region.
- Development of alternate strategies to meet shortage of green and dry fodders in almost all regions of SAARC countries.
- Health management of livestock to get hygienic products from healthy animals and minimize the losses due to livestock health hazards.
- Diagnosis, control, prevention and elimination of zoonotic diseases, which is essential to provide better health to human population.
- Development of epidemiological and surveillance data to control emerging, re-emerging and trans-boundary diseases.
- Inadequate trade and market policies of live animals as well as livestock products which are affecting the income of the livestock keepers.
- Development of human resources to provide quality services in livestock sector.
- Training and capacity building of livestock keepers to implement scientific programmes.

Opportunities in Livestock Sector

SARC countries are having large populations of different livestock and poultry species with unique characteristics but their productivity is very less as compared to European counterparts. This leads to lesser profit to livestock keepers. Some of the traditional knowledge available with livestock keepers should also be documented and validated. Improvement in productivity of livestock and poultry will ensure food as well as nutritional security along with the income to the livestock keepers. Following are the major opportunities for enhancing livestock sector in the region:

- Livestock products are important source of protein of animal origin in the food in terms of milk, meat and egg for a large human population of South Asia.
- Indigenous AnGR is known for heat and draught tolerance and disease resistance, which provides scope for allele mining for these traits.
- Large export potential for animal germplasm including semen/ embryos, animal products and by-products.
- Indigenous Traditional Knowledge available in local areas can provide researchable issues for animal production and health care.

Review of Policies and Programs

Major Policies and Policy Gaps

Overall livestock development mainly depends on genetic merit of animals/ bird, economic and easy access to feed, fodder and water resources, sound health and reproductive status of animals, management practices like housing, record keeping, Marketing and availability of credit and insurance etc. In SAARC nations, livestock is mostly kept under crop-livestock production system with small herd/flock sizes. The livestock keepers are generally poor in terms of knowledge and resources which creates problems in adoption of new technologies. In such conditions, role of government and non-government organizations become very crucial. Governments of SAARC nations have established many institutions for education, research and extension of livestock sciences and also developed various policies and programs for all round development of livestock sector.

Availability of animals of high genetic merit for further improvement of large populations of livestock and poultry is the major problem in this sector. There is a need to develop and/or strengthen suitable breeding policies at the national level. Germplasm requirements of different countries should also be addressed through inter governmental breeding policy of the SAARC nations, which is presently lacking. For example, in genetic improvement of buffalo, India and Pakistan may play a vital role. Similarly policies may be developed for better management of feed and fodder resources. Some of the diseases

like FMD, Brucellosis, Avian Influenza etc. are largely responsible to the economic losses being faced by livestock sector in the present day scenario.

Skill development of livestock keepers for different aspects of management is equally important to increase the profitability of livestock keepers and productivity of animals. Besides, there is a need to exchange the knowledge of veterinarians, academicians and para-veterinarians so as to take up various research and extensions activities related to the livestock sector. Such activities should be executed through a well defined policy at the SARC level.

Marketing of livestock and livestock products always influences the livestock production and productivity. It has been observed that livestock keepers, being an unorganized sector, are not getting the due return of their product. Marketing policies are generally governed by demand and supply rather than cost of production. Therefore, suitable policies should be framed for fixing the prices of livestock products at national as well as at international level amongst the SAARC nation for a smooth export and import.

Major Programs in Livestock Sector

As per framed policies in livestock sector, programs may be developed for livestock and poultry sectors in SAARC countries. These programs may be different for different species, areas within the country and between countries. Following major programs may be considered for different areas of livestock sector development:

- Genetic improvement programs within country and between SAARC nations.
- One Health programs for animals of the SAARC countries.
- Feed and fodder management and conservation programs.
- Promotion of export and import of livestock and livestock products.
- Skill development of livestock keeper.
- Human resource development for veterinary and animal sciences.
- Extension programs for establishing large livestock and poultry units.
- Collaborative research programs and exchange of research outputs for developing the livestock sector in SAARC nations.

Recommendation of Priority Programs for Livestock Sector

1) Livestock health management

Background and Justification

Monitoring animal health and preventing animal disease outbreaks is vital to the economy and safety of the country's food supply. Production of healthy livestock helps to ensure a safe food supply and keep consumer prices stable. Animal disease outbreaks can cost the

country millions of dollars due to animal slaughters, trade halts, and subsequent disease eradication efforts. For example, avian flu and swine flu in the recent past has been a threat to human health and therefore, resulted in to huge economic losses. Animal diseases with human health implications can adversely impact public health, global trade, and the stability of the agricultural segment economy. Healthy animals are more likely to result in: safer food supplies; higher farm productivity; reduced environmental impacts; reduced use of antibiotics; and improved animal well-being.

Therefore, due emphasis is needed on animal health management issues. There is a need to join hands in eradication programs of trans-boundary diseases as well exchange of knowledge related with prophylactic and curative measures of the livestock diseases.

Objectives

Provide good health to the livestock so as to get healthy products of international standards and to reduce adverse impact of zoonosis.

Component/ Activities

- Eradication of trans-boundary diseases of Livestock & Poultry.
- Livestock: FMD and Brucellosis; Poultry: Avian Influenza.
- Exchange of veterinary diagnostic, recombinant vaccines and other prophylactic technologies for control of livestock and poultry diseases.

2) *Feed and fodder resource management*

Background and Justification

Feeding is the key for a profitable and sustainable livestock farming. The cost of feeding has long been recognized as the major cost and the largest cash expense in animal production. It has a direct impact on the growth rate and health status of the animal as well as on the quality of the animal products. In addition to this, it also has effects on the environment. Therefore, animal nutrition is a key for a profitable and sustainable farming. Animals' nutrient requirements can vary among different species (swine, poultry, cattle etc.) but also among the same species in different status and age groups (pregnant cow, lactating cow, growing calves etc.) or under different conditions (external temperature, external stress etc.).

To meet the future demands of production of milk, egg and meat, including productivity and daily weight gains for meat animals would need to be increased significantly, by fulfilling the demand of feed resources of livestock in the SAARC nations. Feed and fodder shortages notwithstanding, considerable potential exists to increase production levels across the range of growing, milch and beef animals and poultry by addressing the problem of imbalanced nutrition. The limited data on improving production efficiency in animals through balanced feeding suggests that there is considerable scope for the

enhancement of milk, egg and meat production with the existing feed and animal resources. This can be made possible through the transfer of scientific knowledge, in an easy to use and easy to implement manner to rural livestock product producers. The aim should be to promote feeding of a balanced ration in sufficient quantities and containing all essential nutrients. To promote this, initiatives should be taken by the SAARC countries.

Objectives

Provide a balanced feeding to livestock so as to exploit their full production potential.

Component/ Activities

- Use of local grasses, crop residue and horticultural waste in feed formulation for Livestock and poultry.
- Up-scaling of fodder production area with high yielding fodder crops including alternate ways of fodder production.
- Preservation of feed and fodder for meeting off-season requirement.

3) Exchange of genetic and reproductive material

Background and Justification

The improvement in genetic merit refers to the overall improvement in a flock/herd brought about by selection for a number of traits that contribute to the breeding objective, such as more milk, high growth rate and more meat/egg production etc. Genetic improvement benefits individual breeders and the broader livestock industry by increasing productivity and profitability. Genetic improvement has the potential to: assist in meeting market requirements; improve overall productivity and profitability; and improve specific traits of economic importance of a flock/ herd.

Genetic potential for milk, egg and meat in future generation of animals may be improved by using animals with high genetic potential as parents. Selecting parents with high genetic potential is a highly complex and scientific process and requires collaborative efforts with farmers, breeding services providers, semen production centers and research institutes. It becomes more complicated in our situation where animal holdings are small, farmers do not keep any records including milk records, feeding and management is varied and not optimum, animal identification is resisted, AI is not popular, AI services are inadequate.

The use of traditional breeding and molecular technologies for identification and selection of animals of high genetic merit and use of such animals at maximum level by using assisted reproductive technologies like AI and ET is essentially needed for overall development of livestock industry. Therefore, the SAARC nations should cooperate in exchanging germplasm of high genetic merit especially for the livestock breeds which are available in more than one SAARC countries.

Objectives

Genetic improvement and propagation of germplasm of high genetic merit.

Component/ Activities

- Exchange of germplasm of high genetic merit for improving cattle and buffaloes in SAARC Countries (Semen/Embryo/Live animals).
- Establishment of Gene Bank for major livestock and poultry breeds of the region.
- DNA Bank for all breeds of livestock and poultry for research and academic purposes.

4) Training for quality human resources

Background and Justification

SAARC nations have responsibility of the management of a large livestock wealth to acquire food and nutritional security as well as socio-economic upliftment of the communities engaged in the business of animal husbandry. There is a need to develop adequate human resources in the field of education, research and extension for livestock. With sharing of experiences and knowledge between the SAARC countries, suitable human resources may be developed. Trainings in the field of genetics, nutrition and health management etc. may be organized by the SAARC for achieving the goals in this regard. Further, the training for identification, characterization and conservation the domestic animal diversity of SAARC countries is also need of the hour.

Objectives

Exchange the knowledge of livestock management for developing adequate human resources.

Component/ Activities

- MAS/Genomic Selection/ Progeny testing for genetic improvement programme along with molecular and breeding data analysis.
- Assisted reproductive tools for livestock improvements.
- Advancement in Veterinary Diagnostic and vaccines.
- Disease Surveillance and monitoring for better livestock health management.
- Characterization of unexplored livestock & poultry populations and conservation of existing Trans-boundary SAARC livestock and Poultry breeds.
- Formulation of balanced ration for Livestock and poultry by using local feed and fodder resources.
- Change in feeding and management of livestock to mitigate green house emission.
- Hygienic milk/meat production for ensuring food safety.
- Value addition to livestock and its products for better economic returns from dairy and poultry farming.
- Mitigation of climatic change situation through improved management practices.

5) *Advancing animal laboratories and livestock farms*

Background and Justification

Majority of livestock in SAARC countries is reared under crop-livestock production system, which is generally based on low-input and low-output management. To cater the increasing demand of animal products due to fast growing human population the region, it is essential to put a part of livestock under industrial production system, which is based on high input and high output management. This kind of production system requires skill among the livestock keepers and use of advances technologies in this area. The SAARC nations must exchange their expertise in developing capacity to handle advanced technologies like embryo transfer, cloning, genomic selection, veterinary diagnostics and vaccine production etc. With the use of such technologies, industrial units of poultry, dairy, piggery, small ruminants may also be established for which skill development of livestock keepers is also important. At the same time the herd/flock size of the livestock kept under low production system may also be increased both in terms of quantity as well as quality. Therefore, skill development with supply of better genotype to such livestock keepers will help in increasing the livestock production as well as productivity as grass root level. In view of above, the SAARC nation should exchange their expertise in capacity building of fellow countries.

Objectives

Establish advanced animal laboratories and livestock farms under industrial production system.

Component/ Activities

- Embryo Transfer and cloning for faster multiplication of superior germplasm.
- Genomic selection of livestock and poultry for improved productivity.
- Establishment of medium to large scale Dairy and Poultry Farms.
- Formulation of Start-ups for small ruminants, pigs and backyard poultry farms.

6) *Policy formulation for regional co-operation*

Background and Justification

Many livestock and poultry breeds are reared in more than one SAARC countries like Nili, Mehsana, Nili-Ravi, Surti, Tarai, Jaffarabadi, Murrah Buffalo; Sahiwal, Red Sindhi, Thararparkar, Haryana, Khillari, Siri Cattle; Barbari, Beetal, Jamunapari, Bengal, Gaddi, Tibetan Goat; Hissardale, Madras Red, Poonchi, Tibetan Sheep; Chori Pig; Bhutia Horse and Aseel, Brahma (Chicken)/ Indian Runner, Khaki Campbell (duck) poultry breeds.

In view of the management of such breeds of livestock and poultry, there is a need to develop a regional focal point to deal with the coordinated efforts for sustainable utilization and conservation of AnGR. The regional focal point for SAARC nations may be

established in India with the responsibility of establishing or strengthening and maintaining regional networks, including regional databases for the use, development and conservation of animal genetic resources. Some of the activities may be establishing or strengthening international collaboration in the characterization, use and development, and conservation of trans-boundary breeds, strengthening research and development, establishing an integrated support arrangement to protect breeds and populations at risk from emergency or other disaster scenarios and to enable restocking after emergencies, establish regional and global networks of gene banks for animal genetic resources and harmonize approaches to genetic improvement and conservation through exchange, establishing and/or strengthening the development of national databases to enable information sharing among SAARC countries, strengthening technical cooperation and establishment of facilities for technology transfer and exchange of experience, and enhance educational and other training opportunities, trade, export potential and marketing of livestock and its products between SAARC countries. Therefore, policy development and mutual cooperation through consultations among the SAARC nations would be needed to resolve many issues pertaining to livestock management and trade between the countries.

Objectives

Formulate policies for regional cooperation in livestock management in South Asia.

Component/ Activities

- Review of existing policies regarding trade and transfer of livestock and their products amongst SAARC countries.
- Conservation of trans-boundary breeds of livestock and poultry.
- Strategies for developing export market for of livestock and their raw as well as processed & value added products.
- Education curriculum/ courses for developing human resources for management of Livestock and its products in changing market and climate scenario.
- Faculty exchange programme within SAARC nations for veterinary and animal sciences education.
- Development of strategies for managing natural disaster and other calamities.

Conclusion and Way Forward

Livestock and poultry sector play important role in agriculture production of all the SAARC countries. The region has a huge domestic animal diversity suited to their agro-climatic conditions. However, the livestock production as well as productivity is very low, which is adversely affecting the economic viability of these resources. There is a need to undertake certain programs related to regional coordination, capacity building of livestock keepers, professional trainings along with quick adoption of modern technologies.

Existing policies related to trade and transfer of animals and their products in the region should also be reviewed and improved. Better opportunities for breeding, feeding and health management of animal genetic resources along with the skill development of the farmers and better marketing opportunities for livestock and their products will not only ensure higher profits from this sector but also help in decreasing poverty, hunger and malnutrition of millions of citizens of SAARC countries.

Growth of livestock sector is essential for food and nutritional security of the SAARC nations. Therefore, there is a need to develop suitable strategies for developing policies and programs for the livestock sector. All the SAARC nations have institutions and human resources for taking care livestock and poultry genetic resources in their respective regions. Suitable institutions from all the SARC countries may be identified for the fine tuning the execution of the suggested programs in accordance with the availability of financial resources. However, it must be ensured that the benefits of programs should reach to livestock keepers so that livestock production and productivity increases in all SAARC countries.

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Chapter 15

Fisheries in South Asia: Trends, Challenges and Policy Implications

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Abstract

Fish is one of the most widely consumed food items in the world, and it is getting more popular over time. Fisheries incorporate two types - harvesting from natural waters, and farming aquatic organisms in the captivity. Globally fishery products supply 16.6% of animal protein and 6.5% of all protein for human consumption. About 88% of the fish products in the world goes for direct human consumption, while 12% goes to non-food uses (for example, fish meal). South Asian is the home to around one fourth of the world population, and ensuring nutrition to the growing population is the major challenges in the region. This region has enormous agricultural landmass and unparalleled agricultural diversity along with diversified aquatic ecosystems that could contribute for improving nutrition security, increasing income and reducing poverty. The fisheries production have been heavily affected by the ever-increasing population, gradual shrinking of open waterbodies, fast urbanization, anthropogenic induced climate change and associated natural disasters. With increasing population, the demand for fisheries and aquaculture sector for improving food and nutrition security has been substantially increased. It shows the huge scope of fisheries sector in the region. In this paper, we analyzed the situation of fisheries, challenges and opportunities, and policy implications along with recommended programs in the South Asia.

Keywords: Fisheries, aquaculture, policy and programs, South Asia

Background

Fish provides the best protein food rich in essential macro- and micro-nutrient, vitamins and minerals. Fish farming, fishing and fisheries trade create huge employment opportunities and increase income to millions of peasant poor, and play important role in poverty alleviation and economic growth. Three-quarters of the countries where fish contributes more than one-third of animal protein are low-income food-deficits, which

need to double in production to meet the growing demand of fishes by 2030 (WorldFish, 2017). Generations after generations, many people in South Asia have been catching fish from rivers, streams, floodplains, wetlands and ponds to meet up the demand of family nutrition and improve their livelihoods. The domain of food and nutrition security is complex and multidimensional that could be significantly contributed by fisheries and aquaculture.

South Asia, surrounded by Bay of Bengal, Arabian Sea and Indian Ocean, the SAARC countries are endowed with a long coastline of 12,000 km with extremely high population density along the coastlines that forms a part of Bangladesh, India, Maldives, Pakistan and Sri Lanka possessing the rich coastal and marine fisheries (SAARC, 2008). Among the SAARC countries, Maldives is a nation of 1,190 islands, and Sri Lanka is a single large island, India has a large land mass and also a number of small islands in the middle of the Bay of Bengal, Pakistan is on the upper part of the Arabian Sea and Bangladesh is on the Bay of Bengal, bordering the Indian Ocean. Afghanistan, Bhutan and Nepal are landlocked countries. Bangladesh aquatic resources is dominated by freshwater fisheries and India leading producer of both freshwater and marine fish resources. Among the South Asian countries, Bangladesh is the main country where nutrition to the poor is supplied by fishery products as the country is ideally suited for fish production, with huge areas of floodplains and ponds and manpower with long tradition of fish culture.

As the fisheries sector is highly affected by climate change and rely on the traditional technology, this paper would be helpful for guiding the fisheries and aquaculture sector with clear and strategic path way in the South Asia.

Regional Situation in Fisheries and Aquaculture

Millions of people in the South Asian countries depend on fisheries resources for their food and livelihood security. A number of these countries have great potential to increase and intensify fish production to meet rising demand and contribute to poverty reduction and rural development. Moreover, fish production and fisheries trade can play a vital role in the national economy and livelihoods. Fish production is noteworthy for its flexibility in combination with other smallholder livelihood options including cash earning and generating revenue. Globally, approximately 800 million people depend on fisheries and aquaculture for their livelihoods (WorldFish, 2019). This sector creates opportunities for the poor people who rely on fish for their income, livelihoods and well-being.

Aquaculture deals the farming of fish and other aquatic organisms, which is the major means of animal protein supply and raising of income of the rural poor (Beveridge & Little, 2002). Although livelihood opportunities associated with aquaculture contribute to the food security of large numbers of poor women and men, the direct effects of consuming fisheries products are of even greater significance. Aquaculture or fish farming has been the most rapidly growing agro-food sector in the globe over the last four decades, 1970 -

2010 (WorldFish, 2017). Production of farmed finfish and shellfish has been growing at a rate of 8.1% per annum over this period. The aquaculture industry employs 23.4 million full-time workers globally, with Asia accounting for 92% of employment. Aquaculture now provides around half the fish for direct human consumption (WorldFish, 2017).

Aquaculture has expanded steadily in South Asia in recent years, now contributing 40% of total fishery production in the region. India is the largest producer of aquaculture production (5.7 million tons), followed by Bangladesh with a production of 2.2 million tons in 2016 (FAO, 2018). While Nepal, Pakistan, Sri Lanka, Maldives, Afghanistan and Bhutan are far behind in fisheries production. In Bangladesh and India, aquaculture is emerging as a prime rural industry, contributing to employment generation, food and nutritional security, poverty alleviation and increase of export earnings. Bangladesh earn more than half a billion dollars per year by exporting aquaculture products, which is the second major source of foreign exchange after textiles. In 2016, SAARC countries produced more than 16.0 million tons of fish from aquaculture and open water capture fisheries (Table 1).

Table 1. Fish production (Mt) from capture fisheries and aquaculture in South Asia vs. China and world (2016)

Country	Capture (Mt)	Aquaculture (Mt)	Total (Mt)
India	5,082,332.00	5,703,002.00	10,800,000.00
Bangladesh	1,674,770.00	2,203,554.00	3,878,324.00
Pakistan	513,156.00	156,430.00	669,586.00
Sri Lanka	521,637.00	30,974.00	552,611.00
Maldives	129,191.00	0.00	129,191.00
Nepal	21,500.00	49,043.00	70,543.00
Afghanistan	1,000.00	1,200.00	2,200.00
Bhutan	7.00	150.00	157.00
Total SAARC	7,943,593.00	8,144,353.00	16,102,612.00
China	17,800,000.00	63,700,000.00	81,500,000.00
Global (2015)	93,736,944.00	101,084,799.00	199,741,129.00

Source: WorldFish (2019); World Bank (2019)

At global level, 89% of the total fish produced comes from Asia, and the South Asian countries contributes 27.3% of the world production. Among the SAARC countries, per capita fish consumption per day is the highest in Maldives (more than 200 g) followed by Bangladesh (62.6 g), Sri Lanka (15.8 g) and India (9.2 g).

Nearly 40% of the world's poorest people live in South Asian countries and survive on less than a dollar a day. India has the world's highest proportion of malnourished children with 46% of its preschoolers underweight, followed by Nepal (45%), Pakistan (38%) and Bangladesh (37%), and Sri Lanka 29% (WorldFish, 2009). The high percentages of stunted linear growth in children in South Asia - Afghanistan (59), Bangladesh (43), Bhutan (34),

India (48), Maldives (19), Nepal (49), Pakistan (42) and Sri Lanka (17) - is very alarming, because of its association with long-term adverse effects for the stunted individual and for the community (WHO, 2010). The health and nutrition status of the eight south Asian countries is given in Table 2.

Table 2. Health and nutrition of the people in the South Asian countries (2015)

Countries	Population Under Nourished	Population below Poverty Line
Afghanistan	26.8%	35.8%
Bangladesh	16.4%	7.5%
Bhutan	N/A	12%
India	15.2%	21.2%
Maldives	5.2%	16%
Nepal	7.8%	25.2%
Pakistan	22%	24.3%
Sri Lanka	22%	8.9%

Source: FAO (2015)

On low-lying river deltas, notably the vast delta of the Ganges and Brahmaputra river systems shared by Bangladesh and India, ponds materialize as farmers excavate soil for a plinth to raise homesteads above flood levels. The late 1980s brought recognition that millions of derelict water bodies across Bangladesh and a number of province of India could be stocked to provide additional fish to feed a growing population. The area of cultured ponds in major fish producing countries in south Asia like Bangladesh, India, Pakistan and Nepal has been increasing since then and the contribution of aquaculture to the total fish output has been gradually rising in the region.

Challenges and Opportunities in Fisheries

There are a number of issues related to fisheries and aquaculture sector that need to be considered in formulating research and development program. The major issues are inland fisheries, aquaculture, marine fisheries, freshwater and marine environment, fish biodiversity and conservation, climate change and extreme events (cyclones, tsunamis, anthropogenic factors, weather patterns), physico-chemicals of soil water, nutrients inflow and outflow, production and productivity, fish-stock assessment, modelling, fish harvesting- fishing crafts and gears, post-harvest and processing, socioeconomics and cross-cutting issues (labour, gender, credit, pollutants, adulteration, food and nutrition security, and food safety). These need to be critically addressed to enhance the fisheries production. In addition, this sector is suffering by destruction of fish habitat, pollution, siltation, logging and mining that are posing threat to the fisheries and aqua life across the region. Further, lack of community based management, technical supports, and trade unions with greater legitimacy and ownership are the key challenges faced by the fisheries

sector (SAARC, 2018). Rapid population growth, high dependence on resources and increased land use have resulted in over exploitation of fish-stocks and habitat degradation, and have led to considerable uncertainty, whether the ecosystem will be able to support the livelihoods of the fisheries-dependent populations in future.

Among others, climate change affects the basic livelihoods, livelihood patterns, and ecosystems through land degradation, salt water intrusion, loss of infrastructure, reduced fish and aquatic production, and food and nutrition insecurity (Pound et al., 2018). The main climate induced events are increased variability in rainfall pattern, increased temperature with warmer winter, increased salinity in coastal areas as a result of rising sea level and reduced discharge from major rivers, weakening ecosystems, decline of glaciers in the Himalayas, and increased frequency and/or severity of extreme weather events (Nambi, 2014).

South Asian countries have been experiencing serious environmental degradation in recent years such as ground water contamination, surface water pollution, encroachment of rivers and water bodies, improper disposal of industrial, medical and household waste, deforestation and loss of aquatic habitat and biodiversity. The fragile ecology, delicate flora and fauna, alarming density of increasing population and poverty caused a considerable amount of damages the fisheries production. For instance, with loss of wetlands and forests, Bangladesh is gradually losing its flora and fauna including many aquatic and terrestrial species are becoming rare and some have already become extinct. Among the South Asian countries, Bangladesh is most at risk in fisheries sector from climate change. A low-lying coastal regions of the country prone to annual floods and cyclones are the common climate change events. Other most exposed countries in the region are India, Nepal, Afghanistan, Maldives and Myanmar.

Climate change impacts gradually cover a wide range of livelihoods in a number of aquatic settings all over South Asia. Drought coupled with siltation and lowering water level are reducing over wintering habitat for indigenous fish species resulting into less recruitment into grazing field to grow inland fisheries. Reduced water flow in major rivers has resulted in a severe depletion of riverine fisheries. Water with poor quality and less availability for aquaculture and reduced production of fish are very common. Conflicts among different water users and irrigation to crop fields is another challenges, which needs trade-off so that both the sectors could get enough water resources.

The major elements of climate change that have potential impact on South Asian aquaculture production are regular events like temperature and sea level rise, change in monsoonal rain patterns and water scarcity and extreme events like, tornados. Global warming increase the water temperature that has negative effects on aquaculture in temperate zones because such increases could exceed the optimal temperature range for organisms for farming. Major impacts of cyclones and tornados are loss of human – fish farmers and others, severe loss of aquaculture stocks, livelihood assets and biodiversity,

aquaculture facilities, crafts and gears, and impacts on wild fish. Environmental degradation results narrower gene pool used for fish hatcheries. Salinity intrusion reduces growth of farmed freshwater and coastal fish and shellfishes, deteriorates water quality and causes considerable loss of plants and vegetables on farm site.

Major Programs on Fisheries Sector in South Asia

As aquaculture has been growing rapidly in South Asian countries, the conflicts with other resource users are also increasing. The conflicts mostly include environmental and social issues, myopic planning and ineffective management, which have negatively impacted aquaculture. The governance of fisheries and aquaculture need to be integrated with the Sustainable Development Goals (SDGs), and the Paris Agreement of the Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change. Prospects of increasing aquaculture production can be achieved through effective integration with the national and international policies and programming sets.

The negative effects of climate change could be reduced through promoting climate smart fisheries and aquaculture technologies including appropriate capacity development, R&D, establishing early warning system, aquaculture insurance programs, farmers' incentive policies, and coordinative efforts against climate change in the South Asia. The remedial steps to mitigate the negative effects of climate change on fisheries and aquaculture could be through a SAARC-level task force to be assigned in formulating policies and strategies for enhancing fisheries and aquaculture. To mitigate the climate change impact, the following steps should be considered - introduction of salinity and temperature tolerant and fast-growing fish species for aquaculture; establishment of fish sanctuary for improvement of natural stocks; setting up a common South Asian gene bank for vulnerable species; development of alternate energy and fuel sources for inland and marine capture fisheries; utilization of e-commerce ventures and information communication technology (ICT) for social and livelihood security of fishers and fish farmers.

An attractive option for the landless is fish culture in cages using net boxes placed in open water bodies suitable for both the freshwater and coastal fishes and shellfishes. This farming practice has great potential in brackish-water environments as well as freshwater. New methods of high-yielding brackish-water fish/shellfish polyculture in rotation with saline-tolerant deep-water rice have demonstrated substantial benefits for poor farmers in the highly dynamic deltaic plains. Similarly, improved prawn and shrimp farming and crab fattening technologies and a more developed value chain have the potential to increase production and income generation. As modernization is bringing rapid change to coastal areas, which are typically the area where poor and extreme poor live, the challenges are to ensure that coastal development is environmentally sustainable and at the same time, socially equitable.

In South Asian countries, as in many countries of the developing world, artisanal fisheries and smallholder aquafarming are strong multipliers of local employment – not only in production but also in support services. Small-scale fisheries in South Asian countries directly employ millions of fishers both full time and part time. In addition, millions of people find their employment in postharvest activities and at the wider value chain. Women account for about half of the total fishery workforce, both fulltime and part time, in this region. Women often work in processing, value adding and trading. The welfare of women augments not only their household income and nutrition, but also their social status, which is important in South Asia.

Microenterprises related to fishing and fish farming, such as netting teams provide harvesting services, fingerlings and food fish vendors supply fish seed to farmers and table fish to consumers and fish drying teams prepare high quality dried and fermented products. These livelihood activities can substantially contribute to the income for the very poor, including the landless and ethnic minorities.

This is the fact that the scope for expanding capture fisheries in South Asia is limited, yet they continue to be vital to the well-being of fisher communities and the marginal, poor and landless people. To date, the capture fisheries in this region is an essential source of nutrition, employment and income in most of the coastal and rural areas. In addition to fulltime fishing, seasonal or part-time fishing supplements many other livelihood activities as a recurrent sideline, a stopgap providing fish to eat and sell during the lean season before agricultural crops are ready to be harvested, or a failsafe when harvests fall short.

Over half of the fish catch in developing countries comes from small-scale fisheries, and 90–95% of this catch is destined for domestic consumption. This is a proof that how strongly small-scale fisheries contribute to local food supplies and nutritional security. Effective and careful management of small-scale fisheries and relatively less-intensive (extensive, improved extensive or semi-intensive) aquaculture helps maintain such ecosystem services as conserving wetland and coastal biodiversity. Healthy aquatic ecosystems - floodplains, mangroves, and coral reefs not only help ensure the fisheries sustainability but also support tourism and preserve communities' cultural identity.

In South Asia, there are a number of opportunities for enhancing fisheries in inland waters with the release of carp and other fingerlings and better management of floodplain fisheries. Many reservoirs in the South Asian countries seriously underperform their potential. In Bangladesh, the community-based approach to fishery management and governance has boosted catches and improved the livelihoods of the participating rural poor, while enhancing fishery biodiversity and sustainability. Success has convinced the government of Bangladesh and many project donors to adopt most elements of the community centered approach. This success of co-management can easily be replicated and expanded to the other nations of South Asia after necessary fine-tuning.

Priority Areas in Fisheries Sector

Fresh fish contains 18–20% protein by weight and contains all the essential amino acids needed for human. It is essentially a rich source of a number of vitamins and minerals. Starchy staple grains and tubers do not have these nutrients. A good starting point is making more fish available to the poor to mitigate the persistence of undernutrition in South Asia. The crucial step for South Asian countries now is to address the natural disaster, anthropogenic impacts and reduce risks into development plans for fisheries and aquaculture with an integrated and strategic approach.

Natural and manmade changes are responsible for decreased production in all agricultural sectors – crop, fisheries and livestock. In the past, most of the rivers and floodplains, ponds, canals, and the coastal waterbodies were full of fish. Now, many water bodies are either dead or largely decayed. Presently, lack of rain in time and untimely downpour both are harming the fisheries and aquaculture. Sudden flash floods damage fences and embankments, inundate aquaculture systems and allow stocked fish to escape resulting in huge loss. All these are making the livelihood for fishers and fish farmers unsustainable. Therefore, climate smart fisheries practices need to be adopted in the fish farming communities. Eco-friendly, improved and innovative fisheries and aquaculture management practices with insights on technological, environmental and socioeconomic concerns can ensure sustainable fish production in the region.

Aquaculture production in this part of the world needs to be accelerated to maximum sustainable production to meet the fish protein demand without disturbing the nature. Through applying the modern scientific tools and technologies and improved intensive farming mode, the present unit area production can be significantly increased. Countries like Bhutan, Maldives, and Afghanistan, where aquaculture production is very low and skilled manpower is lacking, need to formulate a strategic plan in the respective countries. To face the overall challenge on aquaculture and fisheries sector, there is an urgent need to educate and to establish a greater understanding and appreciation of the water bodies, aquatic animals and plants, and innovative management practices to people from all strata to pave the way for sustainable fisheries and aquaculture management in the region.

The livelihood, socioeconomic status, and benefit and cost of production involved in fish farming must be taken into consideration. Most of the fish farmers nowadays don't receive a reasonable price for their fish products. To ensure a good price for both farmed and wild fishes, the countries need to explore alternative markets. Meanwhile, with the increasing quantity of farmed fish, quality also needs to be improved and different value added fish products need to be developed. Enhanced and sustainable planning and management of freshwater and marine fishes in natural water bodies and improvement of aquaculture practices can substantially increase fish production in the South Asian countries (SAARC, 2008).

In viewing of these facts, following programmatic recommendations are derived:

- Undertake mass awareness programs on adverse impact of natural and manmade changes to reduce the risk.
- Capacity building for relevant departments, ministries, and other GOS, NGOs and CBOs and strengthening public-private partnership.
- Establish disaster risk reduction cell in the relevant departments with functional core groups up to rural level.
- Formulate a Strategic Plan on Fisheries/ Aquaculture which will help to contribute in preparing future program planning and investment decision in the country level.
- Increase and strengthen inter-sectoral coordination for program planning and implementation.
- Strengthening cooperation among the SAARC countries - sharing of success stories in respect of risk reduction and adoption of better best management practices from one country to another.
- Adaptation of climate change practices, for example, integrating aquaculture and agriculture, farming more resilient and climate tolerant fish, shellfish and aquatic plant varieties, which can help farmers cope with drought while boosting profits and household nutrition.
- Research on innovative ways to further improve the existing adaptability of fishers and aquaculture.

Giri (2017) recommended the “best management practices and capacity building” in aquaculture:

- Revisiting the existing codes in aquaculture in SAARC Member States, and framing and harmonizing new codes to tap the global export market of aquaculture products.
- Establishment of brood banks, seed certification and health certification facilities.
- Development and harmonization of quality standards for fish, fish products and their handling.
- Development of disease surveillance, antimicrobial resistance (AMR), disease management and quarantine measures in aquaculture.
- Prevention in use of hormones, drugs, antibiotics and disease control chemicals in aquaculture and aquaculture products.
- Setting up of accredited fish feeds analytical laboratories in the region.
- Use of Information and Communications Technology (ICT) and smart technology in aquaculture.
- Proper disposal of wastes generated from aquaculture.

- Framing of policy to lease public water bodies, registration of aquaculture, and setting up of Farmer Producer Organizations (FPOs).
- Formulate fisheries insurance policies for farmers' security in case of losses caused by natural hazards.
- Institutional linkages, capacity building and continuous awareness campaign at primary producer level for sustainable aquaculture.
- Creating more investment in aquaculture and creating market chain for the produce.
- Freshwater fish germplasm exchange among the member states.
- Creating mechanism for better information sharing among the SAARC countries on aquaculture development and conducting SAARC aquaculture dialogue.
- Recognize nutritive value of small indigenous species and develop policy towards promoting nutrition sensitive aquaculture.
- Framing of biodiversity and environment compatible stringent Aquaculture Policy in the SAARC region.

SAARC (2019) identified three priority areas on development of aquaculture for commercially important finfishes in South Asia:

- Identification/listing of the commercially important cultivable finfishes of South Asia that are of high market demand and export potential.
- Review research and development needs for sustainable finfish aquaculture development in the SAARC countries.
- Coordination of the regional research, extension and training activities to assist the development of sustainable finfish culture in South Asia.

SAARC Agriculture Centre (SAC) using participatory program development approach through consultation with experts of SAARC countries prioritized programs on fisheries and aquaculture. Some of the major programs are as follows:

- Analyzing vulnerabilities of the fishery and aquaculture sector in the SAARC Region.
- Assessing fish biodiversity, and conservation and management in trans-boundary rivers.
- Assessing climate change impact on fisheries and aquaculture and making fisheries and aquaculture adaptive to climate changes.
- Enhancing small-scale fisheries for improving household nutrition security of the smallholder farmers in South Asia.
- Bringing derelict water bodies in to aquaculture to ensure horizontal expansion of aquaculture for sustainability.
- Practicing aquaculture in seasonal water bodies as a climate change impact mitigation strategy.

- Promote the best management practices in aquaculture towards fisheries farming communities.
- Promote farm-made aqua feeds, brood stock management, and fish disease diagnosis.

Recommendation of Priority Programs for Fisheries Development

1) Establishment of brood banks and seed certifications

Brood Banking Programme through seed multiplication farms for the major South Asian fish and shellfish species and hatchery registration and certification using a standard process under a hatchery better management practice (HBMP) guidelines.

2) Promotion of farm-made fish feeds using local ingredients

Screening and utilization of locally available cheaper ingredients to reduce the dependency on the imported fish meal and soy meal which are the most expensive among the feed ingredients.

3) Exchange of genetically improved and pure gene pool among countries

Assessment of genetic diversity and population structure of the major fish species available in the South Asia and assist countries by exchanging live genes where gene pool deteriorated.

4) Utilize derelict water bodies

There are numerous waterbodies in the form of ponds, ditches, canals and floodplain – should be renovate and restored and brought under aquaculture.

5) Promote aquaculture in seasonal water bodies

The seasonal waterbodies with water for 3-6 months need to be brought under aquafarming particularly for short-cycled fishes like tilapia, silver barb and a number of nutrition-rice small fishes.

6) Prepare nutrient profiling - to list fish as health food

There must be more fishes that are nutritionally rich like mola, *Amblypharyngodon mola* (found to be very rich with high amount of vitamin and minerals) in South Asian countries. Accordingly all potential species should be thoroughly screened to evaluate their nutritional composition and their aquaculture and open water management need to be strengthened.

7) Disease surveillance and monitoring to combat the trans- boundary disease and pest

Transboundary fish diseases pose a serious risk to the South Asian fisheries and aquaculture. The potential threat from the fish diseases should be identified and the best

ways need to be planned and executed for their administration, prevention and control in the transboundary waters.

8) *Enhance fish and aquaculture diversification and formulate water budgeting*

More research and development works need to be conducted to diversify aquaculture. Fish culture is a water-intensive endeavor and requires much more water than conventional agriculture, therefore reduction in freshwater use in pond aquaculture need thorough research and development on intensive and super-intensive culture systems and aqua feeds and treating and recycling the water used.

9) *Encouraging fishermen to use climate smart technology*

Culture of short cycled fish, easily movable structure like small cages and pens and farming fish/shellfish in relatively sheltered area should be encouraged.

10) *Allowing and enhancing FDI in deep sea fishing*

Over the years, South Asia's FDI inflow remain considerably low in comparison to other regions. However, globally FDI has long been one of the major sources of technology transfer, employment generation, and capacity building, and increasing market efficiency in any country. To ensure the proper implementation of deep sea fishing to increase the deep sea catch, well-thought strategy need to be developed to attract and increase FDI.

11) *Capacity building and institutional linkages*

Develop the capacity on current issues/ challenges and advanced technologies to the brood stock, fish farmers, fishers, traders, processors and all the actors of fisheries value chain. In the meantime, functional institutional linkage between producer, service providers, stocker, trader, processor, end user and concerned stakeholder need to be strengthened.

12) *Promotion of public-private partnership on fisheries research and development*

Realizing the fact that about 70% of the economic activities governed by private sector, the private sector engagement in fisheries development through public private partnership approach is crucial.

13) *Reduce tariff and non-tariff barriers in fish trade among South Asian countries*

SAARC Member States are restricting trade barriers imposing higher tariff rates as a tariff barriers; and implementing sanitary and phyto- sanitary measures in importing fisheries products. In the liberalized economies, such types of barriers to be reduced for enhancing fisheries sector in the region.

14) *Multi-country projects including collaborative mariculture*

Short, medium and long-term collaborative projects (both research and development) need to be executed on the emerging issues of fisheries and aquaculture.

15) Micro propagation of selected seaweed

Seaweed farming, though has a very high potential, is a poorly researched issue in the South Asia. Immediate action need to be taken to domesticate the potential seaweed and brought them under farming in all the South Asian countries with sea border.

16) Establish an intergovernmental/ regional cooperation body

To assess the capacity building needs and gaps of the countries, strength and weakness, possible modalities of capacity and partnership building and support to develop national and international work plans, monitor the progress of each project for fruitful outcome.

17) Identify research capacities of regional partners

Sharing or exchange the technology, knowledge, infrastructures and scientists / expertise/ scholars in the region.

Indeed, effective fisheries management and aquaculture development can only be achieved with public support. South Asian fishers, fish farmers, traders, processors, and general people as a whole need to understand the issues, to be involved in the formulation of management plans and to benefit from the whole process. A key step in building fisheries co-management, fish biodiversity conservation and expanding and promoting aquaculture with community participation is to bring all the stakeholders in a common front with a view to sharing resource and knowledge, creating an environment for meaningful discussion on cross-cutting themes and valuing each other.

In recent years, most of the government of the South Asian nations and the donor communities have placed major emphasis on open water fisheries management, conservation, development and promotion of fish farming, and improvement of institutional framework and need-based training. In this backdrop, all concerned and those are working for the betterment of the fisheries sector of this region – the fishers, fish farmers, general people, local leaders, researchers, policy makers, GO and NGO workers should come forward to conserve the precious fish and ecosystem diversity of the region, manage wild fishery in a sustainable way and to increase the farmed fish production through effective coordination, long-term program and sustainable approaches.

Conclusion and Way Forward

SAARC countries are located in an area with immense possibilities and opportunities for the development of agriculture including fisheries and aquaculture. The people of this region need to recognize the importance of fisheries and aquaculture sector and its potentiality that fosters rural economy. Regional cooperation in areas of mutual interest like fisheries can result in accelerating the pace of growth to optimum levels in this poverty-stricken region of the world. This increased pace can ultimately be used for poverty reduction, ensuring food and nutritional security, and providing livelihoods to

marginalized populations and also act as fulcrum around which the dream of a better tomorrow for the future generations can be realized. The scientific community and the expert should convert this energy into a tangible work plan that can be used as a reference while formulating development initiatives for the fisheries sectors in respective countries.

Transforming the lives of millions of rural and urban population and putting efforts to help people come out of poverty trap is a herculean task. Development of fisheries sector in a sustainable and tangible way provides us a valuable tool to achieve targets of this immense challenge. Since major constraints to fisheries management is the non-availability of scientific data on resources and exploitation, SAARC Fisheries Database should immediately be developed. Technology along with skill and knowledge-base transfer and exchange program for the farmers, fishers and scientists among the SAARC countries need to be initiated. The countries should exchange germplasm and increase trade of fish and fish product. Program should be developed to help fishers, in areas where fishing can no longer support a reasonable standard of living, to gradually move away from dependency on fishing. Special aquaculture program should be designed for Afghanistan, Bhutan and Maldives. Immediate action is necessary to prevent the cross border fishing and for zero tolerance towards IUU fishing. Finally, collaborative long-term program in thrust areas of fisheries and aquaculture under the umbrella of SAC should be designed and carried out.

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Chapter 16

Research and Development on Natural Resource Management in South Asia

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Abstract

The paper presents the thematic area, "Natural Resource Management (NRM)". Discussion has been made taking into account of the concept note on the "Multi-Sectoral Development for SAARC Agriculture Centre through Expert Consultation". A holistic program has been proposed in relation to NRM which addresses best management practices (BMP) covering conservation agriculture, water saving practices, efficient nutrient management, organic amendment and carbon sequestration. The program has been outlined with justification, objectives and activities. The paper focuses on the current situation of natural resource degradation and the challenges and opportunities of adaptation and mitigation for sustainable natural resources in the SAARC countries. Development and implementation of adaptation measures and policies and taking initiatives for mitigation measures where applicable are the right ways to address natural resource management.

Keywords: Best management practices, conservation agriculture, carbon sequestration, nutrient management, water saving

Background

The South Asian countries have made a significant progress in food production with a transformation from a food-deficit into a food sufficient region. Nevertheless, this situation would not remain for long, as because there are many challenges ahead. The major challenges are declining arable land, degrading land & water resources, and climate vulnerability (temperature rise and erratic rainfall). Besides these, every country has agro-ecologically some unfavorable (unproductive) lands viz. coastal lands, acid lands, hills & mountains, haors and charlands, which are the constraints to higher crop production.

The natural resources in the SAARC countries are threatened by both natural and anthropogenic factors. The natural factors include floods, cyclones, drought etc. and the

anthropogenic factors are deforestation, hazardous wastes, unbalanced fertilizer management, pesticides abuse etc. Natural resource management is vital for the economic development of a country. Thus, it is important to develop principles and strategies for sustainable natural resource management both at local and regional scales.

Climate change is a big issue in the context of sustainable crop production. This can cause reduction of agricultural production by 10-50% by 2050 and beyond, if we do not follow upscaling and adaptation of climate resilient technologies now (APAARI, 2012). There is an increasing trend in soil resource degradation which is due to inappropriate management practices, non-judicial crop intensification and inadequate governance over soil resource. Agroforestry systems should receive special attention in climate change mitigation and food security (Feliciano et al., 2018). Hill agriculture deserves special attention in order to improve the livelihood of people in the hilly and mountainous regions.

Reduced availability and degradation of water resources is another threat to food security in South Asia. There have some promising irrigation water saving practices which include alternate wetting and drying (AWD), direct seeded rice (DSR), drip irrigation, etc. The AWD practice helps saving of 25–30% irrigation water compared to the conventional flooding system (Lampayan et al., 2015; Richards & Sander, 2014).

Regional Situation of NRM

Hills cover more than 80% of the total lands in Nepal, Bhutan and Afghanistan, and in Bangladesh hilly area is 12%. Agricultural potential is severely limited due to steep slopes, soil erosion, low soil pH, low soil organic matter and water scarcity. At present, 44% of Sri Lankan agricultural lands are vulnerable to soil erosion. Only 17% of total land in Nepal is cultivable.

There are new promising technologies that have been generated in South Asia. For example, conservation agriculture (CA) appears to be an excellent approach in South Asian agriculture which has both economic and environmental benefits. Unfortunately, the CA practice is not yet adopted widely in rice-based cropping systems in South Asia (Kassam et al., 2015).

With the advancement of time, deficiency of micronutrients has arisen. The HarvestPlus program is underway to address micronutrient biofortification of cereals, pulses and some other food crops in South Asian and other countries. Swaminathan (2014) says, "We have to increase our food production and ensure that it gives us all the nutrients we need. Hidden hunger is one variant of hunger which arises from lack of micronutrients". Reports are available about heavy metals contamination of soils and water, and eventually they enter into foods (vegetables and cereals), especially in the industrial areas (Jahiruddin et al., 2017; Rahman et al., 2019).

Depletion of soil organic matter and nutrients is another big concern in South Asia. Appropriate technologies are required for restoration and stability of soil organic carbon for sustainable crop production. Biochar is a good example of stable organic material (Downie et al., 2009; Sohi et al., 2010). Better management practices reduce GHGs emissions from agro-ecosystems, and also sequesters atmospheric carbon into terrestrial ecosystems (Sapkota et al., 2017).

Challenges and Opportunities in NRM

Climate vulnerability, declining soil & water resources, deforestation, soil erosion and non-judicial organic matter & nutrient management are the major challenges in South Asia. Large gap exists between research results and farm results which shows a weak Research-Extension-Farmer linkage. However, there are good opportunities to address these issues in relation to NRM. The opportunities include climate smart agriculture, conservation agriculture (minimum tillage), water saving practices, sustainable agro-forestry practices, carbon sequestration, organic amendment (e.g. biochar) and better nutrient management (right form, right amount, right time and right place of nutrient addition) are the good opportunities of sustainable management of natural resources. Apart from food security, there is a challenge for nutrition security in the region that needs to be addressed with appropriate policies and programs.

Review of NRM Policies and Programs in South Asia

The NRM policies and programs across the SAARC countries are not fully known, so it is difficult to put comments on any policy gaps and suggest new policies. However, some generalized remarks are given. Linking Policy and Strategic Framework with the relevant Sustainable Development Goals of United Nations is extremely important. Achieving SDG- 1 (No poverty), SDG- 2 (Zero hunger), SDG- 3 (Good health and wellbeing), SDG- 8 (Decent work and economic growth), SDG- 9 (Industry, innovation and infrastructure), SDG- 12 (Responsible consumption and production), and SDG- 13 (Climate action) need to be focused while developing policy and strategic framework for South Asia.

Lack of a clear policy guidelines and coordination between policies at different levels is also a major barrier for scaling up the adoption of climate-risk adaptation and best management strategies at the farm level. Therefore, institutional policies that address local issues and bridge the gaps between national, regional, and local climate change challenges are important (Aryal et al., 2016; Aryal et al., 2019). Country's Climate Change Strategy and Action Plan, National Agricultural Policy, and Land Use Policy need to be revisited and strengthened. There have some initiatives, but inadequate, at govt, non-govt. and community levels to cope with the NRM degradation. This could be taken into consideration while designing the policy guidelines.

Recommendation of Priority Programs under NRM

1) Best management practices for food security under local bio- physical and socio-economic conditions

Background and Justification

Identification of the best management practices (BMPs) is very important in the context of natural resource management (NRM) in South Asia. There are many types of BMPs of which conservation agriculture, sustainable nutrient management and water saving practices should receive priority consideration.

The practice of conservation agriculture (CA) is based on three pillars: minimum tillage, previous crop residue retention and suitable (e.g. legume based) crop rotation. This practice helps increase organic carbon by decreasing organic matter mineralization and adding crop residues, as reported in Indo-Gangetic Plains (Ladha et al., 2009; Jat et al., 2013). Sapkota et al. (2017) reported soil carbon increases by 4.7 Mg C ha⁻¹ after 7 years of CA in the rice–wheat cropping system of the Eastern Indo-Gangetic Plains. Minimum tillage can give similar crop yield in comparison with conventional tillage system (Bell et al., 2017; Salahin, 2017); benefits are cost saving through labor saving, fuel saving and irrigation water saving (25-33%). Legume based or any suitable crop rotation may help reduce fertilizer inputs, increase nitrogen availability, and sustain soil health and crop yield (Prochnow & Cantarella, 2015).

Increasing cropping intensity and diversified cropping systems on decreasing arable land raises a question about profitability and sustainability of current nutrient management in South Asia. A major challenge is to develop efficient programs for maintenance of nutrient levels at an adequate level for profitable crop yield. Aryl et al. (2019) noted an increased emission of nitrous oxide from crop land due to increased use of nitrogen fertilizer. For instance, between 2003 and 2010, the fertilizer application in India has increased from 105 to 179 kg ha⁻¹, Pakistan from 106 to 217 kg ha⁻¹, Bangladesh from 160 to 184 kg ha⁻¹, Sri Lanka from 231 to 259 kg ha⁻¹, and Nepal from 5 to 23 kg ha⁻¹ (World Bank, 2013).

Fertilizers currently support 40-60% of crop production. Meeting future food security requires a judicious use of fertilizer nutrients. The 4R Nutrient Stewardship guidelines have been developed by the fertilizer industry as a process to guide fertilizer Best Management Practices (BMP). This **4R** concept refers to applying the Right Source of nutrients, at the Right Rate, at the Right Time and in the Right Place (Johnston & Bruulsema, 2014). Nitrogen fertilizer-use efficiency in South Asia is very low; it is only 30–40% (Farnworth et al., 2017; Tewatia et al., 2017). The 4R Nutrient Stewardship supports higher nutrient use efficiency and environmental sustainability, while supporting the farmer's profitability.

In South Asia, water use efficiency is very low; in Bangladesh only 25-30% irrigation water is used by the crops, the rest lost due to flood irrigation particularly in *boro* rice cultivation which contributes about 55% of country's rice production (BBS, 2018). However, in the SAARC countries some water saving technologies have been developed. Alternate wetting and drying (AWD), direct seeded rice (DSR), raised bed and drip irrigation are the promising technologies. Cultivation of low water requiring crops such as maize, wheat and pulses could be another option instead of *boro* rice cultivation. The AWD technique helps save 25–30% irrigation water compared to the conventional flooding system (Lampayan et al., 2015; Richards & Sander, 2014). Rahman (2019) reported higher rice yield with 60% irrigation water saving for dry direct seeded rice system compared with puddled rice system. Drip irrigation could be a good means for efficient use of water resource particularly for horticultural crops.

Objectives

- Review the best management practices for achieving sustainable soil fertility and crop productivity.
- Scale out the BMP for diversified crops and agro-ecosystems.
- Find out the strategies for implementation of BMP and associated barriers.
- Develop strategies for wide scale adoption of CA in South Asia.
- Recommend nutrient management strategies that support sustainable cropping intensification and diversification.
- Analyze the status of irrigation water saving practices (AWD, DSR and drip irrigation) in South Asian agriculture.

Components/ Activities

- Adoption of water saving practices (AWD, Drip irrigation).
- Sustainable water shed management for ready water supply.
- Cultivation of less water requiring crops and varieties (drought tolerance).
- Identification of best management practices (BMP).
- CA practice for sustainable soil fertility and profitable crop yield.
- Organic amendments e .g. biochar for increasing soil carbon.

2) Sustainable management for integration of agro-forestry, forestry and crops

Background and Justification

Hills cover more than 80% of the total lands in Nepal, Bhutan and Afghanistan, and in Bangladesh it is 12%. Obviously, hill agriculture is different from plain land agriculture in respect of crops, land & water management. Agricultural potential is severely limited

due to steep slopes, soil erosion, low soil organic matter, low soil pH and lack of irrigation facility.

Jhum cultivation (growing several crops in one pit) is a traditional farming system in Chittagong Hill Tract (CHT). Mango, litchi, pineapple, agar wood plant (*Aquilaria malaccensis*) etc. are now largely grown in CHT. In the foot of the hills there is flat land where rice and some vegetables are grown. Soil erosion can be reduced to a considerable extent by adopting better management practices like minimum tillage, cover crop, surface mulch and using shorter length plot along the slope (Mamun, 2018).

Objectives

- Review the existing agro-forestry practices in the hilly regions of Bangladesh, Nepal, Bhutan and Afghanistan.
- Select sustainable agro-forestry practices for livelihood improvement of people in the hills and mountains.
- Develop implementable strategies for integration of agro-forestry, forestry and crops in the hilly regions.

3) Progress of micronutrient research and zinc & iron biofortification in crops

Background and Justification

Globally, around 30% of the world's population suffers from multiple micronutrient deficiencies. Deficient levels of micronutrient in soils would result in lower crop yield, reduced micronutrient concentration of crop produce and increased disease susceptibility of crops. Farmers commonly use N, P & K fertilizers; use of micronutrient fertilizers is limited. Biofortification, the process of adding micronutrients to food crops through breeding or agronomic approach, provides a good means of reaching malnourished rural population who have limited access to commercially marketed fortified foods and supplements (Hess & Brown, 2009; Bouis, 2013). Agronomic biofortification with Zn (variety selection, fertilizer use) provides a practical and cost-effective option to tackle the global Zn malnutrition problem (Cakmak & Kutman, 2018).

Objectives

- Review the status of micronutrient deficiency in soils and crops in varied agro-ecosystems.
- Evaluate the effectiveness of zinc and iron biofortification in cereals and pulses by fertilizer application.
- Formulate strategies for promotion of micronutrient fertilizer use in crop production.

4) Soil and water degradation in the industrial areas and strategies for its remediation

Background and Justification

With the advancement of time, urbanization and industrialization have progressed in South Asia causing soil and water degradation. Industrial discharge is a major source of heavy metal contamination in soils and subsequent uptake by crops. Industrial wastes and effluents are being discharged randomly on soils, into canals, rivers, along the road sides or in the vicinity of the industrial areas without any treatment. The rivers around Greater Dhaka City (Buriganga, Lakhya, Balu, Turag) are highly polluted with heavy metals and organic pollutants. Reports are available that a significant amount of cadmium, lead and nickel is transferred from soils to vegetable crops (spinach, tomato and cauliflower) grown in industrially polluted soils of Konabari and Keraniganj. Contamination of As, Cd, Pb and Cr in rice grains is also reported in Bangladesh (Norton et al., 2017; Jahiruddin et al., 2017; Rahman et al., 2019; Meharg et al., 2013). The rice component of the diet alone may contribute up to 46%, 57%, 50% and 60% of the Maximum Tolerable Daily Intake (MTDI) for As, Cd, Pb and Cr, respectively (Jahiruddin et al., 2017).

Objectives

- Assess the pollution of heavy metals (e.g. cadmium, lead, chromium) in the industrial areas.
- Determine the concentration of heavy metals in vegetables and other crops grown with industrial effluent irrigation.
- Formulate the management strategies for remediation of heavy metals contamination in the industrial areas.

5) Liming and organic amendments in low pH soils for higher crop production

Background and Justification

There is a large area of acid soils distributed across the regions of Southeast Asia, parts of East Asia and parts of South Asia. Acid sulphate soils are widely distributed in the coastal plains of Southeast Asia and it is very much present in Bangladesh coast. Acid soils are an important issue because of its adverse effect on soil fertility and crop productivity. In Bangladesh, geomorphologically acid sulphate soils, peat soils, acid basin clays, terrace soils, piedmont soils and hill soils are slightly acidic to strongly acidic in reaction which constraints crop production in more than 30% of lands in this country. Acid soils possess toxic concentrations of Al^{3+} , Fe^{3+} and Mn^{2+} , lower concentrations of P and low availability of bases which together cause reduction in crop yield. Legume crops (pulses) are highly affected by soil acidity. Liming should be practiced to raise soil pH to neutrality as to enhance nutrient availability and favour crop growth. Liming is not

needed when rice is grown under wetland condition since in this condition soil pH approaches neutrality. Organic amendment with available manure (FYM, poultry manure, vermicompost, trichocompost, bioslurry, biochar) would help improve soil health and crop productivity.

Objectives

- Review the liming and organic amendment effects on soil health and crop yield.
- Promote liming and organic amendment technologies for sustainable soil health and crop production.
- Create farmers' awareness regarding liming and organic amendment practices.

6) Adaptation of climate resilient agricultural practices in different agro-ecosystems

Background and Justification

Agriculture in South Asia is vulnerable to climate change due to increasing variability in rainfall and rising temperature which leads to the incidence of extreme climatic events such as floods, droughts, heat/cold waves, and storms. The situation of climate change vulnerability might cause a reduction of agricultural production by 10-50% by 2050 and beyond, if adaptation strategy is not implemented (APAARI, 2012). The critical challenge is to manage soils and water in coastal and drought regions in a sustainable way and to adapt the sustainable production system with the climate change vulnerability. Agroforestry systems should have received special attention in climate change mitigation and food security (Feliciano et al., 2018).

South Asian countries have made a remarkable progress in food production during the past three decades and the region has been transformed from a food-deficit into a food sufficient region. Nevertheless, it's a great challenge to maintain food security on a longer term under the situations of climate change vulnerability, decreasing arable land and increasing population. Upscaling of climate resilient technologies is an opportunity to address this issue in the region.

Objectives

- Review the practices for sustainable natural resources and crop production in the climate vulnerable areas.
- Identify the potential adaptive and mitigation practices.
- Formulate strategies for promotion of climate resilience agriculture practices.

Conclusion and Way Forward

There exist numerous issues in relation to degradation and management of natural resources in South Asia. Promotion of technically and ecologically sound approach and

practices could be future agenda for sustainable natural resource management. Development and implementation of adaptation measures and policies and taking initiatives for mitigation measures where applicable would be the right ways to address land, soil and water degradation. Community-based approaches supplemented with technical and financial support could be the best route to adoption of a viable practice. With advancement of time, there are increasing diverse and complex problems. Hence, the NRM research needs to be integrated with other areas of research, especially crops and horticulture sub-sectors. Sustainability goals demand that adequate strategies are built in to reduce further degrading of natural resources (soil, water, forests) and efforts are made to rehabilitate the already degraded resources. It is important that global (FAO), regional (SAC and APAARI) and country level priorities and policies need to be harmonized as well as complimentary.

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Report of Regional Experts Consultation Meeting on Multi-Sectoral Program Development for SAARC Agriculture Centre

(16-18 July 2019, Dhaka, Bangladesh)

Introduction

South Asia is home to nearly 1.74 billion people in 2015 and projected to grow to 2.04 billion in 2030 and 2.29 billion in 2050 (United Nations, 2017). About 30% of the 700 million poor people are in absolute poverty with income of less than US\$1 per day (World Bank, 2017). Nearly 22% of world's population reside and out of that more than 50% people are engaged in agriculture. However, South Asian agriculture is handicapped with constraints and challenges such as low investments, lack of technology development, value chain efficiency, human resource and infrastructure, climate change, weak market structures and systems, food and nutrition security, and poverty.

SAC had developed regional agriculture program in 2007 that guided the SAC in formulating programs for last 10 years (2007-2017). Meanwhile, SAC Agriculture Vision 2020 envisioned in 2013 for the promotion of agricultural research and development and technology dissemination initiatives for sustainable agricultural development and poverty reduction in the SAARC Member Countries, is going to be terminated by 2020. In this context, SAC in collaboration with Asia- Pacific Association of Agricultural Research Institutions (APAARI) organized a regional expert's consultation meeting on "Multi-Sectoral Program Development for SAARC Agriculture Centre" during 16-18 July, 2019 in Dhaka, Bangladesh.

Objectives

The main objective of this program is to develop long-term program for 10 year to be implemented by SAARC Agriculture Center in the South Asia region and to road mapping for the SAARC Agriculture Vision 2030. The specific objectives were: assess the current status of agricultural research and development, and policy issues in the region vis a vis global developments in technologies, innovation and development processes; identify challenges and opportunities, and priority areas in policies and programs for agricultural research and development in the region; and identify need based demand driven program framework in agriculture and allied sectors for long-term.

Program Structure

In this 3 days program, National Experts from the SAARC Member Countries presented on "National Agricultural Research and Development: Policy and Program Priorities" and Thematic Experts presented on each thematic areas (crops,

horticulture, livestock, fisheries, NRM and agricultural policy and agricultural research). Review panels, development partners and professionals from cross-cutting issues were reviewed the papers and gave suggestions for the further improvement. We had intensive discussion on generating ideas to formulate SAARC Agriculture Vision 2030. Finally, the meeting ended up with fruitful group brainstorming outcomes on issues/ challenges, opportunities and program activities on each thematic area.

Outcome of the Program

A book "Agricultural Policy and Program Framework: Priority Areas for Research & Development in South Asia" is the outcome of this regional consultation meeting.

Pictures of the Consultation Meeting





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