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Contents

1 Acknowledgments

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2 Executive summary

In 2016, ACIAR requested the Australian National University (ANU) and the International Food Policy Research Institute (IFPRI) to develop a Small Research and Development Activity (SRA) in the context of the Australian Centre for International Agricultural Research (ACIAR) research program on Agricultural Development Policy. The SRA was tasked to develop the building blocks of a large research proposal to support the ACIAR program in the Eastern Gangetic Plains (EGP) that would also complement the ongoing Sustainable Resilient Farming Systems Initiative (SRFSI) and the SDIP Phase II aim to increase water, food and energy security.

The SDIP aims to improve the integrated management of water, energy and food in three major Himalayan river basins—the Indus, Ganges and Brahmaputra—covering north-east Pakistan, northern India, Bangladesh, Nepal and Bhutan. SDIP draws on Australia's expertise and technologies in the water, food and energy sectors and is delivered through a combination of partners including: ACIAR, CSIRO, International Centre of Excellence in Water Resources Management (ICE WaRM), International Centre for Integrated Mountain Development (ICIMOD), World Bank—South Asia Water Initiative Phase II (SAWI), International Finance Corporation (IFC) and The Asia Foundation (TAF).

SRFSI is being implemented in specific districts in the EGP: across Eastern India, the Nepalese Terai and western Bangladesh. It has four key objectives: 1) Understand farmer circumstances with respect to cropping systems, natural and economic resources base, livelihood strategies, and capacity to bear risk and undertake technological innovation; 2) Develop, with farmers, more productive and sustainable technologies that are resilient and profitable for smallholders; 3) Catalyse, support and evaluate institutional and policy changes that establish an enabling environment for the adoption of high-impact technologies; and 4) Facilitate widespread adoption of sustainable, resilient and more profitable farming systems.

Specifically, the key aims of the SRA were, as a response to rural poverty challenges in the EGP, to identify the underlying policy and institutional drivers operating across this politically diverse region. A component of the project was to collaborate with decision makers in both the public and private sectors to develop options that unlock the potential of agriculture in the EGP and to define enabling policies to overcome barriers to CASI (conservation agriculture for sustainable intensification technology) adoption and constraints to scaling up across the three countries.

The principal SRA project outputs include:

1. Institutional mapping of key actors who influence food, energy and water policies – at macro and micro levels - along with implementation pathways and the possible effects on rural livelihoods present within the EGP;
2. Desktop studies on existing policies in sustainable agriculture in terms of resilience, risks and rural livelihoods and barriers to adoption of appropriate CASI innovations and practices;
3. Foresight workshops with findings to assist key decision makers in understanding connected risks in the food and water policy development and implementation, as illustrated through IMPACT model results and, if possible, supplemented by micro-level results from the GFWS platform calibrated to EGP sites where data are available;
4. Findings of a pilot step one of a Risks and Option Assessment for Decision-making (ROAD) process to explore the effects of various policies and innovations on resilience and prosperity of rural livelihoods in the EGP; and

5. Summary of key findings.

The key SRA outcomes include:

1. New insights by key actors across the food-energy-water nexus in the EGP on risks and opportunities associated with global change in the agriculture sector, especially in terms of appropriate CASI practices and innovations and
2. Better understanding of proposed better practices and innovations risks to sustainability and agricultural livelihoods.

3 Introduction

Poverty in the farming sector of the Eastern Gangetic Plains (EGP), which includes parts of Bangladesh, India and Nepal endures despite the biophysical potential to increase food production and farm profitability. This region has fertile soils, and abundant groundwater resources, and sufficient rainfall. However, research findings from the first phase of the Sustainable Resilient Farming Systems Initiative (SRFSI) indicate that lack of access to finance to utilise improved technologies and farm machineries, and poorly developed agro-processing and supply chains, are the key contributing factors that hinder poverty reduction. Conservation agriculture for sustainable intensification (CASI) has shown great potential at small scale, but there are barriers in scaling up over the region. Further, there appear to be socio-economic and institutional constraints that inhibit farmers from crop diversification and that may contribute to both market and production-related vulnerabilities.

In response to rural poverty challenges in the EGP, this project helped to identify the underlying policy and institutional drivers operating across this politically diverse region. Specifically, the key aims of the project were, as a response to rural poverty challenges in the EGP, to identify the underlying policy and institutional drivers operating across this politically diverse region. A component of the project was to collaborate with decision makers in both the public and private sectors to develop options that unlock the potential of agriculture in the EGP and to define enabling policies to overcome barriers to CASI (conservation agriculture for sustainable intensification technology) adoption and constraints to scaling up across the three countries.

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5. Recommendations.

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The project commenced with a One-day Workshop with key decision makers in New Delhi which provided a framework of understanding of the opportunities and barriers to CASI in the EGP. There was also a One-day workshop in March 2017 in

Kathmandu, also with key decision makers that focused on constraints to sustainable intensification and priority issues.

Saci-WATERs, a non-governmental organisation based in Hyderabad, and a project partner delivered the institutional mapping of all three countries. IFPRI (New Delhi) provided a country study of India in terms of agricultural practices and constraints and also a review of the policies for sustainable intensification in the EGP. IFPRI Washington DC provided a report on the insights on the food-energy-water nexus challenges in the EGP. In addition, a country report on Nepal and Bangladesh were commissioned by experts from these two countries. The workshop reports, country reports, and policy reports are all provided, in full, in the chapters of this report.

4 Policy Research in Food-Energy-Water Nexus in Eastern Gangetic Plain - Foresight workshop New Delhi, India, September 2016

The foresight workshop on *Policy Research in Food-Energy-Water Nexus in Eastern Gangetic Plain (EGP),* was held on 7th September 2016. The key objective of the workshop was to build a better understand of the challenges and opportunities in the food-energy-water nexus in EGP of South Asia.

The workshop sought to identify the following: (1) identify key risks factors within EGP (2) assess their consequences on food and water systems, and (3) explore possible solutions to overcome the threats. The workshop was a prelude to develop an appropriate, integrated and risk-based decision support for resilience food system and improve rural livelihoods in the EGP. The learning from this workshop would set context and precedent to the direction that the project titled- “Improving policies and Institutions for sustainable intensification of agriculture and resilient food systems in the Eastern Indo-Gangetic Plains”.

The workshop was divided into four parts. The inaugural session brought out perspectives, gaps and needs as perceived by policy makers and bureaucrats within the region. Session I highlighted the future challenges and also characterized the unique conditions of the Eastern Gangetic Plains in a water-energy-food context. Within session II the causal risk in food-energy-water nexus was defined. Finally, session III outlined the way forward beyond the workshop.

4.1 Inaugural Session

Chairperson: Dr. R S Paroda, President, TAAS and Former Chairman, HFC (Inaugural session) and Dr. Vijay Paul Sharma, Chairman, CACP (Future Challenges in Food-Energy-Water Nexus in South Asia and the EGP)

Chief Guest: Australian High Commissioner to India. Her Excellency Ms. Harinder Sidhu and Dr. Ramesh Chand, Member, NITI Aayog

Under the chairmanship of Dr R. S. Paroda, Dr. John Dixon, ACIAR; Dr. Kuhu Chatterjee, Regional Manager ACIAR, based in Delhi; and Prof R Quentin Grafton, The Australian National University gave a warm welcome and introduced the participants to the Small Research Activity (SRA) on Policy Research on the Food-Energy-Water Nexus in the Eastern Gangetic Plains.

Dr. John Dixon, ACIAR, noted the long-standing partnership between South Asia and Australia focusing on the pressures and risks in the Gangetic Plains, which underpin food security in the region and globally. He also mentioned that the focus of the work will be located in the Eastern Gangetic and Brahmaputra basins. The field evidence would support policy and regulatory frameworks and help support the continued development of knowledge platforms in critical areas. The participation of all participants in this foresight workshop is extremely important to enrich the discussion to ultimately lead to enhanced food, energy and water security and climate-resilient economic growth.

Prof R Quentin Grafton welcomed the participants on behalf of the Australian National University and reiterated the focus of the activity on improving policies and institutions for sustainable intensification of agriculture and resilience in the Eastern Gangetic Plains. The activity builds on an earlier and ongoing project -Sustainable and Resilient Farming System (SRFSI) which has a sustainable investment portfolio focused on Conservation Agriculture for Sustainable Intensification (CASI). Key activities of CASI include deficit irrigation, widely practiced in the region, even though water is relatively abundant, machinery investments to support zero tillage, and activities focused on enhancing crop diversification for better risk management and increased resilience. The SRA will look at the potential of scaling up of the identified technologies, building on a risk assessment across the food-energy and water nexus in the region.

Dr. A.B. Pandya, Advisor, Ministry of Water noted that the nexus in the EGP (Eastern Gangetic Plains) is a very special area for three reasons. Agriculture in the area is significantly affected by the monsoon, leading to seasonal flooding. At the same time, dry-season irrigation has increased arsenic contamination. Second, the eastern part of the lower basin is divided by the Ganga River. The north bank (eastern bank) is characterized by ample water supply, whereas the south or western bank is water short and purely monsoon fed. This part requires proper water management strategies, including reservoirs, etc. The third issue is energy. Energy is essential for water management throughout the year and involves significant pumping efforts. Energy sources are insufficient, particularly green sources of power, such as hydropower are not easily available and concentrated in the upper parts of the Ganga basin. Without energy, food processing is not taking off and the potential for increased profitability is hampered. The region has the potential to become another Punjab, but it to achieve this will require very careful water management. Moreover, activities need to ensure that the poor benefit from sustainable intensification.

The Australian High Commissioner to India, **Her Excellency Ms Harinder Sidhu**, provided her insights starting with her own background and role in the former Australian Department of Climate Change. Based on her experience she encourages the workshop participants to look at interlinkages and impact of climate change on overall economy. This is a challenge that matters to both India and Australia. She further stated that the FAO in its 2014 report on the nexus described that the world's biggest challenge by 2050 will be to grow food for 9 billion people, which will require a 50% increase in food, 55% more water and 40% more energy resources. Agricultural already uses one third of the planet's land resources and 70% of its withdrawn water resources. The issue is most acute in India and South Asia, home to 44% of the world's poor. An added dimension will be the impacts of climate change with increased intensity of extreme events, effects on the poor and particularly women and girls who are the most vulnerable. There is therefore a need for collaborative efforts and partnerships between science and policymakers.

Water variability challenges apply to both South Asia and Australia. Both are significant food producers and experience regular cycles of floods and droughts, which is the basis for enduring partnerships on agriculture. To move this partnership forward, the first International River Symposium in Delhi will be held the following week.

DFAT has been delighted to support SDIP to facilitate collaborative research, to remove barriers to adoption of sustainable intensification practices. This workshop brings together people from diverse backgrounds from the region. The diversity of the group bodes well for insightful and lively interaction. A key issue to look into is the feminization of agriculture – how can we engage women and improve their incomes and livelihoods?

Dr. Ramesh Chand, Member, NITI Ayog, then provided his insights on the importance of the water-energy-food nexus for sustainability, efficiency and for agricultural growth, which is currently unsustainable. He noted that efficiency of production depends on the nature of the nexus, and that there was a need to focus on long-term thinking of long-term effects of alternative policies and investments. He felt that the study would be very useful for policymakers in this country.

He remarked that the EGP has underdevelopment agriculture and economic development. A third of the population is poor, anemia and stunting are severe. India's investments in the SDGs should therefore focus on this region. He suggested that Punjab might not be the model to replicate in the EGP but could provide important lessons. While agricultural growth has been impressive in the Punjab area, there has been a heavy overexploitation of natural resources, including over-exploitation of groundwater resources. He felt that West Bengal could reach high productivity levels, even above those achieved in Punjab as West Bengal's land administration is advanced, and income is higher than in other parts of the EGP.

Among the factors that will shape the final outcomes on the nexus in the EGP he suggested to focus on the following: 1) Technologies, such as water-extraction technologies; 2) Governance and institutional issues, such as land reform; 3) Input/output pricing policy, and 4) appropriate policies that avoid overexploitation of natural resources. He then classified northern India as having an “unhealthy nexus”, EGP as having an “undeveloped nexus”; and West Bengal as having a “healthy nexus”, apart from the arsenic challenges. Finally, he cautioned the increased replacement of wheat with winter maize, as maize is less “natural resource friendly” and should rather replace rice.

He also suggested to assess the nutritional consequences of alternative cropping choices because malnutrition and hunger are severe in Eastern India; crop diversification and reduction of drudgery in agricultural activities can both enhance nutritional outcomes and need to be assessed as part of future agricultural patterns in the region. Sustained fish and pulses production need to be part of future production patterns. On the policy front, price and procurement policies need to be adjusted to take into account not only the private cost but also the social cost and that to the environment.

4.2 Session I: Challenges & Opportunities for Policy Research on the Food-Energy-Water Nexus in EGP

The following session focused on Key Challenges across Food, Energy and Water Systems in South Asia and the Eastern Gangetic Plains: The IFPRI IMPACT and the FE2W Global Food and Water Systems Platform model.

Dr. Claudia Ringler from IFPRI focused on four challenges across the food-energy-water nexus in the region: 1) Continued food insecurity and malnutrition for a large share of the population (15% India; 16% Bangladesh and 8% Nepal), additional pressures from climate change; 2) Agricultural systems performing below potential – hampered by water and energy challenges, an overly focus on subsidies, lack of diversification, and underinvestment in agricultural R&D; 3) Already severe water stress in India – and growing stress in Bangladesh and Nepal; and 4) Challenges to switch to more renewable energy systems to support the SDGs and the Paris Climate Agreement (fertilizer subsidies.. electricity subsidies.. solar subsidies..).

She then introduced the IFPRI IMPACT model as a foresight tool to support assessment of the water-food nexus with some insights on energy. Key output indicators from the model include calorie availability, malnutrition measures, share at risk of hunger, water consumption, yield growth and total production, and changes in crop harvested area.

She concluded that 1) Joint water-energy-food planning in the region can reduce adverse impacts from growing stresses in the individual sectors from climate change, growing populations, etc. 2) There is a large need to save water resources decoupled from energy needs (f. ex. In agriculture – breeding efforts that conserve water and energy, i.e. drought and heat tolerance; for water pollution – nitrogen efficiency and combined green and grey infrastructure), 3) The SDGs require closer interactions across the food-energy-water nexus to ensure that improving targets in one SDG do not reduce likelihood of achieving other targets and goals, and 4) that the EGP have a great potential for FEW analysis as water stress is as of yet much less severe compared to the rest of India or Pakistan; and there is scope for un/ less subsidized energy supplies and for more diversified agricultural production.

Dr. John Williams, The Australian National University provided summary of model results from the Global Food and Water Systems Platform. He highlighted the ‘knife

edge' risk in producing enough food at a global level and also in South Asia within existing resource constraints fresh water supply.

The last component of session I followed on more in-depth country experiences in the EGP, under the chairmanship of Dr Vijay Paul Sharma, Chairman, CACP.

Dr Avinash Kishore, Research Fellow, IFPRI, described the agricultural setting in the EGP with low land holdings, high labor availability, and overall high population density (800-1600 people per square kilometer), low crop diversity, high input use (but still below Punjab levels), and overall low agricultural profitability. The prevailing crop rotation is rice-wheat in Bihar and the Nepalese Terai and rice-rice in Bengal and Bangladesh with total yield of 5-6 tons per ha per year. The region has experienced a late onset Green Revolution and experiences overall high water variability. The reminder of his talk focused on pump and tubewell ownership. He notes that declining water tables, especially in the pre-monsoon season, will lead to the increased use of submersible pumps and increased inequity.

The second speaker, **Dr. Sharmind Neelormi**, Associate Professor, JU, Dhaka, focused on Bangladesh's role in the EGP. Agriculture in the country only provides 15% of GDP but still 50% of employment. Water is highly variable and there is a strong climate change poverty nexus. The areas most affected by floods (the southwest and northwestern part) are also the most poverty stricken areas. The livestock sector is not well developed but generally in the hand of women. Feminization of agriculture is substantial, sometimes up to 80% of young people migrated, leaving behind women and old farmers.

The third speaker, **Dr. SK Ambast**, Director, Indian Institute of Water Management, noted for India challenges of both water wastage and challenges in the land reform, that have both hampered progress in agriculture. He also identified livestock and fisheries as important for livelihood security, including for the landless. He noted the important linkages of agricultural intensification with energy access and use.

The fourth national speaker, **Dr. Ashutosh Shukla**, ISET-Nepal, Kathmandu, noted that the agriculture sector contributes 34% of GDP in Nepal and employs 64% of the population directly in agriculture and forest based enterprises. He described the rapid rural-urban migration and labor migration to Gulf countries and South-East Asia, leading to increased feminization of agriculture. As additional challenges in the country he identified that 65% of children (6 months to 6 years of age) are malnourished and 5% are chronically malnourished. On the energy front, he noted

that much has been talked about hydropower development and exports but little has been achieved and power outages remain significant in the country affecting socioeconomic development.

Key challenges along the food-energy-water nexus in Nepal include: 1) Increasing human pressure on land and land based resources; 2) insufficient attention on water use efficiency; 3) the geo-political trap hydropower development is caught up in; and 4) the resulting low level of energy assurance for investment and technology innovations in food production, storage and processing. These challenges are further compounded by climate change.

4.3 Session II: Causal Risk in Food-Energy-Water Nexus

Chairperson: Dr. DK Marothia, Member (Agriculture), Planning Commission, GoC

Facilitators: Ms. Safa Fanaian, SaciWATERs; Prof. R Quentin Grafton, ANU;

Dr. Claudia Ringler, IFPRI; and Dr. John Williams, ANU; Dr. Nazmun Ratna, Lincoln University

The morning session of the Foresight workshop set the context on the issues and challenges in Food-Energy-Water Nexus that are faced in Eastern Gangetic Plain. Building on this, the afternoon session with sector experts and key collaborators set out to interpret this information into causal connection and risk for policy implications.

Presentation: The session began with a brief presentation on Risks and Options Assessment for Decision-making (ROAD) along the Water-Energy-Food Nexus by Dr. Claudia Ringler, IFPRI and Prof R. Quentin Grafton, ANU. The presentation expanded the ROAD process that incrementally assists in identification and evaluation of risks and options for effective decision-making. Dr. Ringler and Prof. Grafton outlined the purpose and reasons for the ROAD process that was to be carried out through group work in the afternoon sessions.

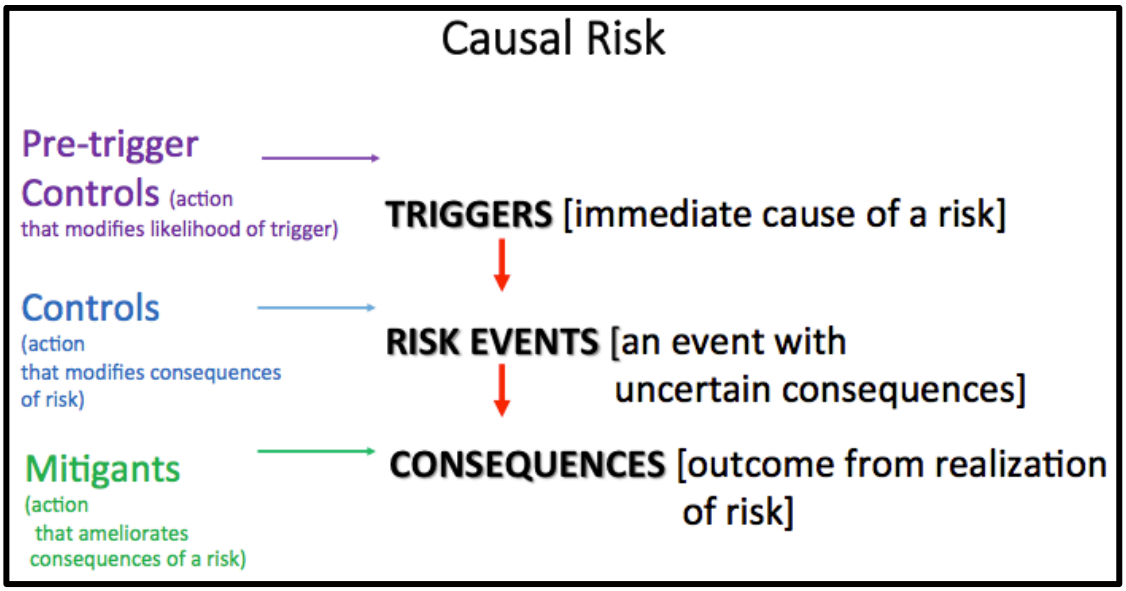


Figure 4-1: Definitions and connections for defining scope of causal risk

The first step (Figure 4.1) here defines the scope of decision-making for assessment. This includes identifying the boundaries within which decisions are made (here it was the Eastern Gangetic Plain); decision makers and the stakeholders. Following this,

the risks[1] experienced are identified along with the consequences of the risk defined and the triggers that cause the risks. Defining the risks, triggers and consequences allows mapping of possible options for action. Handling decisions or actions to on risks and their consequences can be done at different levels. This can be undertaken either before the risk is triggered (pre-trigger) or while controlling the risk when it occurs (Controls) or when dealing with the consequences of the risks (Mitigants).

The sequences of steps in the ROAD framework a decompose risk into causal risk pathways. Each pathway combines events with actions (controls and mitigants) and also the connections between management and outcomes. Its intent is to show what needs to be done? What are the effects of actions and inaction? What is being managed? And to what end?

Causal Risk Group Exercise: To initiate the first step in the ROAD process, the workshop participants were divided into five groups. Each group consisted of 5-6 people and was led by a facilitator. The group work was divided into two sessions, pre-tea session and a post-tea session (Figure 4.2).

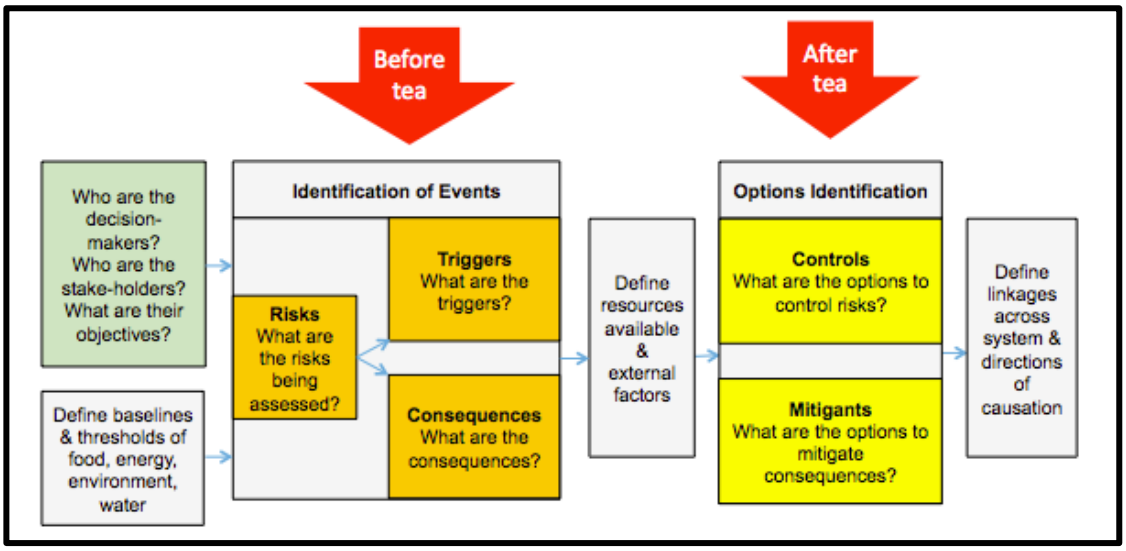


Figure 4-2:Pre-tea and post-tea session for group work on causal risk scoping

The before-tea session consisted of defining and identifying one major risk per group. The after-tea session involved identification of options to address the triggers, risks and consequences identified in the pre-tea session. This included *Pre-triggers, Controls and Mitigants*. *Pre-triggers* are considered those actions that modify likelihood of a trigger occurring or the consequences of a risk. C*ontrols* are considered as those actions that modifies occurrence of risks. Finally, *mitigants* are considered as those actions that ameliorate the after-the-event consequences of a risk.

After the respective options were listed and agreed upon by each group, priorities associated with each option were to be estimated through an investment exercise. The investment exercise allowed each individual within the group to invest in top five options. Further, as a group, they could jointly invest in their preferred priority areas

[1] Risk can be defined as a possible event (or a series of events) with uncertain or probabilistic consequences.

across all groups. At a next level, the group as a whole could jointly invest in ten priority options across any other group's options.

Outcome of the exercises within each group is as follows:

4.3.1 Group 1-

Facilitated by Ms. Safa Fanaian, (SaciWATERs).

Before-tea session

The first task set for the group was to identify and prioritize one major *Risk* that is faced within the Eastern Gangentic Plain. The group carried out this exercise by identifying as specifically as possible the risks, listing them out, collating them and arriving at one final priority risk. Through consultation the group narrowed on one risk that was considered as a priority for the EGP region, i.e.- *Low or Underperformance of Agriculture (food insecurity).* Results of discussion listed in Figure 4.3

Learning: A similar exercise was carried out to identify the triggers, threats, and consequences. The challenge was to make the points that emerged from the group into specific suggestions rather than generalized statements.

After-tea session

This session involved identification of options to address the triggers, risks and consequences identified in the before-tea session. Post-it notes were shared and the group started listing all possible options starting the exercise with pre-triggers, followed by controls and then mitigants associated. Once the options were listed, priorities associated each were brought out by an investment exercise. The investment exercise showed that the group priorities were leaning more towards mitigants as compared with patterns seen within other groups. They also decided to invest as a group more towards their own options. Results listed in Figure 4.3

Learning: The pattern of investment was most congregated in the area of mitigants rather than pre-trigger controls. Having a discussion about the trends in investment would also have been good to understand the decisions that can be made in the short terms vs. those that can be done in the long term. After which there could be an exercise to revise investments.

The exercise results of Group 1 are mentioned in Figure 4.3. The investment pattern is also listed for the options.

The investment legend for all groups is as follows:

$- Individual investments

€- Group investment

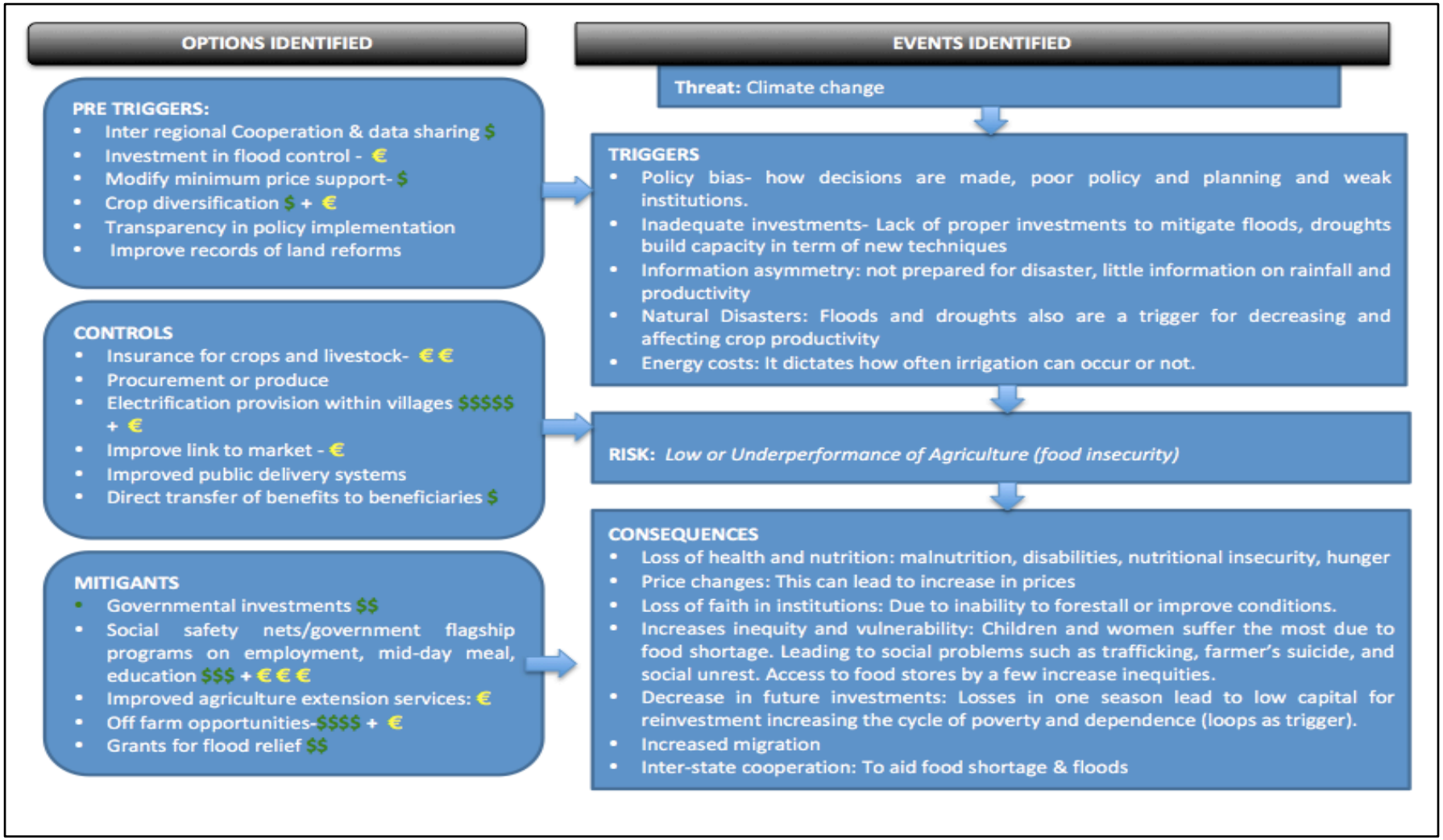


Figure 4-3: Causal Risk Scoping Exercise -Group 1

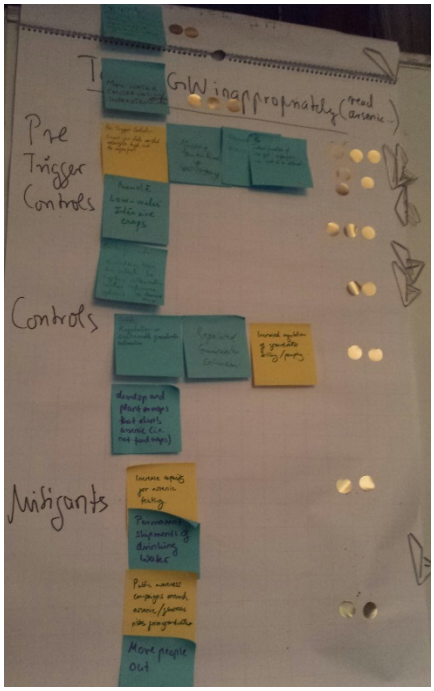
4.3.2 Group 2

Facilitated by Dr. Claudia Ringler (IFPRI)

Before-tea session:

The group brainstormed around potential risks and several were listed. However, many of the listed risks did not fit the description of risk under ROAD framework. The potential risks identified ranged from climate change related threats to energy price shocks and population increase to policy inertia and rural-migration. The group discussed the identified risks and classified them into threats (ex. lack of innovation or research & development efforts), triggers (energy price shocks), risks (tapping groundwater inappropriately) and consequences (institutional dysfunction, arsenic poisoning). The discussion narrowed down and identified one risk that definitely qualified as a ROAD type risk and then proceeded to use that in the proceeding steps.

Learning: Every participant should have in front of them clear definitions of the terminology in front of them at all times. The exercise flowed quite easily as soon as the risk has been identified.



After-tea session: In this exercise, the group participants had no challenge to identify controls, the classification between those that operated before the trigger and those that acted upon the actual risk was challenging. However, a difficulty was presented in identifying the difference between pre-trigger controls and controls.

A final challenge was the voting for the most effective strategies. The groups internal voting was straightforward but the final diagram was difficult for other group members to understand. Also, the instrument used for the second round voting was not ideal. To ensure that I could decipher my own writing I transcribed all the cards onto another page after the exercise had been completed.

Learning: The voting component was considered valuable and appreciated by all participants. A debriefing at the end on what worked and what did not was useful. A result that emerged (and tested with other types of participants) is that most of the investments were suggested for the pre-trigger controls and the least were for the mitigants.

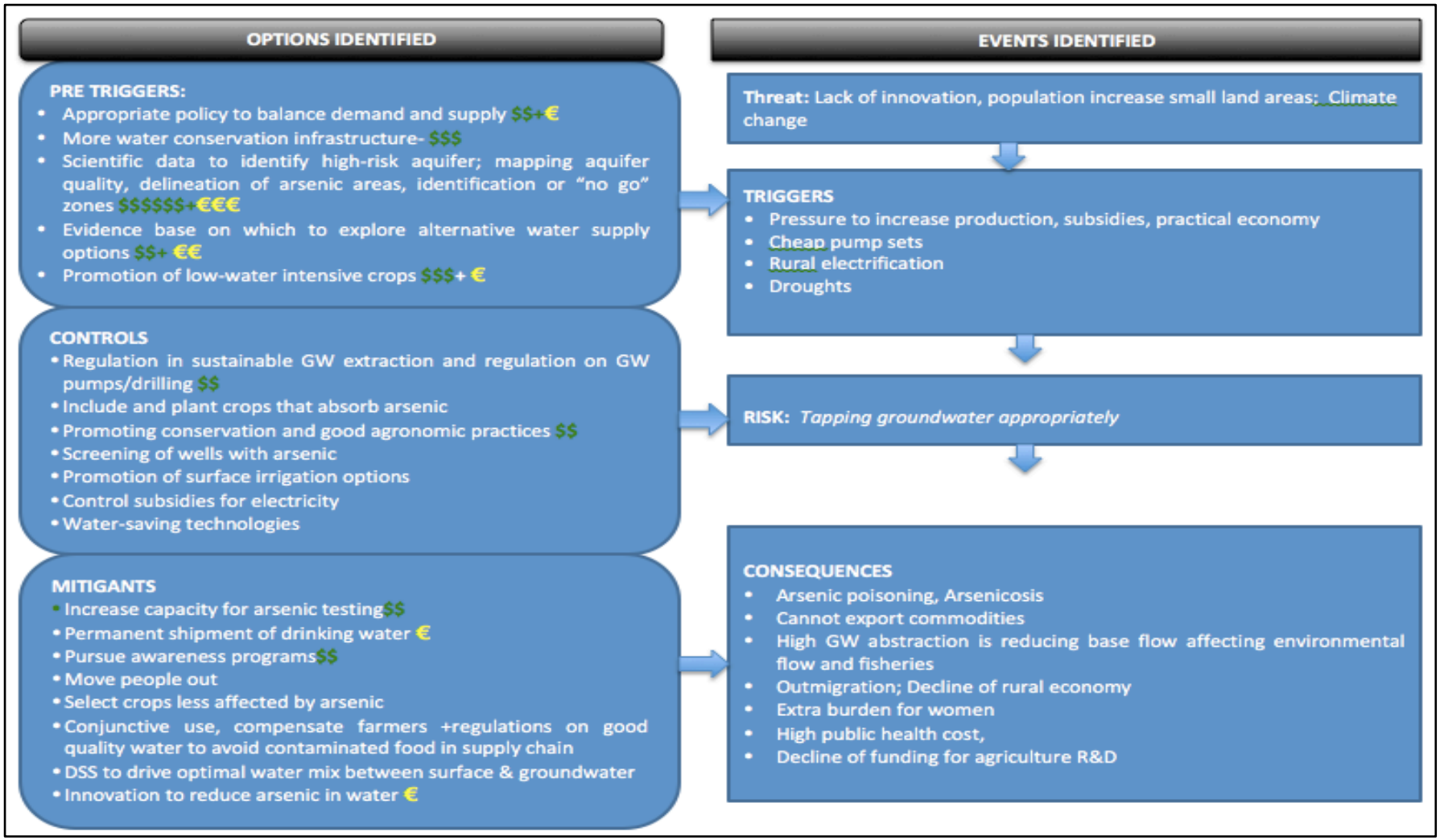
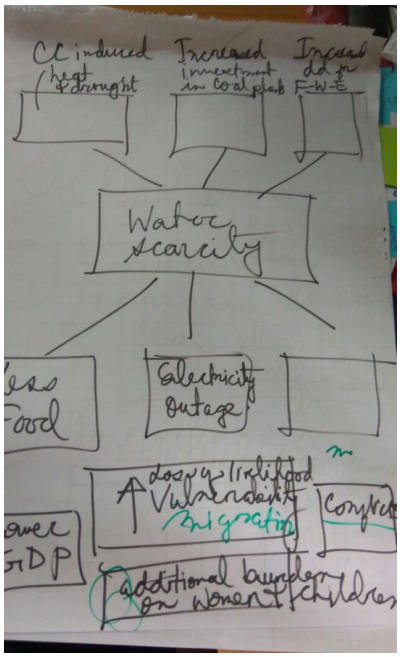


Figure 4-4: Causal Risk Scoping Exercise -Group 2

4.3.3 Group 3

Facilitated by Dr. Nazmun Ratna (Lincoln University)

Before-tea session:



The group participants wrote out the biggest risk on the cards provided. Two of the participants identified very quickly and two asked for more time. This was put together on the board and evaluated respect to other risks. Each participant then identified the most important risk and gave explanation for their choice. After which the group arrived at the consensus that WATER SCARCITY as the biggest risk. They also identified the triggers and consequences for the identified risk. The events identified are listed in Figure 4.4.

Learning: It was clearly evident that the participants had difficulty to distinguish between threat and risk. The definitions for both were given along with examples for associating and listing out risk within the region. Mini recorder can be placed at each table to capture the discussion, if note takers are not present. Planning of foresight workshops may include a post-workshop debriefing of the facilitators and note takers.

After-tea session: This session saw the identification of options for selection of pre-triggers, controls to risks and mitigants of resultant consequences. Through this exercise it was identified that there is more that should be done at the level of pre-triggers than at the level of mitigants and controls. The theme that resonated with the group was prevention and conservation before the risk occurred. The investment exercise within this group reflected the similar line of thought as most of the groups investments occurred in at the pre-trigger level than for controls and mitigants.

Learning: Investment patterns of the group defined and highlighted priorities of the group involved.

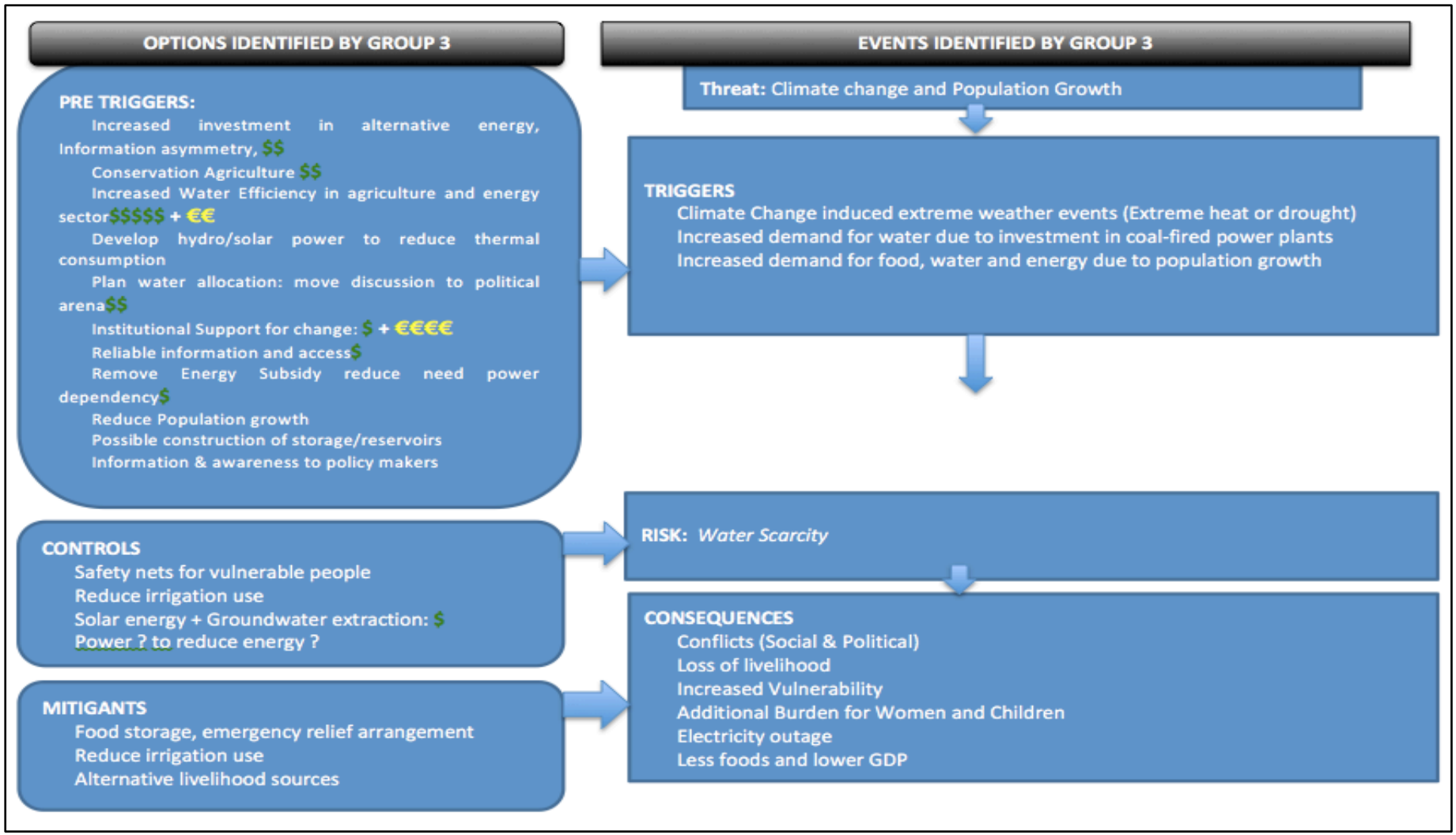


Figure 4-5: Causal Risk Scoping Exercise -Group 3

4.3.4 Group 4

Facilitated by Dr. John Williams

Before-tea:

The group was a mixed representation from different backgrounds and experiences. The members in the group listed out various risks associated in the region on post-it and based on discussion came to the conclusion that the largest risk within the EGP is that of – "Water Quantity/Quality Reduction". The triggers that influence and contribute to this risk along with the consequences were listed out on post-it notes and similarly discussed. The larger conclusion arrived at within the group are listed in Figure 4.6.

Learning: Clarity in the defining the concepts was a challenge. Concrete examples would have helped in arriving at more defined discussion and avoid facilitator confusion.

After-Tea Session: Mapping out the solution options for challenges faced in EGP followed an easier path. The consequent solution option were listed out and prioritized. The prioritized investment patterns were more dominant at the preventive section in pre-trigger controls along with mitigants addressing consequences once the risk has occurred. While the internal group investment patterns were visible as the external groups arrived for group investment, this could have influenced external group investment. The external investments favored mitgant options.

Learning: Utilization and placement of the notes on the chart needs to be planned in advance. This important as it allows for proper space for listing out solution option and allowing place for group investment to not be influenced by the internal priorities.

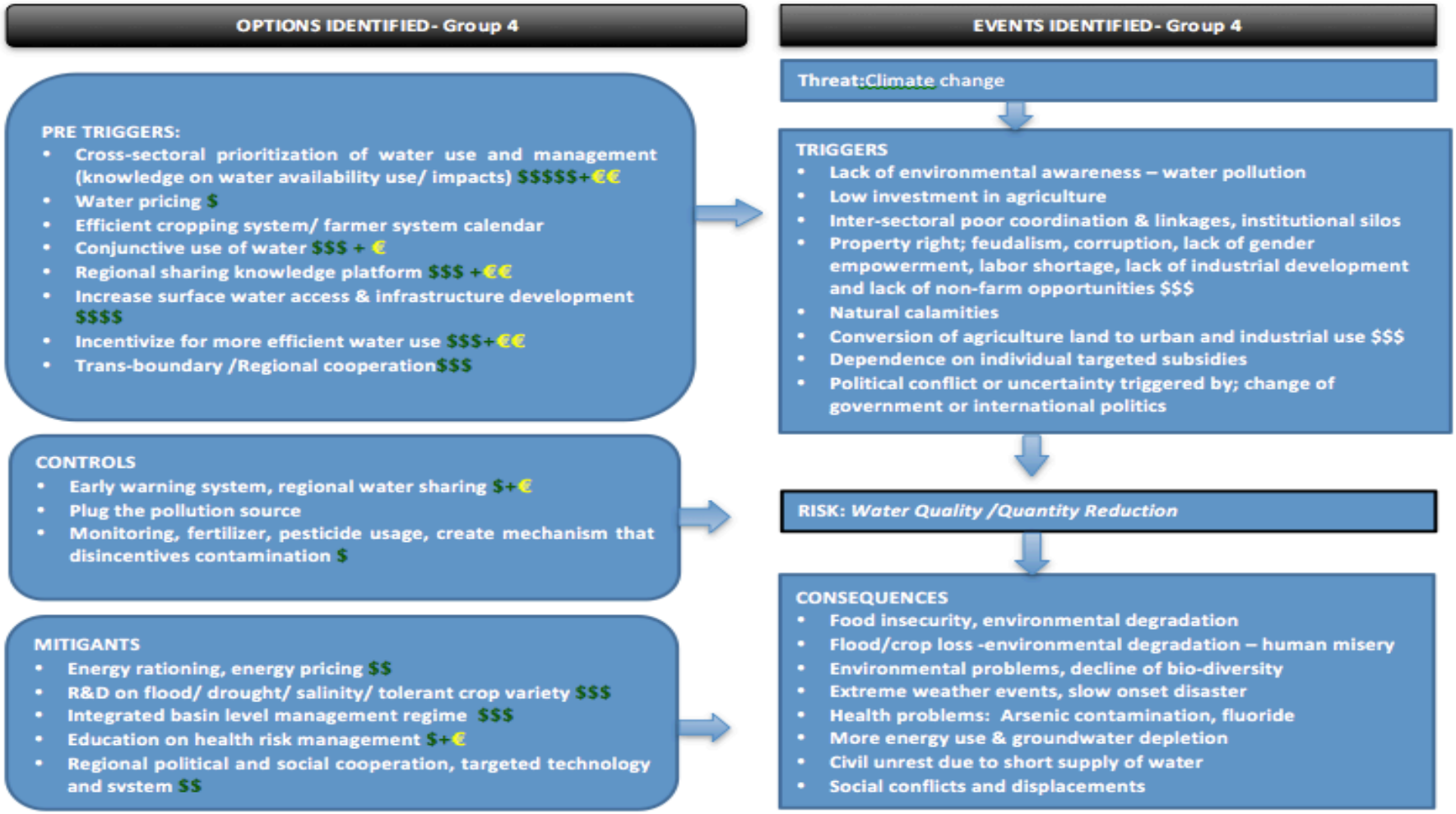
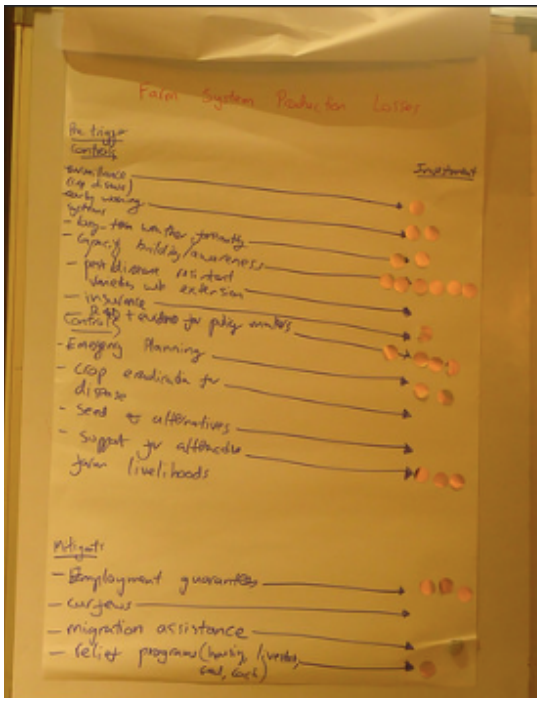


Figure 4-6: Causal Risk Scoping Exercise -Group 4

4.3.5 Group 5

Facilitated by Prof. Quentin Grafton (ANU)



Before-tea Session: Risks prevalent in the region were listed individually on post it note. These were placed on the board and through a discussion one risk that was accepted by the group: 'Farm Systems Production Losses'. Further the triggers and consequences were also similarly identified by the group and consulted upon. The results of which are expressed in Figure 4.6.

Learning: The challenge faced in the group discussion was that some members of the group confused the difference between what is a 'risk' and what is a 'threat'. This was clarified and the group was asked to identify responses that were as 'concrete' as possible.

After-Tea Session: The identification of options followed a similar manner of individual identification along with group consultation to finalize the most important options to address risks. The investment exercise saw the priorities for investments defined by individual preferences. The majority of the investments were made within the pre-trigger controls, this reflects that the group as a whole prioritized precautionary approach to address risks.

Learning: It would help if each facilitator had a list of concrete examples to explain key terms as a 'cheat sheet'. A need was also identified for someone dedicated to record each step of the facilitation in all groups. This means taking high quality photographs, jotting down 'key lessons learned' from facilitators and feedback from selected members of groups.

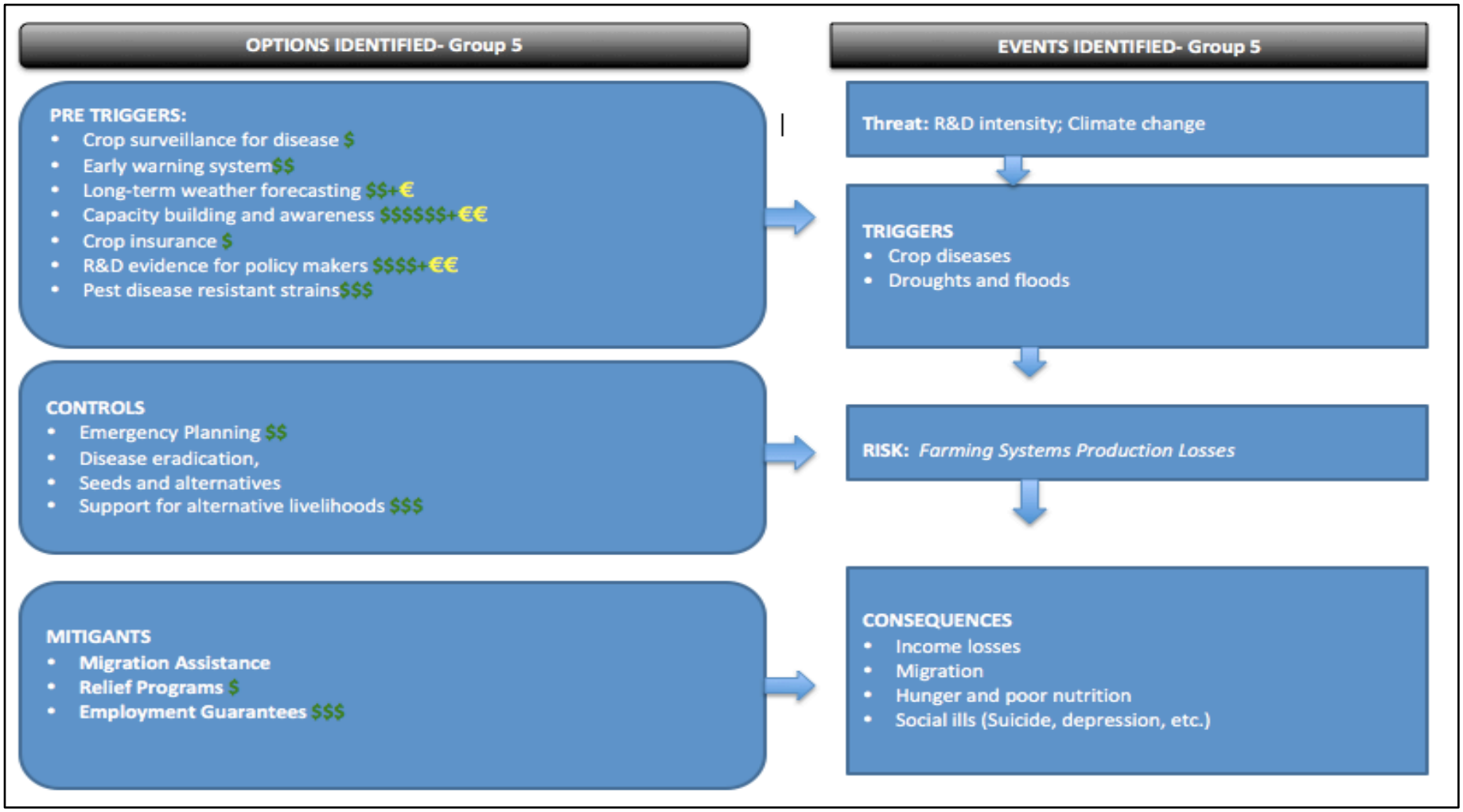


Figure 4-7: Causal Risk Scoping Exercise -Group 5

4.4 Ways forward

The Delhi Workshop is the first step in a series of actions and deliverables provided under he SRA led by the ANU. These deliverables include:

1. Institutional Mapping
2. Country Reports on Food and Nexus Issues
3. Policy Overview
4. Summary of Key IMPACT Modelling Results
5. Additional Foresight Workshop planned in 2017
6. Project proposal to ACIAR on further work

5 Sustainable agriculture in the Eastern Gangetic Plains of Bangladesh: Issues and Challenges

5.1 Introduction

Bangladesh is formed at a deltaic confluence of the Ganges and the Brahmaputra and the Meghna River system. Starting from the southern slopes of the Himalayas, the Ganges travels 2400 km of Indian territory, after entering Bangladesh through near Rajshahi, the main branch of the Ganges is known as the Padma River until it is joined by the Jamuna River. The Ganges basin in Bangladesh is located in the driest parts of the country. The basin covers lower part of the Northwest, a part of the central and whole of the Southwest regions.

Since independence in 1971, Bangladesh has been one of the countries with moderate food insecurity. Despite the excellent growth achieved in production of staple food grains over the past three decades, due to sustained growth in population and subsequent food demand, the country faced food insecurity and occasional famine-like situations (Dorosh and Shahabuddin, 2000). Although the political leaders have been claiming attainment of food autarky since the 1990s, Bangladesh remained as receiver of food aid and one of the top five net importers of food. Recent literature, however, projecting that climate change can be quite detrimental to local food production (Karim et al., 1998; Habibullah et al., 1998). In addition other aspects of food security such as access, distribution, intra-household distribution and food quality will add additional stresses to already 'uncomfortable' food security scene and pose risks of food insecurity (Ahmed, 2008b; Basak, 2009). In contrast, a few others clearly infer that despite facing environmental challenges Bangladesh would not be facing food insecurity, especially in view of past performance of maintaining growth (Miah ed., 2005).

Despite the economic advancement to lower middle income country, agriculture remains the largest employer in Bangladesh by far with 47.5% of the population directly employed in agriculture. Around 70% of population also depends on agriculture in one form or another for their livelihood (Government of Bangladesh [GoB]; 2015a). Following independence in 1971, agricultural production in Bangladesh increased at around the rate of 2% per year. The growth rate accelerated during the 1990s and early 2000s to around 4% per year. A remarkable 5.1% growth was achieved in 2010-11. As predicted with economic growth, since the 2010-11, the growth rate in agriculture fell sharply in 2011-12 to 2.7%, and weakened further to only 2.2% in 2012-13.

The performance of agriculture sector in Bangladesh, however, is predominantly governed by the performance of rice with more than 75% of the cropped land is still cultivated for rice production. The policies and issues of food security in Bangladesh always rotate around the production of paddy. Access to rice by poor and ultra-poor has a huge political influence, hence each political party focuses on self-sufficiency in paddy production. The government tries to maintain the upward trend in production of paddy in a bid to maintain at least an access to carbohydrate, notwithstanding deficiency in nutritional target.

In this report we analyse the issues surrounding the food-water-energy-environment nexus in the EGP[2] with a focus on paddy production; and discuss the challenges of sustainable

[2] Our discussion also focuses on Ganges Dependent Area (GDA)[2], which is very central to policy discourse in Bangladesh due to its vulnerability to various hazards like salinity, cyclones and sea level rise. For water resource planning, Bangladesh has been divided into regions based on hydrological conditions. The GDA is located mainly in

agriculture. We start our discussion in Section 2 describing the hydro-meteorological setting for Ganges basin in Bangladesh. In Section 3, we analyse the trends in paddy production in terms of changes in growth rate, land use, yield and labour force participation. Section 4 discusses the impact of the increased use of irrigation and fertilizer considering Food-Water-Energy-Environment Nexus in the Ganges basin. In Section 5 we look at two recurring natural hazards, drought and flood and their consequent impact on paddy production. Section 6 discusses four major challenges in pursuing sustainable agriculture in Bangladesh and the report concludes with a brief review of national policies in Section 7.

5.2 Ganges Basin in Bangladesh: the Hydro-Meteorological Setting for Agriculture

The Ganges, one of the longest rivers in the world originates at the Gangotri glacier in the Himalayas and flows across the plains of North India. Starting from the southern slopes of the Himalayas, the Ganges travels 2400 km of Indian Territory. From the entrance into Bangladesh in Rajshahi, the river flows another 112 km before joining the Brahmaputra at Goalundo, 270 km north of the Bay of Bengal.

The Mahananda from the Darjeeling District braches into two arms: the right arm joins the Ganga upstream of Farakka and the left arm flows into the Ganges soon after it enters into Bangladesh. In Bangladesh, the Gorai River is the main distributary, which leaves the Ganges River about 65 km above the confluence of the Ganges and Brahmaputra Rivers. The river empties into the Bay of Bengal.

Bangladesh enjoys a humid, warm, climate. Its climate is influenced primarily by monsoon and partly by pre-monsoon and post-monsoon circulations. Monsoon generally starts in early June and continues till early October. Besides monsoon, the easterly trade winds are also active, providing warm and relatively drier circulation. In Bangladesh there are four prominent seasons, namely, winter (December to February), Pre-monsoon (March to May), Monsoon (June to early-October), Post-monsoon (late-October to November).

The agriculture system is dependent on the availability of water across the year. Rainfall, surface and ground water are major sources of water availability. The mean annual rainfall is about 2300mm (Selvaraju et al., 2006), but there exists a wide spatial and temporal distribution. Due to inter-annual variability sometimes the timing of onset of monsoon exhibits anomalies for a few days to weeks. Peak flows inside Bangladesh occurs depending on the timing of onset of monsoon. In general, peak flows occur in July to August; the Brahmaputra exhibits its peak flows in July, while it occurs in the Ganges in August. Since over nine-tenths of the surface flow is received from outside Bangladesh, the rise and fall of the water level in rivers is governed predominantly by the amount of rainfall beyond (upstream) the country's political boundaries (Ahmad et al., 1994). An examination of hydrographs of major rivers suggests that the surface flows of the major rivers start to lower significantly following the withdrawal of monsoon in October. The rivers attain their lowest flows during January and March. During low flow, ingress of salinity occurs through the coastal rivers, which affects dry season agriculture. As a result,

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the Southwest Region (SWR) and the South Central Region (SCR), which together make up the Southwest Area (SWA), with small parts of the Northwest and Northcentral Regions making up the balance. Source: (Banglapedia, National Encyclopedia of Bangladesh); retrieved from http://en.banglapedia.org/index.php?title=Ganges_Dependent_Area

farmers tend to forfeit the most preferred crop (i.e., Boro) and cultivate, if at all possible, crops of lesser return.

5.3 Agriculture: Changes in Production and Labour Force

In keeping with the stylized facts of development, the share of agriculture in Bangladesh's GDP has been on a regular decline for the past four decades (Table 5.1). This trend is a part of the qualitative transformation (industry, manufacture and service sectors being larger contributing sectors) process of Bangladesh's economy. While there has been an accompanying declining trend in agricultural employment along with rising wages, almost half of the national workforce continues to be employed directly or indirectly in the agriculture sector (GoB, 2015a).

Table 5-1: Structural changes in Bangladesh' economy 1975-2016

	1975	1985	1995	2000	2004	2007	2010	2015	2016
Share of GDP(%)									
Agriculture	62	41.8	30.9	27.8	21.0	16.2	17.8	15.6	15.1
Industry	11.6	16.0	17.6	18.2	21.0	17.8	26.1	28.0	29.8
Manufacturing	7.0	9.9	9.6	9.9	16.0	17.2	16.9	20.2	
Construction and mining	4.6	6.1	7.0	8.6	8.0	9.14			
Service	26.4	42.2	51.5	54.0	55.0	NA	56.0	56.4	56
Share of employment (%)									
Agriculture	78.0	72.0	NA	62.5	60.3	48.1	NA	NA	NA
Industry	8.0	9.0	NA	12.0	12.7	NA	NA	NA	NA
Services	14.0	19.0	NA	25.5	27.0	NA	NA	NA	NA

Sources: World Bank and Bangladesh Bureau of Statistics (BBS)

Notes: Shares of GDP do not sum to 100 percent because categories overlap. For example, manufacturing, construction, and mining are sub sectors of industry.

It is worth noting that livestock outperformed crop sector but equally could not sustain the momentum it had gained during 2005-2010. This is an area in which special efforts are made to ensure that public services (veterinary, extension, insemination, etc.) are yet to be developed to the level required to realize the full potential of the sector. In 2012-13, fisheries achieved the target with a GDP growth rate (6.2%) at a time when the subsector has been marked by a radical structural transformation with the spread of organized and commercial aquaculture.

5.3.1 Production of Paddy

A wide range of crops grow in Bangladesh. They are broadly classified, according to seasons of cropping, into two major groups.

Kharif crops: Kharif crops are grown in the spring or summer season and harvested in late summer or early winter. Kharif season is divided into Kahrif I (March to June) an Kharif II (July to October).

Rabi crops: Rabi crops are sown in November and harvested in the spring or early summer).

Along the coastal belt, often Rabi crop is sown in late December and harvested in early summer, where the timing or Rabi crop is a bit earlier for the rest of the countries. Kharif crops are mostly rain fed and partially irrigated as they are grown in pre-monsoon and monsoon season. Rabi crops are grown in the dry season when there is almost negligible rainfall coupled with low flow in the surface, so Rabi crop is mostly irrigated.

Rice is the predominant crop in all seasons. Three types of rice are grown: Aus, Aman and Boro. Aus is grown in Kharif I, Aman in Kharif II, and Boro in Rabi season. Aman is mostly rain fed and Boro is completely irrigated paddy. Aus is cultivated in a small part now a days, and are not irrigated. Figure 5.1 shows trends for each kind of rice production, along with another major cereal Wheat for the period of 1972 to 2012.

Since late 90s, most of this growth in rice production has occurred through development and adoption of improved rice varieties, use of good quality seed along with fertilizer. During the period of 2009-14 we can also see use of salt- heat- water logging/ submergence tolerant varieties and high yielding varieties (HYV) supported by irrigation in dry season for Boro. Boro was introduced in low lying areas replacing rain fed Aus/Aman and rice of local varieties were replaced with HYV. Along with wheat, the total food grain production (cereal) has grown rapidly in Bangladesh (3.2% per annum) outstripping the population growth rate. Over the decades, Boro shares the major chunk of the total paddy production followed by Aman (Figure 5.1).

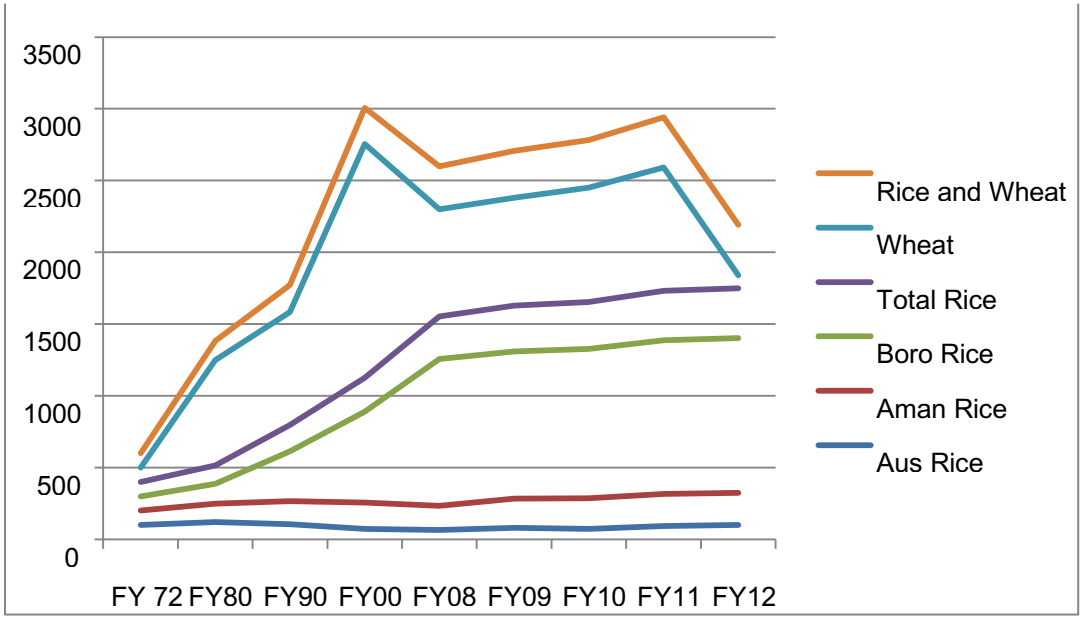

Figure 5-1: Trends of production growth of different types of paddy and wheat

Source: Government of Bangladesh 2015a. Background Paper on Agricultural Sector, Seventh Five Year Plan, Planning Commission, Dhaka

5.3.2 Land use pattern

The spatial distribution and trend of area where paddy is cultivated varies from region to region. The temporal trends in Aman area follow the pattern more or less similar to the country trend. South west and south east have the highest proportion of net cropped area under Aman cultivation (about 80% in 2012-13).The net cropped area under Boro cultivation is the lowest in

the south west region, about 40%. The main reason for that is the unavailability of fresh water for irrigation in the dry season and salinity (Mainuddion et al., 2013).

In terms of distribution of crop area as percentage of net cropped area for different types of paddy in different regions, Boro accounts for the lowest portion of area covered in the southwest region (Figure 5.2). On the contrary, northwest region exhibits a higher level of land use by Boro (65%), slightly lower than that of Aman.

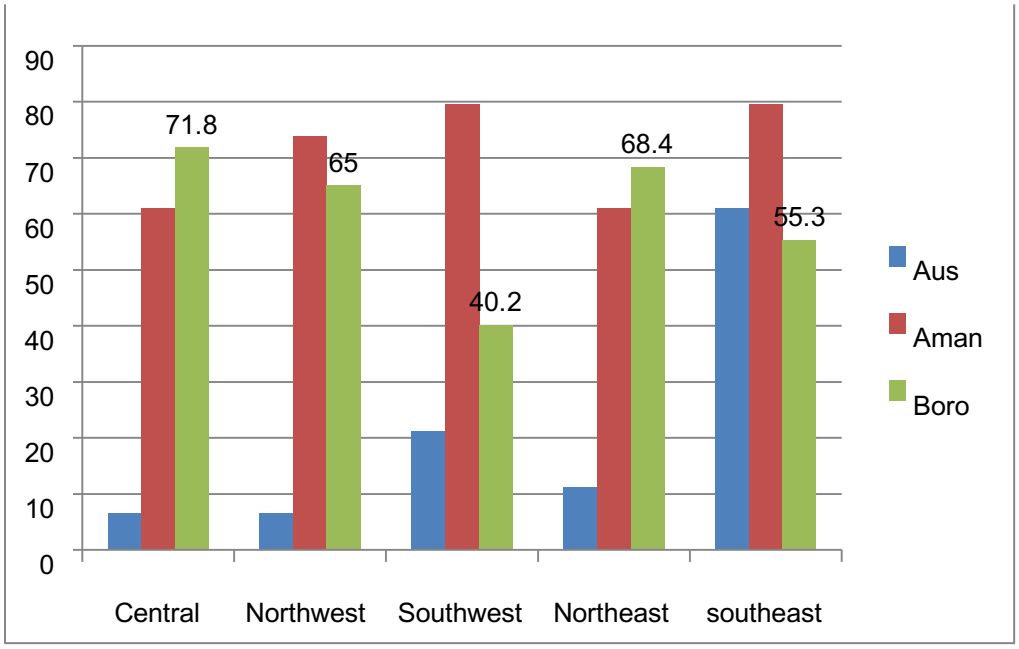

Figure 5-2: Crop area as % of net cropped area in different regions, 2012-13

Source: Qureshi A.S., Ahmad Z.U., Krupnik T.J. 2015

Table 5.2 indicates that there have been significance expansions of High Yielding Varieties for all the major types of paddy. Owing to the fact that HYV provide higher yield, these have become the predominant varieties. Currently, 70% of Aman varieties are HYV, while for Boro it accounts for more than 85%.

Table 5-2: Land use trend by different paddy

	Area ('000'Acres)				
		1994-95	2002-2003	2007-2008	2012-13
Aus	Local	3066	1920	885	653
	HYV	1020	1153	1385	1949
	Total Aus	***4111***	***3073***	***2270***	***2602***
Aman	Broadcast	2361	1719	761	913
	T.Local	6158	5061	3308	3128
	HYV	4606	7261	8405	9822
	Total Aman	***13823***	***14041***	***12474***	***13863***
Boro	Local	628	440	311	163
	HYV	5847	9061	0119	10082
	Hybrid Varieties (HYB)			1956	1518
	Total Boro	***6582***	***9501***	***11386***	***11763***
		24517	**26615**	**26130**	**28228**

Source: Compilation from Seventh Five Year Plan Documents, Planning Commission, Government of Bangladesh 2015b.

5.3.3 Yield of paddy

Average yield of Aus, Aman and Boro rice has increased consistently, with some ups and downs as, at an average rate of 0.0236, 0.0284, and 0.0561 tonne/ha/year, respectively during this period 1976-77 to 2009-10. However, the rate of yield growth is much higher and strongly linear since 1994-95 (Table 5.3). The rate of growth in Boro rice is 115% and 80% higher than that of Aman and Aus rice. Boro is fully irrigated crop so the risk of this suffering from water stress is much less than Aman and Aus rice, which are rain fed. Due to variation in rainfall over space and time, Aus and Aman rice suffer from in-seasonal water stress which is the main reason of their low yield and yield growth (Islam and Mondal, 1992; Jensen et al., 1993). In addition to that, Aus and Aman rice (particularly Aman) also suffer damage due to inundation and flood from heavy rainfall (Roy, 2013).

Table 5-3: Trend of Yield of different types of paddy

	Per Acre Yield(KG)				
		1994-95	**2002-2003**	**2007-2008**	**2012-13**
Aus	Local	353	470	461	516
	HYV	685	821	794	934
	Total Aus	***718***	***602***	***664***	***823***
Aman	Broadcast	436	489	2377	480
	T.Local	383	619	502	646
	HYV	506	983	918	1063
	Total Aman	***615***	***792***	***774***	***930***
Boro	Local	537	794	727	840
	HYV	1045	1310	1534	1562
	HYB			1816	1903
	Total Boro	***993***	***1286***	***1560***	***1596***
		687	**946**	**1107**	**1199**

Source: Compilation from Seventh Five Year Plan Documents, Planning Commission, Government of Bangladesh 2015b.

5.3.4 Labour Force Participation

Agriculture in Bangladesh has seen decreasing participation of male labour force over the years.

It is reported that adult male participation in agriculture has sharply declined from 83% in 1988 to 56% in 2000 (Table 5.4).This has however, increased to some extent to a level of 65% in 2008. Participation of women in agriculture on the other hand remained almost the same in 1988 and 2000, but has increased by about 8% in 2008.

Table 5-4: Changes in Labour Force Participation in Agriculture

	1988	2000	2008
Male	83%	56%	65%
Female	59%	58%	66%

Source: BBS and LFS

Findings also indicate that decrease in agricultural activities by adult male was due to less involvement in crop cultivation in recent years. About 79% adult males were engaged in crop cultivation in 1988 which has dropped to only about 42% in the year 2000. Although there had been some increase in male participation in crop cultivation in 2008, reduced involvement is due to mechanisation. In recent years many of the farm operations (i.e. tillage, irrigation, threshing of paddy, etc.) are now fully or partially mechanized.

Women involvement in crop cultivation has also sharply declined from about 23% in 1988 to about 3% in 2000 and 4% in 2008. This is mainly because of the fact that involvement of women in post-harvest operations, particularly for rice processing (i.e. winnowing, drying, parboiling, husking /milling, etc.) have been largely mechanized. At present, women are being involved mostly in livestock and poultry production activities rather than crop production activities. Participation of adult women in livestock and poultry production activities increased from 43% in 1988 to 51% in 2000 which further increased to 69% in 2008. Involvement of women in homestead gardening in recent years has also increased in recent years. Findings showed that in 2008, 18% of adult women household members took part in homestead gardening compared to about 9 to 10 percent in the years of 2000 and 1988 respectively. Credit support from NGOs (sometimes supported by training) has largely facilitated involvement of women in livestock and poultry rearing as well as in homestead gardening in rural Bangladesh.

Labour Force Survey (LFS) data also indicate that only 2.45% of the women participated as wage labour compared to 24.63% for men in 1988. Participation of women in agricultural activities as wage labourer has further decreased to about 1% in 2000 and 2008. On the other hand, participation of male wage labourer has also decreased to some extent from about 25% in 1988 to about 22% in 2000 and 23% in 2008. The analysis also showed that agricultural wage rate for both men and women increased overtime. However, wage of women was always low compared to men throughout all the periods since 1988. In 1988, compared to men, female wage in agriculture was 26% less while in 2000 and in 2008 it was less by 42% and 39% respectively.

5.3.5 Food-Water-Energy-Environment Nexus

In this section we focus on irrigation and fertilizer use and analyse their impact on food-water-energy-environment nexus in Ganges Basin. Farmers have been practicing irrigation using surface water from nearby sources for a variety of crops including Aman and a number of non-grain Rabi crops. There have been local Aman species/ cultivars that requires very low level of supplementary irrigation. Traditional irrigation techniques have been used extensively. With the advent of green revolution in the mid-60s, and with the development HYV seeds, people began to irrigate land heavily. The initial results have been excellent in terms of grain yield. However, over the years, the requirement for fertilizers and irrigation has increased significantly as a result of the gradual deterioration in land quality due to the erosion of major nutrients, micronutrients, and organic carbon contents from the top soil.

Irrigation

Various technologies have been used for irrigating crops which have contributed to rapid expansion of irrigated area. The conventional irrigation methods (Low Lift Pump, *Dhone*, Swing Basket, Treadle Pump etc.) were replaced by modern methods (i.e Deep Tube Well and Shallow Tube Well). In addition, surface water irrigation also sharply declined, losing its importance due to lack of new surface irrigation project and the ineffectiveness of earlier project. Major groundwater extractions (62%) occurred through Shallow Tube Wells (STWs).

The surface water systems of the country largely depend on upstream countries: Nepal, India, Bhutan, and China, with which Bangladesh shares 54 common rivers. Increasing upstream water withdrawal and the diversion of water from the main transboundary courses reduced the flow in Bangladesh significantly during the dry months (Rahman et al., 1990; Ahmad et al., 1994; Halcrow and associates, 2001). Consequently, the possibility of surface water irrigation in the country has been reduced considerably.

To maintain self-sufficiency in food production, farmers have adopted to the use of modern irrigation techniques. Mechanized pups have replaced the traditional method of transferring water. Table 5.5 shows gradual development of various forms of irrigation with respect to time and technology.

Table 5-5: Area under irrigation in Bangladesh

Irrigation source	1984-85	1989-90	1994-95	1999-2000
Groundwater				
Shallow Tube Well (STW)	586	1037	1638	2252
Deep Tube Well (DTW)	287	384	502	465
Manual	16	16	25	65
Subtotal for ground water	889	1437	2165	2782
Surface water				
Low lift pumps	351	484	538	624
Canals	147	176	352	424
Traditional	354	478	250	202
Subtotal for surface water	882	1138	1140	1250
Total irrigated area	1771	2576	3305	4032

Source: Agriculture Statistical Year Book, BBS, various year

It is evident from Table 5.5 that the total irrigated area more than doubled from 1985 to 2000. Moreover the contribution of surface water and ground water was almost equal in 1984-85. The recent expansion of total irrigated area was made possible due to about a threefold increase in ground water irrigation, as against only about 44% increase in surface water irrigation during the same time.

The growth in irrigation is not uniform over the regions and appears to be slowing down in recent years. There is no growth in irrigation particularly since 2007-08 in the central, northwest and southwest regions. Southeast and southwest region is the least irrigated area (about 45% of the NCA) of the country. The main reason for this is the lack of fresh water for irrigation and salinity in the soil and water during the dry season (Mainuddin et al., 2013). Significant increase in irrigation area physically in these two regions may not be possible in short-term.

About 95% of the Boro area is irrigated. Other 5% may be grown in the low lying area where irrigation is not necessary. Usually, no irrigation is provided for Aus and the crop suffers from water stress. However, the Government of Bangladesh has been focusing on expanding rain-fed Aus rice production, encouraging the introduction of saline and submergence-resistant varieties (Hussain, 2013). Aman, due to variation in rainfall and prolong-period of no rainfall, sometimes suffer from water stress which is affecting its productivity. Supplementary irrigation is necessary in some years to have good yield of Aman (Jensen et al., 1993). However, only about 10-11% of the total cultivated area is currently (2009-10) under supplementary irrigation and the area irrigated is slowly increasing.

In terms of relative efficiency of input use Bangladeshi farmers are least efficient in irrigation water management compared to land, labour, power tiller and fertilizer use. From the extant literature it is evident that the main source of inefficiency is the high nominal price of diesel. As a result farmers who are using diesel instead of electricity are incurring higher irrigation expenditure for the same amount of irrigation water per ha and are expenditure inefficient relative to farmers who are using electricity. Not all pumps have the same level of efficiency. Lowering of groundwater table at many places in Bangladesh also cost farmers more in terms of energy expenditure for pumping the same amount of irrigation water.

The low efficiency might also be a manifestation of average prices of irrigation water paid by water user groups in case of surface water irrigation projects handed over by Bangladesh Water Development Board (BWDB). Although farmers using STW and LLP are mostly privately owned and are efficient compared to farmers using canal irrigation projects and government owned DTW, some of them may be using more water than required due to indivisibility of shared tube well. But this is subject to further research. One-fourth of crop share as a payment method for irrigation water at many places also gives rise to a flat seasonal fee (marginal cost being zero) and overuse of water in many cases.

These findings are very important in the context of food inflation and high input prices. Increasing diesel price is increasing expenditure on irrigation, cultivation as well as food prices. In any case since Boro rice production requires a lot of water as an input, farmers must increase efficiency in irrigation water allocation to Boro rice production. Hence, agricultural extension will play a very important role. Introduction of rice varieties that require less water for irrigation per hectare is deemed mandatory. In order to run the pumps with electricity, stability in power supply is a must that will reduce irrigation expenditure as well as cultivation expenses drastically. In this endeavour there is no alternative to 100 percent rural electrification. However, in order to induce efficient use farmers must be encouraged to pay marginal prices for maintenance and cost recovery of public irrigation projects.

Fertilizer usage

In order to strike stability between safeguarding environmental components and increased agricultural productivity, it is necessary to look into the impact of fertilizer use. Before the 1950's, the peasant-farmers of Bangladesh used to apply organic manures such as cow dung, bone meal etc. in Aus and Aman rice fields and farmyard manure (FYM), mustard oil cake and fishmeal for the mustard and vegetable crops. Consumption of chemical fertilizer began to increase rapidly with the introduction of HYV rice (i.e. IR5 & IR8) and use of LLPs. Now-a-days, chemical fertilizers consist of more than 75 percent of total fertilizers used for rice production. The farmers of Bangladesh mostly rely on chemical fertilizers for higher production, without or less application of compost. Such a fertilizer management practice leaves a massive deterioration of soil fertility, resulting loss in organic content.

By analysing the rice yield data for 35 years (1971-72 to 2005-06), it is found that rate of rice production is continuously increasing over the years. In 1971-72, the average rice yield was 1.05 metric ton per hectare and reached at 2.52 metric ton per hectare in 2005-06 (BBS, various years). Therefore, average rice yield increased 2.4 times in 35 years largely due to the increased use of fertilizer. In 1975-76, fertilizer application was 0.36 kg per hectare in agricultural land, whereas in 2007, this application was above 298 kg per hectare (Government of Bangladesh 2015).

In 1985-86, fertilizer has contributed 36 percent to the total soil fertility whereas in 2002-07, this contribution was 40 percent. Thus, the increasing response of fertilizers over the time indicates the degradation of soil fertility. Therefore, it is urgent to conserve and add nutrients to the soil

through the balance application of compost and inorganic fertilizers, which can help, maintain and increase the nutrient reserves of the soil.

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% (Z. Karim, 1997). Farmers normally use urea in recommended doses. However, they apply P and K fertilizers at the rates that are far below the recommended amount because of high prices. 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.

Land degradation, serious health hazards and degradation of aquatic resources are caused by excessive use of chemical fertilizers, pesticides and lack of crop diversification (monocropping of rice) during Boro season. At the same time, over exploitation of groundwater for irrigation is causing a reduction of the groundwater aquifer in the Barind Tract. These factors will create serious problems for the environment and agricultural production in the future especially when combined with climate change.

Soil degradation is commonplace in Bangladesh, whether man-made (for example, through unbalanced use of fertilizers) or due to natural factors (salinity ingress in coastal areas, or landslides on the hilly terrains). Estimates by BARC (2000) indicate that soil related problems may be a major constraint on agricultural growth. Organic matter depletion is observed in 7.5 million hectares of land. Declining soil fertility, soil erosion, and salinization affect respectively 5.6–8.7 million hectares, 5.3 hectares, and 3.05 million hectares of land. It is estimated that Bangladesh soil loses annually some two million metric tons of nutrients. Unless compensated through balanced application of nutrients every year, the fertility of land is expected to decline and so will its productivity. As per Seventh Five Year Plan document (GoB, 2015), about one percent of crop GDP will be lost every year. Sustainable land management is therefore a major challenge for now and also in the future.

5.3.6 Natural Hazards

Bangladesh is generally known as a hazard-prone country (Rahman et al*.,* 1990; Ahmad et al*.,* 1994), and most of her physical contexts of vulnerability may be attributed to water-related hazards. In this section we will discuss drought and flood, both of which are prominent in EGP and GDA.

Droughts

Every five years, Bangladesh is affected by the major country-wide droughts. However, local droughts occur regularly and affect crop production. The agricultural drought, linked to soil moisture scarcity, occurs at different stages of crop growth, development and reproduction. Monsoon failure often brings famine to the affected regions and as a result crop production reduces drastically. The dry season (November to April) experiences moisture stress often leading to phonological drought. However, due to concerted efforts by agricultural scientists, relentless efforts by the farmers (with the help of government), drought, especially in the Western part of Bangladesh, has become a ‘managed hazard’ now days.

Most of the drought prone areas in Bangladesh are in the EGP (northwest and southwest regions). In the pre-diversion period meteorological drought was common in the Ganges basin, This kind of drought is referred to as a sustain period of time without significant rainfall (Linseley et.al. 1975). During the pre-diversion period, agricultural drought was minimized by irrigation from the surface water resources that include the Ganges and its distributaries, ponds and other water bodies. This type of drought occurs when rainfall and soil moisture are inadequate for healthy crop growth during the growing season, leading to extreme crop stress. In the post-

diversion period, due to the reduced flow in the Ganges system, hydrological drought has become a regular phenomena. Linseley *et. al*. (1975) defined it as a period during which stream flows are inadequate to supply established uses under a given water management. The uses include discharge required for fisheries, navigation, domestic and industrial sectors and surface water irrigation.

Bangladesh experienced drought in 1973, 1978, 1979, 1981, 1982, 1989, 1994, and 1995. The drought in 1973 accentuated the famine in 1974, the EGP was the most affected areas. The drought during 1978-79 was the most severe drought resulting in wide spread damage to crops (rice production which was reduced to 2MT only). Rice production losses due to drought in 1982 were about 50% more than losses due to flood that same year. Losses in 1997 drought is estimated to be 1 Mt and valued at about US$500 million (Silvaraju et al., 2006).

The drought problem in Bangladesh reaches its peak during the Rabi season that extends from mid-October to early April. December, January and February are the months with negligible rainfall across the GBM river system in the Eastern Himalayan region (Ahmad et al., 1994). As a result, river flows are at their minimum. From March to early April, the temperatures shoot up rapidly, particularly during the day. These condition leads to high potential evapotranspiration (PET), causing acute moisture stress in the top soils. When residual moisture can no longer support the standing crops, drought develops and adversely affects crop production. The land with very poor moisture-holding capacity, found the Barind track (part of the northwest), faces the worst consequences of drought during the Rabi season.

However, groundwater irrigation involves high production costs, especially for the poor farmers engaged in subsistence agriculture. Half of the farming community in Bangladesh, with no exception in the northwest, does not have any crop land; either they are share croppers, or they offer physical labor. For the share croppers, irrigation appears to be an economic burden which the owners do not share.

Floods

About 20% of the landmass in Bangladesh experience regular flooding every year, and a two-third of the country can be affected in a year of severe flooding. The whole of the GDA in Bangladesh is flood prone. People and their livelihoods, especially agriculture, have adapted to such annual events over the centuries and found ways to take advantage of the phenomenon.

Besides the increasing extent of inundation, increase in population and infrastructure in the flood plain are also largely responsible for such increase in damage. In 1998, one of the most severe floods in recent times inundated 65% of the whole country. The duration of the flood was more than two months, during which the government had to provide shelter and food to more than 20 million people.

Major flood events are accompanied by sharp decline in Aman and Aus production, while in most cases Boro takes the compensating role. Observing the trend of rice production (for all major varieties), it is interesting to note that Boro performs as a compensating role, while the Aman production is largely damaged by the monsoon flooding farmers try to recover from that loss through investing more on Boro (Table 5.6).

Table 5-6: Comparison of losses resulting from recent large floods

Item	1988	1998	2004	2007
Inundated area of Bangladesh (%)	60	68	38	42
People affected (million)	45	31	36	14
Total deaths (people)	2,300	1,100	750	1110
Livestock killed (no's)	172,000	26,564	8,318	41,700
Crops fully/partially damaged (million ha)	2.12	1.7	1.3	2.1
Rice production losses (million tons)	1.65	2.06	1.00	1.2
Roads damaged (km)	13,000	15,927	27,970	31,533
No. of homes (fully/partly) damaged (million)	7.2	0.98	4.00	1.1
Total losses				
Tk (billion)	83	118	134	78
US$ (billion)	1.4	2.0	2.3	1.1

Source: World Bank (2007)

Stress tolerant varieties, with the help of agriculture researchers and Agriculture extension services, GoB-NGO collaboration in many areas have been expanding. Farmers get yield rates of flood tolerant rice varieties between 4 to 5.5 tonne paddy per hectare during Aman season even after submergence of growing rice plants for over two weeks during floods.

5.3.7 Challenges of Sustainable Agriculture

Considering food-water-energy-environment nexus, we can summarize that the key consequences of agricultural growth in Bangladesh are (on the supply side) poor water resource management, high energy prices for irrigation and soil degradation due to fertilizer, in the face of a rapidly growing, increasingly urbanized and more affluent population with changing tastes (on the demand side). The supply side consequences are likely to be aggravated by few interrelated external factors threatening food-water-energy security and thereby posing enormous challenges for the future of sustainable agriculture in Bangladesh. In this section we discuss four external factors: transboundary water management, salinity and water-logging, climate change and feminization of agriculture.

Trans-boundary Water Management

In addition to natural seasonality of rainfall, expansion of irrigation in the upstream basin areas particularly in the Indian states of Uttar Pradesh and Bihar has further constrained water

availability in the dry season in Bangladesh part of the Ganges basin. On the Ganges and its tributaries, at least 34 barrages/ structures are functional in India and Nepal. The actual amount of water being diverted through these diversion structures is not known. However, as many as 400 lift irrigation points along the Ganges in the Indian States of Uttar Pradesh and Bihar siphon off water between 600 m3/sec- 1,100m3/sec before the river reaches to Farakka (Mirza, 2002). Diversion of water through Farakka through a massive barrage has caused a drastic reduction of the Ganges discharge in areas downstream of the barrage in India and in Bangladesh in the dry season.

In the Ganges basin of Bangladesh, regular water supply from upstream is particularly needed during the dry season (November to May) for agriculture, domestic, river regulation and industrial purposes, maintaining river depths, sustaining fisheries and forestry, and keeping in check the inland penetration of sea water from the Bay of Bengal causing salinity. Until commissioning of Farakka barrage in 1975, the river was unregulated and the supply of water in the dry season was adequate (Mirza, 2002).

Of the 54 common rivers between Bangladesh and India, there is a dry season water sharing treaty only for the Ganges River. The treaty is based on water available at the Farakka Barrage (a Barrage constructed over the river Ganges in the West Bengal state of India during 1961-1975 which is 17 km upstream of the Bangladesh border). There is an increase in water use upstream of Farakka Barrage; as a result, the Bangladesh share of water in the dry season is also getting reduced day by day. This situation may worsen further if the Indian River Linking Project is executed by India.

Salinity and Water-logging in Southwest Region

One of the major pitfalls of weal transboundary water governance in the Ganges basin is the salinity in the Southwest region. The most dramatic hydrological effect has been observed in the region ever since the Ganges flows have been withdrawn by the upstream neighbour India by building and commissioning of the Farakka barrage in 1975 (Mirza 2004, Halcrow-WARPO 2001). The adverse impacts reached their height during the period between 1990 and 1996, when the Gorai River has been found completely disconnected from its tributary, the Ganges River (DHV-WARPO 2000). As a consequence, most of the smaller rivers in the region choked during every dry season, allowing salinity to penetrate inland towards north. Accordingly, the mixing zone between freshwater and brackish water has been shifted towards north. During the dry season, a combination of extreme low flow and increased salinity accelerates the processes of sedimentation in the riverbed, which eventually choke the river and drastically reduce its drainage capacity (Rahman et al., 2000). This is how drainage congestion becomes a regular phenomenon in that river, resulting into overbank spillage during each peak monsoon. Consequently, the entire basin becomes water logged for a certain period of the year.

Under climate change induced increasing salinity along the coastal rivers, the above processes will be aggravated. This in turn will further complicate the current state of water logging (Ahmed et al., 2007). It is inferred that water logging will be spread over a larger area, involving increasing number of smaller river basins within the southwestern and south central regions.

Climate Change

It is acknowledged globally that Bangladesh will be at the forefront of adverse impacts of climate change, while her marginal population will bear the brunt of most of the adverse impacts (Huq et al., 1996; GoB 2012). Scientific analyses suggest that warming of the surface will aggravate moisture stress and drought (Habibullah et al., 1998; Selvaraju et al., 2006), while excess evaporation of moisture will give rise to wetter peak monsoon in the country (Alam et al., 1998).

Therefore, the phenomena of too much water during monsoon and too little water during drought will exacerbate the prevailing situations under climate change, affecting lives and livelihoods of people and putting subsistence based agriculture at severe risks (GoB 2012). Meanwhile, a change in cyclonic behaviour would further deteriorate coastal living conditions. Sea level rise is expected to push saline front propagating inland, which will further complicate coastal productive system (CEGIS 2006). With increasing flow volume in monsoon, the erosion problem will be aggravated along the braided rivers. Coastal erosion in the sea facing areas will force people to leave their ancestral lands as agriculture in those areas will become extreme hazardous (Ahmed, 2008).

All these snapshot effects will have secondary implications such as food and health insecurity, loss of lives and livelihoods, damage to infrastructures, loss of productive assets and damage to national/local economy (GoB, 2012, Yu et al., 2010). A dynamic computable general equilibrium model (GCE) was used by Yu et al. (2010) to estimate the impacts of existing climate variability along with future climate change in Bangladesh on agriculture sector. It was estimated that the agricultural GDP growth rate will decline within a range of 3.13 to 3.46 percent per year during 2005–50 under the 'Climate Variability Scenario'. This drop in the growth rate causes substantial economic losses over the 45-year period 2005–50. For example, existing climate variability results in a loss of US$ 120.96 billion in agricultural GDP during 2005–50 (measured in 2005 prices) with an average economic loss of US$ 2.68 billion per year, which is, under 5% discount rate, about US$ 25.78 billion with an annual loss of US$ 0.57 billion. This means that 1.1 percent of agricultural GDP is lost on average each year as a result of existing climate variability.

Feminization of Agriculture

A new development in the agriculture sector in recent years is that the proportion and also the absolute number of male farmers and farm workers have fallen while those of female farmers and farm workers have risen. The proportion of women in the total number of employed agricultural workers has increased from 20 percent to more than a third of the total since 1998/99. This development will have policy implications relating to the organization of agricultural production and the nature of support to the sector.

In the southwest region, because of lower cropping intensity and prevalence of higher incidence of poverty, migration to nearby cities or to big cities, are quite common. Usually male members of the families migrate, leaving behind women and rest of the family members. In such cases women have to take all the farm and non-farm responsibilities. Department of Agriculture Extension maintains Women's Clubs to train them with agricultural skills at grassroot levels. Water conflict especially during dry season in the drought prone northwest is quite common. Women in this part face huge challenge colleting drinking water, also face food insecurity as a consequence of crop loss, if any. In case of flood and cyclone, difficulties in household management coupled with serious threat to health, women takes the primary responsibility to the agricultural cultivation, when men are not around.

Most of the technologies developed for agriculture are related to pre-harvest crop production activities in which male farmers are mostly involved. Women friendly pre-harvest as well as post- harvest technologies for crop production and processing technologies need to be developed for effective participation of women in agriculture. This needs attention from both the researchers and planners.

The Government of Bangladesh decided to provide "Input Assistance Card" to the farmers to access subsidies through these cards. Department of extension, in 2015, identified more than 20 million farmers throughout the country, there has been no sex disaggregated data. The

manual for identification of farmers states about the ownership of land or a contractual lease deed in favour of a person to become a farmer. In terms of ownership, or having contract by her own name, women in Bangladesh involving agriculture sector are lagging behind. The Government of Bangladesh provides “Gender Budget” for different Ministries, supplementary to main budget speech, where the activities taken by different Ministries are stated. Agriculture Ministry, in its gender budget statement, calls for investment on female farmers, through providing skills appropriate to the changing cropping pattern in the country. In Gender Budget, 2015, there was a strong commitment to include females as farmers and provide them with the “Input Assistance Card”.

5.3.8 Policies for Sustainable Agriculture

With regards to agriculture, the Seventh Five Year Plan aims to accelerate the transformation from semi-subsistence farming to agriculture commercialisation through productivity gains, diversification, value addition and agro-processing. The plan supports diversification into higher value-added activities and employment opportunities for surplus agriculture labourers into non-farm activities. The plan aimed to integrate environmental, climate change and disaster risk reduction considerations into all development assistance projects, government budgetary allocations and implementation processes in order to ensure sustainable and equitable growth and development.

Within this policy framework, the National Agriculture Policy aims to encourage sustainable and profitable agricultural production, through the development and dissemination of new technologies; increased productivity; employment and income generation; commercialisation; adaptation to climate change; marketing; enhancement of quality to meet export standards; agro-processing; encouraging production of diversified, nutritious crops; and empowering women.

The current focus of the Ministry of Agriculture is to make farming more profitable so that farmers will remain on their land and continue to produce food in order to ensure national food security. They are focusing efforts on Southern Bangladesh and surface water irrigation, rather than the northern agriculture dependence on groundwater irrigation. The ministry has specific policies supporting development of key agricultural industries such as cereal production, horticulture (vegetables and fruits), export industries, and research and development. Policies also exist for important agricultural support services such as agriculture extension, finance, environmental sustainability and natural resource management.

Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009) prioritizes six thematic areas, of which, “Food security, social protection and health” are one of the major six pillars. Under this pillar, GOB will focus on

1. Increase the resilience of vulnerable groups, including women and children, through development of community level adaptation, livelihood diversification, and better access to better services and social protection.
2. Develop climate change resilient cropping system (agricultural research to develop crop varieties which are tolerant of flooding, drought and salinity, and based on indigenous and other varieties suited to the needs of resource poor farmers), fisheries and livestock systems to ensure local and national food security.

A Climate Public Expenditure and Institutional Review was conducted in Bangladesh which revealed that the GOB typically spends around 6 to 7% of its annual combined development and nondevelopment budget on climate sensitive activities. The amount was estimated at about US$ 1 billion/annum (GED, 2012). The review also revealed that other than major 37 ministries,

a large number of local government institutions at Upazila and Union Parishad carry out climate sensitive activities. Disaster management sector generally spent about 17.5% of all direct spending in CCA (GED, 2012).

Irrigation will be crucial in the context of climate change. Introduction of 'Alternate Wetting and Drying (AWD)' irrigation technique by the Department of Agriculture extension (DAE) has been found to be promising in increasing water use efficiency for crop production. In the comparatively dry northwestern region (and Barind region), Barind Multipurpose Development Authority (BMDA) ensures irrigation for rice where 100 hour free electricity bill for irrigation of Aman season are provided to the farmers from the Ministry of Agriculture (MoA) since 2009. A 20% rebate in the electricity bills for irrigation throughout the country to encourage irrigated cropping has also been provided by the government. Both the Bangladesh agriculture development Cooperation (BADC) and BMDA are in pursuit of increasing irrigation coverage by taking newer projects and programmes in every year.

Soil resources of the country are experiencing pressure for increased food production. Increasing cropping intensity and mineralization of soil organic matter exhausts the soils capacity to support crops. Soil Resources Development Institution (SRDI) under theMoA is working to improve soil health and preserve it for future generation. The institute prepared *Upazilla* Land and Soil Resources Utilization Guide for 459 upazillas throughout the country that will help farmers to apply fertilizers according to the need based on fertility status of the soil. Moreover, MoA is working with the Ministry of Land to enact proposed Agricultural Land Conservation and Land Use Act, 2011 to safeguard agricultural lands from encroachments for developments.

5.4 Concluding remarks

Sustainable agriculture in Bangladesh, given the hydro geophysical context, regional politics and uncertainty with future potential threat under climate change, entails a thorough and all-inclusive review of current policies surrounding food-water-energy- environment nexus. The post-green revolution period has not experienced any major breakthrough in terms of technological advancement on the one hand, and the poor and marginal farmers who comprise the majority of total farm population cannot afford the high cost of using high input technologies in agriculture on the other. Our discussion indicate that Bangladesh not only needs investment in R&D to develop stress tolerant crop varieties and alternative energy sources, but also the policy incentives for private sector involvement in commercialization of agriculture and for inclusion of marginal farmers to local or regional value chain. To conclude, of utmost importance is perhaps the regional dialogues among national and international stakeholders and decision makers across the countries to build a resilient food-water-energy system in the Ganges basin.

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6 Sustainable Intensification of Agriculture in the Eastern Gangetic Plains of India

6.1 Introduction

Eastern Gangetic Plains (EGP) cover the states of Bihar, West Bengal and eastern parts of Uttar Pradesh in India, the *teraii* region of Nepal and Bangladesh. We will focus mainly on Bihar and West Bengal in this report.

A large fraction of the population in EGP in lives in rural areas (89% in Bihar and 74% in West Bengal) and depends directly or indirectly on agriculture for livelihoods and income. Population pressure on land is high and the average landholding size is small—even by South Asian standards. The region is also home to the highest density or rural poverty in the world and the incidence of poverty is the highest among agricultural laborers and sub-marginal farmers cultivating less than 0.5 ha land. Agricultural intensification, therefore, is essential for reducing poverty in the region. Long-term data on economic growth and poverty also show that among different sectors of the economy, growth in agricultural GDP makes the biggest dent in poverty in India (Ravallion and Dutt, 2002).

Green revolution started late in the EGP, and even today, crop yields, cropping intensity, adoption levels of new technologies and inputs and profits from agriculture are lower in the region compared to the western Indo-Gangetic basin. This is true especially for Bihar, but also for West Bengal. Resource depletion and degradation are emerging as major challenges to sustainable agriculture in the EGP even at low levels of agricultural productivity. The region is also highly vulnerable to climate change (Sehgal et al, 200x). Sustainable intensification of agriculture to make farming more profitable and more resilient to weather shocks and climate change is, therefore, a high priority for the policy makers in both states.

This paper tries to assess the performance of agriculture in Bihar and West Bengal, the two main EGP states in India, on five dimensions viz., livelihoods, risk, productivity, sustainability and intensification in preparing the roadmap for sustainable intensification of agriculture in eastern IGP.

6.2 Livelihoods from Agriculture

A large fraction of the working population in EGP depends directly on agriculture for livelihoods and income. According to Census of India 2011, cultivation or agricultural labor is the main occupations of 77.3 percent of all working men and women in Bihar and 44.2 percent of them in West Bengal (Table 6.1). Working women in these two states are more likely to be engaged in farming than working men because they have fewer employment opportunities in other sectors of economy.

Table 6-1: Distribution of Workers by Occupation in Bihar, West Bengal and India in 2011

State	Gender	Total Workers	Cultivators*	Agricultural Laborers*
		(in millions)**		
Bihar	Persons	27.97	8.19 **(29.3)**	13.40 **(48.0)**
	Male	20.48	6.46 **(31.5)**	8.25 **(42.6)**
	Female	7.49	1.74 **(23.2)**	5.16 **(62.6)**
West Bengal	Persons	29.48	5.65 **(19.2)**	7.36 **(25.0)**
	Male	22.39	4.65 **(20.8)**	5.08 **(22.7)**
	Female	7.093	1.00 **(14.1)**	2.28 **(32.2)**
India	Persons	402.23	127.31 **(31.7)**	106.78 **(26.5)**
	Male	275.01	85.42 **(31.1)**	57.33 **(20.8)**
	Female	127.22	41.90 **(32.9)**	49.45 **(38.9)**

* Numbers in parentheses show the percent of total workers in a group

** All numbers are rounded off to second decimal place

Source: http://censusindia.gov.in/Tables_Published/A-Series/A-Series_links/t_00_009.aspx

The population pressure on land is high in the region. There is only 0.3 ha of cultivable land per agricultural worker in Bihar and 0.57 ha in West Bengal. Landholdings are also very small in both states. The average landholding size is only 0.39 ha in Bihar and 0.77 ha in West Bengal. Holdings smaller than 1 ha account for 90 percent and 83 percent of all landholdings in Bihar and West Bengal respectively (Table 6.2).

Table 6-2: Average Landholding Size in Bihar and West Bengal in 2011

Size of holdings	Bihar		West Bengal	
	Number* (millions)	Area (Mha)	Number* (millions)	Area (Mha)
Below 0.5 ha	12.05 **(74.44)**	1.94	4.21 **(59.12)**	1.58
0.5-1.0 ha	2.69 **(16.62)**	1.72	1.64 **(23.04)**	1.31
1.0-2.0 ha	0.95 **(5.85)**	1.19	0.98 **(13.76)**	1.56
> 2.0 ha	0.50 **(3.08)**	4.85	6.83 **(4.08)**	4.45
Total	**16.19**	**6.39**	**7.12**	**5.51**

Note: * Numbers in parentheses show the percentage share of holdings in the given size group in all holdings

All number are rounded to nearest second decimal places

Source: Agriculture Census 2011

Generating employment for millions of farmers and farm laborers, including women who find work mainly in agriculture, and securing sustenance for their families from very small landholdings is the major livelihood challenge for agriculture sector in eastern Gangetic plains of India.

High population pressure on land combined with relatively low crop yields results in lower average per capita income of farm households in Bihar and West Bengal than the national average (row 1 of Table 6.3). The average annual farm incomes in EGP states annual farm incomes are also nearly half of the national average in these two states (Rs. 3677 and 4054 vs. Rs. 7255). Such low farm incomes are a major problem for the region, especially for Bihar, where farmers have few other sources of income. According to the Situation Assessment Survey of Farmers (SASF), agriculture and allied sectors account for nearly three-fourth (71.4%) of the income of farm households in Bihar compared to 65.2% in India and only 42.5% in West Bengal. Comparing SASFs in 2003 and 2013, Chandrasekhar and Mehrotra (2016) find that Bihar and West Bengal were the only two states in India where per capita income of farm households declined over this ten year period. In all other states, incomes remained stagnant (Assam and Jharkhand) or increased significantly.

Table 6-3: Per capita income of farm households and its sources

	Bihar	West Bengal	Haryana	Punjab	India
Per capita income (INR)	7823	10,868	29,570	41,195	15,052
Sources of Income (%)					
Wages and salaries	23.7	45.5	26.6	42.9	32.4
Agricultural Income	47.0	37.3	34.6	46.4	48.2
Livestock Income	24.4	5.2	33.9	6.4	17.0
Nonfarm Income	4.8	12.0	4.8	4.3	2.3
Gross returns from agriculture (Rs./ha)	38295	60023	58981	83601	51713
Net returns from agriculture (Rs./ha)	19135	24074	35351	52906	31068

Source: NSSO 70th round (Govt. of India)

6.3 Productivity and Efficiency of Agriculture

Increasing productivity and profitability of agriculture are essential to increase farm and farmers' income in Bihar and West Bengal. Sustained growth in productivity and profitability can come only from efficient use of the factors of production—land, labor and capital without compromising sustainability.

We use five different indicators to measure the input use efficiency of agriculture in Bihar and West Bengal. These indicators are: a) crop yields (in k/ha); b) cost of production per unit of output; c) labor productivity measured in kilograms of produce/hour of human labor used; c) net returns from crops measured in rupees/ha and d) kg of produce per hour of irrigation as an indirect measure of water productivity. We estimate values of these indicators for the two main cereal crops—rice and wheat—for years 2007 to 2012 using farmer level data on cost of cultivation of these crops collected by the Commission on Agricultural Cost and Pricing (CACP) of India. Rice and wheat together account for nearly two-thirds of the gross cropped area in Bihar. In West Bengal, rice accounts for nearly 53 percent of the gross cropped area and is grown both in monsoon and dry seasons. Wheat is a minor crop in West Bengal covering around 0.32 million hectares of area which is less than 5 percent of the state's GCA.

Crop yields: Average yield of rice is around 2-2.5 tons/ha in Bihar and 4 tons/ha in West Bengal compared to 5 tons/ha in Haryana and 6 tons/ha in Punjab. There has not been a significant increase in rice yields in either of the two states over the last few years (Figure 6.1). Rice yields in Bihar have not only stagnated at very low levels, but they also show larger inter-year variations. Thus, rice is a low productivity-high risk crop in the state.

Wheat is another major crop of Bihar accounting for more than 25 percent of the GCA. At around 2.5 tons/ha, wheat yields in Bihar are also significantly below the national average and much below the yields levels in Punjab and Haryana. At 2.8 tons/ha, wheat yield in West Bengal is also below the national average (Figure 6.2). Recent surveys by IFPRI and Michigan State survey show that most farmers in Bihar continue to use more than 25-30 year old varieties of seeds with low yield potential and high susceptibility to biotic and abiotic stresses. This may be one reason for low yields in the state.

The total yield of rice plus wheat in Bihar is less than the rice yield of Punjab. This comparison between the eastern and the western parts of the Indo-Gangetic plains underscores the yield gaps in the rice-wheat system in Bihar.

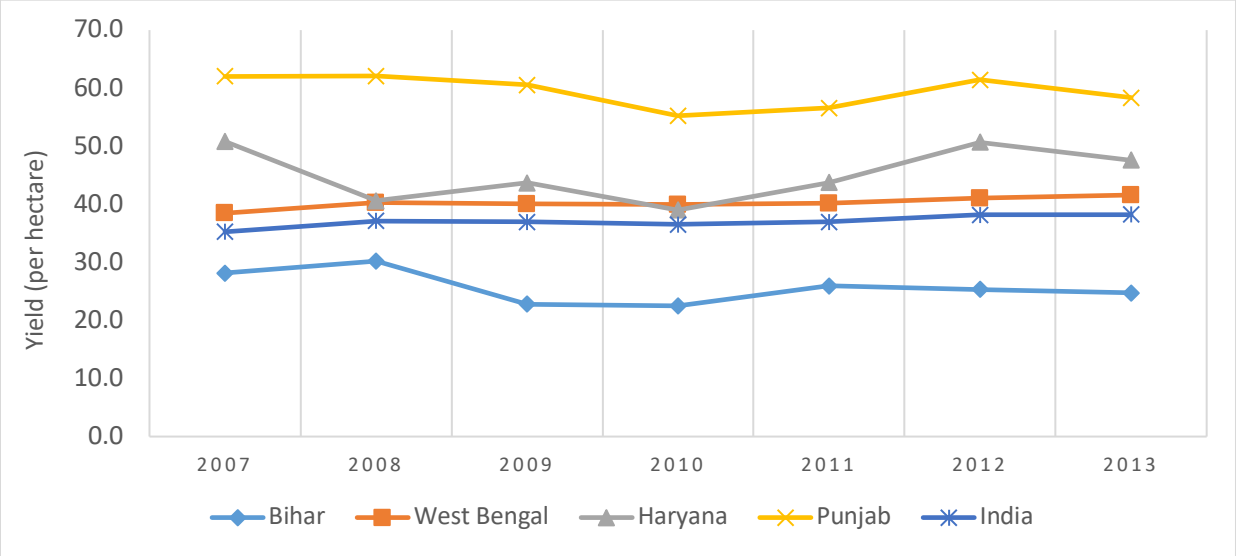


Figure 6-1: Rice yield per hectare

Source: CACP

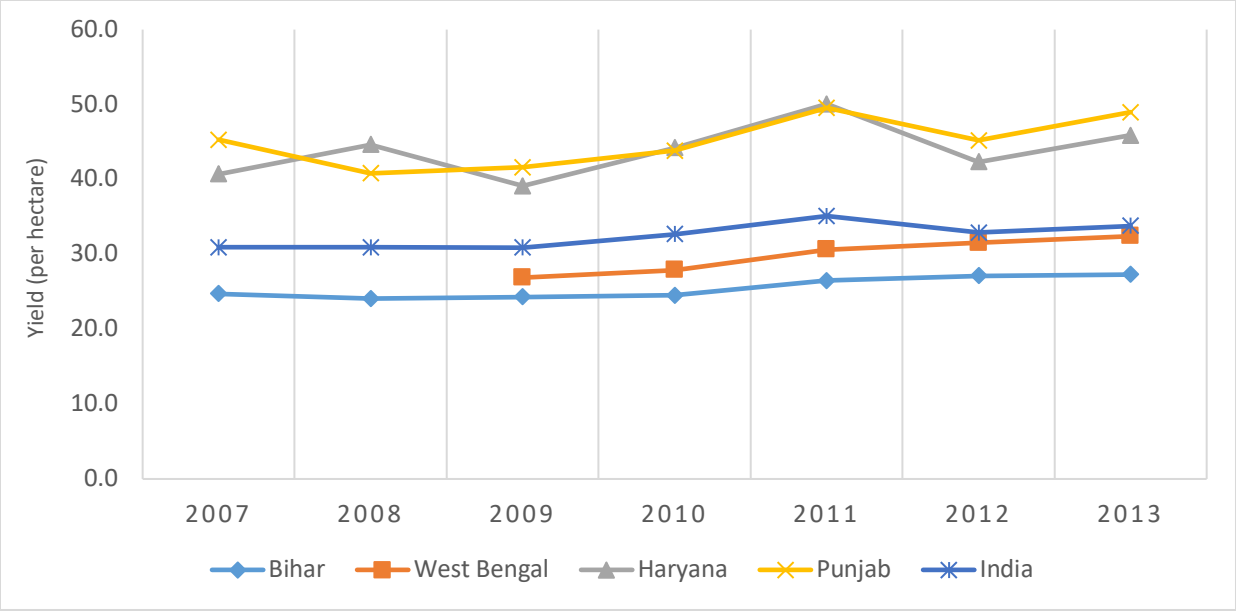


Figure 6-2: Wheat yield per hectare

Source: CACP

Cost per unit of production: Among the major rice producing states of India, the operational cost of cultivation of rice (Rs/ha) is one of the lowest in Bihar due to lower use of inputs and cheaper wage rates in the state. However, the cost of production (measured in Rs/quintal) is high and operating profits are low in the state due to low yields and lower price realization (Table 6.4). Unlike Punjab and Haryana, farmers in Bihar and West Bengal do not benefit from government procurement of rice at the minimum support price (MSP). Increasing crop yields and securing higher prices for the produce—both are essential to increase net profits from rice cultivation in Bihar and West Bengal. The story is very similar for the wheat too.

Table 6-4: Cost of Cultivation (Rs./ha) and Cost of Production (Rs/quintal) of Rice in 2012-13

	Bihar	West Bengal	Haryana	Punjab
Operational cost of Cultivation (Rs/ha)	18006.17	28731.01	28670.77	25781.62
Yield (Qtl/ha)	24.26	39.50	46.86	67.97
Operational Cost of Production (Rs/Qtl)	637.98	635.31	604.25	376.08
Total Value of Main & By-products (Rs./ha)	27,718.05	48,898.20	85,811.80	91790.47
Farm harvest price (Rs/Qtl)	1142.54	1237.93	1831.24	1350.46

Labor productivity: Labor productivity of rice in Bihar, measured in kilograms of paddy/hour of wage labor used, was 3 kg in triennium 2010-12 and 2.91 kg in triennium 2004-06. The state witnessed only a small increase in labor productivity in spite of increase in use of machines

mainly due to low yield realizations in recent years due to weather shocks. While labor productivity remained stagnant, wages rates increased nearly threefold in this period. In comparison, the farm harvest price of paddy increased by 1.94 times only. As a result, wage expenditure (which includes imputed wages of family labor) increased from 45 percent to 56 percent of the gross value of produce of paddy between 2004-06 and 2010-12.

Labor productivity of rice in West Bengal was 3.50 kg/hour in 2010-12 and 2.97 kg/hour in 2004-06. Stagnant yields and low levels of mechanization of agriculture are possible reasons for the negligible increase in labor productivity of rice cultivation in the state in this period. Agricultural wages are nearly 50 percent higher in West Bengal than in Bihar (Rs. 24 vs. Rs. 18 per hour). Yet farmers there use more labor hours per hectare of paddy and rely less on machines than in Bihar. Expenditure on machines has increased rapidly in West Bengal between 2004 and 2012, but it is still below the machine expenditure levels in Bihar (Table 6.5). Reasons for persistent low use of mechanized equipment in paddy farms of West Bengal in spite of high wage rates, high cropping intensity and high crop yields are not very well understood. Wage rates have increased more rapidly than the crop yields and farm harvest prices in West Bengal too resulting in increase in share of wage costs from less than 50 percent of the GVP in 2004-06 to more than 60 percent of GVP in 2010-12.

Low and stagnant yields and unremunerative prices of produce make wage costs unaffordable for farmers in Bihar and West Bengal, resulting in increased demand for mechanization of agriculture.

Table 6-5: Muscle and Machine Power in Cultivation of Paddy in Bihar and West Bengal in 2012

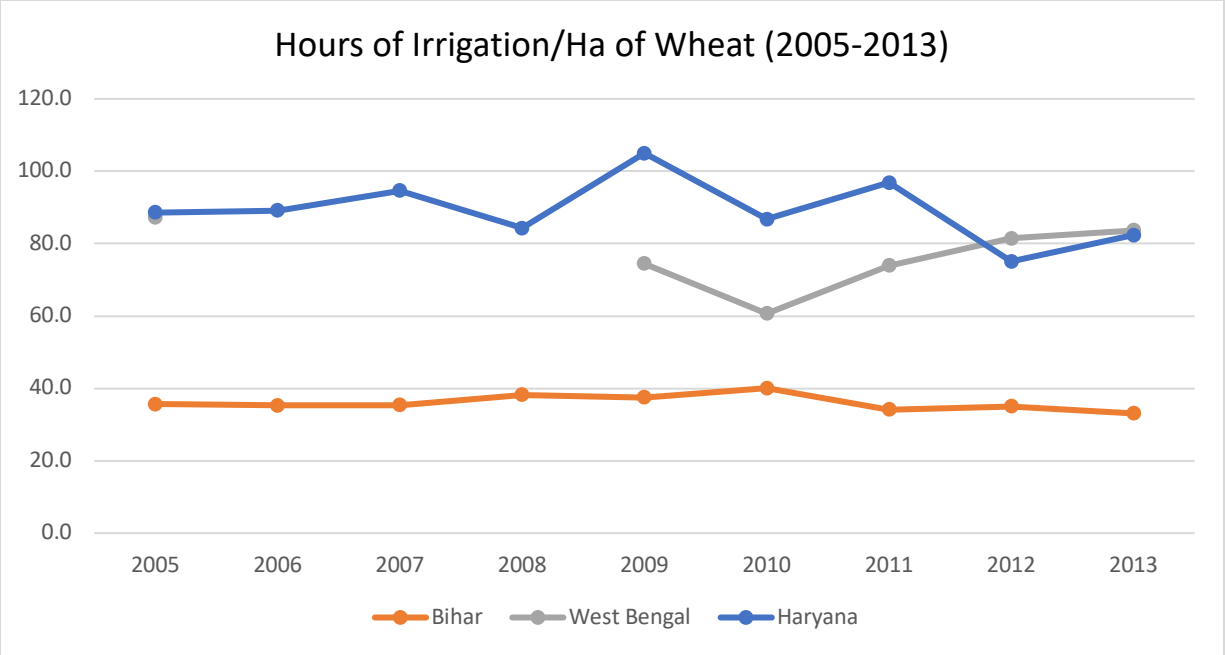
	Bihar	West Bengal	Haryana	Punjab
Year = 2012				
Human Labor (Person Hours)	807.96	1115.64	521.50	380.80
Animal Labor (Pair Hours)	28.21	62.65	1.21	0.62
Machine Expenditure (Rs/ha)	2462.56	2355.23	4087.92	5098.44
Wage Rate (Rs//hour)	18.37	23.88	33.02	34.98
Total Wage Expenditure (Rs/ha)	14842.23	26641.48	17219.93	13320.40
Total Value of Main & By-products (Rs./ha)	27,718.05	48,898.20	85,811.80	91790.47
Year = 2004				
Human Labor (Person Hours)	874.87	1200.01	636.75	451.25
Animal Labor (Pair Hours)	48.75	104.35	1.40	2.12
Machine Expenditure (Rs/ha)	1009.82	823.71	3115.06	3653.01
Wage Rate (Rs//hour)	6.21	7.79	12.80	10.62
Total Wage Expenditure (Rs/ha)	5432.94	9348.08	8150.40	4792.28
Total Value of Main & By-products (Rs./ha)	13,376.03	22,505.10	36,742.64	42,414.24

Note: All expenditure values in current prices

Source: CACP

Water/Energy productivity: Improving water use efficiency is essential for sustainable intensification of agriculture. Unfortunately, we do not have data on volumes of water used to grow different crops in Bihar or West Bengal. We do not have data on water discharge rates of pump-sets either. We only have data on total hours of pumping per hectare of crop from CACP. Since there has not been a secular decline in depth to groundwater table in most of Bihar and West Bengal, the energy used in irrigation can be a rough measure of the volume of groundwater applied to crops. It is a useful measure because energy for irrigation is scarce and expensive in EGP. Farmers feel the energy squeeze and economize on it by practicing deficit irrigation (**Shah, 200x**).

Farmers in Bihar practice deficit irrigation both in wheat and rice because irrigation is expensive. They apply less than 40 hours of irrigation to a hectare of wheat crop compared to 70-80 hours of irrigation/ha in Haryana, Punjab and even West Bengal where wheat is a relatively minor crop (Figure 6.3a). Deficit irrigation to wheat may be one of the reasons for its low yields in Bihar along with delayed sowing and use of old and outdated varieties of seeds. Pump-owners, on average, 4-5 additional hours of irrigation per ha of wheat than water buyers, but their yields are not significantly higher. Thus, water productivity of water buyers is higher than that of pump owners. It is also interesting that average hours of irrigation to wheat by pump owners has significantly declined after 2010 (Figure 6.3b) possibly in response to a sharp rise in the cost of diesel. Both pump owners and water buyers in Bihar seem to be providing the minimum possible amount of irrigation to their wheat crops now.



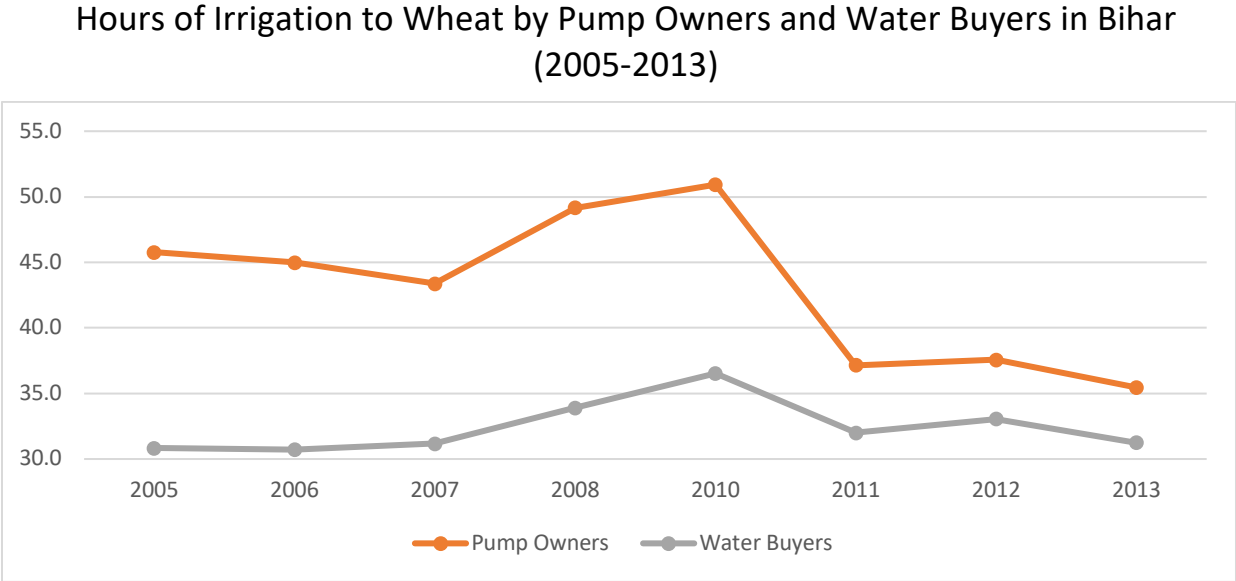


Figure 6-3: (a) Hours of Irrigation per Hectare of Wheat (2005-13) (b) Hours of Irrigation to Wheat by Pump Owners and Water Buyers in Bihar (2005-2013)

Paddy is grown only in monsoon (Kharif) season in Bihar while in West Bengal, it is grown both in monsoon (Amon) and winter (boro) seasons. Boro paddy is irrigated intensively while in kharif or Amon season, farmers rely mainly on rainfall and provide only supplemental irrigation from pumpsets. In years of normal monsoon rains, like 2008 and 2011, farmers barely irrigate paddy in Bihar. Even in years of severe drought, like 2010, paddy gets only life-saving irrigation of 20-30 hours/ha. Pump owners and larger landholders irrigate more than the sub-marginal farmers and water buyers. This high dependence on monsoon rains frequently results in reduction in crop area and productivity (Kishore, Joshi and Pandey, 2015). The state government offers cash subsidy on diesel to farmers in drought affected blocks to protect their crops from moisture

stress, but the scheme has not been effective due to poor targeting, high transaction costs and late and uncertain payments (*ibid*).

West Bengal receives more rainfall than Bihar and monsoon rains have been more steady in the state. Even then farmers provide more irrigation to paddy in West Bengal than in Bihar (Figure 6.4) and harvest higher yields. This is because groundwater irrigation is significantly cheaper in West Bengal than in Bihar (Figure 6.5). Increasing electrification of pumpsets in West Bengal has helped moderate the rise in pump rental rates in West Bengal. In both Bihar and West Bengal, nearly 90 percent of farmers rely on pump rental markets for groundwater irrigation.

It is our surmise that both land and water productivity of the rice-wheat system in Bihar may increase from its current levels if irrigation became more affordable and farmers were to apply more water to their crops. Affordable irrigation will ensure timely transplantation of rice and timely sowing of wheat preventing yield losses due to droughts and dry spells in kharif and terminal heat in the rabi season.

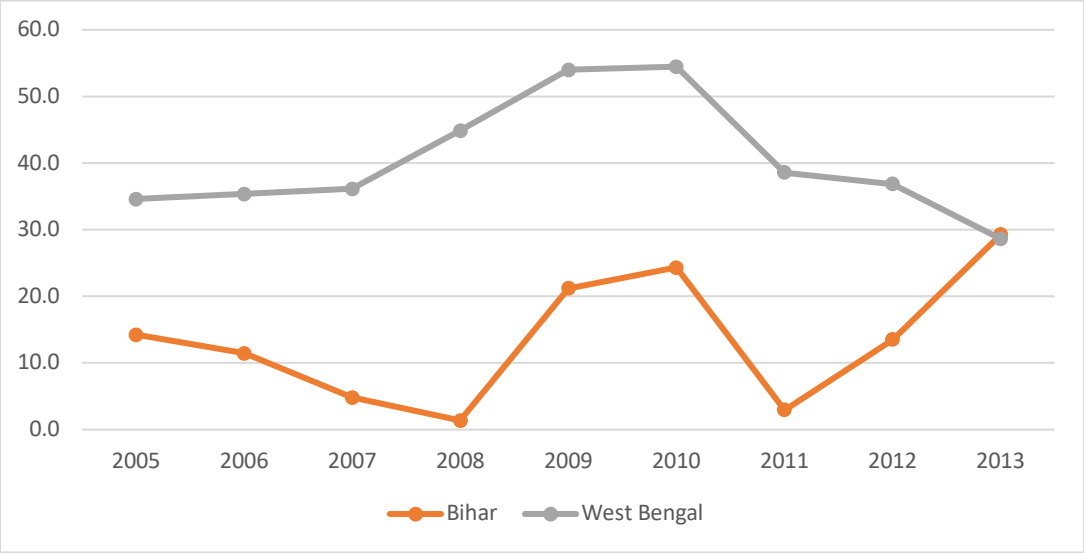


Figure 6-4: Hours of Irrigation per Hectare to Paddy in Bihar and West Bengal (2005-2012)

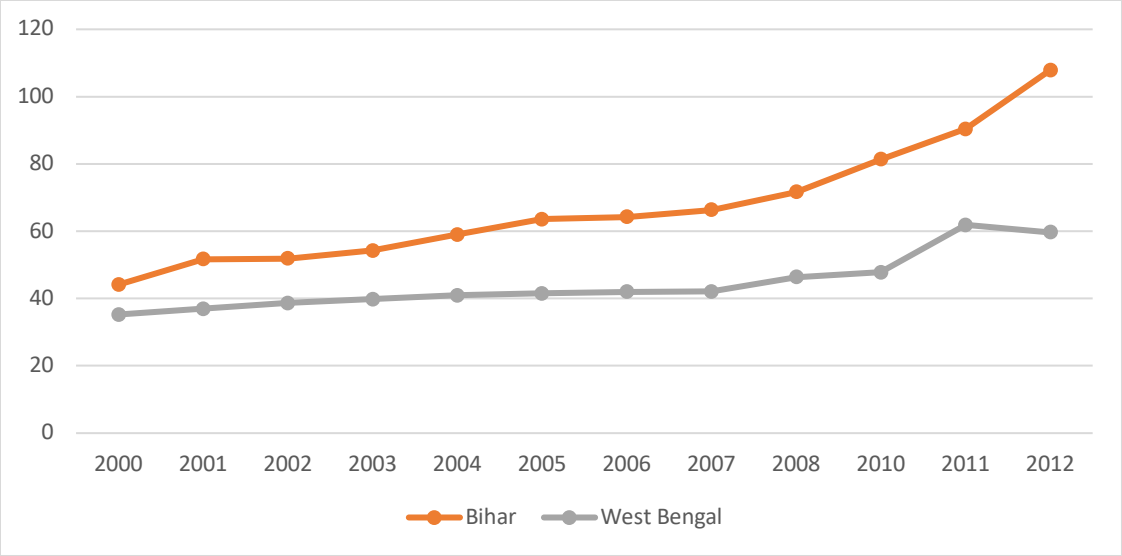


Figure 6-5: Pump Rental Rates (Rs./hr) in Bihar and West Bengal (2000-2012)

Net returns from agriculture: Agriculture is the main source of income for a large fraction of the population in Bihar and West Bengal. A large majority of farming families in both states earn less than $2/day. Increasing net returns from agriculture is essential to reduce poverty and increase household incomes in the region. We use data from the cost of cultivation surveys of rice and wheat to see the trend in net returns/ha to farmers from these two crops. Net returns/ha is calculated as gross value of produce (farm harvest price X yield of the main crop and the residues) minus the total cost of production. Total cost includes expenditures on family and hired labor, own and rented machinery, seeds, fertilizers, irrigation, pesticides, land revenue, interest on working capital and land rent.

Returns from rice cultivation have declined in Bihar from 2007 to 2013 from Rs.15719/ha to Rs. 13,680/ha in current prices (Figure 6.6). The decline is even sharper in real prices. Stagnant yields, low price realizations and rising wage rates, machine rentals and price of other inputs like seeds, fertilizers and irrigations is responsible for this decline in net returns from rice. Farmers in West Bengal earn twice as much from rice cultivation (Rs. 27085/ha) as their counterparts in Bihar and their returns have marginally increased in recent years at least in nominal terms. The real returns, however, have been stagnant in West Bengal too. Average net returns from paddy are five-to-seven times higher than that of Bihar in the western Indo-Gangetic plains of Haryana and Punjab. High yields, assured prices, low cost of irrigation and higher level of mechanization helps farmers in western IGP to be more efficient.

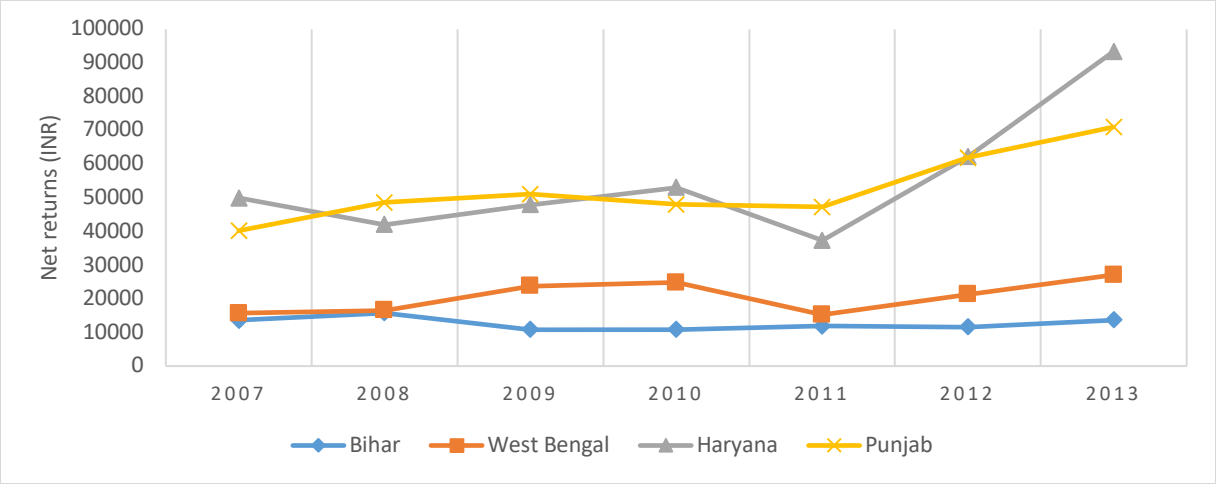


Figure 6-6: Net Returns (in Current Rupees) per Hectare from Rice

Source: CACP

Wheat growers in Bihar earn more profits than those in West Bengal (Rs. 30,962 vs. Rs.18393/ha). The returns, however, are low in both states compared to Haryana and Punjab. Wheat yields in EGP have stagnated at low levels and farm harvest prices in the region are significantly below the minimum support price. These two reasons combined with rising cost of inputs explains modest returns.

Increasing crop yields, securing more remunerative prices for the produce and increasing labor productivity through mechanization could help improve profitability and efficiency of rice and wheat cultivation in eastern India.

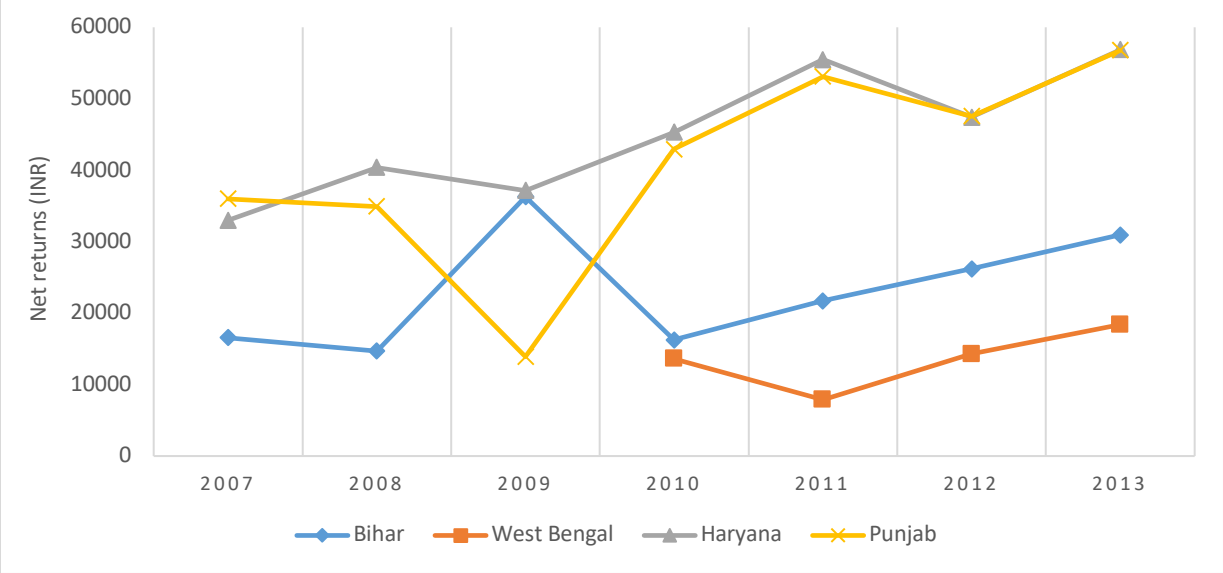


Figure 6-7: Net Returns (in Current Rupees) per Hectare from Wheat

Source: CACP

Low and variable returns from farming (Figure 6.7) contribute not only to persistent poverty and vulnerability, but also make farming a less attractive profession for young men and women. The

Situation Assessment Survey of Farmers (SASF) shows that 55.3 percent of all farmers in Bihar and 48.6 percent of them in West Bengal do not like farming as a professions compared to 41 percent of farmers in all India (Table 6).

Table 6-6: Farmer preference for farming

	(a) Like farming	(b) Dislike farming	H_0: (a) - (b) = 0
Bihar	44.7	55.3	10.6***
West Bengal	51.4	48.6	2.8**
Haryana	61.2	38.8	22.4***
Punjab	61.1	38.9	22.2***
All India	59.0	41.0	18.0***

Source: NSSO 59th round

When probed further, most farmers cited low profitability and high risk in farming as reasons for not liking it as a profession (Table 7). One in five farmers in Bihar who do not like farming, considers high risk to be a reason. In comparison, less than 10 percent of farmers in West Bengal cited risk to be the reason for not liking farming.

Table 6-7: Stated reasons for dislike farming

	Bihar	West Bengal	Haryana	Punjab	India
Not profitable	69.5	74.6	77.4	69.9	66.2
Lack of social status	4.1	5.3	3.4	6.9	5.3
High risk	20.9	9.7	11.1	7.5	19.3
Others	5.5	10.5	8.0	15.7	9.1
Total	100.0	100.0	100.0	100.0	100.0

Source: NSSO 59th round

6.4 Risk in Agriculture

Agricultural production, productivity and incomes are not only low in the EGP, but also vulnerable to abiotic and biotic stress and price shocks. A district level assessment of vulnerability of agriculture to climate change by Indian Council of Agricultural Research (ICAR) shows that 36 of the 37 districts in Bihar and 11 of the 18 districts in West Bengal are highly or extremely vulnerable to climate change due to their high exposure and sensitivity levels and low adaptive capacities (Table 6.8). Districts of North Bihar were rated the most vulnerable to climate change among the 161 districts of the Indian part of the Indo-Gangetic Plains (IGP).

Table 6-8: Number of Districts in Different Vulnerability Classes in Indo-Gangetic Plains

States	Total districts	No. of districts in different vulnerability classes			
		Low	Moderate	High	Extreme
Bihar	37	0(0)	1(3)	12(32)	24(65)
West Bengal	18	0(0)	7(39)	10(56)	1(5)
Haryana	19	13(68)	4(21)	2(11)	0(0)
Punjab	17	17(100	0(0)	0(0)	0(0)

Source: Sehgal et al (2013)

Note: Figures in the parenthesis are percent of districts

The Situation Assessment Survey of Farmers (SASF)—a survey of a representative sample of farmers from across India in 2013 shows that more than half of all farmers (53%) in Bihar had experienced crop loss in recent years compared to 47.1% farmers in all India and 31.2% farmers in West Bengal. 71 percent of farmers in Bihar and 41 percent in West Bengal who reported crop losses attributed it to droughts (Table 6.9).

Kishore, Joshi and Pandey (2015) report that the drought in 2009 resulted in the maximum loss in area and production of paddy in Bihar even when more severe shortfall in rains was reported in other parts of India like Punjab, parts of Uttar Pradesh and Telangana. The drought led recession in the agrarian economy of the state in 2009 pushed millions of households into transitory poverty and negated the positive effects of the overall economic growth and development in the state.

Since 2009, droughts have become a common occurrence in Bihar—a state otherwise known for floods. With the exception of 2011, which was a year of normal rainfalls, large parts of Bihar have experienced droughts or delayed onset of monsoon every year since 2009. (*ibid*). Analysis of district level data shows that these droughts have had a big negative impact on yield and production of paddy—the staple crop of Bihar (Kishore, Joshi and Pandey, 2015).

Table 6-9: Crop Loss and Its Reasons

	Did you experienced crop loss (yes=1, no=2)		If Yes, stated reasons for crop loss			
	Yes	No	Inadequate rainfall/ drought	Disease & Insect & animal	other natural causes	Others
Bihar	53.0	47.0	72.5	26.5	15.8	8.6
West Bengal	31.2	68.8	40.6	26.5	31.0	20.6
All India	47.1	52.9	52.3	35.9	23.7	9.3

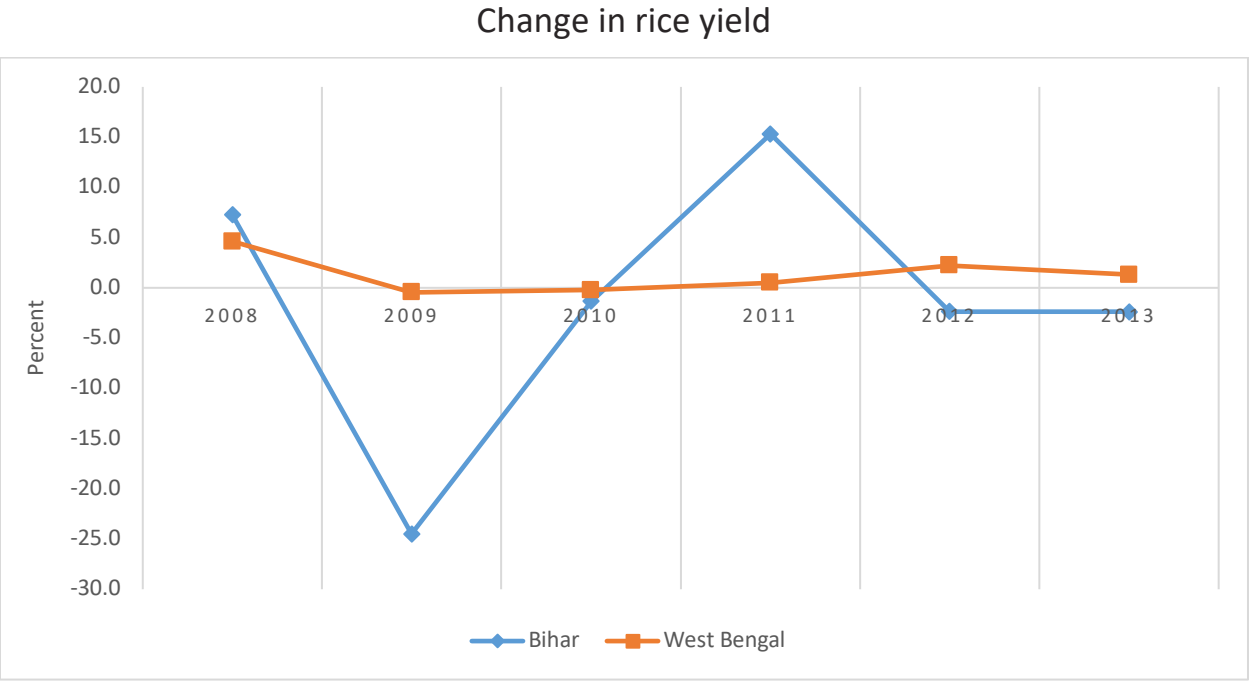
Source: NSSO 70th round

Note: Other natural causes includes (fire, lighting, storm, cyclone, flood, earthquake etc.)

The risky nature of the crop enterprise in Bihar and West Bengal is evident from figures 6.8a and 6.8b where we plot change in rice and wheat yields from the previous year for years 2008 to 2013. There have been no two consecutive years of positive growth in rice yields in Bihar. Rice yield in the state almost always regresses to the mean after a year of positive growth. As a result, average yield has remained at the same level over the last ten years. In West Bengal too, rice yields have increased only marginally over the last few years. Figure 6.8a also shows high vulnerability of rice to droughts in Bihar. Yield went down by nearly 25 percent in the drought of 2009 and declined further in 2010 which was the second consecutive year of drought in the state. After Jharkhand, the drought in 2009 had the biggest impact on rice yields of Bihar.

Wheat yields have registered a small positive growth over the previous year in most years (Figure 6.8b) in both Bihar and West Bengal. Wheat is an irrigated crop. Its yield, therefore, is less affected by the vagaries of monsoon rains. However, in years of drought or delayed onset of monsoon, late transplantation of paddy results in late sowing of wheat too—affecting its yields due to rise in temperatures during the grain-filling stage. Irregular rainfalls, thus, affect the productivity of the entire rice-wheat system.

Not only crop yields, but net returns from crops has also been unstable and stagnant over the last several years (figures 6.6 and 6.7). This is in part because price of rice and wheat do not increase even in years of low production. Government of India maintains a large buffer stock of rice and wheat to ensure affordable access to grains to consumers. It releases grains through open market sales operations when prices are higher. Consumers benefit from this operation, but farmers' income is negatively affected. Farmers in eastern India, unlike their counterparts in Punjab and Haryana, do not benefit from country's food policy in years of high production because there is little procurement of rice or wheat at minimum support price in years of high production and low prices.



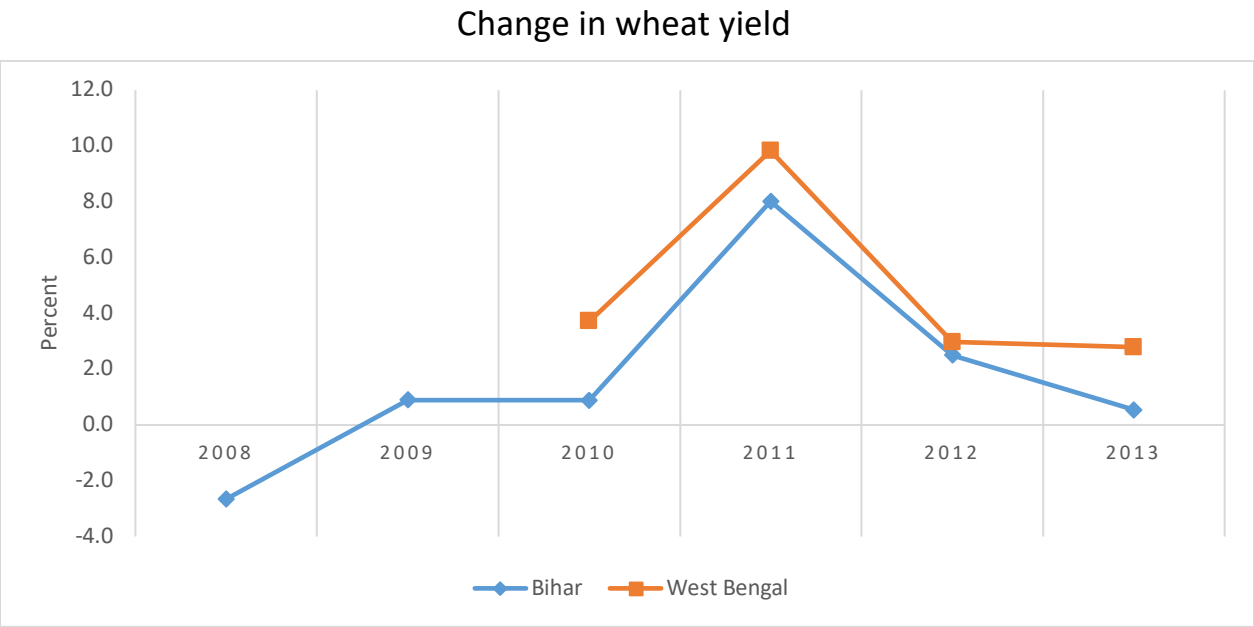


Figure 6-8: (a) Change in rice yield (with keeping previous year as base) (b) Change in wheat yield (with keeping previous year as base)

Source: CACP

6.5 Sustainable Management of Soil and Water in Agriculture

Sustainable agriculture is the production of food, fiber, or other plant or animal products using farming techniques that protect the environment, public health, human communities, and animal

welfare. This form of agriculture enables us to produce food without compromising future generations' ability to do the same.

In this section on sustainability, we focus on two resources critical to farming: soil and groundwater.

Soil Health: Soil in EGP, though fertile, is low in organic carbon content and available phosphorus. Deficiency of iron and zinc is also widely reported from areas with young alluvial soil. The soil organic carbon (SOC) is not only low, but also declining due to excessive mining of soil fertility, non-incorporation of crop residues into the soil, inappropriate tillage, reduction in area under leguminous crops and poor crop management. Increasing atmospheric temperature and changing rainfall patterns are also causing loss of SOC.

Imbalanced application of chemical fertilizers is resulting in further deterioration of soil texture and fertility. Farmers tend to over apply Urea and seldom apply secondary nutrients (Sulphur, Calcium and Magnesium) or micro-nutrients (like Zinc, Iron, Copper, Boron, Molybdenum and Manganese) affecting both productivity, soil health and net incomes from agriculture. Distortionary subsidies on fertilizers, especially, Urea and poor understanding of soil quality and its nutritional requirements are two main reasons for imbalanced use of fertilizers.

Excess application of Urea is resulting in contamination of surface water bodies and aquifers. According to the Central Groundwater Board (CGWB), 9 districts in Bihar and 2 districts in West Bengal are affected by excess nitrate (> 45 mg/liter) concentration in groundwater. In addition, over-application of Urea also releases Nitrous Oxide, a powerful greenhouse gas with a long atmospheric life, into the atmosphere.

Government of India has launched a flagship program to provide soil test based soil health cards for all 140 million landholdings in the country to encourage balanced application of fertilizers in agriculture. However, the implementation of the scheme is slow in EGP. Further, a randomized control trial in three districts of Bihar shows that providing soil health cards with crop-specific fertilizer use recommendations has negligible effect on fertilizer application by farmers in wheat or rice crop (Fishman, Kishore, Rothler and Ward, 2016). The RCT indicates the need for a more intensive engagement with farmers to persuade them to move towards more balanced fertilizer use.

Promotion of conservation agriculture (CA) practices like zero or minimum tillage and better crop residue management can also improve soil quality. However, a recent primary survey in 4 districts of Bihar and West Bengal shows negligible adoption CA technologies and practices in the region. Low awareness of CA and limited availability of equipment required for it are two big reasons for its low adoption.

Groundwater: Bihar and West Bengal are richly endowed with fresh groundwater at shallow depths replenished amply by rainfall, rivers, and floods (WRIS, undated)[3]. The annual withdrawal of groundwater for agricultural and non-agricultural uses is less than 40 percent of the net groundwater availability in all 589 blocks of Bihar and 303 of the 341 blocks in West Bengal (Table 6.10). Central Groundwater Board (CGWB) collects data on depth to groundwater table four times a year—April/May, August, November and January—from a network of 723 hydrograph networking stations (HNS) in Bihar and 1338 in West Bengal. Data from these HNS shows that even in pre-monsoon season (April/May), when water table is deepest, depth to water level was less than 5 m below ground level (bgl) in 46% of all HNS and

[3] http://www.india-wris.nrsc.gov.in/wrpinfo/index.php?title=Bihar

less than 10 m bgl in 97% of all HNS in Bihar. In West Bengal, depth to water table was less than 5 m bgl in 36.2% of the HNS and less than 10 m bgl in 79% of HNS.

Secular decline in groundwater table—a common problem in many parts of India—is not recorded in rural Bihar and West Bengal. A comparison of water level in May 2015 with respect to decadal mean of water level from May 2005 to May 2014 of 482 HNS in Bihar showed rise in water levels in 257 stations and fall in 219 of them. The rise or fall in water table was in the range of 0-2 meters in most HNS (CGWB, 2016a). Similarly, in West Bengal, out of 543 HNS, 269 wells (49.54%) have shown rise whereas 274 wells (50.46%) have shown fall in water level. The rise and fall of water levels is mostly restricted within 0-2 m in West Bengal too (CGWB, 2016b). Our own analysis of seasonal fluctuation in water levels of monitoring stations in West Bengal shows a significant positive correlation between the depth to water table in April and the rise in water level from April to November. Some experts (Revelle and Lakshiminarayana, 1975; Khosla, 2003; Shah, 2014) have even suggested developing groundwater irrigation in the region to draw water tables further down in the pre-monsoon season and create space in the deep alluvial aquifers to absorb monsoon floods.

Groundwater levels in most of Bihar and West Bengal are resilient in long term, but it does fall below 9 meters in pre-monsoon months in some parts of these states resulting in seasonal failure of tubewells equipped with centrifugal pumps. Water table was deeper than 10 meters in more than 20 percent of all HNS in West Bengal in April 2015. Centrifugal pumps cannot lift water above 9 meters. A submersible pump is required. Submersible pumps are more capital intensive and require electricity connection or diesel generators to operate them. Due to these entry barriers, rental markets in submersible pumps are less competitive and results in rent extraction from water buyers by better-off farmers who own submersible pumps (Mukherjee, 2007). Sekhri and Landefeld (undated) show that even short run shocks around 9-meter cutoff, may result area under cultivation of food-grains and water intensive crops fall by 7 to 8 percent.

Increasing scarcity of groundwater, even if seasonal and short-term, suggests the need for more judicious use of groundwater in agriculture. Increasing water productivity of crops and changing cropping pattern away from highly water-intensive crops like boro rice to other crops like wheat, maize, potato and pulses may help conserve groundwater. Reducing groundwater use for agriculture will also help reduce the use of energy for irrigation—a scarce and costly resource in EGP. In addition, many of these interventions will may also help reduce potential health hazards caused by irrigating crops Arsenic contaminated water (Senanayake and Mukherji, 2014). Excess concentration of Arsenic in groundwater is a problem in 15 of the 18 districts in West Bengal and 8 of the 39 districts in Bihar (Table 6.10). Contamination of groundwater (with excess Arsenic, Nitrate, Fluoride and Iron) is a more widespread and perhaps a more pressing issue for Bihar and West Bengal than the depletion of groundwater levels. Groundwater contamination, especially with Arsenic, is also linked to intensive use of groundwater in agriculture. However, high dependence on irrigated agriculture for poverty alleviation, livelihoods and regional and national food security often means that efforts to mitigate the problem which limit water supply in the short term can have adverse consequences for the poorest sections of the population—the smallholder farmers and agricultural laborers (Senanayake and Mukherji, 2014). Fortunately, many of the strategies to improve water productivity of crops and water use intensity of region's agriculture can also address or mitigate the impact of decline in water quality (*ibid*).

We need more research to identify technologies and practices that would minimize the trade-offs between sustainability and profitability of agriculture and devise policies and institutions that can help scale-up the adoption of such technologies and practices in EGP.

Table 6-10 Dynamic Groundwater Resources and Groundwater Quality Problems in Bihar and West Bengal

	Bihar	**West Bengal**
Annual Replenishable Ground water Resource (Billion Cubic Meter or BCM)	29.19	30.36
Net Annual Ground Water Availability (BCM)	27.42	27.46
Annual Ground Water Draft (BCM)	10.77	11.65
Stage of Ground Water Development (%)	39	42
# Over Exploited Blocks	0	0
# Critical Blocks	0	1
# Semi-Critical Blocks	0	37
# Safe Blocks	589	303
Number of Districts Affected (in parts) by Excess		
Fluoride (>1.5 mg/l)	9	8
Nitrate (>45 mg/l)	9	2
Arsenic (>0.05 mg/l)	15	8

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7 Promoting Conservation Agriculture-based System Intensification in Nepal

7.1 Introduction

The importance of agriculture, water and energy in the development of Nepal cannot be overstated. In 2016/2017, Nepal experienced a relatively high economic growth rate of 7 per cent, attributed largely to the performance of the water, agriculture and energy sectors. The value of agriculture grew by more than 5 per cent as a result of the best monsoon season in recent years. Rice production, for example, reached a record high level, growing by around 25 per cent from the previous year (MoF 2017). In recent years the availability of electricity has also improved dramatically, contributing to the overall growth of the economy.

Accounting for about 32 per cent of Gross Domestic Product (GDP), agriculture remains the mainstay of the Nepalese economy (MoF 2016) and plays a critical role in the food and nutritional security of the Nepali people. More than 80 per cent of the rural population depend on agriculture for their livelihoods and agriculture is the source of employment for two-third of the country's economically active population.

7.2 Nepalese Terai

Nepal is divided into three ecological regions: Mountain, Hill and Terai. The Terai region of Nepal (also called Terai-Madhesh), is located in the southern part of the country and runs east-west (Figure 1) as an extension of the Indian Gangetic Plains. The region is characterised by a sub-tropical climate with hot, humid and monsoonal summer months and relatively dry winters. The Terai is the most densely populated region in the country, occupying around one-fifth of the total area but containing more than half the total population (CBS 2015). The Terai is endowed with rich and diverse natural resources: fertile alluvial soil, snow-fed permanent rivers, extensive underground water reserves, and agricultural and forest biodiversity. Agricultural crops suitable for tropical and sub-tropical climates grow well in this region.

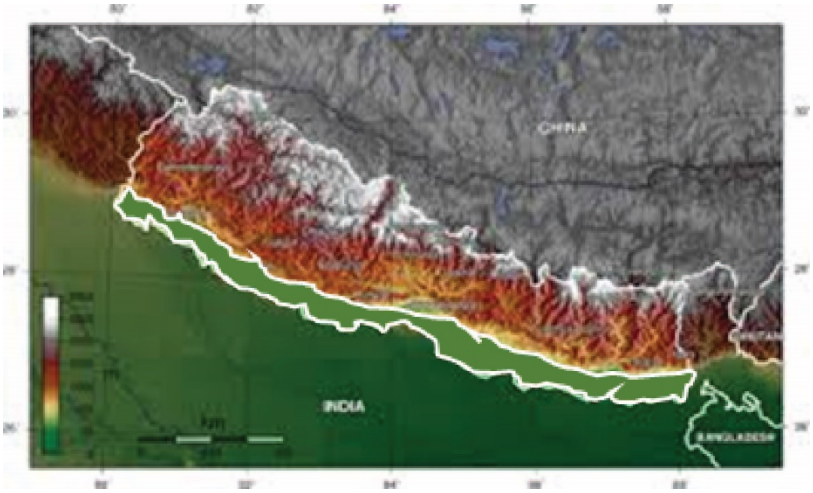

Figure 7-1: Terai region of Nepal (also called as Terai-Madhesh), which is located in the southern part of the country and runs east-west

Source: Google Image

7.3 The Natural Resource Base of Nepalese Terai

Abundant water resources, vast forests and fertile land form the natural resource base of the Terai. This section summarises the state of each of these three resources with reference to irrigation, energy and agriculture.

7.3.1 Water

Nepal has been frequently referred to as the second richest country in the world in terms of its fresh water resources (CBS 2015). A study conducted in the 1990s found that Nepal had surplus water resources of both surface water (200 billion cubic metres) and ground water (12 billion cubic metres) (APROSC 1995). Groundwater, rivers and rainfall are the major sources of water in the Nepalese Terai.

The Ground Water Resource Development Board of the Government of Nepal estimates that 726,000 ha of land in the Terai has good potential for shallow tube wells and 305,000 ha of land has marginal potential for both shallow and deep tube wells. A further 190,000 ha of land has good potential for exploiting deep aquifers. Peck and Griggs (2008), while comparing Nepal with India and Bangladesh, described Nepal's groundwater supplies as having high recharge rates and high saturated thickness. Statistics shows that the area irrigated by groundwater in Nepal almost doubled from 206,000 ha in 2002/03 to 409,013 ha in 2015/16 (MoF 2017). This growth, however, was well below the groundwater irrigation target of 612,000 ha in the Terai set out in the country's Agricultural Perspective Plan (APP) (1995-2015), which placed high priority on groundwater irrigation, mainly through shallow tube wells, as a primary driver of agricultural development in the country (APPROSC 1995).

Rivers and streams originating from the mountains and hills constitute the second major source of water for the Terai. CBS (2015) estimates that 6,000 rivers, rivulets and tributaries run through Nepal, with a total length of 45,000 km. The Koshi, Gandaki and Karnali are the three main river systems running through eastern, central and western parts of the Terai. Other major rivers contributing to groundwater recharge and surface irrigation in the Terai are the Babai, Kamala (east), Narayani, Bagmati (centre), Rapti, Seti and Mahakali (west).

The Government of Nepal and India signed three major agreements in 1954, 1959 and 1996 for the construction of large scale barrages and canal projects in Koshi, Gandaki and Mahakali respectively. The first two agreements led to the construction of mega irrigation infrastructure in the eastern and central Terai that also irrigate significantly larger areas across the border in India. Although this infrastructure provides irrigation in parts of central and eastern Terai, it also represents a constant threat of flooding and loss of river banks due to old and obsolete barrage infrastructure and sedimentation of rivers.

In addition to programs run by the Ministry of Irrigation, irrigation programs in the Terai are also provided by the Janakpur Agriculture Development Project under the Ministry of Agricultural Development, the Agriculture Development Bank of Nepal and private service providers. In total, year round irrigation is available for 253,000 ha of arable land in the Terai (http://www.gwrdb.gov.np/about_us.php).

Rainfall is also a major source of water for agriculture and groundwater recharge in the Terai. To illustrate its importance, significant decreases in the yield of summer crops such as rice and maize, which account for 80 per cent of total cereal production, have been reported for years of below-normal monsoonal precipitation (Karki et al. 2017).

7.3.2 Energy

Farmers depend on electricity, petroleum products, bio-gas and human-animal power to meet energy requirements for agricultural production and post-production activities. Human-animal power was traditionally the dominant form of energy for production related activities such as field preparation, planting, weeding, pesticide or fertiliser application and harvesting, but the shortage and high cost of labour combined with promotion of agricultural mechanisation has led to greater use of equipment such as tractors, power tillers, levellers, weeders and threshers. Petroleum products are the source of energy for the operation of these machines, while electricity is mainly used to power post-production processing activities. Both electricity and petroleum products are used to provide energy for irrigation.

The agricultural sector accounted for only 1 per cent of the total national demand for energy in 2008/09. Petroleum products constituted 95 per cent of agriculture's consumption (GON 2013). Alternative sources of energy for agriculture include solar power and hydroelectricity. The use of electricity, which accounts for about 5 per cent of total agricultural energy consumption, increased by 8 per cent between 2001 and 2009 (GON 2013). Hydroelectricity in particular offers very significant potential. Nepal has some 83,000 mw of hydropower generation potential of which 42,000 mw has been judged as financially and technically feasible (Hydropower Development Policy 2001). Despite this, both the generation and consumption of electricity in Nepal is far below its potential. In agriculture, even though diesel power is up to ten times more expensive than hydroelectricity and diesel fuel has to be imported, diesel powered pumps are still the dominant form of energy for irrigation, particularly from the shallow well pumps that are most popular among smallholder farmers.

The Nepal Oil Corporation, which has sole authority to import petroleum products in Nepal, estimates that petroleum products provide about 15 per cent of the national energy need. This proportion is believed to be higher in agriculture because of the heavy reliance on diesel for irrigation pumps and agricultural machinery. Farmers use diesel-powered pumps for irrigation for two main reasons. Firstly, until recently electricity was not regarded as a reliable energy source, and there is still not enough supply to satisfy the national electricity demand, even for household consumption let alone for agricultural use. Second, providing electricity services, particularly to agriculture, has not been prioritised because of the high cost of infrastructure and regulation. Thus agriculture accounts for 10.5 per cent of total petroleum based fuel consumption in Nepal as compared to less than 1 per cent of electricity consumption (GON 2013).

Being at the point of entry for imports and having an open border with India, availability and access to petroleum products is not an issue for farmers in the Terai, but the cost of fuel is a significant barrier. The Government of Nepal has implemented programs to promote electricity as the primary source of energy in agriculture. These programs provide subsidies on the cost of agricultural electricity, budgetary support for the installation of solar pumping systems for irrigation, rural electrification subsidies and promotion of renewable energy from solar and bio-gas. For example, in 2016 the government introduced a clean energy development levy of NRs 5 per litre of petroleum products to generate revenue to support energy generation from solar power and bio-gas. Additionally, the Nepalese government's water resource strategy and irrigation policy prioritise multi-purpose projects that not only generate electricity, but also provide irrigation.

7.3.3 Forests

Agriculture, forests and climate change are closely linked. Low agricultural productivity in a region where the majority of the population depends on agriculture for their livelihood leads to

deforestation in the search for more arable land or income from forest products. Deforestation then contributes to increasing GHG emissions, which leads to climate change. Climate stress to agricultural practices resulting from erratic rainfall and extreme weather events further reduces agricultural performance. This vicious cycle of agriculture, forestry and climate change is evident in the Nepalese Terai (DFRS 2014).

Once the subject of a popular adage in the country "Forest of Terai - Wealth of Nepal", forests in the Terai are declining due to encroachment, deforestation, poor management and unsustainable exploitation. The Forest Resource Assessment of the Government of Nepal (2014) estimated that forests covered 411, 589 ha or some 20 percent of the total physiographic region of Terai in 2010. This figure was 16,500 ha less than forest cover in 2001 and 32,000 ha less than in 1991. This represents a rate of decline of forest cover in the Terai of about 0.40 per cent per year. Clearing of forests for agriculture, livestock grazing and human settlement have been identified as the main human interventions responsible for this decline.

7.3.4 Land

The Terai is naturally blessed with fertile alluvial soils. While it covers only 23 per cent of the total area of Nepal, it provides more than half the cultivable and three quarters of the irrigable land resources of the country and is occupied by about half the total population (Table 7.1).

Table 7-1: Share of Terai on Nepal's population, land and irrigation

SN	Description	Nepal	Terai	Percent
1	Population (2011)	26,494,504	13,318,705	50.2%
2	Total land (Sq km)	147181	34019	23.1%
3	Total Cultivable land (000 ha)	2641	1360	51.5%
4	Irrigable land (000 ha)	1766 (Year round 42%)	1338	76%
5	Irrigated land (000 ha)	1392	Not Available	

Source: CBS (2015); DOI (2016); MoAD 2016

The Terai is also known as an industrial hub, where the majority of enterprises are involved in value adding manufacturing. It is therefore a popular destination for internal migrants because it offers socio-economic opportunities in both manufacturing and agricultural enterprises. The Terai has become a destination for real estate development and value adding industries because of the availability of better infrastructure and its proximity to large Indian markets. Not surprisingly, population density and growth in the Terai is the highest in the country. Yet all of these changes put pressure on land and water resources, and as a result the available arable land for agriculture is diminishing.

Further, remittance[4] has become the most significant source of income for many households in Nepal, particularly in the Terai. Remittances are largely spent on non-productive consumption such as land purchase, housing and imported goods. The demand for residential land in the Terai has increased values and made the rate of return from agriculture unattractive for farmers, some of whom are converting agricultural land to other purposes. In the absence of a strong regulatory framework to enforce land use planning regulations, valuable irrigated land in areas such as Chitwan and Sunsari has been consumed by urban development.

[4] *Transfer of money by foreign workers to their home country*

The complexity of competing priorities is reflected in government policy. The Government of Nepal, through in its annual plan and budget (2016), announced the development of planned cities in 18 different locations of the Terai, pointing to structural change that is seeing a decline in the relative importance of agriculture. While resisting this change may not be possible, it is possible to ameliorate its effects by improving agricultural productivity and increasing the rate of return from agriculture.

7.4 Conservation Agriculture-based System Intensification (CASI) in Nepal

Principles of continuous minimum mechanical soil disturbance, permanent organic soil cover and diversification of crop species grown in sequences and/or associations underpin the concept of conservation agriculture in Nepal (Shrestha 2016). Conservation agriculture has been widely understood as an agricultural practice that uses zero or minimal tillage and leaves as much plant residue as possible in the soil. The primary goal of conservation agriculture is to conserve, improve and sustain natural resources through efficient, effective and integrated management of existing resources. The Ministry of Agricultural Development's Planning Division reports that direct seeded rice and zero/minimum tillage wheat are emerging conservation agricultural practices receiving increased research and budgetary support from the ministry. These practices are becoming more common in the central and western Terai districts of Chitwan, Bara, Parsa, Nawalparasi, Rupandehi, and Kapilbastu, with an estimated 600 ha of cropping supported by agricultural extension programs under the Ministry.

Other sustainable agricultural practices include Integrated Pest Management, Integrated Nutrient Management, the use of organic fertilizers, cultivation of climate resilient crop varieties such as drought tolerant rice, and legume intercropping in cereal crops. Water saving irrigation technologies are also popular, but more in other parts of the country than in the Terai where access to and availability of water is relatively better. Some community based and non-governmental organisations such as HELVETAS are promoting riverbed farming, a practice in which agricultural activities are undertaken in the marginal public land of riverbeds during winter, as an alternative livelihood for landless people.

ICIMOD has developed a database of conservation technologies, known as Nepal Conservation Approaches and Technologies (NEPCAT), some of which are CASI technologies. Riverbed farming, no-till or minimum tillage, direct sowing, the system of rice intensification, rehabilitation of grazing land, protected gullies, hedgerow management, and mulch-based farming are being popularised as alternative practices in Nepal that promote conservation agriculture-based sustainable solutions in Terai agriculture. However, many of these approaches are adopted on a very small and local scale and are promoted by non-government organisations which have focussed on very limited areas. Thus these approaches, despite their significant potential, have so far had only limited effect because they are driven by constraints at the household or local level rather than driven by national policies or up-scaling investments.

Few studies of conservation agriculture are available in Nepal. Karki (2012) compared conservation and traditional agriculture in Chitwan, central Terai, finding that for maize the benefits of conservation agriculture can be seen through significant reduction in the cost of production (30 percent) rather than through yield differences. However in the long run (after 4 years), yield differences were also significantly higher using conservation agriculture-based practices. Improved soil quality and energy savings were other benefits of conservation agriculture in the long run.

Wider adoption of conservation agriculture practices is constrained by factors such as competing uses of crop residues, lack of access to appropriate machinery, increased pest dynamics from residues, inadequate knowledge for change, uncertain land use rights and poor research and development (Karki 2012). Conservation practices such as Integrated Pest Management practices (IPM), incorporation of legumes into cropping systems, use of bio-organic fertilizers, Integrated Plant Nutrient Management which address these constraints are gaining popularity in Nepal (Mandal et al. 2015). For example, Shrestha (2016) reported a yield increase of 15 to 25 per cent and a 40 per cent reduction in pesticide use from IPM interventions in rice.

The Agriculture Perspective Plan (1995-2015) prioritised system intensification of agriculture, particularly focusing on technology and ground water utilisation in the Terai (APROSC 1995). A Pocket Package Strategy was employed which first categorised agricultural regions based on their capability, such as level of infrastructural development, natural resource base, and stage of agricultural development, and then offered various program packages suitable for different agricultural development regimes. In 2016 the Ministry of Agricultural Development started the Prime Minister's Agricultural Development Program which also takes a similar approach to system intensification in the Terai focusing on the development of pockets, zones or super zones of a particular agricultural commodity. The Terai rice super-zone is one example. These programs have promoted agricultural mechanisation, direct seeding, and system intensification along with value addition interventions for economies of scale in production and marketing. Systems of Rice Intensification (SRI) technology has drawn the attention of both policy makers and farmers, and in parallel the Ministry of Agricultural Development has prioritised IPM programs, minimum tillage and subsidies for organic and bio-fertilisers.

7.5 State of Terai Agriculture

Figure 7.2 compares the area and production of major Terai crops with national statistics.

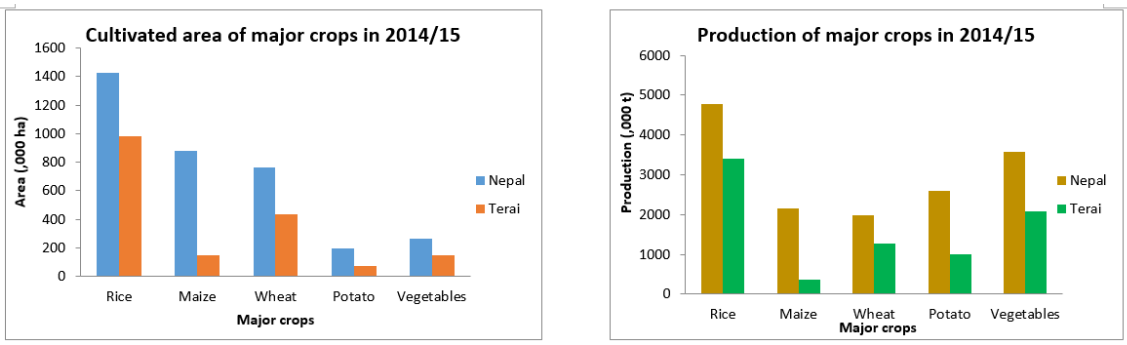

Figure 7-2: Terai share of cultivated area and production of major crops in Nepal (Source: MoAD 2015)

Of the five major crops illustrated in Figure 7.2, more than half the rice, wheat and vegetable growing areas lie in the Terai, along with 38 per cent of the potato and 17 per cent of the maize growing areas. At 69 per cent of the total area and 71 per cent of national production, rice is the major Terai crop. Wheat (64 per cent of national production) is also grown extensively in the Terai region. While the contribution of maize is relatively low (18 per cent of national production), there is a trend to increasing maize production in the Terai, especially in the winter and spring seasons in areas where vegetable production is difficult due to the shortage of labour. This increase in maize production is mainly through the adoption of hybrid varieties,

rather than area increase. In addition to these cereals, the Terai also contributes 58 per cent of the total vegetables and 39 per cent of total potatoes produced in Nepal.

Not surprisingly, the Terai is considered the grain basket of Nepal. Figure 3 shows that the Terai region contributes 55 per cent of national cereal production from 46 per cent of total area cultivated under these crops. In 2014/15, the total area under cereals was 3.38 million hectares and the total production was 9.27 million tonnes (MOAD 2015).

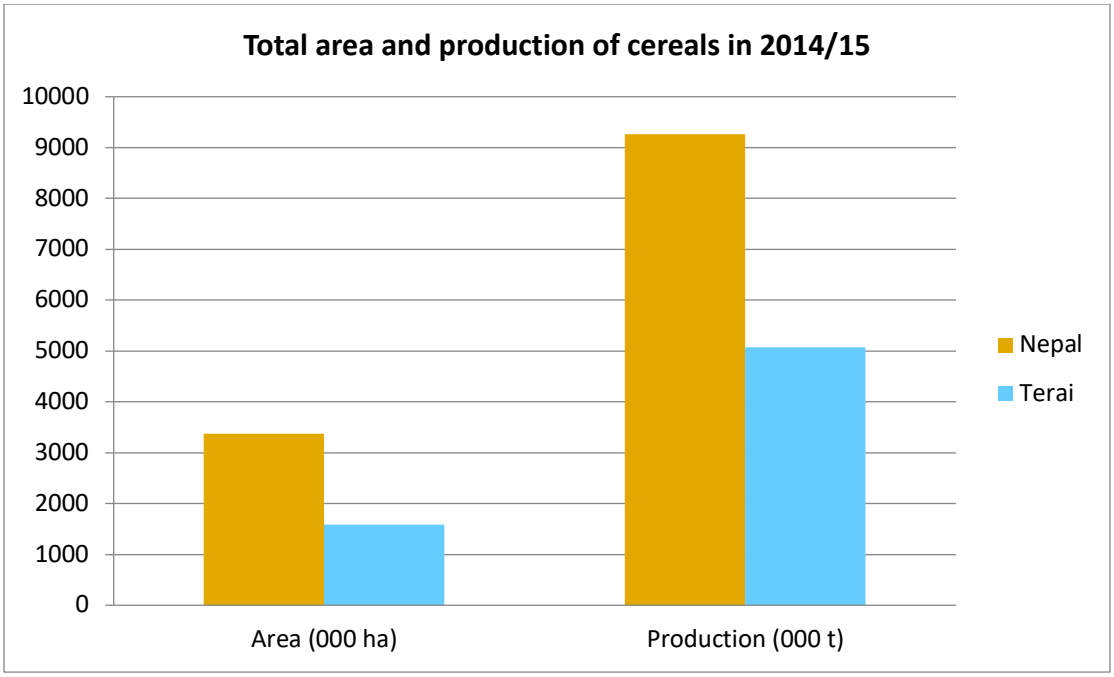

Figure 7-3: Area and production of cereals in Terai and the whole country (Source: MoAD 2015)

Figure 7.3 represents the area and production of Nepal's six principal cereal crops - rice, maize, wheat, millet, barley and buckwheat. Among them, rice, maize and wheat account for 91 per cent of total area and 96 per cent of total production. Thus the agricultural performance of the Terai is a major determinant of food sufficiency in Nepal. The production of these crops, however, largely depends on the timing and magnitude of monsoon rains. With an unfavourable monsoon, the production of cereals decreased by five percent in 2015/16 compared to the previous year, but increased by 13 per cent and reached almost 10 million tonnes in 2016/17, when the monsoon was favourable (MoF 2017). This illustrates the extent to which Terai agriculture depends on the availability of water.

Considering the importance of the region for agricultural production, research programs for rice, maize, wheat, pulses, and oilseeds are well established in the region. Terai-based research centres have released 177 varieties for local conditions out of the 250 varieties released for the whole country (SQCC 2017). The rice breeding system of the Nepal Agriculture Research Council, in collaboration with the International Rice Research Institute (IRRI), has developed drought (Sukkha- 1 to Sukkha- 6) and submergence (Swarna sub-1 and Shamba masuli sub-1) tolerant rice varieties for the Terai. Efforts are being made to release drought tolerant wheat and heat tolerant maize varieties for the Terai.

Analysis of the past ten years' (2006/07 to 2015/16) area, production and productivity of the major crops grown in the Terai (Appendix 1) reveals that areas planted to major crops have been relatively stagnant. The area under rice actually decreased from 1,009,000 ha to 934, 000

ha, but yield increased slightly from 2.60 to 3.27 mt/ha. The area under maize remained the same at 168,000 ha with an increase in yields from 2.28 to 2.86 mt/ha. The area under wheat increased marginally from 403,000 to 430,000 with a marginal increment in yield from 2.47 to 2.63 mt/ha. The only significant increase can be seen in the area under vegetables, which grew from 106,000 ha to 159,000 ha with a corresponding yield increase from 12.5 to 14.5 mt/ha. Overall, these results illustrate that despite its significant potential, agriculture in the Terai has improved little in the last decade.

Terai soil management has contributed to stagnant productivity. The blanket application of chemical fertilisers, stubble-burning practices in western areas and unregulated pesticide use in vegetables and potatoes have reduced soil organic matter content and contributed to degradation of soil physical, chemical and biological properties.

If agricultural production in the Terai is to increase, sustainable intensification is needed. As rich as it is, the natural resource base of the Terai needs conservation, replenishment and protection from exploitation. To achieve sustainable intensification, the future behaviour of agricultural stakeholders will be largely shaped and driven by institutions and policies focused on the nexus of food, water and energy.

7.6 Promoting CASI in Nepal: Policy and Institutional Aspects

The Niti Foundation, a policy think tank in Nepal, summarises the Nepalese policy process as based on normative procedures; far from democratic standards of policymaking; largely a partisan affair; content and processes limited to sectoral experts; external agency and donor dominance of processes and outcomes; and inadequate indigenous capacity to contest or to offer alternative options (nitifoundation.org/policy-process).

Nepalese policies can be categorised as either guiding or binding. Guiding policies provide a general framework to broadly guide subsequent planning and budgeting processes as long as powerful stakeholders back up the policy. These policies are of indefinite time horizon, not regularly reviewed, considered active until substituted or amended, and may never be implemented. The provisions of guiding policies may be triggered at the interest of powerful and influential stakeholders, otherwise they are typically static and outdate quickly. Figure 7.4 illustrates the hierarchy of these policies in order of their comprehensiveness (broader at the bottom).

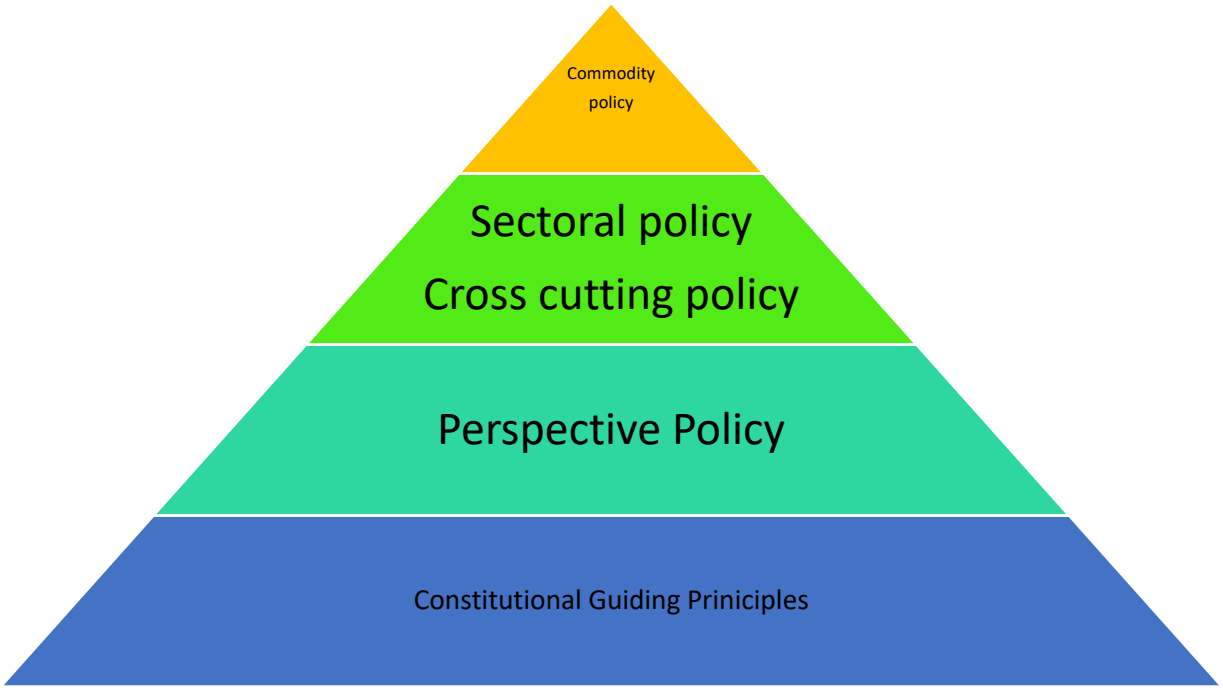

Figure 7-4: Levels of guiding policies

The second type of policies are binding in nature. Provisions in these policies are either legally binding, or regularly monitored and supported by instruments, incentives and investments. In the Nepalese context, annual plans and executive orders are well supported by action instruments and therefore attract the attention of wider segments of stakeholders. Since binding policies usually have a short life cycle, they are more issue-based and most often act as the initial point of intervention for scaling out effective approaches. They are thus more transient in nature. Figure 7.5 illustrates the hierarchy of binding policies in Nepal in order of their binding strength (extensive at the bottom).

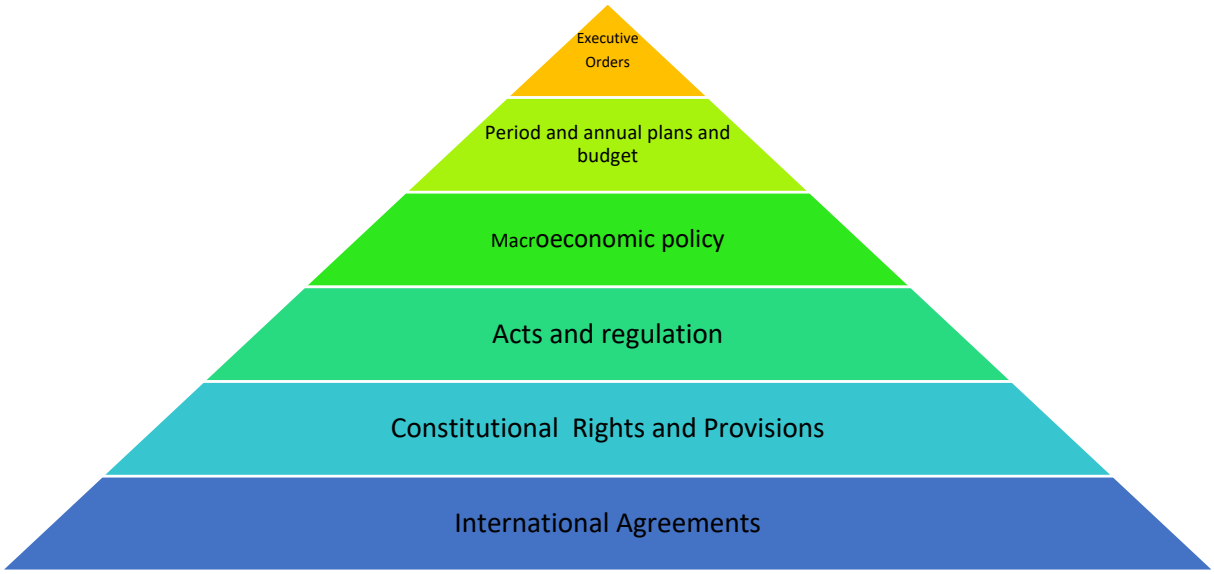

Figure 7-5: Levels of binding policies

While assessing policies related to the promotion of CASI in Nepal, the first observation is that there is no specific CASI policy. The fact that in Nepal there are dozens of policies that directly relate to agricultural development (Refer to Figure 7.6), yet no specific CASI policy, means that the pathway for CASI implementation will be a challenge requiring an evidence-based policy dialogue from the bottom up.

One of the greatest challenges in Nepalese policy development is the difficulty in ascertaining policy priorities from a diverse set of competing objectives. Further complicating this process, most policies are formulated through a silo approach, resulting in poor system-wide adoption and action. Given the complexity of the problems faced by agriculture, including questions about whether to intervene or not (role of public and private sector), and where to intervene (for example, commercialisation or livelihood improvement; production growth or sustainability), the design and implementation of effective agricultural policies will remain a challenge. In the case of implementing a CASI approach in the Terai, formulating a specific CASI policy is one option to achieve adoption across the region quickly. Ensuring that the policy formulation approach is participatory would raise awareness and encourage dialogue about the benefits and impacts of CASI.

Anecdotal evidence suggests that changes to policy in Nepal strongly follow either a change in the government or the intervention of leaders. Occasionally policy change is a response to global trends. It is common that policies are formulated to contain wish-lists and although such policies are made in good faith, they lack detailed analysis of possible options and trade-offs and become a compilation of possible solutions without clear priorities and action plans. In Nepal, inadequate policy analysis capability, lack of wider stakeholder participation in the formulation process, and the non-binding nature of many policies, are seen as critical reasons for the problem of weak translation of policy into action (GON 2015). If a CASI policy were to be formulated, it must take into account these shortcomings.

There is abundant evidence in Nepal that formulating a policy does not automatically guarantee effective action. For example, land use policy has not stopped the conversion of agricultural land to non-agricultural uses. Conversely, a lack of policy has not constrained effective implementation of popular initiatives, such as IPM programs that have become popular across the country and are funded significantly without an IPM policy. However, policy formulation has begun recently to institutionalise the benefits of the program. On this basis, the opportunity to upscale CASI initiatives in Nepal is not constrained by the absence of a CASI policy. Other approaches to communicating CASI benefits and promoting them to farmers through extension programs and farmer field schools can bring about effective behavioural changes. To draw lessons from the IPM experience, best practices should be identified and approaches documented. It is possible that a one-size-fits-all strategy for the promotion of CASI in the Terai may not be suitable, as social dimensions have been a major reason for idiosyncratic differences in the adoption of agricultural practices in the region, and the Terai is socio-economically and culturally heterogeneous.

Figure 7.6 maps the landscape of Nepalese agrifood-water-energy policies that are relevant to agricultural development. In this figure, policies close to the horizontal axis represent guiding policies, and away from the axis represent binding policies.

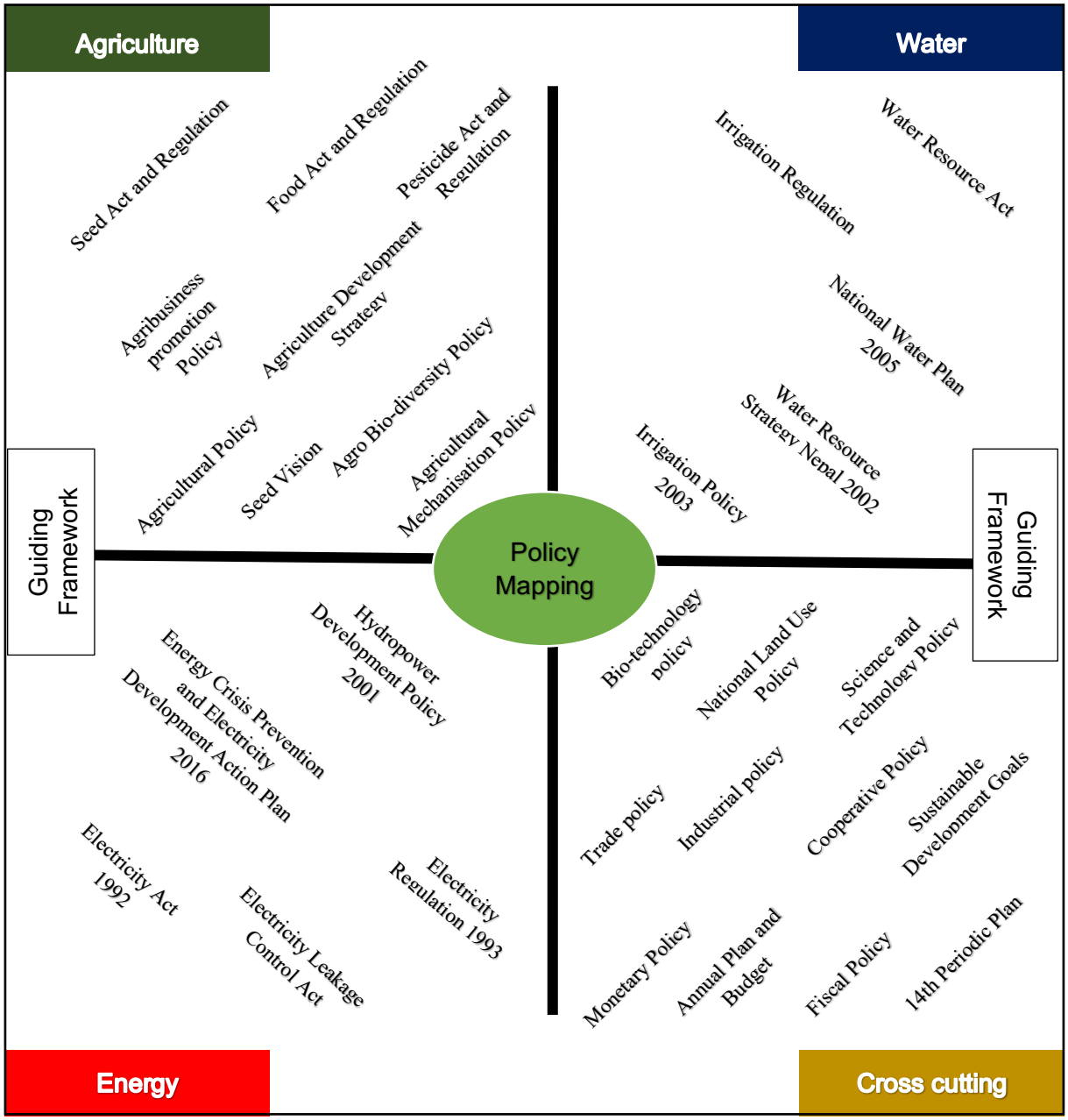

Figure 7-6: Policy Mapping - Agriculture-Water-Energy-Cross Cutting (Developed by Author)

On one hand, Figure 7.6 shows a level of 'policy obsession' among stakeholders. On the other hand, since most of the guiding policies are comprehensive, it is always possible to find provisions in these policies that support CASI. At the same time, the map also highlights the lack of a binding policy to promote and upscale the CASI approach in the Nepalese Terai.

Although these policies related to agriculture, water and energy are intricately nested, institutions and stakeholders responsible for implementing or enforcing these policies are separate. Additionally, understanding, accountability and commitment among these institutions are not at the same level. For example, responsibility to prioritise and develop irrigation infrastructure for agriculture lies with the Ministry of Irrigation and not with the Ministry of

Agricultural Development. On the other hand, water resources come under the jurisdiction of at least three ministerial level organisations - the Ministry of Irrigation, the Ministry of Water Resources and the Water and Energy Commission. **Error! Reference source not found.**[5] r epresents stakeholders active in the agrifood, water and energy sectors.

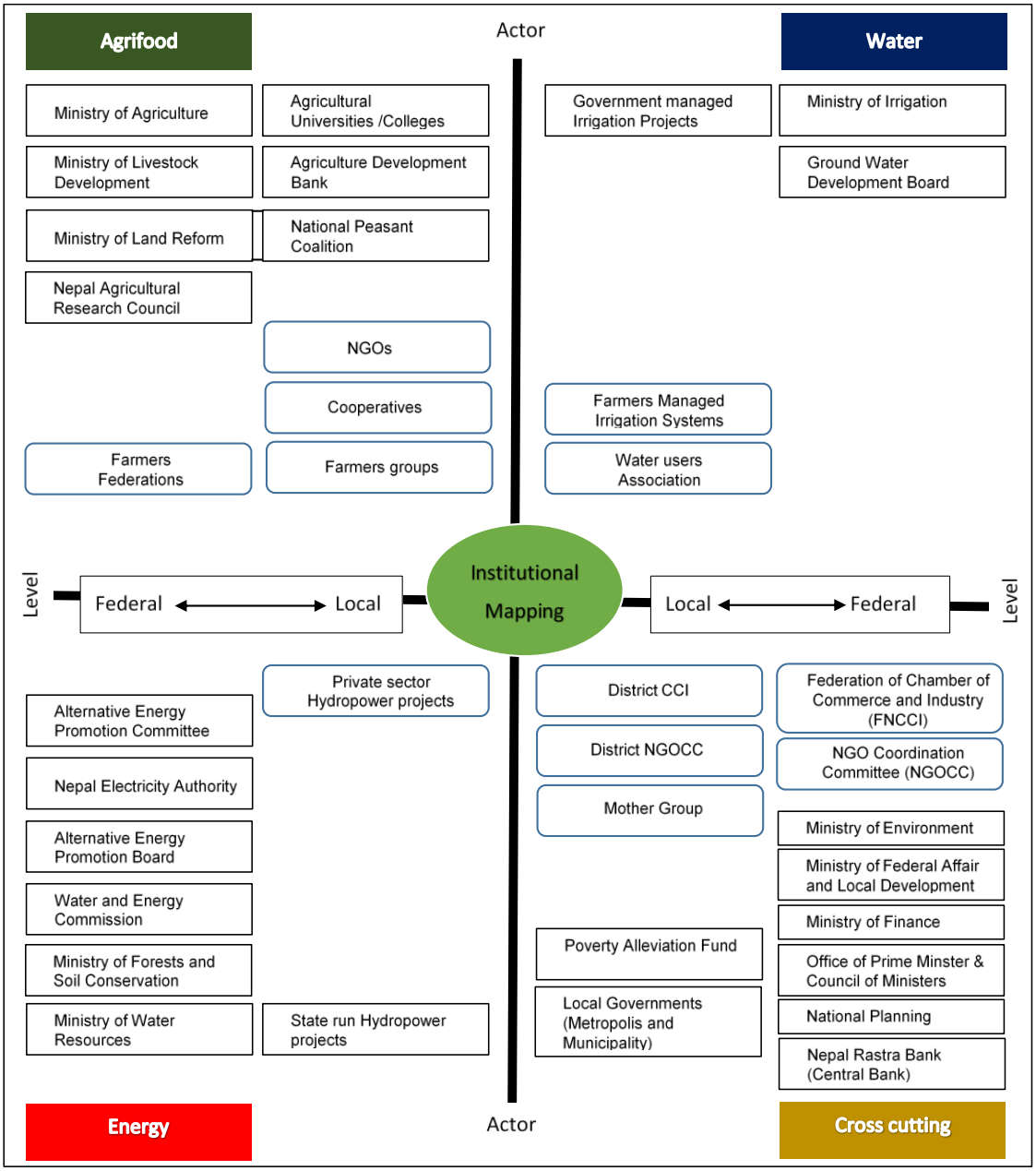

Figure 7-7: Institutional Mapping - Agriculture-Water-Energy-Cross Cutting (Developed by Author)

[5]*Actors close to vertical axis operate at local level and away from the axis at federal level. Actors in rectangular box represent state actors and in eclipse box represent non-state actors.*

Figure 7.7 suggests that the number of organisations currently responsible to formulate and implement agriculture, water and energy related policies and programs are numerous and diverse. State and non-state actors operating at different levels (federal and local) of governance further increase this complexity. Thus to effectively and holistically implement and upscale CASI practices, a multi-stakeholder platform consisting of stakeholders representing agriculture, water, energy and cross-cutting sectors at each level of governance would be needed.

7.7 Opportunities and Challenges of Upscaling CASI in Nepal

7.7.1 Opportunities

Committed public sector

Economic liberalisation in Nepal brought about by structural reform in the 1990s and accession to the World Trade Organisation (WTO) in the early 2000s raised the optimism of the private sector in agriculture. The liberalisation process led to an ideological shift towards a redefinition of the state's role to promote the private sector. As a result, Nepal moved to a more market-based economic regime by gradually phasing out subsidies on basic agricultural inputs such as fertiliser and installation of groundwater irrigation. The government also began removing controls over the capping of fertiliser prices. Similarly, the subsidy on installation of shallow tube wells (STWs) was removed in 2000/01 (ANZDEC 2002). Unfortunately, the demand for fertiliser and installation of shallow tube wells decreased drastically after the removal of subsidies (ANZDEC 2002). Although liberalisation as a macro-economic policy framework remain fundamentally unchanged, subsidies on fertilisers and irrigation systems have been reintroduced, which can be attributed to the transitional political environment of the country. At the same time, government energy policy has been protective for decades. The government remains involved in the sector through the state-owned Nepal Electricity Authority and the Nepal Oil Corporation. Similarly, the government has been the sole provider of agricultural research and extension services although extension services are devolved to local government. Thus the public sector is a major player in Nepal agriculture.

Besides core interventions from the Ministry of Agricultural Development and the Ministry of Irrigation, other government ministries are currently implementing cross cutting agricultural programs that support and are aligned with CASI initiatives. The decentralised small infrastructure development program, environmentally friendly local governance programs and development programs targeted at women, indigenous communities, marginalised and poor communities, are implemented by the Ministry of Federal Affairs and the Local Development and Ministry of Poverty Alleviation in support of CASI initiatives in the Terai.

Strong local government

The Constitution of Nepal 2015 provisions shared responsibilities for agricultural development among federal, state and local level governments, with a dominant share of those roles entrusted to the local level. After two decades of political void, local government representatives in Nepal were elected in 2017. The implementation of food, water and energy policy now includes input from local government, which should mobilise additional resources, some of which could be directed to CASI initiatives. For example, local leaders who advocate for CASI could expedite scale-up processes. Demonstrating the benefits of CASI at the local level can raise the awareness of critical stakeholders and win their support.

Fresh Agriculture Development Strategy (2015-2035)

The Agriculture Development Strategy (2015-2035) is one of the most widely discussed strategic documents in Nepal. This strategy is unique in many ways: it was developed by experts and refined by policy makers over five years of intense consultation; farmer-wings of major political parties were actively involved in the policy process; it was supported by 13 development partners working in Nepal; and the strategy was endorsed by the Nepalese Parliamentary Committee before finally being approved by the government. So there is widespread commitment to implementing the Agriculture Development Strategy. Its objectives and provisions align well with CASI-based approaches. By linking CASI with ADS objectives and program logic, more widespread support can be harnessed for scaling up CASI initiatives.

Public Policy Dialogue Forum available for CASI awareness

The Ministry of Agricultural Development and the International Food Policy Research Institute (IFPRI) South Asia have created and institutionalised a Public Policy Dialogue Forum to bring important agricultural issues into the policy debate. Other Policy Think Tanks such as Sambriddi have begun actively raising agricultural issues in public debate. At this time when the government in Nepal has introduced programs under the Prime Minister's Agriculture Development Initiative across the country, there is an opportunity to include CASI in these programs as a separate mission. Various CASI practices such as direct seeding, minimum tillage, system of rice intensification and IPM have already been introduced as cross-cutting interventions. The forum can be utilised to voice the need and approach for scale-up of CASI technologies to address the socio-economic and technological problems of the Terai nested in the food, water and energy sectors.

Emergence of public-private partnership

Recent public sector efforts to promote private sector involvement in the agricultural sector have taken place together with the private sector's representative body – the Federation of Nepalese Chambers of Commerce and Industry (FNCCI). Typical examples include the Public-Private Partnership model of 'One Village One Program' between the Ministry of Agricultural Development and the FNCCI, provision of competitive grants to promote private sector led value chain development, and transfer of government-owned irrigation systems to local communities. Again, this presents an opportunity to expand partnerships that promote CASI.

Active NGOs and CBOs at local level

Besides multilateral and bilateral donors in agriculture, various national and international non-governmental organisations and community-based organisations are active in the agricultural sector in Nepal. Some of them (such as IRRI, CYMMIT, ICIMOD, Bio-versity International, HELVETAS, CEAPRED, LI-BIRD, RRN, IDE, FORWARD, CARE and Heifer International)[6] have been actively engaged in CASI related activities as well as working closely with the government. There are further opportunities to upscale these activities and partnerships.

[6] *This is not the exclusive list of NGOs and CBOs working in the sector.*

7.7.2 Challenges

Cautious private sector in agriculture

Private sector confidence to enter into the food, water and energy space has largely been affected by the country's macroeconomic and political environment. Inconsistency, particularly regarding subsidies and state intervention in agricultural affairs, has resulted in a private sector that is reluctant to enter into the agricultural space, particularly in the areas of research, extension, fertiliser trade and irrigation. For instance, although all public monopolies for domestic and foreign trade in agricultural inputs and final products were eliminated with greater promise for private sector promotion (Chapagain & Phuyal 2003), the subsidy regime for inputs was soon restored. Thus the private sector has been reluctant and unable to compete with the government-owned enterprises such as the Agriculture Input Corporation Limited, particularly in the fertiliser sector. Cause for optimism exists, however, since the private sector is enthusiastically participating in agribusiness value chain and seed sector development.

Feminisation of agriculture

The agricultural sector in Nepal is going through structural transformation which is atypical in nature (Tiwari 2016). Labour forces are leaving the low productive agriculture sector, however they do not join the manufacturing or industrial sectors within the country. Rather, the active labour force, particularly males, are leaving to work overseas. Remittances from overseas workers have now become the second largest contributor to GDP after agriculture, forestry and aquaculture and the major source of household income in the Terai. Consequently, Terai agriculture is experiencing feminisation of the sector. Policy initiatives are needed that appreciate women's increased role in Terai agriculture and encourage interventions that build capacity for women to assume new roles. This presents a challenge in some parts of the Terai where women do not open up to the outside world. A second challenge is to strike a balance between enhanced capacity and greater responsibility for women, and not over-burdening them. Support for small scale mechanisation that is already available, needs to be customised to the needs of and the suitability for women.

Research and extension effort to promote and upscale CASI not adequate

The adage that 'in the search for a few big impacts, small but numerous outcomes are being neglected', fits well with CASI related R and D activities in Nepal. Every year, significant government resources are directed towards funding subsidies on large scale agricultural and irrigation projects. This process does not include a CASI specific programmatic approach.

Regional embeddedness

Nepal's open border with India offers both opportunities and challenges. It is hard for Nepal to develop and enact agricultural policies without considering Indian policy in context. For example, policy related to input subsidies cannot be regulated without being close to the Indian subsidy level. At the same time, best practices in one country can quickly transmit farmer to farmer across the border. IRRI's regional initiative has been effective in fast tracking varietal development and upscaling the adoption of improved rice varieties across Nepal, India and Bangladesh. Similar effort would be required to promote CASI across the Gangetic plains, which is time consuming as it involves different countries in the region.

Silo approach among stakeholders

In the past, stakeholders who operated in the field of energy, food, agriculture and water, designed and implemented policies, programs and projects from the lens of each individual organisation and discipline, resulting in a lack of cohesive development efforts.

7.8 Conclusion

Nepal has experienced unprecedented economic growth at an annual rate of 6.9 per cent since the mid-1990s. At the same time agriculture has grown by 5.3 per cent annually, largely attributed to favourable monsoons and increased availability of electricity. This high growth rate is a reminder that timely availability of water and energy are the most important drivers of agricultural growth in Nepal. Water not only multiplies the effect of other factors of production such as improved seeds and fertilisers but also enhances confidence and certainty among farmers to remain in the sector. Similarly, undisrupted availability of electricity contributed to a double-digit (11 per cent) growth in the industrial sector, in turn creating more demand for agricultural outputs. The Government of Nepal has recently announced that attaining sustainable, inclusive and high economic growth is one of its immediate developmental objectives, with agricultural development priorities for increasing production and productivity, agricultural modernisation, commercialisation and mechanisation, and improvement of public service delivery (GON 2017).

Further, Nepal has recently undergone significant changes in governance structure, sharing agricultural governance across the three layers of government: federal, state and local. To comply with this new structure, the Government of Nepal has handed over to the local level several agricultural programs previously implemented by central agencies. These programs are the Commercial Agriculture Production Pocket and Block Development Program, agricultural production related activities, the Agriculture Market Infrastructure Construction Support Program, Fishery Development Program, One Ward One Agriculture and Livestock Technician Program, along with the Small Irrigation, Agriculture Promotion Service Program and agricultural income generation targeted programs (GON 2017).

Similarly, irrigation related programs such as underground shallow tube-wells, irrigation renovation and maintenance project, new technology based irrigation projects, prosperous Terai-Madesh Irrigation Development Program, and the special land-based river control program, have been handed over to the local level. One the one hand this process will enhance the participation of grassroots stakeholders in the design and implementation of agricultural and irrigation related programs. On the other hand, the capacities within a new institutional set up of local government to co-ordinate and implement these activities will be grossly inadequate as political leaders resume offices after almost two decades. Central government is expected to continue capacity development to fill this gap so that the benefits of the decentralisation process can be realised.

That the government's outlook of achieving integrated development of the agricultural sector and sustained growth of the economy "by making the agriculture system scientific, commercialized, environment and eco-friendly" (GON 2017, p. 18) places the CASI initiative in as a priority, provided it is framed as an initiative that aligns with and supports the government's objective of agricultural modernisation.

The need, however, is to establish an innovation platform where all these stakeholders can design and implement their interventions according to their capabilities to institutionalise a knowledge innovation system around CASI. Although specific CASI policy is not in place, other existing policies and institutions are enough to continue a CASI-based theory of change. Owing

to the nature of CASI, implementing it through a multi-stakeholder partnership model with the coordination of local government seems the most realistic option in the current Nepalese context.

7.9 Acknowledgements

I would like to express my sincere gratitude to Emeritus Professor Ray Collins, UQ and Professor R. Quentin Grafton, ANU for giving me helpful feedback in the original version of this report. My special thanks also go to Senior Crop Development Officer Dr Mahendra Khanal, Senior Plant Protection Officer Mr Sujan Dhungel and Senior Agricultural Economist Mr Binod Bhattarai from the Ministry of Agricultural Development Nepal for providing me agriculture specific data and other relevant reference materials.

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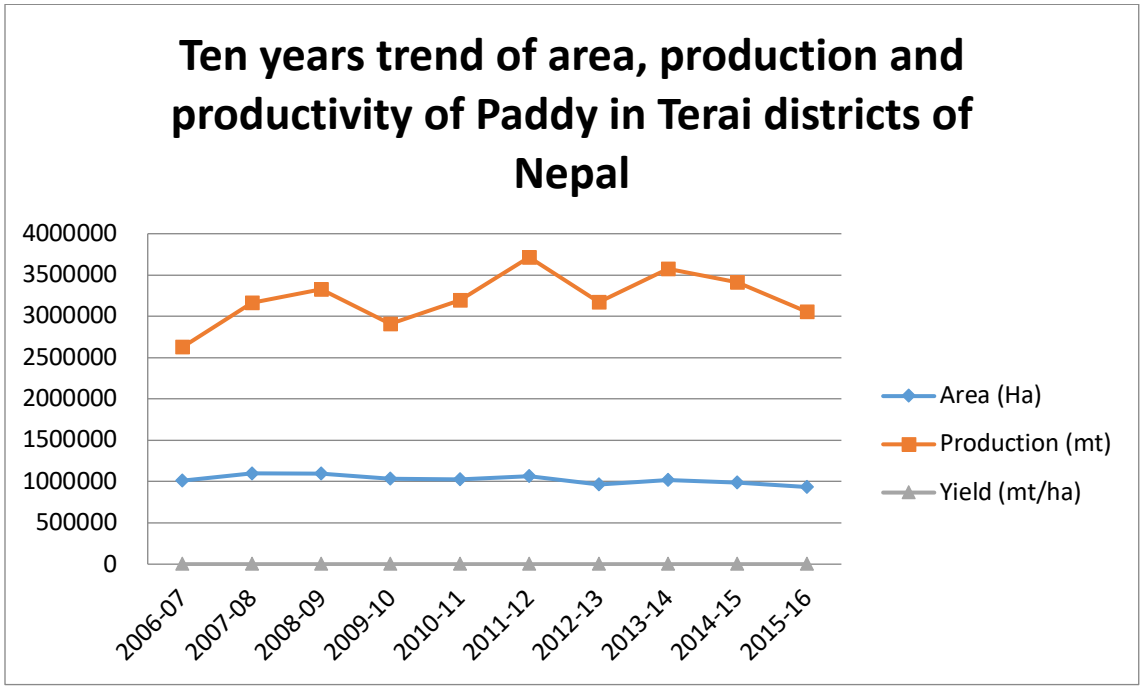
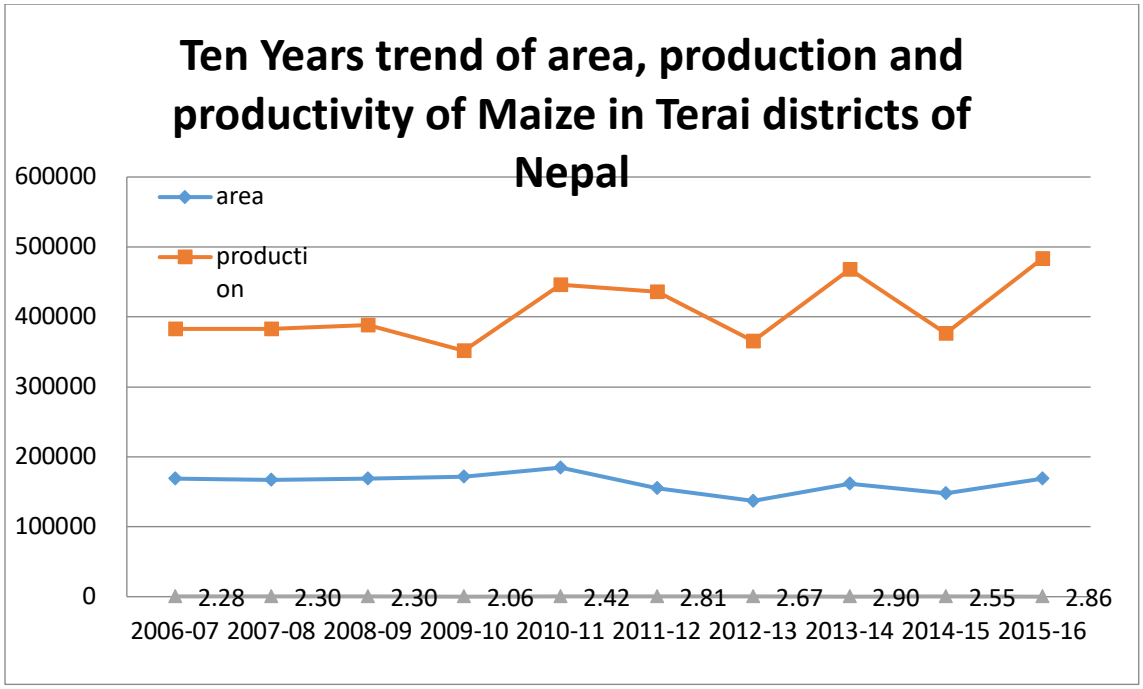
7.11 Appendices

7.11.1 Appendix 7.1: Trend of area, production and productivity of major agricultural commodities in Terai districts (FY 2006-07 to 2015-16)

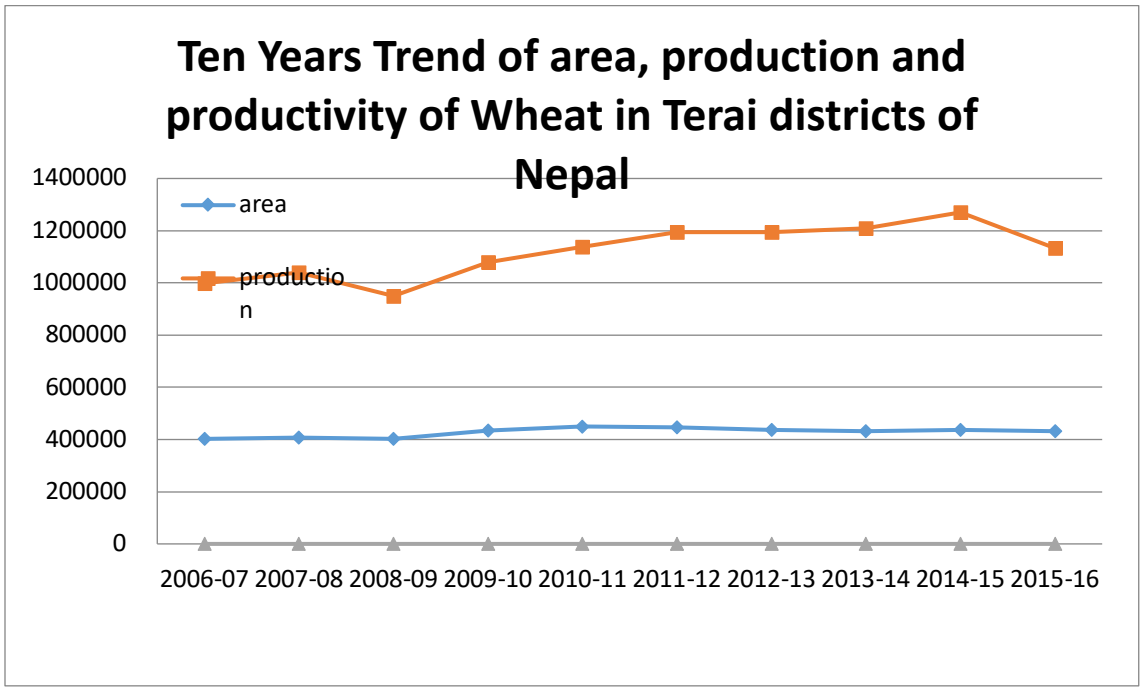
Paddy



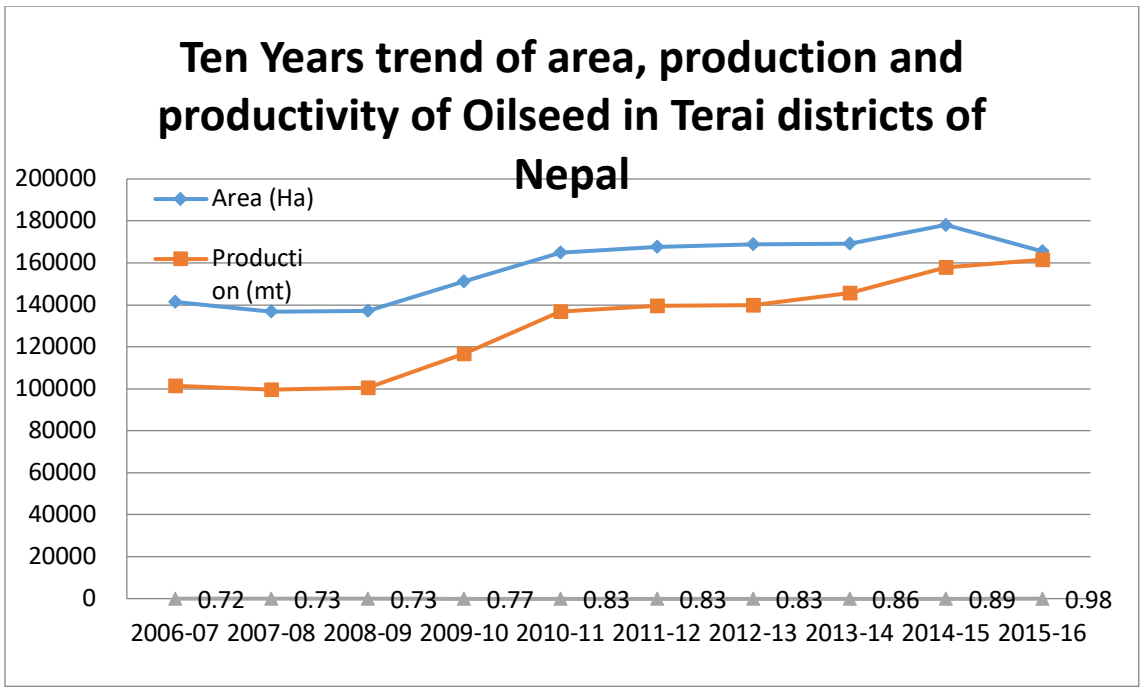
Maize



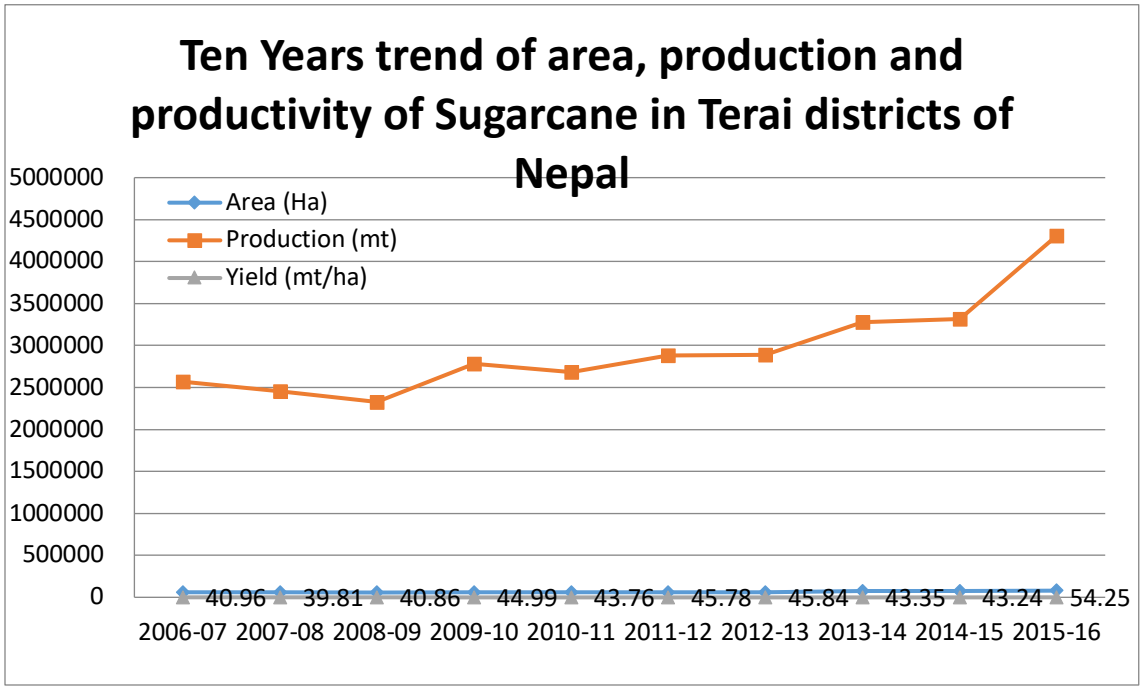
Wheat



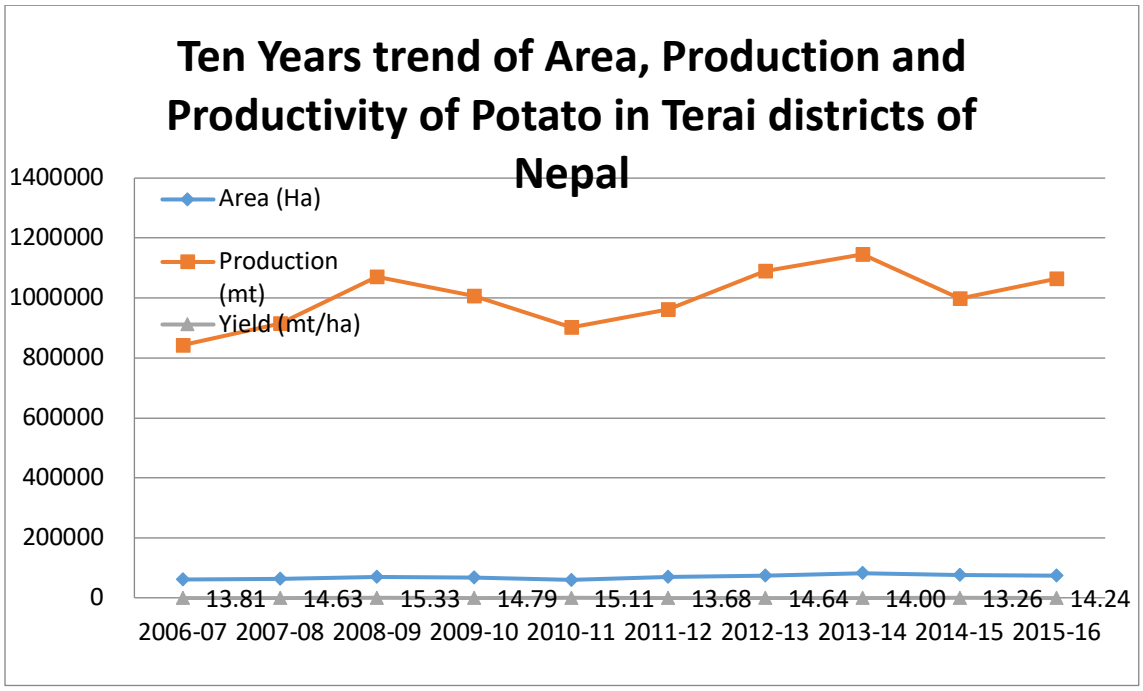
Oilseed



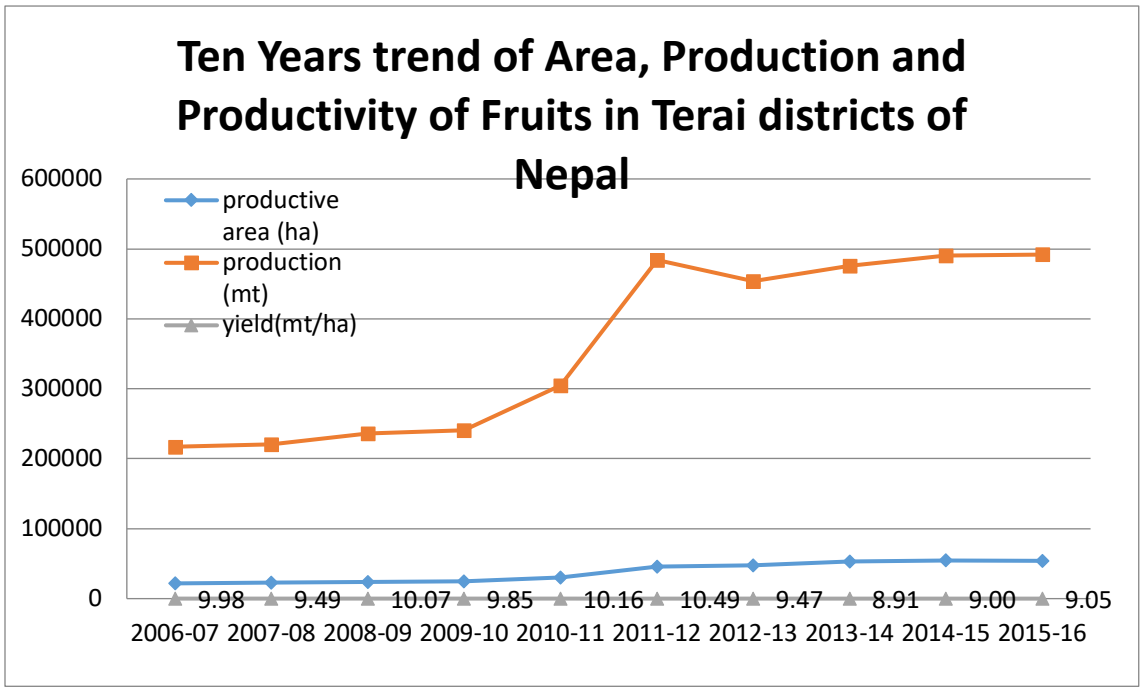
Sugarcane



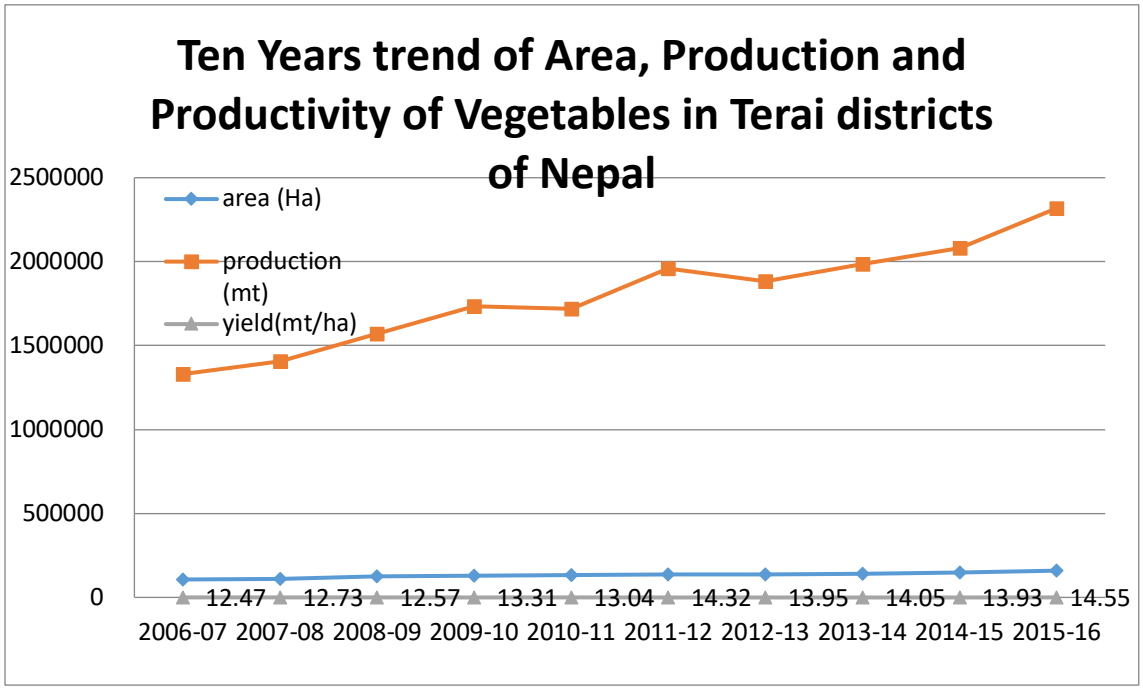
Potato



Fruits



Vegetables



Source: Statistical information on Nepalese agriculture, MoAD (2006-07 to 2015-16)

8 Mapping high-level institutions, policies & programs towards agricultural development in Eastern-Gangetic Plain

8.1 Summary

This report is an output of research undertaken by SaciWATERs under Australian National University (ANU)-SRA (Small Research Activity). The aim of this research report is to identify key high-level institutions, their mandates, resources, policies, and programs in the agricultural development in Nepal, Bangladesh & India region of Eastern-Gangetic Plain. The report also attempted to identify existing challenges and opportunities for scaling out of promising agricultural technology in the region. We used an explorative methodology in identifying key institutions through secondary sources and interviews. Information from secondary sources and informant interviews were used to generate this report. Through this research we tried to capture opinions on the capacities and limitations and this information will be used for identifying bottleneck for up-scaling of promising agriculture technologies. The key findings from the analysis are

a. India (With focus on Bihar & West Bengal)

There is support through several flagship programs from the state and central government. The implementation of the programs is politically driven as the center and state have governments with different interest and focus. The implementation of agricultural policies and programs are the prerogative of the state government and it is fragmented. From the discussions, it was found that there is inefficiency in implementation of the programs intend to achieve the desired impacts. Lack of coordination, human resource capacity, information exchange and learning are other key limitations among the key stakeholders particularly from the government department, research institute, and even NGOs are independently working in isolation. The lack of staff, budget and poor extension services are identified as bottlenecks in the region including sufficient support for irrigation scheme including subsidized electricity.

b. Bangladesh

In Bangladesh, the institutions are far more developed especially in the northwest region of the country. There is a conducive policy support for the agricultural development. However, there is a need of continuous support in terms of policies for strengthening the institutions to improve inter-departmental synergies between government, non-governmental agencies, and the community. NGOs network are strong and effective. They continue to play an important role in the community led development. As per the opinion of different interviewed stakeholder, technology intervention is needed further improvement in the region.

c. Nepal

Nepal has the history of political instability that has affected support the development of the region particularly agricultural sector. There is a lack of efficient extension network to build the support mechanism. Migration is rampant in the region resulted in shrinking in cultivated area due to non-availability of labor and inputs. The organizations relevant to achieving that impact are: distributed across the public, civic and private sectors; are independently funded; and function in isolation. The organizations relevant to achieving that impact are: distributed across the public, civic and private sectors; are independently funded, and need good coordination.

8.2 Introduction

Agriculture is a major contributor to rural income for the population of Eastern Gangetic plain of South Asia comprises of three countries i.e. India, Bangladesh, and Nepal. Rice and wheat continue to be the major crop in the region and there is huge demand to improve from current levels of productivity alongside ensure sustainability of resources (Timsina and Connor, 2001; Ray et al. 2013). There has been the adoption of technologies from the advent of green revolution in the region such as high- yielding varieties, fertilizer, and irrigation. However, over the years, there has been a continuous decline in the marginal returns due to overexploitation of available resources and use of inputs resulted in deterioration of soil, pest and insect infestation and stagnant productivity. Hence, there need to logically optimize intensive farming and sustainable use of resources by the adoption of resource conservation technologies (RCTs) and management. There is an affinity for resource-conserving technologies, conservation agriculture, improve input efficiency to reduce the negative impact on the environment. Agriculture is given greater importance in these countries in terms of support programs, policies and resource allocation in the region. But, there has been a minimum performance in terms of agricultural productivity particularly in the last two decades. Climate change has added greater woes to the agriculture sector in this region as these countries have been a hot spot of climate-related hazards such as floods and droughts (CCAFS, 2011). Though, several flagship policies, programs, mandated institutions and resource allocation for these regions, often questions are raised on how far these support programs are being efficiently implemented in these countries. Understanding the key institutions, programs, and implementation channels are important to identify gaps and inform policies to plug key gaps for improving the sector. This can bring necessary institutional innovation to support the current set up and program –institutional linkages in implementing the programs/policies. This report attempts to map key high-level institutions, its mandates and key roles in supporting development towards sustainable intensification and resilient agriculture and also attempt to identify key constraints and opportunities to scale out.

8.3 Approach & Methodology

This information collected for this report is primarily from a secondary source and key informant interviews. The key informants were individuals from respective government and non-governmental organizations having more than 10 years of experience in the agriculture development sector (List of personnel interview in given in Appendix 8.1. The secondary sources include key government ministry websites, reports and policy documents.

We tried to identify institutions under four broad categories a) what are the key government ministries that are relevant to agriculture development in the country? The key institutions subsidiary to the ministry mandated carry out activities for agriculture development b) Institutions that are involved in research education and policy support for agriculture development c) On the ground implementation of key programs, key players including governmental & non-governmental organization and private players. e) International agencies that support government through their support through loans & grants. By gathering this information, we also tried to look at their past set of activities linked with the development of agriculture and these could be leverage for up-scaling of technology.

The key questions asked to the key informants were a)What are the key challenges & opportunities for up-scaling of promising agriculture technology in the region (EGP) (Inadequate capacity, knowledge & networks, subsidies etc.) b) How significant are the non-government players such as NGOs, international agencies etc. in development of agriculture in the region

(technical support)? C) What role do they play (e.g. technical knowledge dissemination, social mobilization, and value addition, advocacy)? D) How effective are the convergences of different institutions (ministries, department, NGOs & others) ineffective scaling up of potential technologies? Identifying a time frame wherein technologies are up-scaled is not within the scope of this report.

8.4 India

India has the federal system wherein the distributions of power are between Center and the state governments. The power is divided across legislative, administrative & executive powers. Under the central government, ministries mandated for the development of agriculture& allied structure, water resources and rural development are a) Ministry of Agriculture and farmers welfare b) Ministry of rural development, Panchayat Raj & Drinking water and sanitation c) Environment, forest, and climate changed) Water resources, river development & Ganga Rejuvenation. These ministries devise policies and program at a pan-India level where these programs are being implemented by the department at the state level. There is support from the center to the state to implement these programs that can be tailored based on the context of the state.

8.4.1 A. Policy Formulation, Coordination & Supervision

Ministry of Agriculture and farmers welfare (MOA&FW, 2017)

The Ministry of Agriculture and farmers welfare has departments such as i. Department of agriculture, cooperation & farmers welfare (AC&FW) ii. Department of Animal Husbandry, Dairy, and Fisheries (AHD &F) c. Agricultural Research and Education (DARE).Through these departments, entire programs/policies are implemented. The Department of Agricultural Research and Education (DARE) coordinates and promotes agricultural research & education in the country. The DARE provides necessary government linkages for the Indian Council of Agricultural Research (ICAR), the premier research organization for co-coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the country. Around 100 ICAR institutes and 71 agricultural universities spread across the country, this being one of the largest national agricultural research systems in the world. The AC&FW is divided into 27 divisions for better coordination and monitoring of the programs with the corresponding state government (Figure 8.1).

Ministry of Rural Development (MORD, 2017)

There are two departments under this ministry are i) Department of Rural Development and ii) Department of Land resources. Major programs that are being operated are i) Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for providing wage employment and rural asset development. (ii) National Rural Livelihoods Mission (NRLM) for self-employment and skill development, (iii) Indira Awaas Yojana (IAY) for providing housing to BPL households, (iv) Pradhan Mantri Gram Sadak Yojana (PMGSY) for construction of quality roads (v) National Social Assistance Program (NSAP) for social pension (vi) Integrated Watershed Management Program (IWMP) for improving the productivity of the land.

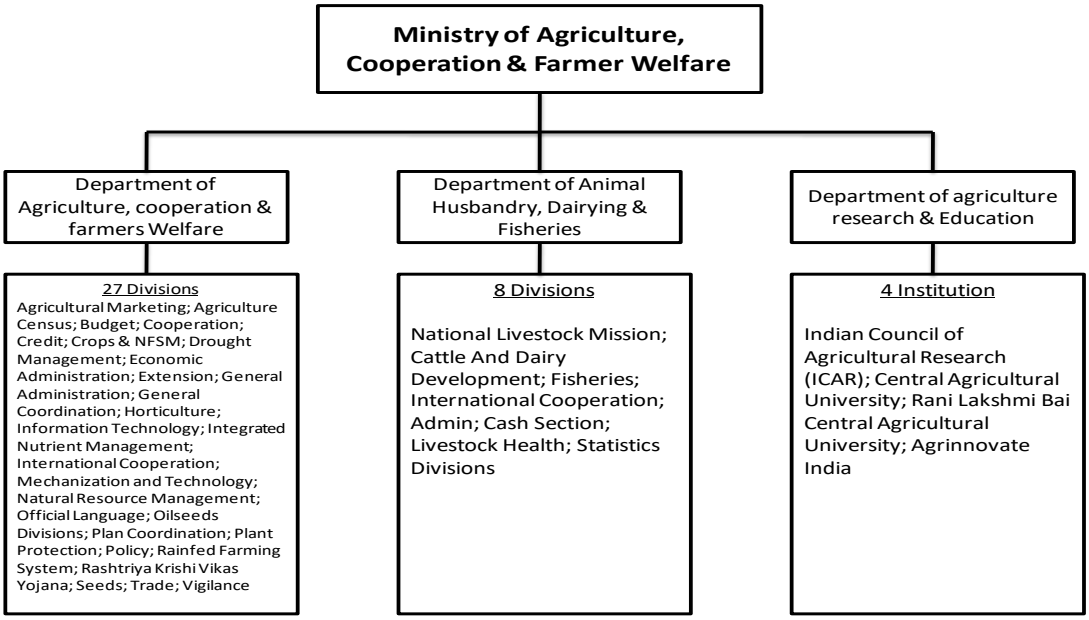


Figure 8-1: Organizational structure of Ministry of Agriculture, Cooperation & Farmers Welfare

Ministry of Environment, forest& Climate Change (MoEF&CC, 2017)

The ministry is responsible for planning, promoting, coordinating, and overseeing the implementation of environmental and forestry programs in the country. The main activities undertaken by the ministry include conservation and survey of the flora of India and fauna of India, forests and other wilderness areas; prevention and control of pollution; afforestation, and land degradation mitigation. It is responsible for the administration of the national parks of India.

Ministry of Water resources, river development and Ganga rejuvenation (MoWR, RD & GR, 2017)

The Ministry of Water Resources, River Development & Ganga Rejuvenation is a body that formulates and administers rules and regulations and laws relating to the development and regulation of the water resources in India. The key programs implemented by this ministry are i. Irrigation Management program ii. Flood management program iii Rainwater harvesting initiatives iv. Repair & restoration of water bodies etc. Under this ministry, there are key institutions mandated to design policy and programs. The institutions are Central Ground Water Board, Central water Commission, National water development agencies, Ganga flood control commission etc.

National Ganga River Basin Authority

National Ganga River Basin Authority (NGRBA) is a financing, planning, implementing, monitoring and coordinating authority for the Ganges River, functioning under the water resource ministry of India. The mission of the organization is to safeguard the drainage basin which feeds water into the Ganges by protecting it from pollution or overuse.

Ganga Flood Control Commission (GFCC)

Ganga Flood Control Commission (GFCC) carries out several activities such as 1. Preparation and updating a comprehensive plan of flood management. 2. Techno-economic appraisals of Flood Management Schemes.3. Assessment of adequacy of waterways under roads and rail

bridges. 4. Programming of implementation of flood management works.5. The framing of guidelines for quality control and maintenance. 6. Monitoring of all flood management schemes and important flood management schemes funded by Central Government. 7. Documentation and Dissemination of recommendation of special studies. 8. Performance evaluation of completed Flood Management Schemes.

Niti Ayog

The National Institution for Transforming India (NITI Aayog) is the premier policy 'Think Tank' of the Government of India, providing both directional and policy inputs while designing strategic and long-term policies and programs for the Government. This provides relevant technical advice to the Centre and States. NITI Aayog has considered equivalent to planning commission consider itself as the state of the Art Resource Centre, with the necessary resources, knowledge, and skills, that will enable it to act with speed, promote research and innovation, provide strategic policy vision for the government, and deal with contingent issues.

8.4.2 B. Research, Education & Policy Support

The Department of Agriculture Research & Education (DARE), Indian Council of Agriculture Research (ICAR) is mandated for agricultural research and education. There are several research institutes and universities under ICAR, wherein agricultural research is carried out. There are biophysical research institutes such as crop and soil based but also policy research that supports agriculture-related policy formulation. Once a promising technology is developed and tested analyzed by the independent institutions and promoted for large-scale dissemination.

8.4.3 Agriculture development Program Implementation

Prime Ministers Krishi SinchayYojna (PMKSY)

The primary objectives of PMKSY are to attract investments in irrigation system at field level, develop and expand cultivable land in the country, enhance ranch water use in order to minimize wastage of water, enhance crop per drop by implementing water-saving technologies and precision irrigation. The plan additionally calls for bringing ministries, offices, organizations, research and financial institutions occupied with creation and recycling of water under one platform so that an exhaustive and holistic outlook of the whole water cycle is considered. The goal is to open the doors for optimal water budgeting in all sectors. The tagline for PMKSY is "more crop per drop. PMKSY has been formulated amalgamating ongoing schemes viz. Accelerated Irrigation Benefit Program (AIBP) of the Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR), Integrated Watershed Management Program (IWMP) of Department of Land Resources (DoLR) and the On-Farm Water Management (OFWM) of Department of Agriculture and Cooperation (DAC).

Mission on Integrated Development of Horticulture

This scheme is brought enhance horticulture production, doubling farm income and improving nutritional security. This supports the farmers in improving farm-level productivity, improving water use efficiency, providing technology support to high-value agriculture. These schemes are being implemented through National Horticultural Board and state Department.

Prime Minister Fazal BhimaYojna

The main aim of this program to provide more efficient insurance support to the farmers of thereby strengthening through crop insurance to prevent them incur heavy losses if the crops get damaged due to natural calamities and other unavailable circumstances.

National Mission for Sustainable Agriculture

This mission objective is to make agriculture more productive, sustainable and climate resilient; to conserve natural resources; to adopt comprehensive soil health management practices; to optimize utilization of water resources; etc. “Soil Health Management (SHM) is one of the most important interventions under this mission. SHM aims at promoting Integrated Nutrient Management (INM) through judicious use of chemical fertilizers including secondary and micro nutrients in conjunction with organic manures and bio-fertilizers for improving soil health and its productivity; strengthening of soil and fertilizer testing facilities to provide soil test based recommendations to farmers for improving soil fertility; ensuring quality control requirements of fertilizers, bio-fertilizers and organic fertilizers

mKisan - A Portal of Government of India for Farmer Centric Mobile Based Services

This scheme provides information on markets, inputs, agro advisories to the farmer, contingency plans and Package of Practices (POP), information of prices, collection center etc through their mobile telephone. This is one stop shop for the farmers (http://farmer.gov.in/FarmerHome.aspx0.)

Sub-Mission on Agricultural Mechanization

The Mission objectives are (i) Increasing the reach of farm mechanization to small and marginal farmers and to the regions where availability of farm power is low; (ii) Promoting ‘Custom Hiring Centers’ to offset the adverse economies of scale arising due to small landholding and high cost of individual ownership; (iii) Creating hubs for hi-tech& high value farm equipment; (iv) Creating awareness among stakeholders through demonstration and capacity building activities; (v) Ensuring performance testing and certification at designated testing centers located all over the country.

Mahatma Gandhi National Rural Employment Guarantee Act

The MGNREGS Act aims at enhancing the livelihood security of people in rural areas by guaranteeing hundred days of wage-employment in a financial year to a rural household whose adult members volunteer to do unskilled manual work. The work primarily focuses on developing asset creation and maintenance.

National Livestock Mission

The Mission is designed to cover all the activities required to ensure quantitative and qualitative improvement in livestock production systems and capacity building of all stakeholders. The Mission focus on improvement of livestock productivity and support projects and initiatives required for that purpose subject. These Mission objectives are sustainable development of livestock sector, focusing on improving the availability of quality feed and fodder. There is three submissions under this mission are a) sub-mission on fodder and feed development b) sub-mission of livestock development c) submission on pig development in north-eastern region d) sub-mission on skill development, technology transfer, and extension. The other schemes such as sector scheme for development of fisheries, Integrated nutrient management including organic farming and soil health etc.

National Bank for Agricultural & Rural Development (NABARD)

The mission of the NABARD is to promote sustainable and equitable agriculture and rural prosperity through effective credit support, related services, institution development and other innovative initiatives. The initiatives include building an empowered and financially inclusive rural India through specific goal oriented departments which can be categorized broadly into three heads: Financial, Developmental, and Supervision.

8.4.4 D. International Development Organizations

Since independence, they have been significant support from international organization in aid to improve the sector. Asian Development Bank, IFAD, FAO, CGIAR institutes support research and agricultural development activities. There are activities for commercialization of smallholder agriculture, grass-roots institution building, and women's empowerments including natural resource development such as watershed and technology adoption (https://operations.ifad.org/web/ifad/operations/country/projects/tags/india). Country programs are targeted specific regions. Currently, the support programs such as flood and drought mitigation, integrated livelihood support project in drought and flood area.

8.5 Bihar & Agriculture

Bihar is blessed with fertile alluvial soil with abundant water resources particularly ground water resources. Hence, agriculture in this state is rich and diverse. The rice-wheat cropping system is followed in this EGP belt followed by maize and pulses. The state is also one of the major producers of vegetables and fruits. As per the 2011 census, agriculture continues to be the major occupation supporting the livelihood of the poor. Around 78% of the people depend on agriculture directly or indirectly for livelihood as cultivators and farm laborers. However, major constraints in this sector are high population pressure as the result there is a high level of fragmentation of land followed by low productivity and lower per capital income. The per capita income in Bihar has declined in the last two decades compared to other states in India. As EGP region, the Bihar is also highly vulnerable to abiotic and biotic stresses. Flood and drought have become common in the state in the last two decades. Climatic variability such as delay in the onset of monsoon, intraseasonal drought have also contributed to the loss of production and affecting large population depending on the agriculture. Bihar has a long history of flooding in the state particularly flooding of 2007, 2008 2012 etc. wherein almost 60-65% of the population living under the threat caused by flood devastation. Enlisting of departments, under the Bihar government mandated for the development of agriculture & allied sector and rural development

8.5.1 Agriculture Development Program Implementation

Agriculture & Animal, and Fisheries Resources Departments (DoA, 2017)

The department of agriculture has three directorates, Agriculture, soil conservation and Horticulture (Figure 8.2). The directorate activities are mainly the implementation of central and state schemes/programs. Department of Agriculture through its Directorates and with the technical guidance of the Agricultural Universities has acted as delivering the vehicle to reach the benefits of technological advancements as well as research findings to the last person down the line involved in farm activities. The directorates under this department are Animal Husbandry, Dairy & Fisheries.

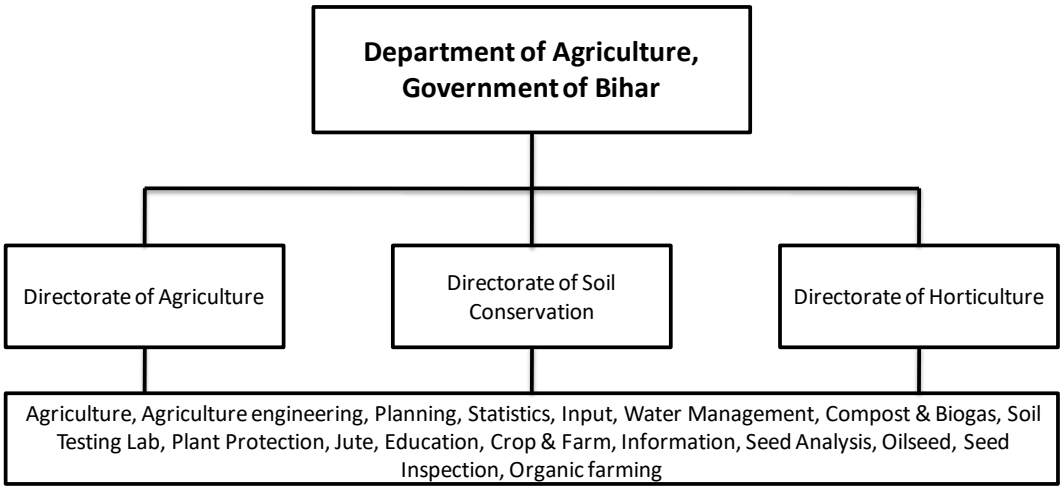


Figure 8-2: Directorates under the department of agriculture, Government of Bihar

Major schemes- and Programs – Bihar State

Enlist of major schemes and programs in the state for agriculture development and increased productivity. The state departments implement both centrally sponsored program as well as state programs. There are several state sponsored programs implemented by different directorates. Some of the programs implemented by the Soil Conservation Directorate are Pucca Check Dam (PCD), Silt Detention Dam (SDD), Water Harvesting Structures (WHS), Runoff Management Structures (RMS), Earthen Check Dam (ECD), Farm Pond (FP), Water Harvesting Tank (WHT), Agroforestry, Dry Land Horticulture (DLH), Farm Bunding, Desiltation of old existing Ponds, Community Pond etc. The directorate of agriculture and horticulture also has more than dozens of programs supported by the state government that includes organic farming, System Rice Intensification (SRI), Agro-Industries etc.

National Horticulture Mission

This is a Centrally Sponsored Scheme launched for the holistic development of horticulture in the country during XII plan. The scheme, which has taken take off from 2014-15, integrates the ongoing schemes of National Horticulture Mission, National Bamboo Mission, National Horticulture Board and Coconut Development Board. In Bihar, the plan for coming year include developing, nurseries development, rejuvenation of practices, organic farming, integrated pest

management, horticulture mechanization, post-harvest management, human resource development and beekeeping

National Food Security Mission

The National Development Council (NDC) in its 53rd meeting held on 29th May, 2007 adopted a resolution to launch a Food Security Mission comprising rice, wheat and pulses to increase the production of rice by 10 million tons, wheat by 8 million tons and pulses by 2 million tons by the end of the Eleventh Plan (2011-12). Accordingly, A Centrally Sponsored Scheme, 'National Food Security Mission', has been launched from 2007-08 to implement the above-mentioned resolution.

Micro Irrigation

The irrigation projects (major and medium) have contributed to the development of water resources, the conventional methods of water conveyance and irrigation, being highly inefficient, has led not only to wastage of water but also to several ecological problems like water logging, salinization and soil degradation making productive agricultural lands unproductive. It has been recognized that use of modern irrigation methods like drip and sprinkler irrigation is the only alternative for efficient use of surface as well as groundwater resources.

Rashtriya Krishi Vikas Yojana

Rashtriya Krishi Vikas Yojana scheme to incentivize States to draw up plans at the grass root levels for their agriculture sector more comprehensively, taking agro-climatic conditions, natural resource issues and technology into account, and integrating livestock, poultry, and fisheries more fully. This will involve a new scheme for Additional Central Assistance to State Plans, administered by the Union Ministry of Agriculture over and above its existing Centrally Sponsored schemes, to supplement the State-specific/ area-specific strategies including special schemes for beneficiaries of land reforms.

Bihar state climate change action plan

Bihar State Action Plan on Climate Change released in 2015 has given prior importance in agriculture and allied sector in the state. The overall strategy of therefore under the BAPCC is, therefore, to transform agriculture and its allied sectors into climate resilient and vibrant production system while developing their full potential and ensuring sustained food and nutritional security in the State.

8.6 West Bengal and Agriculture

West Bengal is a predominantly agrarian state with around 71.23 lakh farming families. A majority of these farmers (98%) are small and marginal farmers with average landholding size of around 0.77 ha. The net cropped area of the state is 68% of its arable land available with a cropping intensity of over 184%. Rice is the principal crop of the region. WB is also one of the major producers of the potato crop. West Bengal is also known for its jute, pineapple, litchi, mango and loose flowers cultivation. The production of oilseeds, pulses, and maize are on the upward trend. West Bengal is also one of the largest fish producing state in India (1.63 million tons of fish in 2015-2016). Tea cultivation is also a large sector, it is the second largest tea producing state in India

The region supports a wide variety of agro-climatic conditions. However, its proximity to the Bay of Bengal makes it susceptible to frequent cyclones, floods, and natural disasters. Further, the

high intensity of crop cultivation, water quality issues and high chemical fertilizer and pesticide usage are causing increasing deterioration in soil quality and crop productivity. Further owing to the majority being small and marginal farmers there is a strong reliance on middlemen for transactions. Due to same reasons, there is also a gap in access to new market and technology along with post-harvest facilities. West Bengal also has water quality challenges of arsenic and fluoride that have shown chances of percolating into the paddy crop.

8.6.1 Agriculture Development Program Implementation

Department of Agriculture

The Agriculture Department is concerned with activities relating to policy decisions on agricultural production and productivity. The department is following the vision of "Doubling farmers' income by 2020 by ensuring farmers' access to Skills, Technologies, Markets and Financial Inclusion. The organization chart of Department of Agriculture, West Bengal is given below (Figure 8.3).

The Directorate and field level offices in the districts and the West Bengal State Seed Corporations, under the Department, are involved in the execution of these policies through the generation and transfer of technology, ensuring availability and timely distribution of agricultural inputs viz., especially seeds, fertilizers, subsidy, credit etc. They also provide support services through soil testing, soil conservation, water conservation, and seed testing/seed certification. This capacity building is carried out through the Krishi Vigyan Kendras (KVK) or Farm Science Centers. There are also 6 Agricultural Technology Management Agency (ATMA) for extension effort for dairy and farmer self-driven accountability.These bodies are also involved in plant protection and quality control of fertilizers, pesticides etc. Main stakeholders for the Department are--(i) Farmers (ii) Government (iii) Manufacturer, dealers, and retailers of Fertilizer, Seed, and Pesticide (iv) Citizens in General.

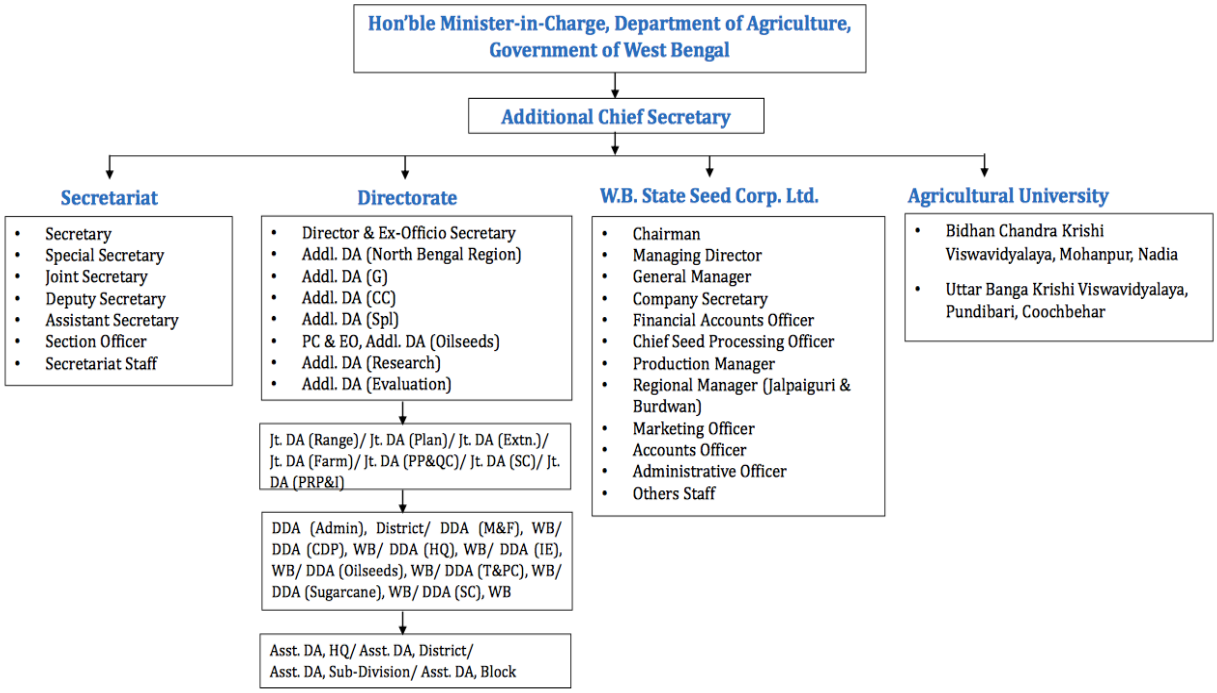


Figure 8-3: Organization chart of Department of Agriculture- West Bengal

Agriculture Marketing Department (West Bengal State Marketing Board)

Agricultural marketing being a State subject, the West Bengal Government regulates the marketing practice of the agricultural produce by small and marginal farmers framing a comprehensive act as known as' The West Bengal Agricultural Produce Marketing (Regulation) Act, 1972'. The Government of West Bengal with a view to focus the attention on the marketing of agricultural produce set up a separate department as Agricultural Marketing Department to deal exclusively with all such matters.

The West Bengal State Marketing Board- the statutory body constituted under the Act and Directorate of Agriculture Marketing is primarily responsible for implementation of the Act with a view to regulate the trade of agricultural produce and create required market infrastructure development. The Board runs 28 principal market yards and about 200 sub- market yards which are managed through 46 regulated market committees. Besides, there are 2918 rural haats / bazaars managed by private operators. There are also 350 daily markets in municipal /semi-urban areas managed privately or by local authorities.

Food Processing & Horticulture Department

This department collaborates closely with the Department of Agriculture and allied departments. This department has their agro-processing centers and outlets. It manages 5 Export Processing Zones. These would add to the existing marketing efforts provided their efficiency is high. The department has West Bengal State Food Processing & Horticulture Development Corporation Limited (http://www.ipshabengal.com) along with a directorate for horticulture.

Fisheries Department

The scope of activities of the Department had been expanding gradually a number of schemes are being taken up for the development of Pisciculture in West Bengal for self-sufficiency in regard to the production of fish in the State and for exploring possibilities for the requirement of fish and fish products across the country and export. Because of the involvement of the Department in multi-directional fishery related activities, it has been renamed as the Department of Fisheries, Aquaculture and Aquatic Resources & Fishing Harbours (www.wbfisheries.in)

Food & Supplies Department

The Department, being the administrative department, is the apex body under the state government. It is responsible for the management of the food economy of the State and for taking policy decisions thereon. The Department has the dual responsibilities of procuring of food grains distributing of food grains and some other essential commodities as well as for monitoring and enforcing orders enacted under the EC Act, 55. It keeps a close watch on the stock position, price level, availability of essential commodities, including food, the operation of Public Distribution System. It monitors the functioning of different directorates under it for implementation of different orders.

Animal Resources Development Department

Animal Resources Development Department is responsible for formulation and implementation of Livestock and Poultry policies and programs of the state to ensure overall development of the entire livestock including cows, buffaloes, poultry, sheep, pig, goat etc. and dairy products of the state. It governance the Directorate of Animal Resources & Animal Health(AR&AH) along with running the Cooperative Milk Producers' Federation Ltd.(WBCMPF), WB Dairy & Poultry Development Corpn Ltd.(DAIRPOUL), WB Livestock Development Corpn Ltd.(WBLDC) (http://www.wbard.gov.in/). Major programs include Employment Generation; Production of

nutritious food at the enhanced rate by providing breed up-gradation; Alleviation of poverty by providing sole/additional income to farmers' family; Production of biomass and drought power; Implementation of National Cattle & Buffalo Breeding Program.

Irrigation and Waterways Department

The department covers the tasks of providing irrigation facilities, offering reasonable protection against flood, alleviating drainage congestion, arresting erosion, maintaining internal navigation channels and up-keeping the natural waterways in the state.

Cooperation Department

In West Bengal Cooperation Department plays a pivotal role in the uplift of Cooperative Movement with its two wings, Cooperation Directorate and Directorate of Cooperative Audit by International Cooperative Principles as per West Bengal Cooperative Act &Rules.http://coopwb.in/about.html

Power and Non-Conventional Energy Sources Department

The Power Department is concerned with electrification and supply of power for both public and private domains. Within the department, the West Bengal Renewable Energy Development Agency/RIDF/WBSEB is mandated to promote Renewable Energy Technologies and create an environment conducive to their commercialization through innovative projects.

Forest Department

The department meets the functions of forest and wildlife management, consolidation of participatory forest management in different agro climatic regions and execution on a very large scale of activities related to social/farm/urban forestry in non-forest areas of the State. West Bengal Forest Development Corporation Ltd. It takes care of large scale harvesting of forest produces, the creation of new eco-tourism centers, production, and marketing of forest products and such allied activities.

NABARD

It has also been assisting the department of agriculture in several programs along with different NGO’s in the region. NABARD has also been implementing several developmental programs like watershed development, projects which among other things, involve the adoption of soil and water conservation measures and resource based crop development that involve the transfer of tested and replicable technologies. These projects are being implemented with NGOs as project implementing agencies. The experience suggests that the NGO officials, with training and capacity building in such technologies, can serve as effective extension workers and the field impact of such extension interventions are clearly visible. In fact, a few NGOs of repute like the Ramakrishna Mission have been playing a very effective role in extending training and extension support to several entrepreneurs engaged in agriculture and allied activities.

8.6.2 Agriculture development Program Implementation (state level)

This is a plan prepared under the National Agricultural Development Program or Rashtriya Krishi Vikas Yojana (RKVY). This plan receives 100% support from central government. The plan includes Comprehensive District Agriculture Plans (CDAPs) covering agriculture and allied sectors based on guidelines issued by the Planning Commission. Soil Health Card, increasing Organic Inputs Production Hubs. Creating Secondary freight subsidy for fertilizer mobility and SWAN connectivity for ADOs Extension Services through Jeebika Sahayaks (Livelihood

Associates). Maintaining training program farmers, fertilizer dealers and retailers in association with FAI focus on Agriculture and Allied Sectors. This also includes electrification of fishing areas along with provision of solar pumps in collaboration with West Bengal Renewable Energy Development Agency/RIDF/WBSEB

AGRISNET information portal

AGRISNET is a Mission Mode Project under National e-Governance Plan of Government of India, Department of Agriculture & Co-operation, and Ministry of Agriculture has decided to launch a Central Sector Scheme titled, “Strengthening / Promoting Agricultural Informatics & Communications” of which one component is AGRISNET. There is also a Kisan call center, operational for information dissemination

Capacity building for Adoption of Technology (CAT)

This is also a centrally sponsored program by NABARD for facilitating the adoption of new/upgraded technology by farmers/entrepreneurs to promote increased productivity and production. The objective of the scheme is to sensitize farmers - preferably marginal, small and tribal communities - to enable them to adopt proven technologies in agricultural developments made by research institutes, corporate houses, NGOs, progressive farmers/entrepreneurs. The entire cost towards such visits/programs is supported by NABARD.

Farmers’ Clubs (FCs)

FC’s in West Bengal is engaged in supplementing extension services of State Government Line Departments in the field of Agriculture, Animal Husbandry, etc., FCs are actively involved in developing awareness/imparting training to farmers regarding the use of bio-fertilizers, production of vermin-compost, crop diversification and adopting more scientific cropping practices.

West Bengal State Horticulture Scheme

This is a Centrally Sponsored Scheme launched for the holistic development of horticulture in the country during XII plan. The scheme, which has taken take off from 2014-15, integrates the ongoing schemes of National Horticulture Mission, Horticulture, National Bamboo Mission, National Horticulture Board, Coconut Development Board. West Bengal follows a State Horticulture Mission Document (SHMD). The priority areas of development includes expansion of land under horticulture, rejuvenation of farming land, nurseries, strengthen organic farming, building community tanks(ponds), post-harvest management Integrated pest management, horticulture mechanization, human resource development and beekeeping

National Food Security Mission

Under the central schemes, this has been started across 12 districts of the State to boost up the production of wheat, pulses, and rice. Apart from this hybrid rice seed production program

Integrated Scheme of Oilseed, Pulses, Oil Palm and Maize (ISOPOM),

Responsible for development of cultivars of rice fortified with Zinc & Iron, research on the suitable pulse and oilseed varieties, potato tissue culture, short duration wheat varieties have been taken up. Also, dryland/rainfed crop production program and special area development program are also in operation.

Prani Bandhu scheme

To lift rural masses above poverty level through Animal Resources Developmental activities in each Gram Panchayat. The scheme assists in the strengthening of Frozen Semen Technology in West Bengal and provide this facility up to G.P. level either through Govt. unit or through engagement of PRANI BANDHU –A self-employment venture.http://www.pbgsbs.gov.in/pds/node/46.

Watershed development schemes:

The two centrally sponsored programs, i.e. Integrated Wastelands Development Program (IWDP) and Drought Prone Area Program (DPAP) are implemented by the P& RD in the western part of the state in five districts i.e. Purulia, Bankura, Paschim Medinipur, Birbhum, and Burdwan. There is another program with support from NABARD as loan and grant which is being implemented in the state.

West Bengal Action Plan On Climate Change

The plan covers the implication of climate change to the sector of agriculture. It collates existing research on climate change and their implication for agriculture and its allied sectors. This is compiled by the Government of West Bengal Department of Environment (detailed report) (Table 8.1).

Table 8-1: Institutions mapped under the framework of building sustainable intensification and resilient households-West Bengal

Sustainable and profitable farming	Research & Development (Crop Improvement; Integrated Management; Institutional innovation)	Agricultural Universities-Bidhan Chandra Krishi Vishwa Vidyalaya (BCKV) and Uttar Banga Krishi Viswa Vidyalaya (UBKV) Food & Supplies Department
	Inputs, extension & Farmers services (Seed System, Input supply; credit supply)	Krishi Vigyan Kendras (KVKs) Directorate of Animal Resources & Animal Health(AR&AH) Farmers' Clubs, Animal Resources Development Department Credit Guarantee Fund Trust for Small Industries (CGTSI), District Central Cooperative Banks, Bangiya Gramin Vikash Bank, Paschim Banga Gramin Bank
	Markets & Information	Cooperative Milk Producers' Federation Ltd.(WBCMPF), WB Dairy & Poultry Development Corpn Ltd.(DAIRPOUL), WB Livestock Development Corpn Ltd.(WBLDC) Agricultural Marketing Directorate, West Bengal State Marketing Board

Enabling Environment	Infrastructure (Social & Physical) & Resource Conservation	Panchayati Raj System, Joint Forest Management Committee (JFM), Farm Machinery Hub, West Bengal Renewable Energy Development Agency/RIDF/WBSEB
	Institution for knowledge generation, exchange, and transformation	Paschim Banga Go-sampad Vikash Sanstha (PBGSBS)
	Social Protection	
	Data & Informatics	International Seed Testing Association, Central Groundwater Board
Resilient livelihood	Gender	Farmers' Clubs (FCs) Animal Resources Development Department
	Youth	
	Nutrition	
Non-governmental Agencies		
Japan International Co-operation Agency (JICA)		West Bengal Forest and Biodiversity Conservation Project (WBFBCP)http://www.westbengalforest.gov.in/acts-pdf/final-brief-note-on-JICA.pdf
World Bank		West Bengal Accelerated Development of Minor Irrigation Project (ADMIN)

8.6.3 Agricultural development and technology up-scaling

The Bihar and West Bengal states of the EGP plain are considered as one of the pockets of poor particularly rural farmers in the country. Migrations of unskilled labor to southern states of India as the wages are comparatively low. Even though rice and wheat are the major crops, the productivity is low compare with another region of Gangetic plain. Frequent incidence of flood also debilitated the development efforts in the region. The absence of required staffs to carry out extension and capacity building of farmers in introducing high yielding varieties to improved technology is one of the drawbacks. There are several rural development programs running in the region such as rural employment scheme, watershed, organic farming, soil and water conservation etc. Policy support is not effective as there is no support for power for energy that will boost agriculture productivity. The water table is not so deep as in southern states, however, the support for free electricity for pumping are absent. There is support for diesel pump through the state government, but the diesel is costly for smallholder farmer that reduce their profit from the agriculture.

There is also convergence issue in these states between state and central schemes and also department responsible for implementing these schemes. The farmers are not updated with the information of recent government programs, markets and prices. Though there is central scheme introduced recently by the government through e-platform they are not year aware of these and continue with the original process of getting inputs and marketing their produce.

There is a need to educate the farmers and the extension of new technologies, improved production practices, markets, processing etc. The contribution of NGOs is very important in the region, they work with their own funding and only very few instance they work with the government. These organization works in capacity building and institutional development for the poor, land and water resource conservation and also the promotion of innovative technologies etc. The coverage of NGOs is limited with minimum resources and area of operation. Convergence and coordination among different department and their staff need further improvement in efficiently implementing the support scheme for the rural poor.

8.7 Bangladesh& Agriculture

Bangladesh continues to be the hotspot of climate change. Over the last two decades, the country has witnessed several disasters majorly flood. Since the independence of Bangladesh in 1971, the country has gone through several strides in agricultural development and poverty alleviation. There have been significant improvements in this sector particularly productivity, thanks to the national and international investment and strategic support. Agriculture continues to be the largest employment sector in Bangladesh and it contributes 16% of the country GDP. Agriculture performance has a significant impact on a national macroeconomic situation such poverty alleviation, human resource development, food security and employment (World Bank, 2016). Rice is the major crop of the country followed by wheat and Jute. Fisheries and livestock sector compliment significantly to the rural economy. Both national and international institutions that are currently mandated to bring development in this sector thereby improving the livelihood of the poor and marginal population that depend directly and indirectly on agriculture. Bangladesh's labor-intensive agriculture has achieved steady increases in food grain production despite the often unfavorable weather conditions such as flood, salt intrusion, and drought. Food grains are primarily grown for domestic consumption compared to other commercial crops such as Fruits, Tea, Jute, and sugarcane. The nation has already started to diversify agricultural from original subsistence to other high-value crops and export oriented crops with huge demand generated through liberalization of agriculture markets. Through the support of several actors, the agriculture sector is on the trajectory of significant transformation towards sustainable intensification and development.

The institutions that play key role in development of agriculture sector is briefly described

8.7.1 A. Policy Formulation, Coordination & Supervision

The ministries policy formulation, planning, monitoring and administration related to agriculture development including ensuring food security and sustainable livelihood are listed under this category.

Ministry of Agriculture

This ministry is mandated in developing policies and plans/programs for agriculture development. Through the policies and resources, the department and institutes under the Ministry designated in developing new and improved technologies, an extension to farmers, input support for increase agricultural production and sustainable management of resources. The organization structure of the ministry is given in Appendicies 8.1 & 8.2. Bangladesh national budget of 2016-17, allocation to the ministry is only 4% of the total budget. The budget allocation majorly focuses on research and development, support farmers through subsidies for input and farmers services and to implement farmer’s welfare program and cheaper credit and loans.

There are subsidiaries under this ministry including research and education institutes, council, policy support bodies, program implementation departments, agricultural information services bodies etc. The list of subsidiaries are a) Integrated Agricultural Productivity Project b) Agriculture Information Service (AIS) c) Department of Agricultural Marketing d) Department of Agricultural Extension e) The National Institute of Biotechnology f) Cotton Development Board g) Barind Multipurpose Development Authority h) Bangladesh Agricultural Development Corporation i) Bangladesh Agricultural Research Institute j)Bangladesh Agricultural Research Council k) Bangladesh Sugarcane Research Institute l) Bangladesh Rice Research Institute m) Bangladesh Institute of Nuclear Agriculture, n)Bangladesh Jute Research Institute (BJRI), o) Bangladesh Applied Nutrition and Human Resources Development Board p)Soil Resources Development Institute q) SAARC Agricultural Information Centre (SAC) and r) Seed Certification Agency

Ministry of Fisheries and Livestock

Similar to the ministry of agriculture, the ministry of fisheries and livestock mandated towards the development of fish and livestock sector. This includes policies and resource allocation to promote the sector including research and development and also provide enabling an environment for production, processing, and marketing. In the 2016-17 national budgets, allocation to this ministry is only 0.5% of the total budget. The fisheries sector is one of major livelihood for the population next to rice. Department, institutes and development cooperation to support in diversified livelihood options. The Department of Livestock, Bangladesh Fisheries Research Institute, Department of Fisheries, Bangladesh Livestock Research Institute (BLRI), Bangladesh Fisheries Development Corporation, Marine Fisheries Academy

Ministry of local government, rural development, and cooperatives

This ministry is responsible for formulation and implementation of programs aimed to alleviate rural poverty. They assist in developing entrepreneurs through microcredit, agricultural credit. The ministry support research and development that help in innovating new model/strategy on rural development through action research. The training institute mandated to provide capacity building to all the stakeholders to enhance their capacity to implement the programs aimed at rural development and to reduce poverty.

Ministry of Disaster Management and Relief

This ministry has the mandate to carry out countries risk reduction reform programs with a mission to build capacity to achieve a paradigm shift from conventional response and relief to more comprehensive risk reduction culture and to promote food security. Building resilience among the community is the major focus of this ministry against hazards that include man-made. This ministry work in cooperation with other ministries such as agriculture and fisheries & livelihood

Ministry of Food

The ministry of food is primarily responsible for the formulation, review, and execution of legislation, policies, plan, procedure, and guidelines to Bangladesh’s overall food system, & food policy. Under the supervision of this ministry, it ensures national food security through procurement, stabilization of food grain prices, construction and warehouses, and storage.

Ministry of Environment & Forest

The Ministry of Environment & Forests is the nodal agency in the administrative structure of the Central Government, for the planning, promotion, co-ordination and overseeing the implementation of environmental and forestry programs. MoEF oversees all environmental matters in the country and is a permanent member of the Executive Committee of the National Economic Council. The Ministry also plays a pivotal role as a participant of United Nations Environment Program (UNEP). The principal activities undertaken by Ministry of Environment & Forests consist of conservation & survey of flora, fauna, forests and wildlife, prevention & control of pollution, forestation & regeneration of degraded areas and protection of the environment, in the framework of legislations. The organizations under these ministries are a) Bangladesh Climate Change Trust b) Department of Environment c) Forest Department d) Bangladesh National Herbarium e) Bangladesh Forest Research Institute (BFRI), f) Bangladesh Forest Industries Development Corporation

Bangladesh Climate Change Trust Fund (BCCTF)

This government trust constituted by the government in reduce vulnerability and improve capacity adapt to the impacts of climate change. This institutional arrangement to the management of funds and the projects undertaken so far includes construction of embankments, river bank protection, water control infrastructure, dissemination of tolerant crop varieties and seeds, afforestation projects and installation of solar panels etc.

The Bangladesh Climate Change Resilience Fund (BCCRF)

This fund is raised through an MOU with the government of Bangladesh and other developmental partners and World Bank to build the resilience to the effects of climate change. This fund also supports to implement Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009). The plan is being implemented in six program areas: food security, social protection, and health; comprehensive disaster management; building resilient infrastructure; increasing the knowledge base; mitigation and low-carbon development; and capacity building and institutional strengthening. Along with infrastructure development, the focus is also to increase the knowledge base such as on impact and adaptation of key sectors including macro economy, poverty, sanitation, and health.

Ministry of Land

This ministry has the mission and vision to ensure the best possible use of land and provides pro-people land services through efficient, modern and sustainable land management. The vision is of efficient, transparent and people friendly land management system.

Ministry of Planning

The planning ministry is mandated to formulate developmental plans for all the sectors with financial outlays including agriculture development. Planning Commission is the apex body entrusted to do the planning under the supervision of the ministry. Institutes such as Bangladesh Institute of Development Studies and National Planning and development Academy (NPDA) give support in planning.

Ministry of Women & Children Affairs

Women and Children Affairs Ministry aimed to alleviate women's poverty. Empower women, stop violence against women, trafficking of women, protection of women in the workplace and women in the mainstream of socio-economic activity. The ministry work to ensure full and equal participation of women in the overall socio-economic development.

Ministry of Water Resources

This ministry is mandated in regulation and development of rivers and river valleys, policies and technical assistant in irrigation, flood control, drainage, and anti-erosion. This ministry is responsible for overall development and management of water resources in the country. There are departments and institutes under this ministry responsible for implementing the program, Research & Policy inputs. These are a. Institute of Water Modeling, b) River Research Institute, c) Water Resources Planning Organization (WARPO) d) Bangladesh Water Development Board, e) Bangladesh Haor and Wetland Development Board, f) Flood Forecasting and Warning Center, g) Joint Rivers Commission, Bangladesh, h) Centre for Environmental and Geographic Information Services

Ministry of Commerce

The regulation and development of overall trade and commerce related activities is the responsibility of the Ministry of Commerce, Government of Bangladesh. The ministry has an organization for the promotion of high-value trade crops such as Tea and other commodities.

Ministry of Power, Energy & Mineral Resources

The major functions of this ministry to manage and implement all activities related to power generation, transmission & distribution including policies. One of the prime activities is to ensure increased standard of living of the rural poor through rural electrification and introduction of renewable energy.

Ministry of Industries

The mission of these ministries to work towards accelerating Industrialization through formulating appropriate Industrial policy, reformulating & renovating state-owned enterprises, developing SME's, micro & cottage industries, protecting standards of products and intellectual property rights and enhancing productivity.

8.7.2 B. Research, Education & Policy Support

Since country's independence in 1971, the government gave important priority to improve the agriculture sector which contributes one-thirds to national growth and 90% of the population. The programs and policies have been implemented through the network of administrative structure present in the system. The departments and institutes under the Ministry of Agriculture implement the programs through Directorate and other executive board. For example, Department of Agricultural Extension, have different wings such as Crops, horticulture, plant protection field service etc. The field services wing has a network at district (Zilla) and sub-district (Upazilla) level to support farming. Under the ministry of agriculture, the research is been extended to farmers based on these extension networks. Agricultural research system is been monitored by the Bangladesh Agricultural Research Council (BARC) under the agriculture ministry. Similarly, Bangladesh's Planning Commission (BPC) under the Ministry of Planning is the authoritative body is shaping the long-term plan for various sectors including agriculture and Fisheries & Livestock.

8.7.3 C. Agriculture Program Implementation

The non-governmental organization (NGOs) plays an important role in Bangladesh, particularly in the agriculture sector. There are numerous NGOs what work with community depends on farming to improve their livelihood and reduce poverty. Bigger NGOs such as BRAC etc. have gained larger space among the community to influence them to adopt and avail better

production technologies and subsidies for better productivity and profits. The NGO platform has been identified as essential to social mobilization and effective platform for effective implementation of programs.

Local Group and Cooperatives

Farmer cooperatives are a formal organization of groups of farmers within communities, hamlets, or regions. These are operated by a local group and they generally share resources and work for the mutual benefit for all members. The advantage of this farmer cooperative they share the benefits and even risks. This community managed organization work to promote sustained livelihoods, rural employment, sustainable resource mobilization and use, empowerment and social reform. Some of the important farmer's organization such as Micro Credit Group of BRAC; Kendriyo Krishak Moitree (KKM); Bhogdanga Krishak Moitree etc. doing a commendable job to bring the people together and assured equal benefits for all.

Currently, the private companies including seed, machinery, fertilizer & chemicals also play a crucial role in the sector. Bangladesh is famous for micro credits programs and successfully helped in agriculture enterprise.

8.7.4 D. International Developmental Agencies

There are several international development agencies investing in Bangladesh in different sectors to support the government for overall development of the people.

Table 8-2: Listing of development organization and their support programs/projects in Bangladesh

Developmental Agencies	Programs/Projects	Sources
World Bank	National Agricultural Technology program; Income support program; Integrated agricultural productivity program	http://www.worldbank.org/
FAO	Increased food and nutritional security program; programs to enhance agricultural productivity through diversification/intensification, sustainable management of natural resource, use of quality inputs and mechanization	http://www.fao.org/countryprofiles/index/en/?iso3=BGD
Asian Development Bank	Rural Infrastructure improvement project; Water and Irrigation management; Participatory livestock development	https://www.adb.org/countries/bangladesh/main
USAID	Feed the Future and other climate change and adaptation initiatives.	https://www.usaid.gov/bd
BMGF	A project supporting agriculture and livestock the production in a sustainable way and effective way to reduce hunger and poverty.	http://www.gatesfoundation.org/What-We-Do/Global-Development/Agricultural-Development

These agencies promote overall development of agriculture sector not only in technology development but also strengthening the different components of the value chain including

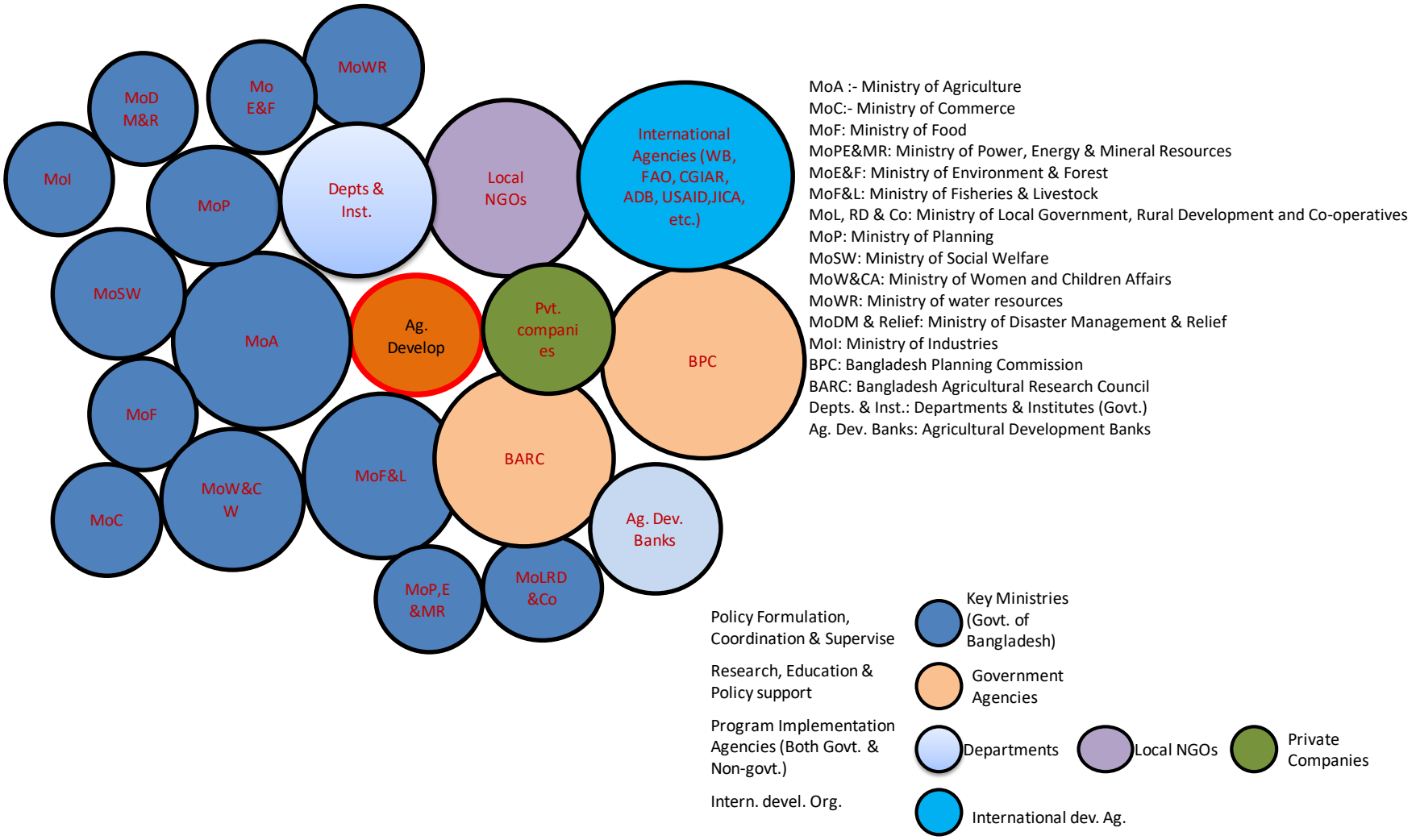
technology adoption, market innovation, capacity building and training, diversification and export promotion.

The key institutions are mapped based on their mandates and key roles to the overall development of agricultural sector in Bangladesh (Table 8.2.).

8.7.5 Policies related to Agricultural Development

The National Agricultural policy of Bangladesh is aimed to make the nation self-sufficient in food through increasing production of all crops including cereal and ensure a dependable food security system. Through the crop production policy, the nation is already focusing on the intensification of food grain production that is a rice-based production system. However, since the last two decades, there is a shift in focus on improving sustainability and protection of the environment. The lists of major policies that are directly and indirectly related to agriculture are given below.

National Disaster Management Policy 2015; Export Policy 2015-2018; National Agricultural Extension Policy – 2015; National Cooperative Policy – 2012; National Small Scale Irrigation Policy – 2014; National Shrimp Policy – 2014; National Agricultural Policy (NAP) – 2013; National Women Development Policy – 2011; Internal crops collection Policy – 2010; Fertilizer Dealer Distribution Policy – 2009; Crops Mobility Policy – 2008; National Poultry Development Policy – 2008; National Food Policy – 2006; National Energy Policy 2004; Cooperative Society Policy – 2004; Micro-Credit Policy-2003; National Integrated Pest Management Policy 2002; National Rural Development Policy – 2001; National Fisheries Policy -1998; National Seed Policy; National Water Policy



*Size and proximity of institutions based on the resource allocation and level of intervention of the institutions (Authors interpretation)

Figure 8-4: Institutions identified having direct and indirect links to Agriculture Development*

8.7.6 Agricultural development and technology upscaling

Bangladesh is an agricultural economy so intervention through any promising technology aimed at increasing the productivity thereby improving the household income. There have been interventions through government and international agencies to introduce technologies to improve agricultural production. The key institutions identified having major role in Bangladesh's countries agricultural development with varied contribution in terms of resource allocation and level of intervention (Figure 8.4) There are very successful cases in the country including high-yielding varieties of rice and other crops. From the key interviews, the role of NGOs in agriculture technology up-scaling has been very significant. These local organizations have played as a link in awareness building and adoption of technologies. They have the opinion that there is still need for further development in terms of infrastructure, subsidies, and technologies. Government policies are farmer supportive and however, there need further improvement and also suggest a convergence of key institutions organization to be more effective and outcome oriented. There are also challenges in the governmental extension system inefficient extension system and non-government organization does fill the gap. The agricultural research education needs further strengthening by improving quality infrastructure and latest research facilities. There seems a good coordination among the various departments and their effective convergence is showing results in achieving the overlapping goal in agricultural and rural development.

8.8 Nepal &Agriculture

Agriculture is a dominant sector within Nepal, engaging two-third of its populations, contributing to one-third of its GDP and constituting nearly half of the country's exports. Comparatively the land under cultivation within Nepal, due to its mountains and rugged terrain is approximately 28% of the total available land area (Kyle & Resnick, 2016; World Bank, 2015).Agriculture is distributed over three regions, the lowlands (Terai), hills and mountain. Most of the agricultural lands in the plains utilize surface water coupled with groundwater for irrigation. The hilly and mountain region agriculture predominantly rely on rainfall and surface run-offs rain-fed storage systems (communal ponds. Marginal and smallholder farmers dominate Nepalese agriculture with average landholding size of 0.8 ha. Most of the farmers are subsistence family farms (around 78%)(Karkee, 2008).Only 28% of the total agriculture land is served by year-round irrigation by canal system and tube-wells and this occurs mostly in the Terai region(Gautam & Bhatta, 2017; Sugden et al., 2014; World Bank, 2015).

Agriculture has been responsible for 92% decrease in poverty in Nepal in the past 20 years. This has been attributed to higher producer prices (78% increase) and also partly to higher yield rates (22%). Cereal crops are the main staple (80% of production) with rice alone being 40% of crop grown followed by wheat and maize. The main crop grown within Terai region is rice, followed wheat in lower lands, Maize grown in the hills. Mountains subsist on growing vegetables and horticulture crops along with livestock (Karkee, 2008). Further agriculture also subsumes income generated through livestock and fisheries. Smallholder livestock system is predominantly seen under which farmers raise small numbers of livestock in small land holdings (Pradhanang et al., 2015). Though agriculture is the major employment generator the country witness increased out-migration observed in Nepal, this is affecting incentives of individuals to invest enhancing agriculture productivity and irrigation. Out-migration has another dimension of

increasing the burden of agriculture on women with low investment capacity (Sugden et al., 2014).

The context of Nepal Governance: In 2015, Nepal's elected parliamentary body the Constituent Assembly passed a new constitution. One of the main objectives of this Constitution was to create a shift, in the next two years towards a federal, democratic and republican system. This system provides governance at three levels: the Federation, the province, and the local level. This has lead to the planned creation of seven provinces, with 75 districts that will remain and serve as units for parliamentary constituencies. At the local level, governments will be represented by the 1000 plus village or municipal development councils (VDC). The new federal system follows a decentralized structure with the focus given on enabling control and policy contribution at different levels. Implementation of this system is in progress and planned to span out over the next few years (Kyle &Resnick, 2016).

The key institutions identified that contribute to agriculture development in the country thereby ensure food security, enhanced economic growth and reducing poverty is generally falling under three-four major categories a) Policy formulation, coordination & supervision b) Research, Education & Policy Support c) Program implementation d) International developmental agencies (Appendices 8.3 & 8.4).

8.8.1 Policy Formulation, Coordination & Supervision

Ministry of Agriculture Development

The governance of agriculture sector of Nepal is said to follow a complex structure with several overlaps. The Ministry of Agriculture development is the main ministry responsible for developing agriculture and its related support structures. The ministry consists of five divisions each division consisting of various committees and sub-divisions to serve specific purposes. The Ministry also oversees two departments, administers a National agriculture research and development fund, governs information and broadcasting center, oversees two departments, and agriculture research. The ministry also has two companies. The five main divisions are

1. Administration Division
2. Monitoring, evaluation and statistics division
3. Food security, Agribusiness Promotion, and Environment Division
4. Planning Division
5. Policy and International Cooperation Coordination Division (PICCD)

In addition to the five divisions, another is Agriculture extension service center. This is to set establish at the VDC level with 3157 community Agriculture extension services centers. The ministry also has two departments: a) Department of Agriculture, b) Department of Food Technology and quality control

Ministry of Irrigation

The Ministry of Irrigation is mandated to work towards the development of irrigation to assist agriculture development targets. Towards this goal, they prepare plans, policies and assist their implementation. The ministry has three division, two departments, and one organization.

The three divisions are as follows: Administration Division; Planning & Program Division; Policy & Foreign Coordination Division

Department of Irrigation: This department manages “planning, development, maintenance, operation, management and monitoring different modes of environmentally sustainable and socially acceptable irrigation and drainage systems - from small to larger scale surface systems and from individual to community groundwater scheme”. They collaborate with the ADS in implementation of the strategy They also carry out “…river training activities to protect the floodways, floodplains and agricultural lands”. The department aims to Provide year-round irrigation facilities; Increase the irrigable area of the country to higher limits.

Department of Water Induced Disaster Management: This department serves to prepare and also mitigate water induced disasters. The formulate plans and policy, map risk zones, strengthen disaster information systems, conduct public awareness, implement disaster mitigation and construction, institutionalize rehabilitation and build the capacity of government and communities for disaster mitigation works.

Ground Water Resources Development Board: Groundwater resources exploration and identification activities in Nepal started as early as 1967 through a technical unit under the Department of Irrigation. The organization is responsible for enhancing groundwater study, investigation activities and to delineate the potential area for groundwater irrigation development. The Government of Nepal (GON) had established Ground Water Resources Development Board (GWRDB) under the former Ministry of Water Resources (MOWR) in 1976. This board is now an organization within the Ministry of Irrigation.

Ministry of Livestock development

The ministry of livestock development is responsible for creating and executing policy and programs for enabling livestock rearing and dairy related entrepreneurship, strengthen the linkage between farmers and companies, increasing commercialization for private and corporate sector involvement; along with providing serves to maintaining livestock health and disease control. The ministry has four divisions, manages livestock extension services at the national, district and local level. The ministry also has a National Dairy Development Board, Dairy research center, department for livestock development, and a Department for Animal Husbandry along with providing a Hospital and dispensary services. The three main policies that are essential for livestock, are Agriculture Development Strategy (2015), Agro-Business Promotion Policy 2006, and Agricultural Sectoral Operating Policies (ASOPs).

1. Divisions:
2. Administration
3. Schemes, Monitoring and evaluation division
4. Livestock development and business development division
5. Policy, Animal Health, and livestock services

Department for Livestock Services- This department is responsible for veterinary hospital and dispensary services, along with animal health, nutrition, breeding management. They are responsible for training and building capacity related to livestock services and advancements. They also run programs for improving mountain agribusiness, community livestock development, market connections and livelihood development.

1. National Dairy Development Board (Dairy Development Corporation)
2. Dairy research center
3. Directorate of Livestock Production
4. National Livestock breeding center

Ministry of forest and soil conservation

Nearly 40% of Nepal is under forest cover. The ministry focus areas include forest and watershed conservation, preservation of agricultural land and increasing productivity and connection with agro-industry, water management, wildlife and biodiversity conservation, timber and non-timber forest product livelihood development. Their flagship programs include community-based forest management.

The ministry has five divisions to assist in the execution of its administration, defining policy, coordinating foreign aid along with monitoring and evaluation and govern plans. The ministry receives foreign aid from institutions such as IUCN, WWF, Global Environment Facility (GEF), DFID, US-Aid, SDC, Government of Finland, JICA, Enhanced Integrated Framework (EIF), GIZ, World Bank, ICIMOD, Australian government, UNDP, APFNet, FAO, ADB,CBOL, IFAD, ASAP (More details).

The ministry also has five departments, a) **Department of Forest**: Works in the area of Community forest management for building community management systems, enhancing private and agroforestry, along with tree improvement. The department assists in National forest protection, product utilization, and management. It also assists in Silviculture within forest and forest seed improvement.

b) **Department of forest research and survey: DFRS** is mandated to conduct forestry research and survey to produce knowledge and information for sustainable management and utilization of forest resources of Nepal. The department works in close collaboration with various national stakeholders and international agencies. The department has three divisions: Forest Research Division, Forest Survey Division, and Remote Sensing and Planning, Division.

c) **Department of Soil and water conservation**: Responsible for planning, implementing and monitoring soil conservation and watershed management programs/activities based on the principles of integrated watershed management.

d) **Department of plant resources**: Responsible for research on medicinal plants, agro-technology for medicinal and valuable plants, chemical and biological research along with bio-prospecting.

e) **Department of National Parks and Wildlife Conservation (Nepal) (DNPWC**) include the conservation of endangered and other wildlife species, the scientific management of habitat for wildlife species, the creation of buffer zones in and around parks and reserves for the sustainable management of forest resources, and the organization of eco-tourism.

Ministry of federal affair and local development

The ministry is responsible for local development and service delivery within the new federal structure. The ministry is guided by the GON's National Strategy for Rural Infrastructure Development. Poverty Alleviation Constituency Development Program flagship program linked to agriculture development. The ministry also looks to include equity and social justice. The ministry has two departments

Department of local infrastructure and development and agriculture roads: They undertake infrastructure development programs for small scale and community irrigation, rural water supply and rural roads for access. These projects are carried out in accordance with decentralization policies for attaining the goals set forth by GoN. They also assist in making the local authorities technically capable and competent and ensuring their accountable participation

Ministry of Land-Reform and Management

The ministry seeks to provide equitable access to land, secured tenure, desired geo-information products and quality services to all. They aim to do through modern and simplified national mapping, cadastral, land administration and land management system. The ministry has three divisions responsible for administration; planning monitoring and valuation; and land management. It also has four departments:

1. Survey Department
2. Department of Land Reform and Management
3. Land management training center
4. Department of land information and archive

Ministry of Energy

The responsibility of utilization and management of water resource lies in the Ministry of Energy. Management of production of energy for the expansion of industrial and economic activities are the key objectives of this ministry. It also is responsible for development of the National Water Plan

Ministry of Cooperatives and Poverty Alleviation

The ministry is dedicated to the development, promotion, and standardization of co-operatives and poverty alleviation programs in Nepal.They were created in May 2012 to assist in the economic development of the country through the development of cooperatives and that of poverty alleviation programs and its implementation. It has two division to assist in the execution of administrative works along with planning, monitoring, and evaluation. The ministry has one department, two board:

Department of cooperation: responsible for registration; regulation and promotion of cooperative enterprises in all over the country. It governs the existing cooperatives in the areas of Saving and Credit, Multipurpose, Dairy, Agriculture, Fruits and Vegetables, Bee Keeping, Tea, Coffee, Consumers, Energy, Communication etc. including production, financial and service

National Cooperative Development Board (NCDB): the main functions to assist the government and cooperative movement on policy matters, to help organize technical and financial assistance to the cooperative movement and to serve as coordinating body between the government and cooperative movement

National Cooperative Federation of Nepal has been working as a voluntary organization and autonomous institution in the public sector. It helps the formulation of cooperative policies and drafting of the co-operative legislation and encourages people for organizing cooperatives based on cooperative values, norms, and principles, as well as need-based and member, centered.

Poor Household Support Coordination Board (PHHSCB) and its Secretariat for handling the Poor Households Identification and Identity Card Management and Distribution. The main jobs of the board are to the identification of the poor household, recommend the social protection measures and issue identity cards for the poor household and update it.

1.1.1 Ministry of Finance

The Secretaries of the sectoral ministries are accountable to the sectoral development budget. They are accountable to the Parliamentary Account Committee and Parliamentary Account Committee where they have to answer the questioned was raised on the achievement of the development objectives and budget expenditure.

8.8.2 Research, Education & Policy Support

National Planning Commission

The National Planning Commission is responsible for agriculture intervention under the Agriculture Development Strategy. It is also responsible for governing the within its National poverty fund through its Poverty Alleviation Division. This NPF will also provide for the ADS. NPC will be responsible for overall policy coordination of the ADS and integration and budgeting of periodic and annual plans consistently with ADS planning. The ADS Implementation Support Unit will report to it. The Vice Chair of NPC will also chair the National ADS Coordination Committee (NADSCC), the highest coordinating body for the ADS.

National Agriculture Research Council (NARC)

The NARC is responsible for agriculture research, its efforts contribute across ministries and in collaboration with International and local NGO's. The NARC's major agricultural research areas include field crops, horticulture, livestock, fisheries, on-farm water management, agro- forestry, related natural resources issues, socio-economic aspects of the farming systems, post-harvest operations, gender issues, and, above all, policy research(NARC, 2010).

National Agriculture Research & Development Fund (NARDF)

NARDF is responsible for carrying out the applied research. It was established in December 2001 under the Working Fund Act, 1986. it has targeted to support the Government, non-government, educational, the private sector, civil society, cooperatives and community-based organizations to conduct agricultural research and development works.

8.8.3 Agriculture development Program Implementation

As any other country, the implementation of programs & Policies is done through various departments under different ministries. There is also support from other government corporations such as Agriculture Inputs Company Limited and National Seed Company Limited, Nepal's National Seed Board (NSB), Agriculture Development Bank of Nepal (Nepal Rasthra Bank), Agriculture information broadcasting center etc. These are strategically placed to ensure sufficient support to encourage in commercial farming with input supply including credit, seeds, and crop management chemicals. There are private players also in this sector. The seed and other input companies have a strong local business network on agricultural input supply.

Under each ministry, implementations of development programs are carried out through departments & divisions. These subordinate bodies have networks at various levels of administration to the local level (ex. Villages) to implementation these programs. For example. Agricultural extension system in under the supervision of Directorate of agricultural extension (DoAE) have 75 district level agriculture development office and have around 400 Agriculture service center catering directly to the farmers. In the agriculture extension system, they are following different approach such as integrated rural development approach, farming system

approach, block production program, Tuki approach etc. Local NGOs and other agencies play a major role in direct intervention in research, technology adoption, capacity building and awareness creation among farmers. Local NGOs helped the community to built farmers group, farmer field school, a market identification that have brought success in terms of livelihood and natural resource conservation.

8.8.4 International Developmental Agencies

Nepal is majorly supported by the external funding through international development agencies such as grant and loans since the 1970s. There had been an increase in these funding for development from these agencies to improve the agriculture linked livelihood and to support poor resource farmer and generate employment. There is accepted understanding that government support for sustained agriculture development. However, there is considerable understanding that agricultural development investment is insufficient and there are a consistent investment and development to bring a large section of the population out of poverty. Some of organization that have been funding for decades for agriculture development in the country are International Fund for Agricultural Development (IFAD), European Union (EU), FAO, Asian Development Bank (ADB), Swiss Agency for Development and Cooperation (SDC), Japan International Cooperation Agency (JICA), Denmark Agency for International Development (DANIDA), World Food Program (WFP), United States Agency for International Development (USAID), Department for International Development (DfID), the World Bank, the Australia Agency for International Development (AusAID), and UN Women etc. These agencies face several challenges to implementing of development projects aligning with the government initiatives.

8.8.5 Nepal-Acts and policies linked to agriculture

This paragraph will list out major policies and Act promulgated having relation to the agricultural development in Nepal. Policies include: Land Use Policy (2012), Agriculture Policy (2004), Irrigation Policy (2013), Water Resources Strategy (2002),Fertilizer policy (2002), Forestry Sector Policy (2000), Leasehold Forest Policy (2002), Biodiversity Strategy (2002), Agriculture Development Strategy (2013), National Water Plan (2005), Technical Specifications for Agricultural and Rural Roads (1998), National Seed Vision (2013) (more details). The other legislation/Act that' contribute to agriculture across sectors and department in include Water Resources Act (1992), Land Act (1967), Forest Act (1993), Soil and Water Conservation Act, Environment Protection Act (1997), Food Act (1996), Pesticide Act (1991), Nepal Agricultural Research Council Act (1992), Mines and Mineral Act (1993) that regulate the conservation and utilization. Local Self-Governance Act (1998), Public Procurement Act (2007), Prevention of Corruption Act, and Fiscal Act (year-wise), are the major acts that regulate development administration (more details). In 2010, the government of Nepal had 10 policies, 18 ACT, 9 regulation and 6 orders related to agricultural development (MoA, 2015).

The government of Nepal is committed to agriculture development. To enable this they have developed an Agriculture Development Strategy (ADS). This is 20-year vision document that focuses on improving governance; increasing productivity; profitable commercialization and increased competitiveness. The ADS is implemented and coordinated by the National ADS Coordination Committee that falls under the Policy and International Cooperation Coordination Division. The program includes flagship programs such as the Multi-Sector Nutritional Plan, the Food Security Action Plan, and the Zero Hunger Challenge Initiative 2025.The ADS includes convergence with other ministries and department such as Ministry of Livestock Development

(MoLD), the Ministry of Irrigation (MoI), the Ministry of Land Reform and Management (MLRM), the Ministry of Forestry and Soil Conservation (MoFSC), the Ministry of Cooperatives and Poverty Alleviation (MoCPA), the Ministry of Federal Affairs and Local Development (MoFALD), the Ministry of Energy (MoE), the Ministry of Finance (MoF), Ministry of communication and technology (MOCT) and Ministry of Education (MOEdu), Agriculture Development Bank of Nepal. The scheme of coordination of the ADS under the new federal system is still under construction (MoAD, 2014).

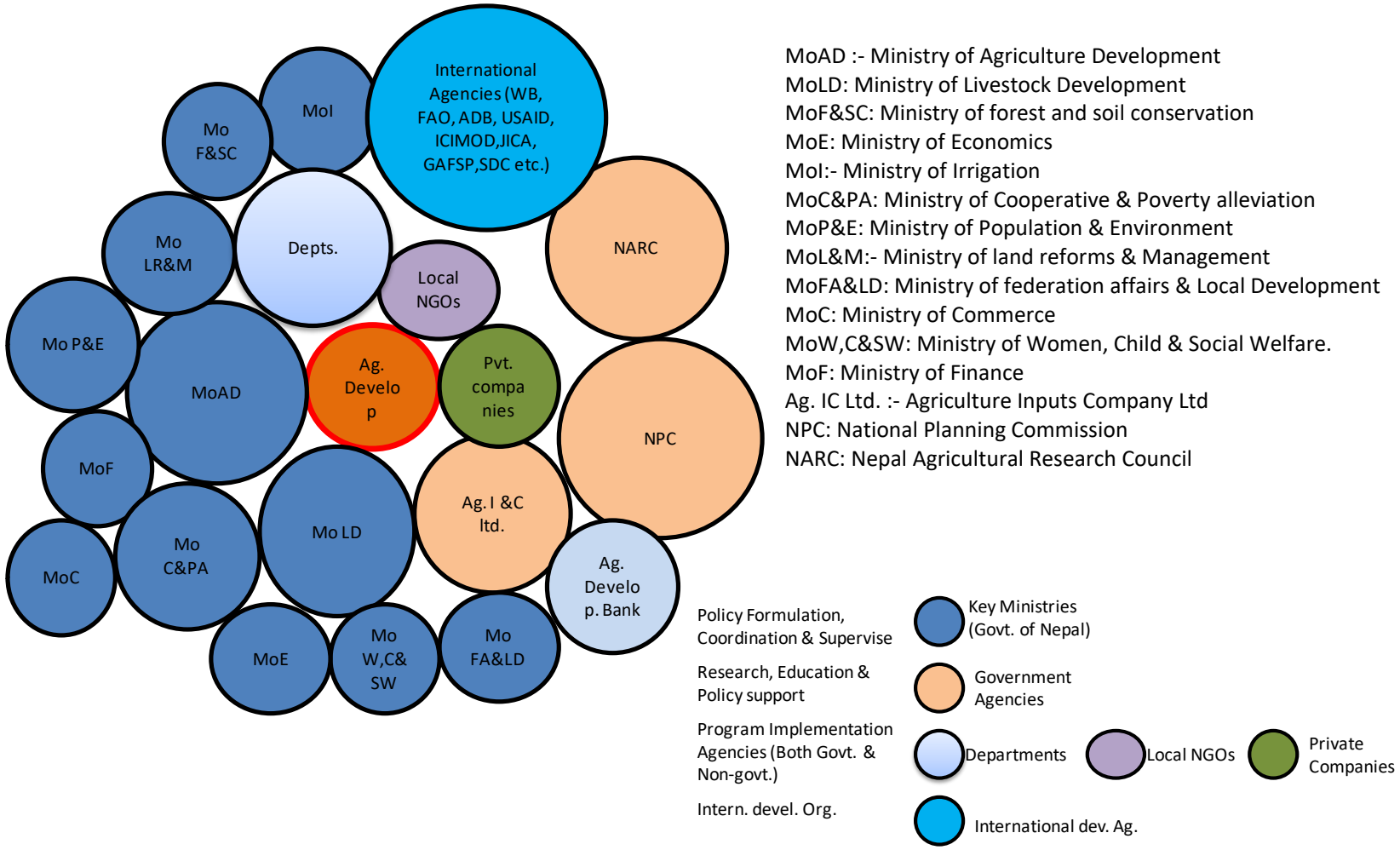
8.8.6 Agricultural development and technology up-scaling

Nepal is a country with limited resource and contribution to yearly budget to agriculture is less than 1%[7] Although agriculture is one of the key sectors, these sectors receive external support through aids from international development agencies. Institutions having a major role in agricultural development are mapped (Figure 8.5) based on the intervention. Several studies on technology adoption have argued that technology adoption will only get intensified if there is continuous support from the different agencies such as government, non-government and other development agencies. These agencies are expected to provide an array of conditions and circumstances for technology adoption and upscale. Extension services were identified as one of the major factors determining the adoption of agricultural technology (Floyd et al. 2003). From the interviews of government and non-governmental organization, it was found that there exist challenges in capacity, knowledge in the governmental department. Non-governmental organization plays a pivotal role in agricultural development in Nepal. As per the department, these institutions work closely with the government and support for direct intervention in adoption of rice varieties (Budhathoki & Bhatta, 2016) and potato in both hill and Terai region & Maize production technology (Barakoti, 2001) Key informant had the opinion that the interaction between NGO and the government is not efficient, however the development agencies implement the program through the support of local institutions or NGOs. The time taken for upscale of any agricultural technology completely depends on the extension service and realization from the farmers of tangible benefits or profit from it (Table 8.3). The department needs more resources in terms of extension workers, supporting support such as input and subsidies, reliable market etc.

[7] http://arkonetwork.com/news/nepal/nepal-budget-2073-74/

Table 8-3: SWOT table from the key interview from different stakeholder in Nepal

Strengths	**Weaknesses**
Favorable climate and soil Agriculture is mostly organic by default	Lack of adequate agriculture extension staff Political instability; Capacity of farmer on technology is low; Current uptake of technology is low; Lack of market and competitiveness; Low price and yields; Inequity in water and irrigation; Inadequate infrastructure for development
Opportunities	**Threats**
Improving infrastructure development; Quality of produce to tap export market Continued support from international development agencies; Scope for improvement of community-based NGO; Potential to improve irrigation system particularly in hills; Off late, increase participation in large-scale management.	Competitive market of technological products; Government support through subsidies is minimum; Increase market demand for good product quality; Corruption, politicization, and inequity in resource allocation; Global trend in reduction in funding for agricultural development; Lack of well-trained department professional



*Size and proximity of institutions based on the resource allocation and level of intervention of the institutions (Authors interpretation)

Figure 8-5: Institutions identified having direct and indirect links to Agriculture Development*

8.9 Further analysis of existing institutional arrangement (EGP) and its effectiveness towards agricultural development

The eastern Gangetic plain's rural economy has benefitted from substantial investment from national and international development agencies in agriculture and allied sector in terms of technology, rural infrastructure, and human capital. While plans and policies to address most challenges of agriculture intensification along with women and youth empowerment do exist, their implementation is limited. A challenge in the implementation of policies is also the current political instability and along with internal and cross-country differences in the case of Nepal. In addition, the region continues to be one among the most vulnerable region to climate change including flood, saline intrusion, and drought, which pose a long-term threat to this sector. Further, in most cases, agriculture and livestock-related policies have not been implemented effectively because of factors including limited human resources and implementation capacity, lack of supportive legislation and monitoring and evaluation, poor coordination and weak planning. These structural challenges limit the effective implementation of the program.

This report is an initial attempt to map key high-level institutions that are playing a key role in countries agricultural development. The factors such as implementation efficiency, network coordination with the lower level of administration, impact over the years are but important to understand, however, not within the scope of the report. In addition, life cycle analysis from technology development, feasibility testing, approval, and dissemination is interesting to understand the time frame which the promising technologies were being promoted after development. There are additional barriers including access for farmers to roads, markets, education, inputs and new knowledge. There is also the added challenge of out-migration and women dependent agriculture. While efforts are being exerted to assist women in agriculture, they are mostly programmatic intervention. There is a gap in their effective uptake due to inherent social discrimination and labor challenges. There are hardly any programs that address these inherent problems.

After decades of investments and resources allocation for the overall development of the region, often questions are asked on how these investments have really improved the intensification of farming and ensured sustainability of the input resources? t is important to understand the ground realities and institutional gaps to improve on a key area for improvement in public expenditure spending. Further analysis can deepen the high-level understanding that has been developed from phase one of this scoping study. There are key questions to be explored further to have a logical conclusion and identify gaps such as a) What are the major formal policies, strategies that influence intervention during design and program implementation and long-term strategies to tackle climate change?

8.10 Acknowledgement

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8.11 Acronyms

AC&FW – Agriculture, Cooperation & Farmers Welfare

CAT – Capacity building for Adoption of Technology

DARE – Department of Agricultural Research & Education

FC- Farmers Club

GFCC – Ganga flood control Commission

IAY – Indira Awas Yojna

ICAR – Indian Council of Agricultural Research

INM – Integrated Nutrient Management

IWMP – Integrated Watershed Management Program (IWMP)

KPS – Krishi Prajukta Sahayak

KVK – Krishi Vigyan Kendras

MGNREGA – Mahatma Gandhi National Rural Employment Guarantee Act

NDC - National Development Council

NGO – Non-governmental Organization

NGRBA - National Ganga River Basin Authority

NHM – National Horticulture Mission

NRLM – National Rural Livelihood Mission

NSAP – National Social Assistance Program

PCD – Pucca Check Dam

RCT – Resource Conservation Technologies

RMS – Runoff Management Structures

SDD – Silt Detention Dam

WHS – Water harvesting structures

ISOPOM – Integrated scheme of Oilseed, Pulses, Oil palm & Maize

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8.13 Appendices

8.13.1 Appendix 8.1: Stakeholders – Bangladesh agriculture

Stakeholder/actor	Full Definition	Mandated Responsibilities	Description
Government Institutions			
PMO	Prime minister's office	Strategic decisions	
Ministry of Agriculture	Department of Agriculture & Livestock services	Research & Development; agricultural development; livelihood improvement	Agricultural policies, plans, regulation; Monitoring implementation of policies and plans, projects, and regulation
Ministry of Fisheries & Livestock	Department of Fisheries and Livestock	Research & Development; agricultural development;	Agricultural policies, plans, regulation; Monitoring implementation of policies and plans, projects, and regulation
Ministry of environment & forest	Department of Environment	Research & address climate change impacts	Planning and fund allocation of climate change resilience projects
	Bangladesh Climate change trust	Secretariat to climate change projects, clearance, fund release etc.	Infrastructure building, Information creation, implementation of climate change action plan
Ministry of water resources	Flood forecasting and warning center	Research and Inform	Infrastructure building, Information creation, implementation of climate change action plan
	Institute of Water Modeling	Research & Inform	
	Bangladesh water development Board	Planning & implementation of water resource projects	
	River research institute	Research and inform	
	Water resource planning organization	IWRM implementation	

International Development Agencies	
Asia Development Bank (ADB); World Bank; Australian government research support; Bill Melinda Gates Foundation;	Research, implementation of agriculture-related projects (Research, Technology development & Adoption; institutional innovation etc.)
Non-governmental Agencies	
Farm producers association; NGOs involved in capacity building of integrated crop management and resource conservation.	

8.13.2 Appendix 8.2: Institutions mapped under the framework of building sustainable intensification and resilient households- Bangladesh

Sustainable and profitable farming	Research & Development (Crop Improvement; Integrated Management; Institutional innovation)	Ministry of Agriculture and concerned departments, International development agencies, and local groups
	Inputs, extension & Farmers services (Seed System, Input supply; credit supply)	Ministry of Agriculture and concerned departments
	Markets & Information	Ministry of Agriculture and concerned departments; Ministry of local government, rural development, and cooperatives; local group and cooperatives
Enabling Environment	Infrastructure (Social & Physical) & Resource Conservation	Ministry of Agriculture and concerned departments; international development agencies.
	Institution for knowledge generation, exchange, and transformation	National research institutes; department of agriculture, Ministry of disaster management, ministry of rural development
	Social Protection	Ministry of rural development,
	Data & Informatics	National research institutes; agricultural Universities
Resilient Livelihood	Gender	Policy research institutes; concern ministry of agriculture, rural development, cooperatives
	Youth	
	Nutrition	

8.13.3 Appendix 8.3: List of government departments and relevant websites- Nepal

Ministry	Website	Department/organization /division	Website
Ministry of Irrigation	http://www.moir.gov.np/index.php	Ground Water Resources Development Board (GWRDB)	http://www.gwrdb.gov.np
		Department of Irrigation	http://doi.gov.np
		Department of Water Induced Disaster Management	http://dwidm.gov.np
Ministry of Agriculture development	http://www.moad.gov.np/en/index.php	Agriculture development strategy	http://www.moad.gov.np/downloadfile/ADS%20English%20Volume%201%20&%202_1485514581.pdf
		Department of Agriculture	http://www.doanepal.gov.np/ne/
		Department of Food Technology and quality control	http://www.dftqc.gov.np
Ministry of Forest and Soil Conservation	http://www.mfsc.gov.np/content.php?id=289	Department of Forest	http://dof.gov.np/home
		Department of Forest Research and Survey	http://www.dfrs.gov.np
		Department of Soil Conservation and Watershed Management (DSCWM)	http://www.dscwm.gov.np
		Department of Plant Resources	http://www.dpr.gov.np
		Department of National Parks and Wildlife Conservation (Nepal) (DNPWC)	http://www.dnpwc.gov.np

Ministry Of Federal Affair & Local Developm ent	http://www.mof ald.gov.np/en	Department of local infrastructure and development and agriculture roads	http://www.dolidar.gov.n p/about-dolidar/
Ministry of land reform and manageme nt	http://www.mol rm.gov.np/index. php	Survey department	http://dos.gov.np/languag e/en/
		Department of land reform and management	http://www.dolrm.gov.np
		Land management training center	http://www.lmtc.gov.np
		Department of Civil Registration	http://www.docr.gov.np/? q=en
Ministry of cooperativ e and poverty alleviation	http://mocpa.go v.np/work-plan	Department of Cooperative	http://www.deoc.gov.np/i ndex.php
		National Cooperative Development Board (NCDB)	http://www.ncdb.org.np/ about-ncdb/backgrounds/

8.13.4 Appendix 8.4: Stakeholders – Nepal's agriculture

Sustainabl e and profitable farming	Research & Development (Crop Improvement; Integrated Management; Institutional innovation)	Nepal Agriculture Research Council, Department of plant resources, Department of Soil and Water Conservation Department of Food technology and quality control. Policy and International Cooperation Coordination Division (PICCD), NARDF Ministry of irrigation. Asian Development Bank (ADB), International Fund for Agricultural Development (IFAD), European Union (EU), FAO, Swiss Agency for Development

		and Cooperation (SDC), Japan International Cooperation Agency (JICA), Denmark Agency for International Development (DANIDA), World Food Program (WFP), United States Agency for International Development (USAID), Department for International Development (DfID), the World Bank, the Australia Agency for International Development (AusAID), and UN Women
	Inputs, extension & Farmers services (Seed System, Input supply; credit supply)	Department of forest research and survey, Agriculture Inputs Company Limited and National Seed Company Limited, NARDF Agriculture extension service center Bandhan Bank, Agriculture Development Bank of Nepal. Land management training center ICIMOD, Nepal's National Seed Board (NSB) Department of Cooperative, FAO.
	Markets & Information	Livestock development and business development division, Department of Forest, Department for Livestock Services Agriculture Inputs Company Limited and National Seed Company Limited, National Dairy Development Board, World Bank, FAO, ADB, IFC, AusAid.
Enabling Environment	Infrastructure (Social & Physical) & Resource Conservation	Department of local infrastructure and development and agriculture roads, Ground Water Resources Development Board; Department of Irrigation, Ministry of land reform and management
	Institution for knowledge generation, exchange, and transformation	Department of plant resources, Dairy Research Center, Nepal Agriculture Research Council Department of plant resources; National Livestock breeding center; Land management training center; ICIMOD, CIMMYT, Dairy research center, FAO
	Social Protection	Department of Water Induced Disaster Management, Department of Livestock Services Poor Household Support Coordination Board (PHHSCB), Department of local infrastructure and development and agriculture roads.

	Data & Informatics	Department of forest research and survey; Agriculture information broadcasting center; National Dairy Development Board; Department of Food Technology and quality control; Survey Department, ICIMOD, FAO
Resilient Livelihood	Gender	Food security, Agribusiness Promotion and Environment Division (Special Division for gender) Department of Forest, Department for Livestock Services ICIMOD
	Youth	Agriculture Development Strategy, Department of Livestock Services, Agriculture Development Bank of Nepal, ICIMOD, WWF, Finance Ministry, Ministry of Agriculture and Livestock
	Nutrition	Department of Agriculture (national food security program), Department of Forest, NARC, NARDF, FAO.

8.13.5 Appendix 8.5: Key Organization Contacted

India – No of interview - 3
Department of Agriculture, Bihar & West Bengal
Centre for Development of Human Initiatives (CDHI), West Bengal
Nepal – No. of interview - 3
Department of Agriculture, Kathmandu
Department of Irrigation, Kathmandu
Institute for Social and Environmental Transition, Kathmandu, Nepal
Bangladesh – No. of interview - 2
Department of Agriculture Extension, Bangladesh
Department of Livestock Services, Bangladesh

9 Policies for Sustainable Intensification of Agriculture in Eastern Gangetic Plains

9.1 Introduction: The need for sustainable intensification of agriculture in Eastern Gangetic Plains (EGP)

Food security continues to be a concern for South Asia (Global Hunger Report, 2017) and especially in the Eastern Gangetic Plains (EGP) with high and rising population density, high incidence of poverty and high dependence on agriculture for livelihoods. Intensification of farming systems is essential to reduce poverty and ensure food security in the region. There are two major challenges to agrarian intensification in EGP. First, most farmers in the region are poor and cultivate very small and scattered holdings even by the South Asian standards. Second, depletion of soil and groundwater is already a major problem in the region even at the current levels of crop productivity and input use intensity. As the population increases, the pressure on land and water will further intensify. Environmental constraints on agricultural change play a profound role on intensification (Pingali and Binswanger, 1987). These challenges are further complicated by climate change, which is predicted to have highly adverse impact on smallholder agriculture in the region (IPCC, 2007; Thomas et al, 2012). Given these challenges, it is important that the agrarian intensification in EGP is environmentally sustainable, climate resilient and inclusive of smallholders. Technology will create new opportunities for sustainable intensification of agriculture, but public policies, institutions and markets are required to leverage these opportunities to benefit tens of millions of smallholders in the region.

Sustainable intensification of agriculture is the only option to ensure livelihood and food security of smallholders in Eastern Indo-Gangetic plain of South Asia. There is little scope to expand the net sown area in the region and even lands already under cultivation are being lost to non-agricultural uses. Meanwhile population pressure on land continues to rise as very high fraction of the working population remains dependent on cultivation and farm labor as their main source of income. Around 80.1 and 60.4 per cent of the total population in Bihar and West Bengal, and 55 and 66 per cent of the population in Bangladesh and Nepal, respectively, are engaged in agriculture. When population pressure on land is so high and rising, intensification, where more labor, capital and technology is deployed to increase land and water productivity will help improve food security and reduce poverty.

Increasing productivity, though essential to increase farm income and ensure food security, may not always lead to sustainability (UNEP, 2011). Sustainable intensification of agriculture requires policies and institutions that help small holders minimize transaction costs and potential risks involved in adopting new technologies and practices and accessing markets. Though sustainable agricultural intensification (SAI) offers workable options to eradicate poverty and hunger while improving the environmental performance of agriculture, but requires transformative, simultaneous interventions along the whole food chain (Spielman,2014).

This report presents a brief overview of existing policies in the food, energy and water sectors in Bangladesh, India and Nepal as they affect (incentivize or inhibit) widespread adoption of technologies and practices for sustainable intensification of agriculture in these countries. We also briefly discuss relevant agricultural research and extension policies and programs and their local effectiveness. Our analysis of policies, institutions, and markets in EGP is based on our own previous work in the region under the ACIAR supported project, Sustainable and Resilient Farming System Initiative (SRFSI) and information available from government documents, reports by international agencies and documents in public domain.

9.2 Major constraints to sustainable intensification of agriculture in EGP

We have identified six major constraints to sustainable intensification of agriculture in EGP.

First, land holdings in the region are exceptionally small even by south Asian standard. Small holdings combined with low or modest productivities, leads to small marketable surplus and low purchasing power, and therefore, high transaction costs and low bargaining capacity in input and output markets and markets financial and information services.

Second, groundwater is available at low depths in EGP, but irrigation is expensive because energy for irrigation is costly and water markets are not competitive. Farmers practice deficit irrigation and realize low yields and profits. High cost of irrigation also makes agriculture less resilient to droughts and terminal heat and discourages crop intensification.

Third, 90 percent of farmers in EGP depend on rental markets to access machine services. However, machine rental markets are underdeveloped or uncompetitive. Machines like seed drills and happy-seeders are often not easily available to farmers and even when they are available, rents are high and machine operators are not well trained.

Fourth, farmers in the region have poor access to markets. As a result they get low prices for their produce resulting in low profits, and hence, weaker incentives to intensify agriculture and adopt yield enhancing inputs and practices.

Fifth, returns from agriculture in the region are not only low, but also unstable due to production and price risks. Low and risky returns is a major reason why a majority of young farmers in EGP report that they do not like farming as a profession and do not see a future in it. As a result, they also less motivated to invest into sustainable technologies and practices.

Sixth, the region has a weak extension system, and weak systems for agricultural credit and insurance. It is partly due to the poorly developed extension system that time to adoption of new varieties of seeds and other technological innovations is often very long. For example, a recent IFPRI survey in Bihar, West Bengal, Bangladesh and Nepal showed that very few farmers in the region were using conservation agricultural tools in the rice-wheat or rice-rice cropping systems. Another survey in Bihar and West Bengal showed that a large number of farmers continued to use 25-30 year old varieties of rice and wheat seeds even when a number of new varieties with shorter duration, higher yield potential and better disease resistance have been released in the last few years. Poor access to credit makes smallholders' liquidity constraints even worse. The liquidity constraints result in sub-optimal input use and inefficient land tenancy contracts that affect both productivity and profits. Absence of insurance makes it harder for small farmers, with low capital and weak safety nets, to try new things that may have real or perceived downside risks.

9.3 Policies for sustainable agricultural intensification

Sustainable intensification of agriculture aims to increase agricultural productivity and farm incomes while ensuring resource conservation. Population pressure on land and water, price signals and governance framework are among the key determinants of adoption or disadoption of sustainable intensification technologies and practices (Garnett et al., 2012). Though technology is essential for undertaking sustainable intensification of agriculture, its effective and speedy implementation on scale requires that appropriate policies and institutions are in place (Reardon and Kelly1999). It entails departure from business as usual as fundamental changes are needed in agricultural development policies and institutions to encourage smallholders to

adopt sustainable crop production intensification (FAO, 2011). Among different policies that have a bearing on adoption of sustainable intensification, we focus mainly on food, energy and water policies and policies related to agricultural mechanization in this report. Institutional mapping for sustainable intensification is the subject of another report prepared for this SRA, and therefore, not discussed here.

It is important to mention here that agriculture is in the state list of India's constitution, and therefore, all agriculture policies and programs are implemented by state governments. Government of India can, however, influence policies and programs it wants the states to adopt by providing financial support for their implementation. Thus, we have two types of agricultural policies and programs in India. Some policies and programs are national. They are implemented with partial or full financial support from the central government. In addition, states also have their own policies and programs for agriculture funded by their own budgetary resources. We will cover both central and state level policies and initiatives in this report.

9.3.1 Food policy

EGP states are poor. Rice and wheat account for more than half of the average household consumption expenditure and seventy percent of calorie intake. As a result, governments are highly sensitive to price of the two cereals and the food policy in all three countries is focused mainly on ensuring that they are available to consumers at affordable prices at all times. Achieving self-sufficiency in rice and wheat and sustaining it, is the cornerstone of food policy and also agricultural research and extension policies in the region. Countries, and even states within India, strive for self-sufficiency and do not rely on national or international markets to ensure food security. All three countries use heavy input subsidies, price controls, quantitative restrictions on imports and exports and other market distortions in the pursuit of self-sufficiency. Subsidies on fertilizers, canal irrigation and electricity for groundwater irrigation incentivizes inefficient and imbalanced application of these inputs and discourages sustainable intensification of agriculture and the much needed crop diversification away from rice and wheat to other high value crops.

In addition to input subsidies and controls on international trade, Government of India also procures rice and wheat from farmers at a minimum support price (MSP) and maintains large buffer stock of these two grains. The price floor does not work in Bihar and West Bengal because the public procurement system of rice and wheat is weak in both states. Not only that, from time to time, the Food Corporation of India (FCI) releases grains from the buffer stock through open market sales scheme (OMSS). The combined pressure from subsidised sales by the FCI under its OMSS and local gluts results in producers getting prices well below the actual economic cost of production in Bihar (Kishore, 2004) and below MSP in West Bengal. Furthermore, a large share of procured grains is distributed to households at highly subsidized prices through the public distribution system (PDS). Total allocation of subsidized rice and wheat for Bihar and West Bengal increased significantly after the implementation of the National Food Security Act (NFSA) in 2013. Much of this increased supply is being imported from other states since the local procurement is small. The big increase in import of highly subsidized grains from other states may further dampen local prices. If so, it will there will further dampen incentives for sustainable intensification.

Public procurement at MSP, maintenance of huge buffer stocks of rice and wheat and their sales at highly subsidized prices through the PDS impose a huge fiscal cost on government of India. India spends more than 1 percent of its GDP and more than 6% of its agri-GDP on food subsidies. These heavy subsidies not only divert resources away from productive investments, but also development of agricultural markets and distort farmers' incentives to increase resource use efficiency and adopt new and better technologies and practices in agriculture.

On one hand farmers enjoy input subsidies that encourage them to use water, energy and fertilizers inefficiently. On the other hand, governments are quick to impose export restrictions, stocking limits, ban of futures trade and similar other restrictive policies as soon as food prices start rising. These restrictions impose implicit taxes on farmers. In their book, the Subsidy Syndrome in Indian Agriculture, Gulati and Narayanan () argued that Indian farmers are net taxed. The same may be true for farmers in Nepal and Bangladesh also. These restrictions, though meant to ensure stable prices for consumers, have a paradoxical effect of increasing price volatility and unpredictability which further discourages investment in agriculture and exposes smallholders to more risk.

The highly protective trade regimes in cereals also creates an equilibrium where self-sufficiency becomes a necessity for countries. The global food crisis in 2008 is an example. Bangladesh faced scarcity of rice around that time. It tried to import rice from SAARC countries, especially, India. India, however, had imposed export restrictions as a precautionary measure. Bangladesh, therefore, had to depend on expensive imports from the world market. This one time episode eroded Bangladesh's faith in South Asian Regional food sharing mechanism and steeled the resolve of its policy-makers to maintain rice surplus status at all times. Increase in fertilizer subsidies to boost domestic production of rice was one manifestation of this new resolve.

In sum, food policy in all three countries is driven mainly by the goals of maintaining cereal self-sufficiency and low consumer prices and deploys highly restrictive and distortionary policies to achieve these goals. These restrictions and distortions hurt farmers and impede widespread adoption of sustainable farming technologies and practices.

9.3.2 Energy policy for irrigation

Groundwater is the main source of irrigation in EGP. Pumping groundwater against gravity requires energy and energy pricing and supply regime for irrigation has a major influence on the size and structure of groundwater irrigation economy in different parts of South Asia. Diesel and electricity are the two main sources of energy for groundwater pumping in this region. Some farmers in India also adulterate diesel with subsidized kerosene meant for household use. The scale of use of kerosene in agriculture, however, is not documented. In 1990s, muscle powered treadle pumps became popular as a means for lifting groundwater among poor, sub-marginal farmers in Bangladesh (Shah et al, 2000). However, data from a recent IFPRI survey of a representative sample of farmers in Bangladesh found very few treadle pump users. Diesel or electric pumps have replaced nearly all treadle pumps in the country.

The energy-divide between EGP and the rest of the region is a major feature of the South Asian groundwater economy (Shah et al., 2003). Groundwater irrigation is almost entirely by diesel pumps in Bihar and Nepal terai and also in large parts of West Bengal and Bangladesh while electric pumps dominate in other parts of South Asia. Because of its diesel dependence, irrigation is expensive in EGP, even more so for farmers who do not own pumpsets and rely on water markets. High cost of irrigation forces farmers in EGP practice deficit irrigation. This results in lower crop yields and low cropping intensity. Expensive irrigation also makes agriculture in the region less resilient to droughts and late onset of monsoon (Kishore, Joshi and Pandey, 2014). In India, state governments in the EGP region have tried to make irrigation more affordable to farmers by providing capital subsidy on diesel pumps and tubewells. Pump density has increased significantly over the last 10-15 years and more sub-marginal farmers own pumps today compared to a decade ago. Still, water markets continue to be just as uncompetitive as they were when pump-sets were more expensive, less fuel efficient and fewer in number. An increase in pump density is unlikely to make water markets more competitive till diesel is the main motive power for pump-sets. Government of Bihar makes a conditional cash transfer to farmers in drought affect blocks of the state to encourage them to apply more water

to their *Kharif* crop to mitigate crop loss. However, our analysis shows that such *ad hoc* attempts at drought mitigation through non-distortionary subsidies do not achieve their intended goal due to various implementation failures (Kishore, Joshi and Pandey, 2015b).

Water markets are more competitive and irrigation more affordable in villages of Bangladesh and West Bengal where farmers irrigate from electric pumps. A shift to a cheaper source of energy for pumping groundwater is essential to ensure affordable access to irrigation in the EGP region. Sustainable intensification of agriculture will not be possible in the region if irrigation does not become more affordable.

Improving power supply to rural areas is one way to make irrigation more affordable, as has happened in parts of West Bengal (Mukherji 2007; Mukherji et al. 2012) and Bangladesh. However, unlike in West Bengal, Bihar and Nepal terai have large deficits of power and rural power supply is unlikely to improve to the extent where farmers could rely on electricity for groundwater irrigation in the foreseeable future—it may take years, if not decades.

In the absence of grid power for rural areas, solar photovoltaic water pumping for irrigation is a suitable option to ensure affordable irrigation for farmers, given the ample groundwater at low depths and 280–300 sunny days in a year with annual average solar radiation of 5.04–5.42 kilowatt-hour per meter squared (kWh/m2) (IMD 2009 cited in GIZ 2013). The economics of solar pumps already look attractive given the high and rising cost of diesel they will replace in EGP. The life-cycle cost of solar-powered pumps is significantly lower than that of liquid-fuel-based pumping systems (Kolhe et al. 2002, Odeh et al. 2006, GIZ 2013). Solar systems have long lifetimes, need minimal attendance and little maintenance, and have near zero operational cost. They also have an additional advantage over fossil fuels: they provide emissions-free power using a renewable source of energy.

Given the potential benefits of solar pumps, policy-makers in the EGP region have started promoting the technology. In the budget for 2014–2015, the government of India earmarked Rs 4 billion (approximately US$67 million) for a new scheme to promote solar-power-driven agricultural pumps. The agricultural roadmap of government of Bihar proposes to install 285,000 solar pumps of 2 HP (or 1.5 kW) capacity by 2022 in several phases, at an estimated cost of Rs 85.5 billion (US$1.425 billion) (Bihar, ED 2012). The high upfront cost of solar pumps (Rs 0.15 million/HP) is, however, a big barrier to the adoption of this technology. In India, state and central governments are trying to address this problem by offering high capital subsidies on a pro-rata basis. For example, Government of Bihar provides 90 percent capital subsidy on solar pumps. Such high subsidies combined with a tight budget constraints limits the number of pumps that can be offered at subsidized rates. Only a few farmers will benefit, and even these farmers will be less aggressive in selling water to their neighbors, given the low capital investment from them. It creates a high-margin/low-volume market for photovoltaic systems, just like it did for drip systems in the past. Moreover, the pro-rata subsidy incentivizes cost inflation and gold plating by solar system suppliers instead of creating incentives for cost-cutting innovations.

The rapidly falling price of solar panels offers an opportunity to provide widespread access to affordable irrigation in Bihar. However, the state government needs to allocate more resources to promote solar pumps, improve the subsidy design and shift focus from capital subsidies to innovative financial mechanisms that can reduce upfront cost of solar pumps to promote their widespread adoption. Our analysis of the subsidy policy for solar pumps in India suggests that it is impeding, not promoting, the spread of solar power for irrigation in Bihar. Other states and countries in EGP should not repeat the same mistakes in devising their promotional policies for solar pumps.

9.3.3 Policy for agricultural mechanization

Mechanization of agriculture is a policy priority in Bangladesh, India and Nepal. Governments in all three countries are also realizing that agricultural mechanization today has to widen its scope beyond labour saving and swift completion of operations to address issues of soil health and sustainability.

Over the last decade, the Government of India has been directing investments to agricultural mechanization through its major multi-component flagship programmes like the Macro Management mode of Agriculture (MMA), Mission for Integrated Development of Horticulture (MIDH), the *Rashtriya Krishi Vikas Yojana* (RKVY) and the National Food Security Mission (NFSM). In 2014, the government also launched the Sub-Mission on Agricultural Mechanization (SMAM)—a dedicated mission for strengthening agricultural mechanization under the National Mission on Agricultural Extension and Technology (NMAET). Extending Green Revolution to Eastern India (EGREI) was launched in 2011-12 to increase crop productivity in eastern India. Providing support to farmers for tools and implements suitable for small land holdings is a key component of EGREI.

Provision of subsidies on the capital cost of implements is a major component of all government schemes for promotion of farm mechanization in India. The subsidy is usually in the range of 25 to 50 percent of the capital cost. For example, in EGREI, a special scheme for eastern India, there is a provision of 50 percent capital subsidy for farm equipment like drum seeders, zero tillers and diesel pumps. Under MMA, there is 25 percent subsidy for machines like tractors, paddy transplanters and plant protection equipment while new and specialized power driven equipment such as zero till, seed-cum fertilizer drill, raised bed planter, rotavator, straw reaper, crop reaper, happy seeder etc., enjoy 40 per cent subsidy. Higher subsidy on the second group of machines suggests that government is trying to promote resource conservation in the agricultural sector, but equal subsidy on rotavator and zero-till machine sends wrong signals to farmers.

Women contribute 60-80 percent of the manual labor used in rice cultivation in South Asia (Ricepedia, 201x), but their participation in mechanized agricultural operations is near zero. Given the large female workforce in agriculture, it is important that women have greater ownership of mechanized agricultural equipment and the machines are designed to be women friendly. The Indian Council of Agricultural Research (ICAR) provides funds for research and technological innovations in the field of gender friendly equipment. Over the last few years, ICAR has developed a number of agricultural implements and hand tools suitable for women. These women friendly tools are being promoted under MMA and the SMAM. Both these schemes offer 10% additional financial assistance for purchase of agricultural equipment by women farmers. Not only that, state governments have also been directed that at least 30 percent of the budget allocation under SMAM should be targeted at women farmers. Whether these provisions favouring women have made a difference on the ground in terms of women's ownership and control over the decisions to purchase and use agricultural implements is not yet documented.

The agricultural mechanization policy of Bangladesh is very different from India. After a food crisis, Government of Bangladesh deregulated the agricultural equipment sector. It withdrew the ban on import of agricultural equipment and eliminated import duties and other domestic taxes of farm equipment. It also allowed marketing of machines without standardization and quality testing and removed spacing norms for shallow tubewells. Unlike India and Nepal, there are no subsidies on farm equipment in Bangladesh. Farmers pay the full cost of machinery. Even bank loans for equipment purchase is available only on a limited scale. Still, agriculture is mechanized to a greater degree in Bangladesh than in India and Nepal. 80 percent of land

preparation is done by machines in Bangladesh compared to 45% in India (Biggs and Justice, 2015). Emergence of competitive machine rental markets has allowed such high levels of mechanization in spite of ultra-small land holdings and low capital endowments of most farmers. A comparative survey of machine rental rates in Bihar, West Bengal, Bangladesh and Nepal by IFPRI showed that the rental rates (normalized by the horsepower of machines and diesel prices) are the lowest in Bangladesh and the highest in Nepal.

Agricultural mechanization policy of Nepal relies heavily on high capital subsidies. The country relies mainly on imports from China and India, but unlike Bangladesh, agricultural equipment are subject to import duties and local taxes in Nepal. Subsidies and regulations hurt, not help, farm mechanization. High subsidies, combined with a tight budget constraint, means that every year, only a small number of farmers or entrepreneurs can get the subsidy. But once the subsidy is in place, it strangles the open market to agricultural equipment. Not only that, in a recent visit to Nepal, we realized that the subsidized machines cost more than what unsubsidised imports from China would. A small number of importing firms collude to drive up machine prices and skim off a large share of the subsidy meant for farmers. We strongly believe that Nepal would do well to follow the example of Bangladesh in deregulating machine imports and taxes rather than using poorly designed and poorly implemented capital subsidies.

Mechanization for conservation agriculture

Conservation agriculture requires machines for zero-tillage, direct seeding, residue incorporation, etc. While machines like tractors, power tillers, pumpsets, threshers and shellers have become popular in EGP, the adoption of CA equipment is slow and limited only to a few pockets where local or international research institutions are actively demonstrating and promoting them. Even after two decades of field demonstrations and promotion, zero-till (ZT) covers less than 1 percent area under wheat in Bihar and Nepal terai. In comparison, nearly one-third of wheat in Haryana is sown using ZT (Joshi, Khan and Kishore, unpublished). In Bangladesh also, seeders and other CA equipment are popular only in parts of Rajbari district. Elsewhere in the country, they are hardly used (CIMMYT, 2012).

Even with large government support, investments in the research and development (R&D), presence of local manufacturing of farm equipment, and the sizable potential for CA equipment to intensify agriculture, their use had not reached a commercial scale in the EGP region. Even in pockets like Rajbari district in Bangladesh and Vaishali district in Bihar, where CA is more common, its use has not reached the take-off stage from where it can spread spontaneously like tractors, power-tillers and pump-sets did thirty years ago.

Need for custom hiring services for CA

Unlike tractors, the CA equipment do not enjoy economies of scope. Each CA equipment is designed for a specific operation. Unlike pumpsets, the operations they perform are often needed only once or twice a year. Limited use, and hence, low capacity utilization of CA equipment is a challenge for their widespread adoption. CA operations are also more deliberate and therefore require better skills and training of the equipment operators. Policy efforts for promotion of CA equipment should go beyond capital subsidy on machines and extension efforts to convince farmers of their benefits. Many farmers who want to use CA are not able to use it because machines are not available on time or their operators are poorly trained. Promoting custom hiring centres that have better access to capital, trained manpower and IT applications to ensure better coordination between farmers and service providers to ensure high capacity utilization can help accelerate the diffusion of adoption of CA (Keil et al., 2016). A IFPRI study on laser land levellers in eastern Uttar Pradesh, also a part of EGP, shows that

first-use subsidy to farmers can increase adoption of new agricultural technologies and practices (Lybbert et al., 2013).

Government of India is actively promoting custom hiring centres under the SMAM. Three of the eight components of the mission relate to establishment and promotion of custom hire centres. The first of these seeks to establish farm machinery banks for custom hiring to promote mechanization in districts with low farm power availability, low tractor density, small and marginal operational holdings, and low productivity of food grains. Districts in EGP qualify on all these criteria. Each CHC set up under this mission is to have the capacity to cover a minimum area of 10 hectares per day and at least 300 hectare in a cropping season. Entrepreneurs (including manufactures), progressive farmers and SHGs can submit proposals for establishing CHCs with a 40 per cent subsidy under the scheme. The scheme provides the flexibility for different business models to be adopted for setting up the CHC, provided the model has provisions for regular maintenance and upgradation of the centres.

The second component of SMAM focuses on increased utilization of hi-tech and high value machines for increased crop productivity of cash and other high value crops. Under this component, CHCs with a capacity to cover 500 hectare in a cropping season can be established in areas with large areas under cash crops or high value crops, and high potential areas. For CHCs costing up to 25 million rupees, entrepreneurs can avail 40 per cent subsidy (limited to 10 million rupees) on their establishment.

In addition to these components on establishment of CHCs, SMAM also offers financial assistance to farmers on hiring charges to farmer members of CHCs, set up through the scheme. Subsidy is higher (Rs 2000/ha per farmer per year) for tractor or power operated operations and lower for manual or animal drawn mechanized operations. Besides this, field demonstrations by the CHCs are subsidized by 4000 Rs/ha for a minimum of 120 ha/season per CHC. Many state governments in India have started promoting custom hiring centres in partnership with private companies, independent entrepreneurs and cooperatives. Many different business and institutional models are being tried out in different parts of India. Governments in Bihar and West Bengal, however, yet to formulate a policy or program for promoting custom hiring centres. The same is true for Bangladesh and Nepal too. Research and documentation of different custom hiring models in different parts of South Asia, even outside the EGP region, to learn what works where and why can provide useful inputs to policy-makers in Bihar, West Bengal, Bangladesh and Nepal.

9.3.4 Extension policies and programs for sustainable intensification of agriculture

Agricultural extension plays a critical role in the dissemination of new technologies and practices, information about weather, markets and relevant public policies, programs and schemes. Bangladesh, India and Nepal have undertaken a series of steps to restructure, retool and reform their public extension systems to make it more decentralized, participatory and responsive to farmers' needs and to leverage the opportunities created by universal access to cell phones and developments in information technology.

In India, the government has established the Agricultural Technology Management Agency (ATMA) with centres in all districts that function as participatory bodies of key stakeholders engaged in agricultural activities. ATMA centres are supposed to be the focal points for integrating research and extension activities and day to day management of the public agricultural technology system (ATS). The government has also expanded the network of *Krishi Vigyan Kendras* (KVKs) or farmer science centres to all districts. KVKs have been established to train and educate farmers and they function as links between research and the field. ATMA

and KVKs have been central to extension efforts in the country. In 2014, the government of India also launched a sub-mission on agricultural extension (SAME) as a part of the National Mission on Agricultural Extension and Technology (NMAET) in 2014 to bring a “focused approach in mission mode to disseminate appropriate technologies and relevant information to larger number of farmer households through interpersonal and innovative methods of technology dissemination including ICT”. Government of India has also launched a 24-hour channel, DD Kisan, dedicated to farmers; set up call centres for farmers called Kisan Call Centres (KCC) and developed a cell phone application to provide interactive extension service to farmers.

In Bangladesh, government updated its extension policy after 16 years to launch the National Agricultural Extension Policy in 2012. The new policy emphasizes on integrated extension service and seeks to promote development of agribusiness and contract farming for export promotion, adoption of climate change specialized extension service and mobilization of farmers groups and federations. The emphasis on promotion of agribusiness and export led agriculture is a change from the old system where extension activities focussed mainly on increase production and productivity and ignored markets and did little to remove constraints to development of agribusiness.

Nepal reformed its extension system in 2002 when the Ministry of Agricultural Development devolved the extension activities to the respective District Development Committees (DDCs). This change followed the decentralization policy of the Government of Nepal and the Local Self Governance Act (LSGA) of 1999. In 2006, Nepal promulgated a new Agriculture Extension Strategy (AES) which emphasizes extension delivery through farmer groups, focus on poor and women, going beyond farms in extension to improve market access and information and building better links between farmers and agro-industries. The AES2006 also advocates pluralistic approach in extension and partnership with international and local NGOs, farmer groups, cooperatives and private input suppliers called agrovets in service delivery.

Extension arrangements in all three EGP countries have many similarities in terms of its organisation and underlying conceptual framework (Sulaiman et al, 2006). The similarities are evident in the changes proposed in the new extension policies also. The proposed reforms emphasize five common elements: 1) need for demand-driven, decentralized and interactive extension services; 2) multi-pronged extension using different service providers and mediums of communication; 3) developing and using farmer groups for extension; 4) going beyond only agronomic advice to add weather, price and public schemes related information and 5) using cell phones and information technology to exchange information with farmers. Extension reforms in all three countries have been helped by donor agencies, multi-lateral institutions like the World Bank and international for a like the Global Forum for Rural Advisory Services (GFRAS). This may be a reason for striking similarities in the approach of extension reforms across countries. It is also interesting to note here that the governments across the region do not emphasize the need to recover the cost of extension from farmers. Public extension will continue to be a free service to farmers in the foreseeable future. Even private companies in the extension business try to recover their cost indirectly by bundling it with other products or services or monetizing the data collected from farmers.

Countries in South Asia formulate new extension policies and strategies to revive their public extension systems and improve the overall quality of extension services and to bridge the gap between farmers and researchers and farmers and markets. However, years after policy changes, public extension services continue to have low coverage and low impact on technology adoption in the EGP region. Our analysis of the Situation Assessment Survey of Farmers (SASF) conducted in 2013 by the National Sample Survey Organization (NSSO) of India shows that less than 10 percent farmers in Bihar and West Bengal accessed extension

services from any public or private institution. Other farmers continue to be the main source of information on agriculture. A comparison between SASF 2003 and 2013 shows that the reach of private extension services has increased in the ten years, but not by much. We do not have similar data from Bangladesh or Nepal, but our impression from several interactions with the farmers in the two countries suggests that the situation there is similar to India. Extension departments, across the region are understaffed and the extension workers are ill-trained and not accountable to their clients, the farmers. There are no formal mechanisms in place to measure their performance and no provision for incentives to reward performance or penalties to deter non-performance.

Private sector companies focus their extension efforts mainly to sell their products (seeds, fertilizers, plant protection, etc.) and are not trusted by farmers. Also, private sector companies focus on larger landholders and farmers who grow commercial crops.

Agricultural extension using cell phones is still uncommon in the EGP region. Even where the service is there, the information delivered is often too generic, repetitive and in a language not easily understood by most farmers.

9.4 Concluding remarks

EGP is a densely populated region with high incidence of poverty and hidden hunger and high levels of dependence on agriculture for food and livelihood security. The region is dominated by very small and scattered holdings that are only becoming smaller with time. Given the high and rising population pressure on land and other natural resources, sustainable intensification of agriculture is essential for the region's development. Policymakers in all three countries—Bangladesh, India and Nepal—and even the state governments of Bihar and West Bengal recognize the need to increase productivity, profitability, sustainability and resilience of agriculture. Slogans like "doubling farmers' income" while "producing more from less" are now common in the policy circles of the region. A number of policies, programs and schemes are in place to promote sustainable growth in agriculture. However, there are three major challenges to realise

First, governments in EGP rely too much on subsidies and much less on incentives to achieve their policy goals, whatever they may be. Most subsidies are not only distortionary, they are also poorly targeted and crowd out public and private investments in agriculture. Rationalizing subsidies in food, energy, water and mechanized equipment sectors is essential to promote sustainable intensification of agriculture in the region.

Second, EGP is land-scarce and water rich, but farmers are not able to use water for agricultural intensification because energy for irrigation is expensive. Improving power supply for agriculture is essential for affordable and equitable access to irrigation in the region. Falling cost of solar systems also offers opportunity to address energy scarcity in the region, but the policy to promote solar power in agriculture needs to shift its focus from high capital subsidies to better access to credit and innovative financing mechanisms for cost-sharing between farmers and companies.

Third, food production and marketing is predominantly a private business in EGP, but markets are fragmented, value-chains are inefficient and very few formal sector companies recognize the need to involve the private sector in all aspects of the food system. However, the region ranks low in the ease of doing agribusiness compared to even other parts of South Asia because of its restrictive regulatory environment, low bureaucratic capacity and poor infrastructure (roads, electricity, markets, internet connectivity, etc.). Predominance of very small landholdings and poor farmers with low purchasing power and small marketable surplus

makes the region less attractive to private companies looking for scale. Aggregating small farmers into some form of collectives (cooperatives, producer companies, joint liability groups, etc.) will reduce the transaction costs doing business for both companies and the farmers and also improve farmers' bargaining power in commercial transactions.

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10 Key challenges across Food, Energy and Water Systems in Eastern Gangetic Plains countries of Bangladesh, India and Nepal

The three countries making up the Eastern Gangetic Plains in South Asia are experiencing rapid growth in population, economic wealth and urbanization. At the same time, the majority of the population remains engaged in agriculture subject to climatic, water, and energy stresses. Alternative investment scenarios suggest that both additional investments in irrigation and water use efficiency, and direct investment in agricultural technologies (i.e. breeding) are beneficial for key food security parameters, such as food prices and net trade position. Irrigation intensive and dependent crops, like rice, would benefit from increased investments in water technologies and expansion while wheat and maize would benefit from further breeding efforts. Lack of investment in these key staple crops, as evidenced by very low and declining investments in national agricultural R&D contribute to food insecurity in the region and globally.

10.1 Introduction

The South Asian region faces continued challenges around the water, energy and food nexus. First, continued food insecurity and undernutrition are realities for a large share of the population in the countries making up the Eastern Gangetic Plains with 15% of the population in India, 16% of the population in Bangladesh and 8% of the population in Nepal affected (FAO, IFAD & WFP 2015). Further food security stresses are expected as a result of adverse impacts from climate change and climate variability on key staple crops grown in the region (Ortiz et al. 2008).

At the same time, agricultural systems in the region are performing below potential. They are hampered by water and energy challenges, an overly focus on subsidies, a lack of diversification of production systems and overall underinvestment in agricultural R&D.

Of particular importance is the already severe water stress in India and growing water stress in Bangladesh and Nepal. As a result of the relative abundance of precipitation and water bodies in the Eastern Gangetic Plains, absolute water scarcity in the Eastern Gangetic Plains is currently limited to some months in a year or to somewhat longer periods during drought years.

On the energy side, there are challenges of switching existing energy systems to more renewable systems to support the implementation and ultimate achievements of the Sustainable Development Goals and the Paris Climate Agreement.

Poor policies on the water, energy and food side have contributed to severe environmental degradation, which are emblematic in groundwater depletion and degradation as well as in rapid increases in water pollution levels.

This paper describes these trends followed by the application of the first step of the ROAD process, which narrowed in on some of the key risks for water, energy and food security in the region, elements of which were incorporated into an analysis of alternative scenarios for water and food security in these three South Asian countries, using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) and concludes with suggested areas of focus for a more sustainable food, water and energy future in the region.

10.2 Growing natural resource scarcity in the Eastern Gangetic Plains

The Eastern Gangetic Plains countries of Bangladesh, India and Nepal in South Asia are subject to substantial challenges but are also in a region full of promises. The Eastern Gangetic Plains region comprises parts of all three countries and specifically the Terai of Nepal, the southwestern part of Bangladesh and eastern India. While the three countries already face significant natural resource constraints at the national level, as suggested by annual groundwater depletion in the Northwest of India (Chen et al. 2014) as well as coastal erosion, flooding and salinity intrusion in southern Bangladesh (Bernier et al. 2016), natural resources are relatively more abundant in the Eastern Gangetic Plains area, while infrastructure, such as electricity and irrigation remain under-developed, and poverty rates are higher. As the model analysis, which is the core of the paper, focuses on the three countries, the following sections will also treat some key threats to future water, food and energy security with a broad brush at the national level.

10.2.1 Growing water stress

Water stress in South Asia is currently among the highest in the world. Already in 2000, 59% of the population in the region lived in river basins with severe water stress, defined as water withdrawals in excess of 40% of water resources. By 2050, this share is expected to slightly increase, to 61%. Similarly, in 2000, 74% of the regional GDP was generated in high-water stressed regions, thus putting entire economies at risk from water stress. This share is expected to grow to 77% by 2050. Given rapid growth in both population and GDP over the time period, the most dramatic increase will be in the number of people living in water-stressed basins, a number that is projected to grow from 0.9 billion in 2000 to 1.6 billion by 2050, while regional GDP under water stress is expected to increase from $0.7 trillion to $8.8 trillion as much economic growth globally is projected to take place in water-stressed Asia (Ringler et al. 2016).

10.2.2 Growing water pollution

Water pollution requires significant energy sources for treatment, particularly as long as conventional energy systems are being used that are driven by fossil fuel sources and key elements that could be reused in agriculture are not recycled during the treatment process. Asia and South Asia already experience some of the highest water pollution levels anywhere in the world and much of this is generated by agricultural runoff. Reasons for high pollution levels are many-fold and are linked to intensive production levels in the key breadbasket regions in the countries. Fertilizer subsidies (for urea) are also a key contributor to agricultural water pollution, particularly in Bangladesh and India. In 2011, fertilizer subsidies accounted for 12% of total government expenditures in Bangladesh or US$ 1.5 billion and still for 6% of expenditures in India or US$15 billion (Huang, Gulati and Gregory 2017).

The Asia region is also expected to experience the largest absolute increase in agricultural pollution levels out to 2050. As Figure 10.1 shows, pollution levels, here for nitrogen loadings, are expected to grow rapidly in the next four decades with an almost doubling in Nepal (increase by 90%), but from a low base, a 58%-increase in N pollution in Bangladesh and a 55%-increase in N loadings in India between the 2005 base year and 2050. While N and P pollution in the region remain understudied, some research has been done on a region-specific pollutant, arsenic. Arsenic contamination can lead to arsenicosis, a disabling disease and can eventually culminate into fatal skin and internal cancers. Various measures and technologies exist to deal with arsenic in drinking and irrigation water but they are not sufficiently applied in the region. Arsenic contamination is severe in the Terai region of Nepal, in more than a million

of wells in Bangladesh, while a further 1 million people are exposed to arsenic in drinking water in West Bangal, India.

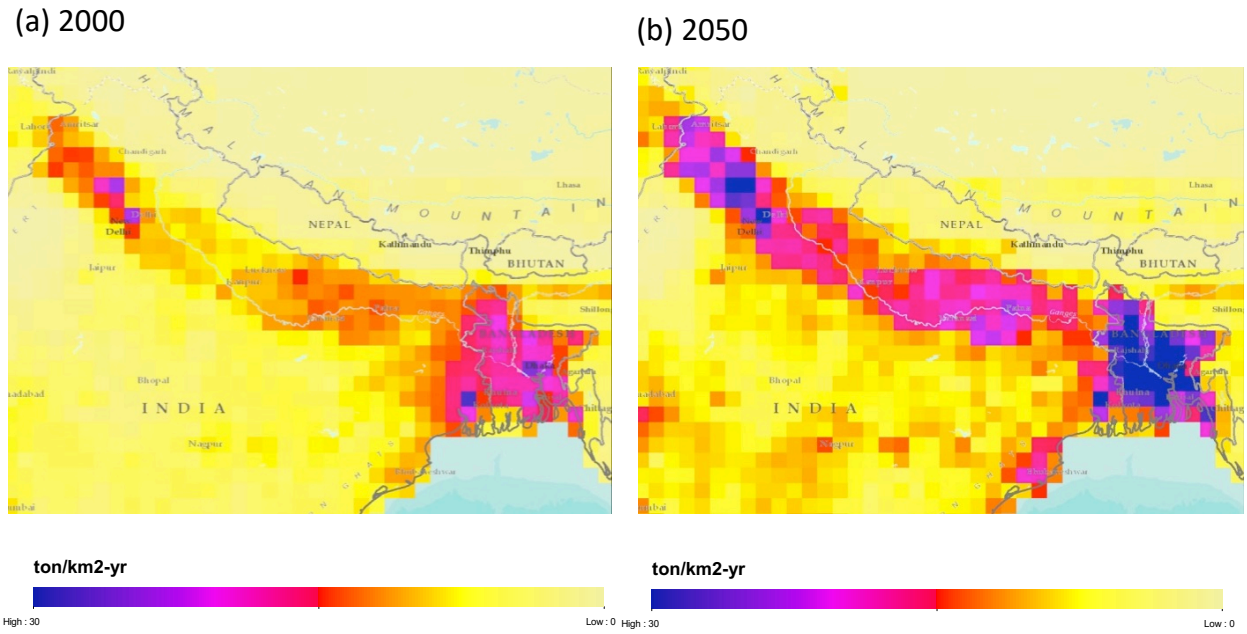

Figure 10-1: Nitrogen pollution loadings, estimated base period (2000-2009) and projected 2050

10.2.3 Climate Change

The South Asian monsoon is critically important for agricultural production in the Eastern Gangetic Plains region that includes the vast, fertile Indus and Ganges basins. With climate change, snow cover is expected to decline while summer monsoon months are predicted to become hotter and drier. Davtalab et al. (2015) using paleoprecipitation reconstruction find that the intensity, frequency, and spatial extent of severe droughts over the Indo-Gangetic Plains increased from 1300–1899 to 1900–2010. As a signal of climate change, increasing intensity and frequency of severe drought in the region requires both investments in adaptation strategies and drought preparedness measures to secure water, energy and food security goals in the region.

According to Ahmed and Suphachalasai (2014), climate change induced changes in rainfall patterns are expected to increase crop production losses in the short term and affect food security in the longer term. Climate change will also affect the energy sector in the region, increasing demand both for cooling and pumping of irrigation water, while on the supply side, hydropower production and water for thermal cooling might be reduced. Increased intensity of extreme events would affect water, food and energy sectors negatively as well, contributing to crop failures, damage to electricity grids and to water infrastructure.

Among the three countries, Bangladesh is particularly vulnerable to the adverse impacts of climate change because it is a low-lying, flat country subject to both riverine flooding and sea level rise, and because a large portion of its population is dependent on agriculture for its livelihood. Based on simulation modeling and household survey analysis, Thomas et al. (2013) suggests that adaptation efforts in Bangladesh should include adjusting planting dates, using improved cultivars better suited for climate change, improving fertilizer application, exploring increased maize production, and bolstering flood and pest protection for farmers.

10.2.4 Stagnating investment in agricultural R&D

Investment in agricultural research is generally a key driver for agricultural growth but investment in the region has been lacking. All countries in South Asia spend less than 1% of agricultural GDP on agricultural research and development (R&D), particularly when compared with countries in East and Southeast Asia. Among the three countries, the R&D intensity ratio is highest in Bangladesh, but ratios have been declining between 2000 and the latest year of data. Moreover, the share of research making it to farmers' fields is sub-optimal. Palanisami et al. (2015) find that only 12% of investment in agricultural water technologies were successful. The authors find only 22% of water technologies were successfully transferred to farmers and that returns to water technologies range average 11% at farm level; with an overall success rate of 12% suggesting there is a need to address gaps in technology transfer and in performance between research stations and farmers' fields.

10.2.5 A changing energy picture

Sources of energy growth have been changing dramatically globally and also in the Asia region. This is indicated by expected annual increases in production growth of wind, solar and other renewables in excess of 9% per year in the Asia region, a close to 8% annual growth in nuclear production and just above 6% in biofuels. However, despite these changes in structural growth of the energy sector, oil, natural gas and coal are expected to continue to make up close to 80% of all energy production in oil equivalents by 2035 (BP 2016 Energy Outlook). One indication of the changing energy landscape that directly affects water and food security is the push for solar power by the Government of India. Around half of all irrigation in India is from groundwater sources and Bangladesh and Nepal have also increased reliance on groundwater. As a result of cheap, individual pumping technologies and innovations on well drilling combined with heavy subsidies for groundwater pumping, chiefly through subsidized/ free electricity which makes irrigation staples, such as rice and wheat profitable, most of the western regions of India (both arid and semi arid), and pockets in AP and Karnataka have been classified as overexploited zones. According to Shah (personal communication), in India, currently 21 million wells use up 28% of India's grid power, contributing 6% of India's greenhouse gas emissions with an annual power subsidy of $12.5 billion, just shy of the annual fertilizer subsidy levels.

Parts of the Eastern Gangetic Plains lack infrastructure investments, including comprehensive electricity coverage and thus farmers in these areas did not benefit from the electricity subsidies. Moreover, groundwater tables in that region to date have not fallen dramatically. However, the Government of India has recently prioritized solar development. This development plan includes substantial subsidies for solar powered irrigation pumps. As a result, solar irrigation pump numbers in India have grown from less than 5,000 pumps in 1985-2012 to 45,000 in 2012-2015 and are expected to shortly reach the 100,000 pump mark. Solar pump subsidies range from 40-80% of the cost of the solar system and are available to farmers in areas without electricity access. The Government of India plans to increase total solar energy to 100 GW by 2022.

10.3 Methodology and Scenarios analyzed

The methodologies used include early steps of the Risks and Options Assessment for Decision-Making (ROAD) process (Grafton et al. 2016, see also Figures 10.2 and 10.3) during a workshop held in Delhi on September 7, 2016, followed by an analysis of some of the options with IFPRI's IMPACT model.

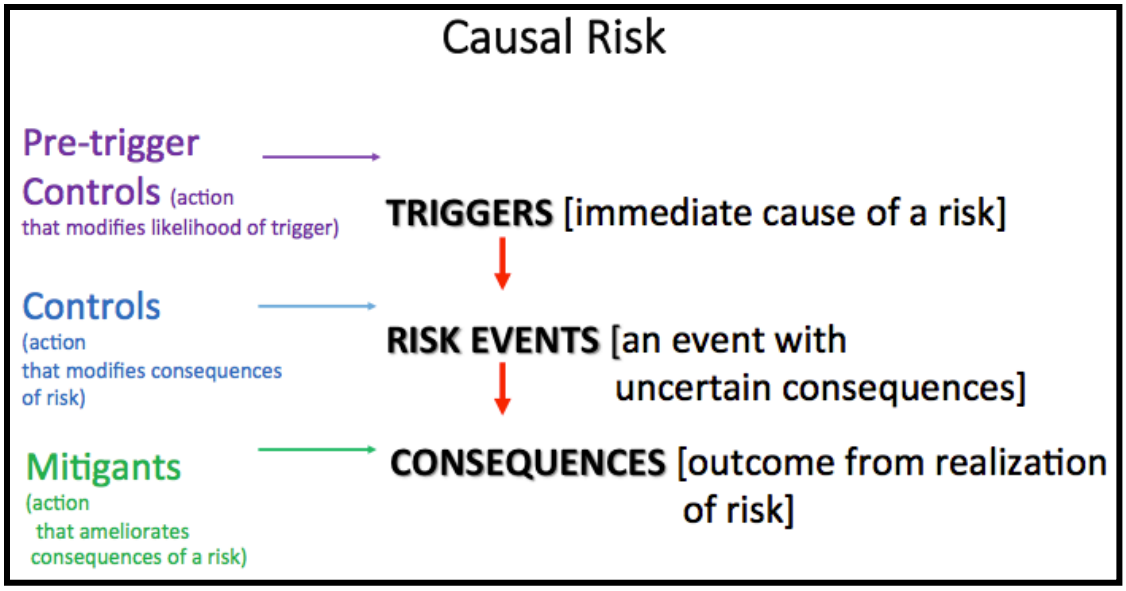

Figure 10-2: Definitions and connections for defining scope of causal risk

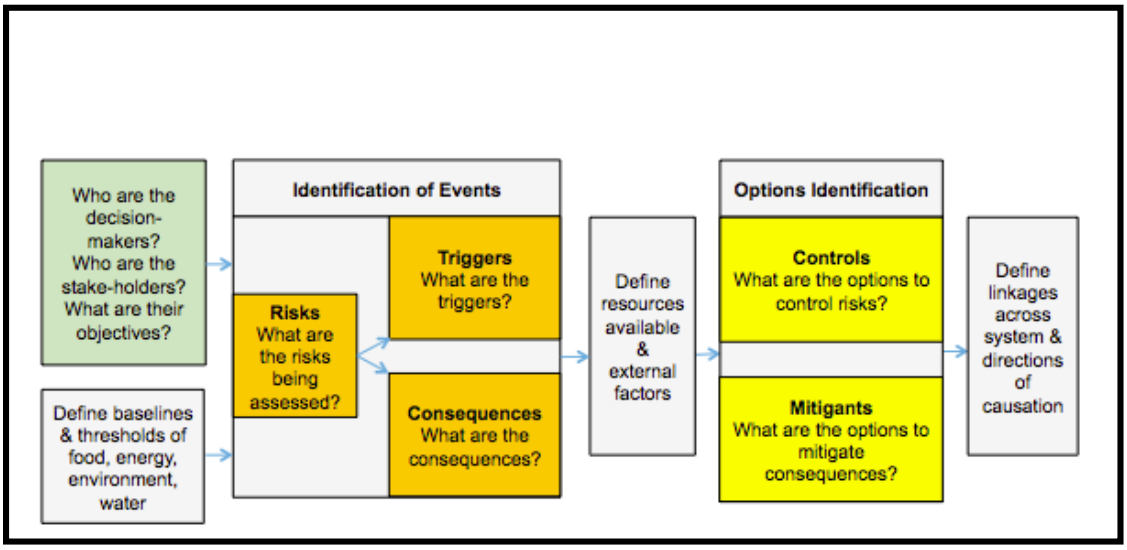

Figure 10-3: Schematic of causal risk scoping

The first step of ROAD defines the scope of decision-making for assessment. This includes identifying the boundaries within which decisions are made. The boundaries for this exercise related to the Eastern Gangetic Plains. Following this, the risks[8] experienced were identified along with the consequences of the risk defined and the triggers that cause the risks. Defining the risks, triggers and consequences allows mapping of possible options for action. Handling decisions or actions to on risks and their consequences can be done at different levels: either

[8] *Risk can be defined as a possible event (or a series of events) with uncertain or probabilistic consequences.*

before the risk is triggered (pre-trigger) or while controlling the risk when it occurs (Controls) or when dealing with the consequences of the risks (Mitigants). Pre-triggers are considered those actions that modify likelihood of a trigger occurring or the consequences of a risk. Controls are considered as those actions that modifies occurrence of risks. Finally, mitigants are considered as those actions that ameliorate the after-the-event consequences of a risk.

The sequences of steps in the ROAD framework decompose risk into causal risk pathways (Figure 3). Each pathway combines events with actions (controls and mitigants) and also the connections between management and outcomes. Its intent is to show what needs to be done, what the effects of action and inaction are, what can be managed and what not and to what end.

After the respective options were listed and agreed upon by each group, priorities associated with each option were to be estimated through an investment exercise. These results were an inspiration for the IMPACT modelling exercise. Specifically, the working groups identified climate change as the threat and resulting food insecurity as the risk (Figure 10.4), rapid population growth, limited innovation and climate change with an associated risk of overuse of groundwater resources and climate change and population growth with associated risk of water scarcity, respectively as key elements in the first step of the ROAD process.

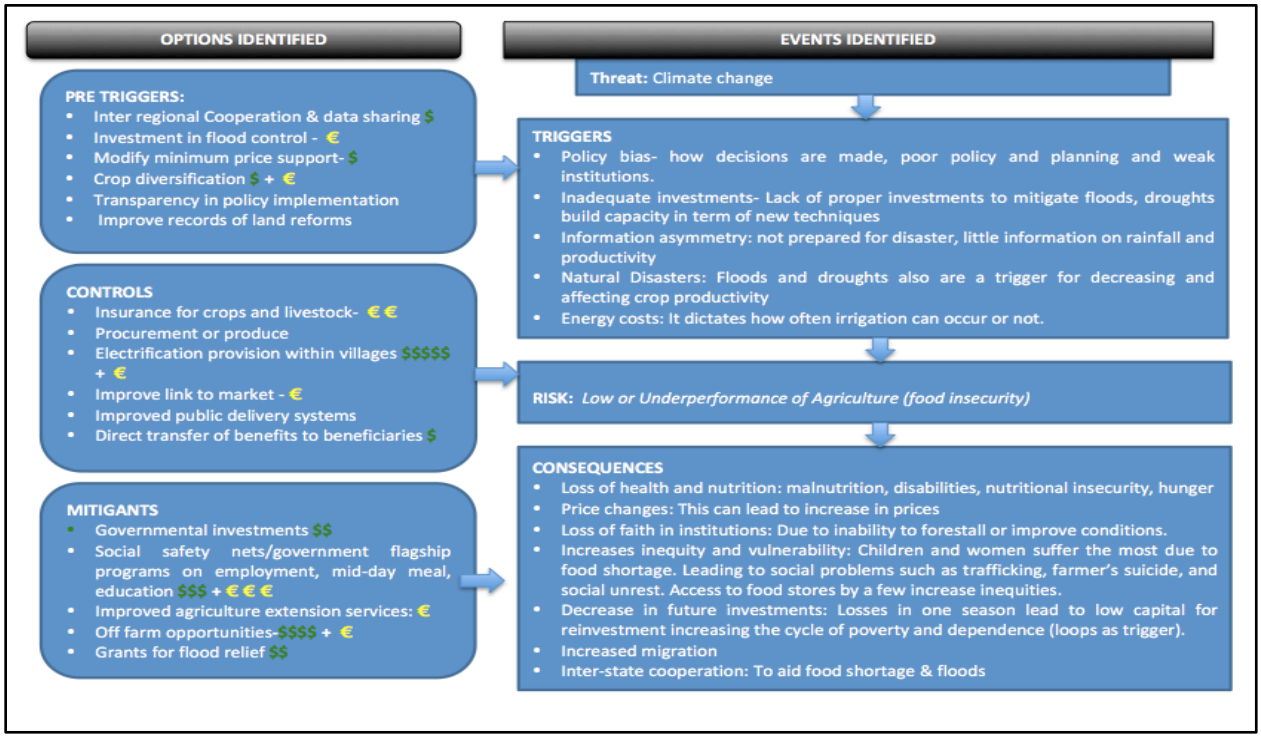

Figure 10-4: Causal risk analysis developed during the Delhi workshop identifying climate change as a major threat and food insecurity as a key risk

In addition to the baseline assessment of the impacts of climate change on water and food outcomes with IMPACTS, we examine the impacts of three alternative interventions that affect these triggers and consequences along the Food-Energy-Environment and Water Nexus with a focus on water-for-food interactions and were informed by step 1 of ROAD: 1) Increased investments in agricultural R&D, 2) Increased investments in irrigated area expansion, and 3)

Increased investments in irrigated area expansion combined with increased efficiency and storage. Scenarios are run with two climate change scenarios[9] (see also Table 10.1).

Table 10-1: Parameters for scenario analysis to 2050

Scenario/Parameters	Yield growth	Irrig Area	Irrig Eff	Storage
No climate change				
Climate change (HADGEM/IPSL)				
Climate change and High investment in agricultural R&D	+0.18%/yr (rice)			
Climate change and Medium investment in agricultural R&D	+0.09%/yr (rice)			
Climate change and investments in expansion of irrigation		40%		
Climate change and investments in expansion of irrigation, irrigation efficiency and water storage		40%	20%	20%

The scenarios are being analyzed with the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT). At the core of IMPACT is a global, partial equilibrium, multi-market, agriculture sector model. Global, climate-sensitive hydrology and water use models are linked to IMPACT as is the DSSAT crop modeling suite (Jones et al. 2003; Hoogenboom et al. 2015) to directly estimate yields of crops under varying management and climate change scenarios from global climate models (Figure 10.5). Food supply is determined for 320 sub-national or national geographic units (Food Production Units (FPUs)) delineated according to intersections of administrative units (chiefly countries) with major river basins. Irrigated and rainfed crop yield and area changes—or livestock numbers and yields—include exogenous sources, such as those from projected public and private sector investment trends as well as impacts from climate change, and endogenous sources, such as farmer responses to changing prices. The model simulates 62 agricultural commodities (crops, livestock, and several secondary agricultural products).

[9] Scenarios are run with the RCP 8.5 radiative forcing pathway leading to 8.5 W/m2 (approximately 1,370 ppm CO_2 equivalent) by 2100 (van Vuuren et al. 2006, van Vuuren et al. 2007). We simulate this climate scenario using two climate models: The Hadley Center's Global Environment Model, version 2 (HADGEM2-ES or **HGEM**; Jones et al. 2011), and the Institut Pierre Simon Laplace's Earth System Model (IPSL-CM5A-LR or **IPSL;** Dufresne et al. 2013). These two specific climate models were selected because they have been previously used in a variety of global modeling comparison studies (Robinson et al. 2014, Wiebe et al. 2015).

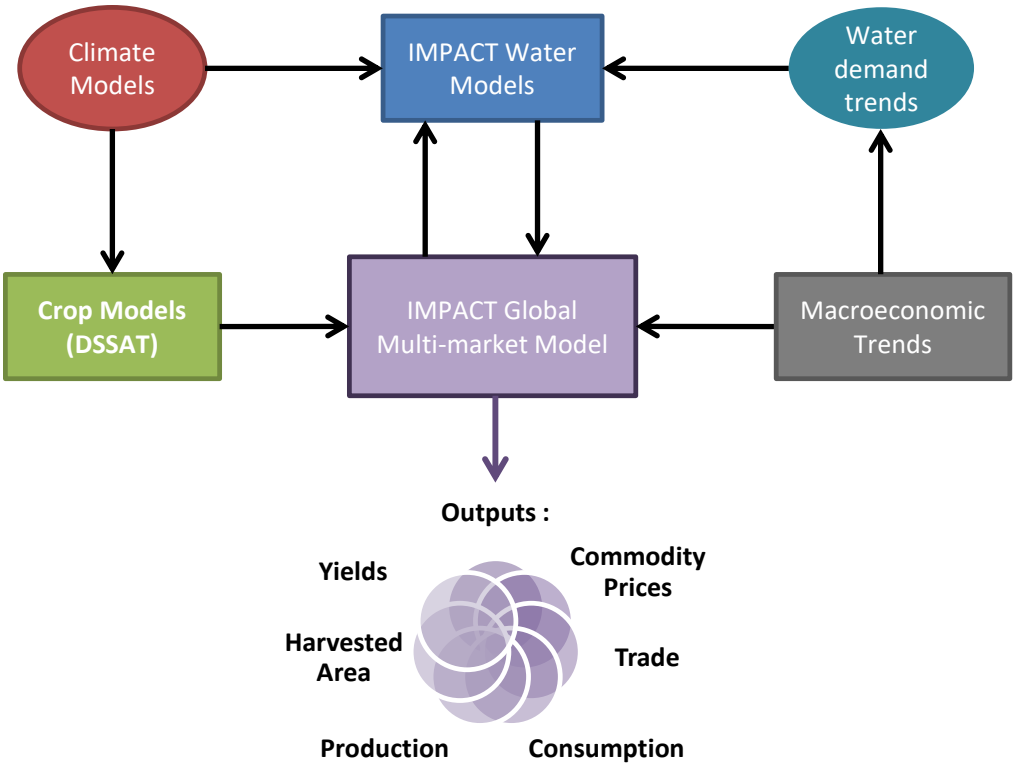

Figure 10-5: The Extended IMPACT Modeling Framework

Water availability is modeled at the grid level and aggregated to the FPU level, with water demand determined through crop/livestock life cycles, cropping patterns, and competition with non-agricultural sectors at FPU levels. Agricultural land use and land use change are modeled at the FPU level based on historical trends and expert opinion on responses to agricultural prices. Commodity markets are cleared annually out to 2050 while the agronomic and water models operate at a monthly time step incorporating standardized crop calendars. Food demands are simulated for 159 countries and regions based on changes in income, population, and prices (Robinson et al. 2015). Key output indicators include calorie availability, malnutrition measures, share at risk of hunger, water consumption, yield growth and total agricultural production and changes in area over time. Of note, the IMPACT model runs at the national level, while the ROAD process was applied to the EGP area only.

10.4 RESULTS

A key indicator for food security are changes in food prices. Lower food prices increase availability of food for poorer populations (Figure 10.6). Compared to a no-climate change scenario, global prices of cereals are 31% and 21% higher under the HGEM and IPSL climate change scenarios, respectively. Under a significant but feasible strengthening of investment in agricultural R&D in the three Eastern Gangetic Plains countries of Bangladesh, India and Nepal (CC_HiR&D), global cereal prices would be 6% and 5% lower under the HGEM and IPSL climate change scenarios, respectively. Under a scenario of expansion of irrigated harvested areas by 40% over the 2015-2050 period (CC_IRRIG) in these three countries, global cereal prices would be 5% lower under both climate change scenarios. Unsurprisingly, as a result of significant water scarcity, irrigated area expansion in the three South Asian countries is limited

and expansion of area without concomitant investments in water use efficiency and or storage would accelerate groundwater depletion and degradation levels and would generate limited impact. The last scenario analyzed therefore combines expansion of irrigation harvested area with improved water use efficiency and expansion of storage (CC_IRRIG_EFF_STR). Under this scenario, global cereal prices are projected to decline by 6% under both climate change scenarios. Of interest here are price impacts for different cereals.

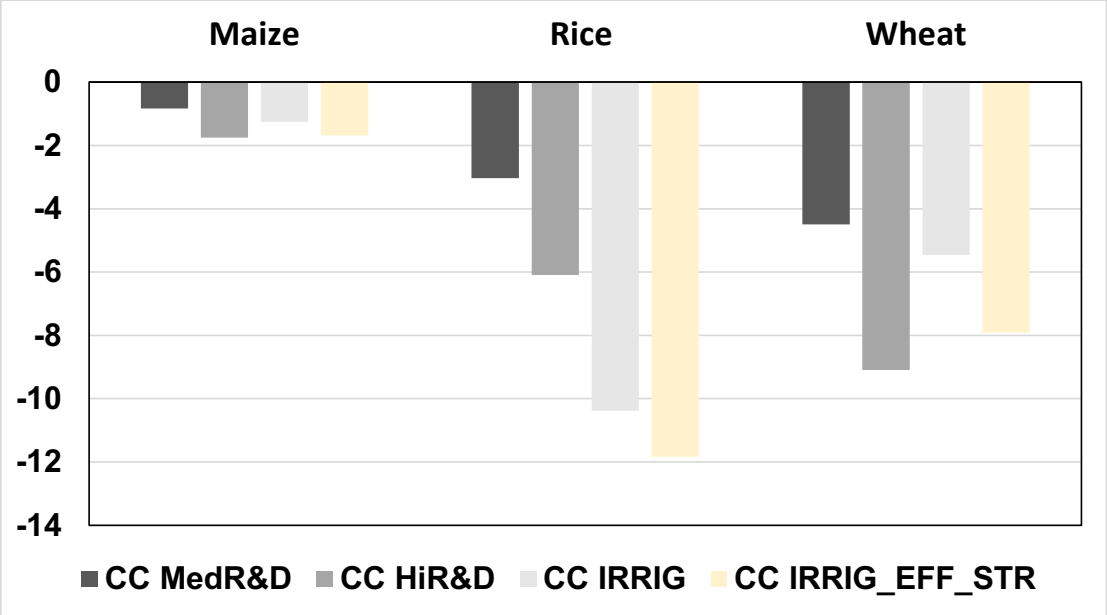

Figure 10-6: Changes in selected cereal prices 2050 (%) compared to 2050 HADGEM baseline values

Source: IFPRI IMPACT simulations for this study.

As Figure 10.6 shows, with a relative small contribution of the three countries' maize production to global maize markets, increased investment in R&D in maize and expansion of irrigated harvested area in maize is going to make a limited contribution to changes in maize prices. The relative contributions are much larger for wheat and even more so for rice. Moreover, the relative impacts of alternative investments vary by crop. For wheat, improved investment in agricultural R&D in the three countries leads to the largest yield improvements and associated declines in international food prices. For rice on the other hand, the scenario of expanded irrigated harvested area combined with investment in water use efficiency and storage yields to the largest international price impact, which is significant at a 12% reduction over the HGEM climate change scenario.

Similar results are developed for pulses, which are particularly important for nutrition security in the South Asia region. Here, projected improvements in agricultural R&D in the three Eastern Gangetic Plain countries result in the largest price declines (6%) compared to 3% under the irrigation expansion and medium R&D investment scenarios, given the relatively limited role of irrigation for this crop.

What would be the impacts of alternative improvements in crop yields, irrigation and water use efficiency and storage on net food trade in the region? Figure 10.7 describes changes in the net trading position for rice and wheat, two key staples crops in the region, under the alternative scenarios. Climate change would overall slightly increase net exports of wheat and increase net

imports of rice under the HADGEM scenario in response to adverse impacts from climate change being relatively stronger or weaker for these two crops in the rest of the world. Compared to the climate change baseline scenario (CC_HADGEM) for 2050, all alternative scenarios analyzed would reduce the rice net import position of the region and increase net export position for wheat of the group of countries with the largest changes under the irrigation investment with storage and water use efficiency scenario. Under this scenario, net wheat exports would increase by 51 million metric tons while net rice imports would decline by 32 million metric tons, a dramatic change compared to baseline values beyond levels achieved in the no-climate change scenario as adaptive investments are only implemented in the three South Asian countries. The second largest improvement in net wheat trade is achieved under the higher agricultural R&D improvements, while the second largest improvement in the net rice trading position is achieved in the irrigation expansion scenario as irrigation is a much more decisive and limiting factor for rice than for wheat in the region. Between 2010 and 2050, the population at risk of hunger is expected to drastically decline in the three countries of the Eastern Gangetic Plains: from 218 million people to 54 million people under a scenario without climate change. With climate change, the 2050 population at risk of hunger is estimated to be slightly higher, at 55 million people in the three countries. Similarly, in the group of developing countries the number of people at risk of hunger is projected to decline from 823 million people in 2010 to 399 million people by 2050. Under the HGEM scenario, climate change is projected to increase the number of people at risk of hunger in the developing world by 18% and by 1.6% in the three South Asian countries; changes under IPSL are 12% and 1.5%, respectively. Under the four alternative scenarios, the number of people at risk of hunger would decline most, by 19 million people under the expansion of irrigation harvested area with improved water use efficiency and expansion of storage (CC_IRRIG_EFF_STR) scenario because the resulting reduction in rice prices is of particular importance for poor people, followed by a decline of 17 million people under the CC_HiR&D scenario. The decline would be lowest under the moderate R&D improvement scenario, at 9 million people and most of the improvement would occur in Africa south of the Sahara in response to changes in global food prices.

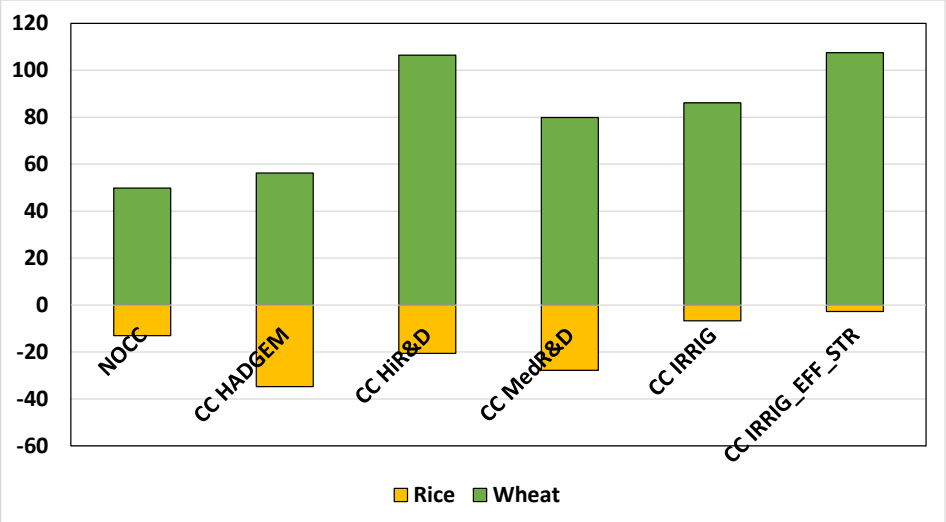

Figure 10-7: Changes in net trade position for rice and wheat (Bangladesh, India, Nepal) (mmt), (HADGEM)

Source: IFPRI IMPACT simulations for this study.

From a nexus perspective, it is important to assess the implications of these alternative development pathways not only for food security but also for water and energy security. Here, we only model implications for water security directly and assess implications for the energy sector qualitatively. Figure 10.8 presents the share of withdrawals across all sectors that are not met due to lack of water availability, investment or access[10] Under the no climate change scenario, the share of unmet water demands is already very high in India, at 20%; compared to much lower shares of unmet water demands in Bangladesh (3%) and Nepal (1%). Under the CC_HGEM scenario, shares of unmet water demand increase in India (24%) and Nepal (4%) but decline in Bangladesh (to 1%) due to heterogeneous changes in rainfall-runoff patterns and autonomous adjustments in agricultural production patterns under climate change. Unsurprisingly, the CC_IRRIG scenario leads to the largest increase in unmet water demands across all scenarios and all three countries. Rapid increases in irrigation water demand without concomitant improvement in use efficiency or water storage would increase the share of unmet irrigation water requirements significantly. In response, the share of unmet water demands increases to 29% in India, 15% in Nepal and 12% in Bangladesh, indicating a worsening of the overall water security. On the other hand, the strong investments in water use efficiency and storage proposed under the CC_IRRIG_EFF_STR scenario leads to the most improved water security situation in the three countries with the share of unmet demand declining to 16% in India, 2% in Nepal and close to nil in Bangladesh.

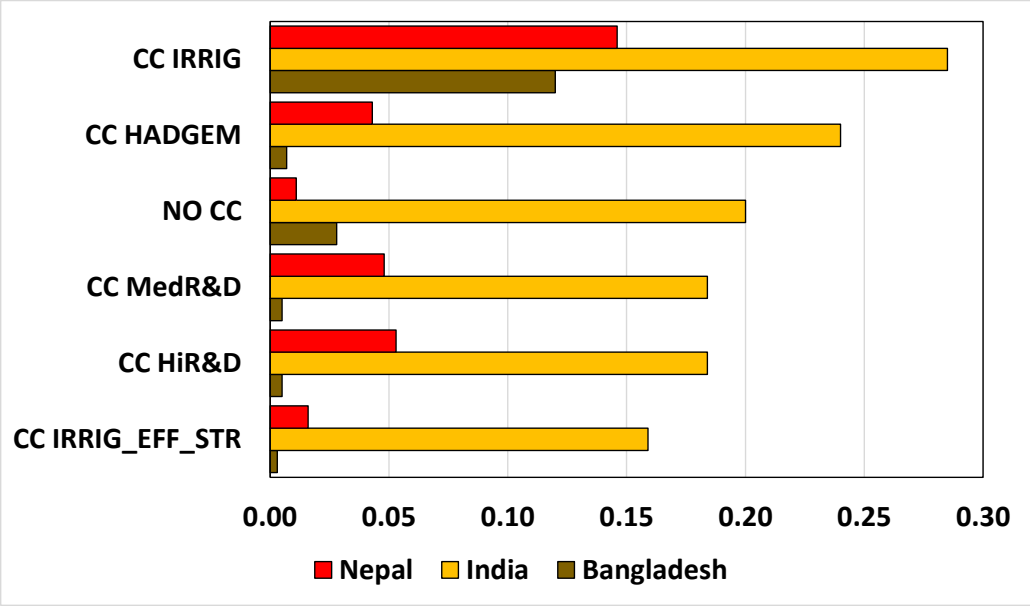

Figure 10-8: Share of unmet water demands, Bangladesh, India and Nepal, under alternative scenarios

Source: IFPRI IMPACT simulations for this study.

What would be the implications for energy security? Across the four scenarios, higher yield increases might or not be associated with increased fertilizer use, depending on the specific

[10] *This indicator is defined as 1 minus the ratio of total water supply to total water demand across the agriculture, livestock, industrial, and domestic sectors.*

technologies employed to achieve yield improvements. Overall cereal production increases in India are largest under the CC_HiR&D scenario and in Bangladesh under the CC_IRRIG_EFF_STR. If adequate care is not taken, fertilizer use levels and thus water pollution levels will most likely increase under the scenarios with significantly higher agricultural production levels. Both fertilizer use and water treatment require energy for production. Similarly, the scenarios suggesting expansion in irrigation likely require increased use of energy for pumping of irrigation water. Much of this additional energy will likely be sourced from solar energy, at least in India, as a result of the government's plan to dramatically increase installed capacity. However, rapid increase in solar energy will likely lead to groundwater depletion in the Eastern Gangetic Plains as it is more challenging to reign in groundwater pumping from solar than electricity supported pumping. However, if additional energy is provided by fossil fuels then greenhouse gas emissions would increase (similar to increased fertilizer use) further fueling climate change. None of the countries in the region currently plans to substantially expand biofuel production to fuel economic growth. Expanded biofuel production might well increase the number of food-insecure people.

10.5 CONCLUSIONS

The Eastern Gangetic Plains region and South Asia overall is experiencing rapid growth in population, economic wealth and urbanization. These developments, in turn, increase demand for water, food and energy and for the increased availability and security of these resources. The three countries in the Eastern Gangetic Plains are already severely water-stressed, face rapid groundwater depletion in parts of the region (chiefly outside the Eastern Gangetic Plains) and are also plagued by severe climate variability and change and growing water pollution challenges from urbanization and agriculture that are not yet being addressed.

As the scenario analysis has shown, depending on the crop in question, additional investments in irrigation and water use efficiency or direct investment in agricultural technologies (i.e. breeding) are more beneficial for key food security parameters, such as food prices and net trade position. Irrigation intensive and dependent crops, like rice, would benefit from increased investments in water technologies and expansion while wheat and maize would benefit from further breeding efforts.

Importantly, investments in agricultural R&D for rice and wheat in the region can have large global impacts for the number of people at risk of hunger due to the large share of the region in global production. Similarly, lack of investment in these key staple crops, as evidenced by very low and declining investments in national agricultural R&D contribute to food insecurity in the region and globally.

Joint water-energy-food planning in the region can reduce adverse impacts from growing adverse impacts from climate change, rapid population growth and growing natural resource scarcity. In particular, there is a need in the region to save water resources decoupled from energy resources. This can be achieved through increased investments in agricultural R&D with a focus on breeding efforts that conserve water and energy. Examples of such efforts in agriculture would include breeding with a focus on water and energy savings, for example, through drought and heat tolerance. Another breeding effort with decoupling impact is nitrogen efficiency which can reduce costly fertilizer subsidies and energy expenditures to treat polluted water. Many other mechanisms exist to address water pollution, ranging from better management of green (wetlands, lakes) and grey infrastructure, maintenance of buffer strips and agricultural management practices that reduce runoff of pollutants and erosion. How could some of these investments be supported? An entry point would be shifting annual unproductive

government investments of approximately US$27 billion for agricultural electricity and fertilizer to more productive investments in agricultural R&D.

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11 Foresight workshop and dialogue – Kathmandu, Nepal, March 2017

The Australian National University UNESCO Chair, in co-operation with the Australian Centre for International Agricultural Research (ACIAR), the International Maize and Wheat Improvement Centre (CIMMYT), the International Food Policy Research Institute (IFPRI) and the South Asia Consortium for Interdisciplinary Water Resource Studies (SaciWATERs) collectively organised a one-day Foresight Workshop and Dialogue in Kathmandu, Nepal on Friday 17 March 2017 on Sustainability and Resilience in the Eastern Gangetic Plains (Bangladesh, India and Nepal).

Some 30 researchers, academicians and civil society members from the three Eastern Gangetic Plain countries and Australia gathered to discuss developments in the water, energy and food sectors over recent decades, key findings, challenges, and opportunities. The workshop focused on gender challenges, regional coordination, and policies need to develop a roadmap for sustainable water, energy and food security.

11.1 Overview of the workshop and Highlights from Presentations

11.1.1 Background and Informational Presentations

The workshop started with an introductory remark by Professor Grafton, the lead of the Small Research Activity (SRA) supported by ACIAR on “Improving policies and institutions for sustainable intensification of agriculture and resilient food systems in the Eastern Indo-Gangetic Plains.” Professor Grafton noted that this was the second event, after a similar workshop in Delhi in September, 2016, to discern insights on challenges and opportunities to advance food, water and energy security objectives in the Eastern Gangetic Plains (EGP).

Professor Grafton described the overall objectives of the SRA and the workshop, and specifically the overall aim of scoping for a platform with decision makers so as to develop long-term improvements in decision making with integration across food, energy and water, and in terms of agricultural and complementary investments in Bangladesh, India and Nepal. Such a platform can help to better assess critical policies and productive investments considering the linkages across the food, energy and water sectors in the EGP and the institutional and decision-making context and identify ways to overcome barriers to adoption of appropriate CASI innovations and practices.

His opening remarks was followed by presentations from several senior researchers and policymakers from the region, including RC Srivastava, Rajendra Prasad, Madhab Karki and Raj Paroda. They all noted the importance of systems thinking across the water, energy and food sectors to strengthen the opportunities and address the unique challenges of water abundance and scarcity, poverty and constrained agricultural development in the Eastern Gangetic Plains region. The experts noted that such efforts were particularly important in light of the current pursuance of Sustainable Development Goals (SDGs). They also stressed that the research agenda needed to move from a commodity focus toward a farming system model and that additional investment infrastructure was urgently needed.

Julie Delforce from the Australian Department of Foreign Affairs and Trade provided an overview of the second phase of Sustainable Development Investment Portfolio (SDIP) II. SDIP is an Australian Government initiative coordinated by the Department of Foreign Affairs and Trade (DFAT). The SDIP II (2016-2020) is the second part of an intended 12 year engagement to 2024. It focuses on the three major transboundary Himalayan river basins- the Indus, Ganges, and Brahmaputra covering parts of Bangladesh, Bhutan, India, Nepal, and Pakistan. At a high level strategic level, the SDIP Goal is “Increased water, food and energy security in South Asia to support climate resilient livelihoods and economic growth, benefiting the poor and vulnerable, particularly women and girls” and further to “Improve the integrated management of water, energy and food in the major Himalayan river basins – especially addressing climate change and the interests of women and girls.” [SDIP II Program Framework (15/8/2016)]

Ms. Delforce outlined the three major components of the vision for SDIP II: One, Strengthened practices for regional cooperation (operating at a regional (basin), national or sub-national level in the region). Two, critical new knowledge generated and used for regional cooperation: within the priorities acknowledged by regional forums, governments and national bodies and addressing said knowledge gaps through science and/ or well evidenced and reflective practice; Three, improved and enabling regional environment, including for private sector engagement: within the policies, regulations, market systems and investment conditions for cross border management of shared water, food and energy resources.

SDIP II has seven delivery partners: the Australian Centre for International Agricultural Research (ACIAR), the Commonwealth Scientific and Industrial Research Organisation

(CSIRO), the International Centre of Excellence in Water Resources Management (ICE WaRM), International Centre for Integrated Mountain Development (ICIMOD), International Finance Corporation (IFC), World Bank, South Asia Water Initiative (SAWI), and The Asia Foundation (TAF). These organisations work collaboratively to deliver a 'portfolio' of outcomes to progress SDIP II objectives and, where appropriate, streamline efforts and collaborate to influence long-term systemic change.

Dr Ejaz Qureshi followed Ms. Delforce with an overview of ACIAR's activities in the region. There are 12 projects in total focused on national needs as expressed by the countries themselves and where tangible impacts can be delivered. Dr John Dixon, also from ACIAR, then described the origins of the SRFSI (Sustainable and Resilient Farming Systems Intensification) in the Eastern Gangetic Plains (EGP) project, under which this SRA activity, and consequently this workshop, are linked.

The EGP is a priority for the governments of the region - Bangladesh, India, and Nepal. SRFSI began in May 2014 with financial and technical support from ACIAR and is led by the International Maize and Wheat Improvement Center (CIMMYT). SRFSI has made progress in its core approach: improving productivity; supporting farmers and local institutions through trainings on value chain and market development; entrepreneurial skills development; and seed system, among other activities (see also Section 1.4 on the presentation by CIMMYT).

11.1.2 Regional Presentations

Three regional presentations were provided by country experts and included:

1. Bangladesh: Sustainable Agriculture, Issues and Concerns in the EGP of Bangladesh, Dr Sharmind Neelormi, Jahangirnagar University
2. India: Challenges to Sustainable Intensification of Agriculture in Bihar and West Bengal, Dr Avinash Kishore, IFPRI, New Delhi
3. Nepal: Agricultural System and Practices in Nepal's Terai: Characteristics and Issues, Dr Ashutosh Shukla, Institute of Social and Environmental Transition-Nepal (ISET-N)

The presentations are available on request.

The key conclusions from these presentations are summarised in section II.

11.1.3 Institutional Mapping and Gender Challenges in the EGP

A third set of presentations focused on institutional mapping and on gender challenges in the EGP.

Safa Fanaian, SaciWATERs, presented "Mapping Institutions and mechanisms in Eastern Gangetic plains-- Integrating food, water and environment systems."

The presentation noted that in Bangladesh programs and policies are top down and primarily donor driven. In India, policies and programs are implemented by state departments. Nepal is currently transitioning toward a decentralised government structure, and many programs are still supported by donors. Important questions from the institutional mapping include: 1) Can successful cases of resilient food cropping systems be up-scaled? 2) What are the existing 'bottlenecks' among institutions for implementation of improved and sustainable practices? and 3) How capable are the existing institutions to provide an enabling environment for adoption and scaling?

Dr Fraser Sugden, IWMI, presented Gender Challenges for Agriculture in the Eastern Gangetic Plains. He noted new challenges for agriculture in the EGP due to persisting inequalities in the

distribution of land and resources as well as constraints to sustainable intensification grounded in gender, class and caste. As a result, appropriate farming-based solutions must directly challenge embedded social structures and include: providing marginalized groups with access to land and ensuring effective engagement with women and youth, especially in the context of demographic change.

11.1.4 Presentation on High-Priority SRFSI innovation platform and CASI

Dr. Mahesh Gathala from CIMMYT provided an overview of SRFSI. He stated that the overall aim of the project is to reduce poverty in the EGP by improving the productivity, profitability and sustainability of smallholder agriculture. SRFSI research seeks to answer two questions: 1) Can farm management practices based on the principles of conservation agriculture (CA) and the efficient use of water resources provide a foundation for increasing smallholder crop productivity and resilience?, and 2) Can institutional innovations that strengthen adaptive capacity and link farmers to markets and support services for both women and men farmers accelerate sustainable change processes?

SRFSI is being implemented in specific districts across Eastern India, the Nepalese Terai and western Bangladesh. It has four key objectives: 1) Understand farmer circumstances with respect to cropping systems, natural and economic resources base, livelihood strategies, and capacity to bear risk and undertake technological innovation; 2) Develop, with farmers, more productive and sustainable technologies that are resilient and profitable for smallholders; 3) Catalyse, support and evaluate institutional and policy changes that establish an enabling environment for the adoption of high-impact technologies; and 4) Facilitate widespread adoption of sustainable, resilient and more profitable farming systems. The overall adoption of Conservation Agriculture and Sustainable Intensification (CASI) technologies, as a result of the project, could reach at least 1.5 million farmers in the EGP by 2020/21, including at least 35% women farmers.

11.2 Key Themes and Findings

11.2.1 Part 1: Resource Management

The Eastern Gangetic Plains countries: Bangladesh, India, and Nepal, have abundant resources, both natural and human, but are facing rapid changes including from climatic effects. Depleting natural resource availability, groundwater depletion, coastal erosion, and floods are some of the problems in these regions. Along with the adversities of climate change, and increasing water stress, population growth and urbanisation is contributing to resource stress, including reductions in water quality.

Water management cannot be isolated from food and energy management. The nexus between the Food, Energy, and Water (FEW) need to be considered as part of resource management in the EGP. Food security and energy management along with water challenges in terms availability and quality have significantly affected the small holder farmers while the excessive use of fertilisers, in some locations,has led to land degradation in the EGP.

Recommendations:

- *Improve knowledge and capacity of smallholders at local level in sustainable use of resources*
- *Enhance Indigenous and Traditional knowledge to support resilient institutional use of resources*
- *Introduce environment friendly and efficient technologies such as mobile hand pumps, and solar energy for irrigation.*
- *Integrate water resource management within the EGP as part of regional co-operation.*

11.2.2 Part 2: Regional Coordination

The challenges in the EGP collectively affect three countries (Bangladesh, India and Nepal). Thus, a collective effort to mitigate the challenges is crucial. Policy support is not evolving as rapidly as needed. Improved EGP policies would strengthen the institutions at the local level in management of the resources. While policies exist to support CASI, many small holder farmers and the community remain unaware of them. When responding to these implementation gaps, a strong regional policy focus is critically important for community level interventions.

Co-ordination among donors needs to be strengthened as they are a major catalyst of change. Donors have the reach to influence policy makers as well as in the community level organisations. A national level commitment will lead to a regional commitment and, eventually, resulting in collective policy implementation.

Recommendations:

- *Scale up successful innovative practices and share*
- *Increase investment in research and ensure adequate data quality and access*
- *Improved extension of latest agriculture technology*

11.2.3 Part 3: Gender Issues in EGP

The agrarian economy of the EGP region has witnessed a shift from male labour dominated agriculture towards more women centered agricultural practices. With increasing urban migration of men, women are at the forefront of agriculture; changing prospects for sustainable intensification of agricultural practice. As a result, insecure tenancy and a lack of access to capital which are particularly acute challenges for women have emerged as major impediments to sustainable intensification. Additionally, irrigation technology and equipment are inadequate

given the physical strength required, which limits women's usage. Information about state services; such as about free tube well installation does not effectively reach rural women.

Recommendations:

- *Collective management of land/pool labor and capital offers opportunities*
- *Shared investments and management of equipment for increased net returns*
- *Capacity building of women*
- *Harness skills and entrepreneurship of returnee migrants*

11.2.4 Part 4: Financing

Many people in the EGP region live below the poverty line while credit constraints remain a major barrier to adopting improved technologies and practices, such as CASI. Limited capital sources for further investment in agriculture have fostered the continuation of traditional agricultural practices within the region. With support from government and international projects, farmers are being made aware of new and technologies and market opportunities, but direct outside farming investment remains inadequate.

Recommendations:

- *Support collective farming initiatives*
- *Support small and micro enterprise*
- *Strengthen farmers network and promote transfer of technology*

11.3 Afternoon Dialogues: Vision, FEW knowledge and evidence

11.3.1 3.1 Vision and Theory of Change Guiding the Foresight Dialogue

The informational presentations with key findings on trends in the region in the morning were followed with two sets of dialogues and breakout sessions in the afternoon. These findings are presented in section III of this report.

The dialogues were prefaced by a brief presentation from Professor Grafton and a previously agreed to vision for enhanced Food-Energy-Water systems in the EGP. Key to the effective implementation of this visions is a 'Theory of Change' that identifies the necessary elements to move from vision to action.

The proposed vision that was presented at the workshop is: Improved **Food-Energy-Water** Knowledge Systems to support sustainable development and inclusive growth with a particular focus on women and girls in the Eastern Gangetic Plains.

The achievement of the vision includes the following key elements of SDIP II, ACIAR's investment strategy under SDIP II, and the demands and needs of the three EGP countries as follows:

1. Resilience to climate and non-climatic drivers of change
2. A focus on long-term environmental sustainability (including groundwater, water quality, land degradation)
3. Build on knowledge and learnings from CASI /phase 1 relating to accelerated adoption of CASI
4. Value chains, markets and rural infrastructure investments
5. Identify appropriate technologies, institutions, governance and policies
6. Strengthen capacity to support policy implementation and assess impacts using appropriate metrics
7. Understand status and short- and long-term trends and recognize associated water, energy and food and nutrition security risks of business as usual
8. Influence trajectories towards sustainable agricultural transformation and regional growth
9. Strengthen women's empowerment and benefits
10. Coordinated strategies and action across local, meso, national and regional scales driven by common theories of change
11. Strengthen cross-sectoral coordination (FEW)
12. Recognition of geographic differentiation across the EGP and the need to target and prioritize actions at scale

The Theory of Change draws on J. Woodhill (Understanding Theory of Change 1/6/2014). According to Woodhill, central to using a theory of change approach is recognising that different actors (stakeholders) often have different perspectives on what would be a desirable change and different ideas about how this change could be brought about.

Developing a 'Theory of Change' can help transform visions and strategies into practice by considering five key elements (see Figure 11.1):

1. The **actors** (individuals or groups) who are trying to bring about change.
2. The **context** or situation that influences the actors and which they are trying to change
3. The **ideas** or theories on which the actors draw when 'looking at' a situation and deciding how best to act
4. The **reflection and decision making processes** that enable actors to develop strategy, review success and failure and make improvements to both their ideas and their strategy
5. The **strategy** which gives the reasons and provides a framework for taking particular action

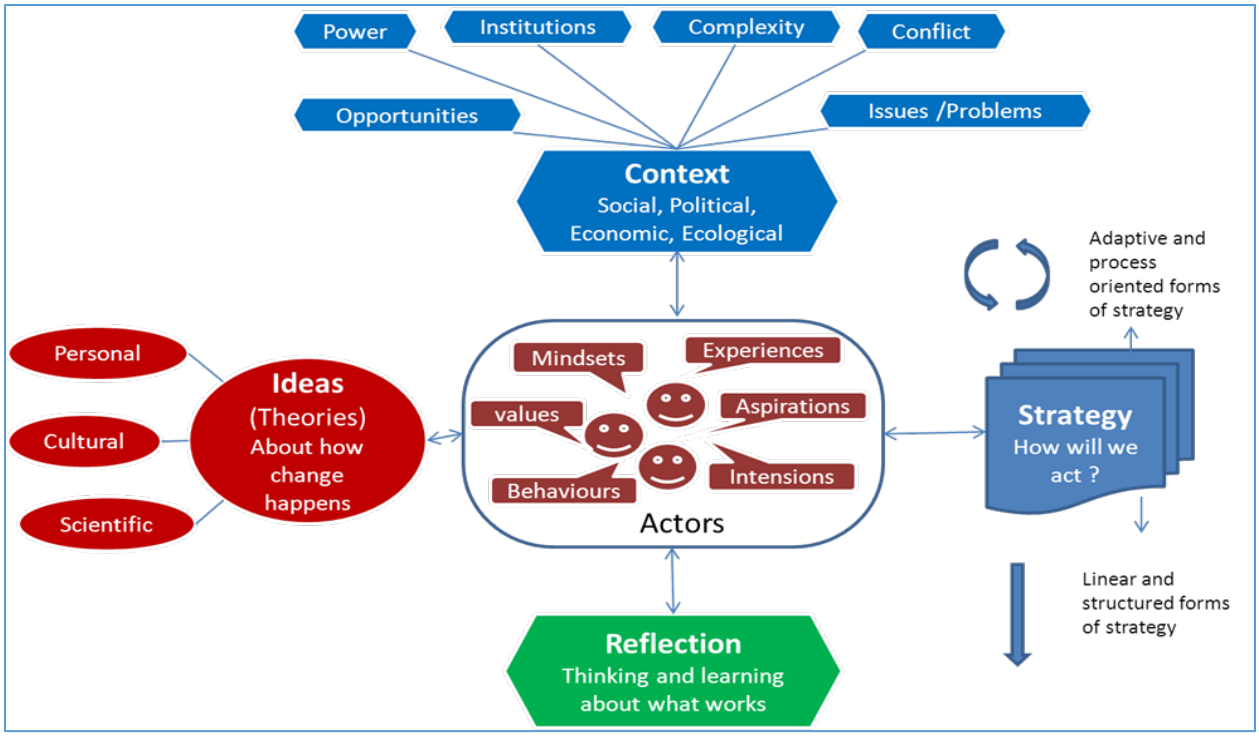

Figure 11-1: Understanding Theory of Change

Source: Woodhill (2014)

11.3.2 FEW knowledge and evidence needed

The first set of dialogues focused on FEW knowledge and evidence needed in terms of: (1) agricultural diversification; (2) agricultural service economy; and (3) sustainable energy and water management in EGP by EGP country. The results are summarized by each country below form the perspectives of: (1) Barriers; (2) Drivers and (3) Research and Policy Focus.

Bangladesh

Barriers	Drivers	Research and Policy Focus
Land fragmentation Increased cost of agricultural equipment Labor shortage Water deficits due to cross-boundary water allocation	Increased livestock production and inclusion in diet with increasing income Enhance nutritional intake Promote suitable variety of seeds Economic incentive for small holder farmers	Agroindustry: Contractual farming Private sector investment in dairy and food processing Infrastructural development to increase access to market Minimal or zero import tax in small machines Promotion of solar energy Research on gender and water access Regional cooperation Tapping energy (further discussion required with Nepal)

India:

Barriers	Drivers	Research and Policy Focus
Market impediments Misdirected or poorly implemented policies Technical capacities of farmers and small service providers	Price stability: both farmers and corporations benefit Redesign subsidies to incentivize adoption, innovation and market development Women's groups to improve their access to inputs, credit technology and markets Custom hiring center models to increase adoption of CASI Encouraging local entrepreneurship in service provision and local processing	Local mapping of food security, nutrition security and resource availability Better crop planning and leveraging technology to get real time data on crop area What are the market arrangements (institutions) in place and how are they affected by various public policies? What policies to make markets work better for the smallholders and more private investments?

Nepal:

Barriers	Drivers	Research and Policy Focus
Lack of technical capacity (farmers) Absence of local government Poor policy implementation Land entitlements (missing landlords, land in the name of men) Poor technological innovation	Migration has differential benefits Lack of capacity at all levels (power-friendly), local government missing or in transition Increasing change in women land holding due to tax relief (more rapid implementation in urban areas); to speed up, possibly rebate on land registration, not clear if gendered land title reduces inequality Poor legal framework Need more women in institutions	Diversified FEW systems in Eastern Terai over 20 years Systems thinking around agricultural production systems Relationship between women, FEW systems in the Eastern Terai Evidence on value chains and planning, linkages with market and continuity in supply Usable technology for women (crop production, processing, energy, postharvest and capacities) Entrepreneurship skills, taking cooperatives to the next level of functioning Women and land ownership Market information systems for information trends Managerial capacity and skill sets for managing competing markets, risk evaluation Food, agriculture, energy, human (gendered) system synthesis—evolution over 20 years

Key barriers identified in both Bangladesh and Nepal relate to land tenure and land size that affect the 'take up' of technological innovations, and quantity and quality of labor in agriculture. Bangladesh also identified water constraints as a key barrier, arising partly from the disproportionate national water allocations for transboundary rivers.

In terms of research and policy focus for Bangladesh, participants identified a range of areas affecting the enabling environment of agriculture, which, in turn, would support agricultural intensification, mechanization and help maintain the natural resource base. They include support to agro-industries, support to rural infrastructure development, promotion of rural energy access through solar energy, more supportive tax policies and enhanced regional cooperation.

Participants from India would like to see a research and policy focus on mapping of resource availability and food and nutrition security, and better understanding of what is and should be grown when and where. Indian participants also would like to see a research focus on enabling conditions for smallholder market access and private sector investment.

Participants from Nepal highlighted that would like to see a research focus on 1) systems' thinking around agricultural production systems; 2) Insights on technologies that can be used by women and men, as well as a 3) Food, agriculture, energy, human (gendered) system synthesis.

11.4 Afternoon Dialogues: Action Plans: Innovation Platforms and Opportunities

A second set of dialogues focused on opportunities and the steps and sequencing to deliver policy important knowledge based on the topic identified in the first set of dialogues, specifically: lack of technological advancement with a focus on solar pumps, commercialisation and value chains, and issues related to the 'feminization' of agriculture given the increasingly more important role of women in farming systems. These findings are highlighted and presented for each country separately.

Bangladesh:

	Research Focus		
Themes	Solar Pumps	Commercialization of value chain	Feminization of agriculture
Sequencing			
Existing evidence	Quantitative and qualitative reports Key messages for implementation Multi-media Relationship building	Limited evidence	WEAI-IFPRI WLE Elementary BARC, BIDS ANU reports
Where is the evidence	WLE Report BMDA reports IDCOL (2007) Policy implementation Gender socio-economic impact on households	Reports: IFAD, UNIDO, FAO, USAID CIMMYT	Reports Gender Budget Policy SRFSI data
Gaps	Economic analysis of adoption of solar pumps by smallholders Policies/incentives for solar irrigation	How to integrate the farmers into local value chain? What are the drivers of commercialization (infrastructure)? Connection between commercialization and macro level food security policy Impact on poverty among women Role of cooperatives in technology adoption	Missing data on Nutrition What are the benefits for women and children with increased agricultural productivity? Nutrition and health Impact of female education on nutrition and health Data on empowerment and resilience: define what is empowerment?
Target decision makers			
How to communicate?			
Scale			

India

	Research Focus	
Themes	Water pump sets: efficiency; solar pumps; electric pumps	Food Value-Chain, Commercialization
Sequencing	Documentation of the efficiency levels; discharge rates; current system; Identify entry points; action research	Livestock value-chains; horticulture value chains; fisheries; mapping existing value chains; market intelligence using technology
Existing evidence	Technology works; but no documentation of business case	Poor market intelligence; crop area and production for high-value crops; MFE and dairy
Where is the evidence	Little on the business models; is there a business case for scaling up solar pumps technology	Data are scant; limited formal evidence
Gaps	Efficiency of water pumps, size and high cost of irrigation Economic analysis of scaling for solar pumps; institutional arrangements are needed; models out there for solar powered group tube wells; community managed solar irrigation systems; subsidy system and its work; other financial arrangements to fund capex; the trans-boundary lessons to be learned from other EGP countries.	Viability of rural based local primary processing, and additional returns to farmers, and availability of resources to scale it out; type of handholding is needed; role of aggregation models/financial institutions. Analysis of market emergence: strengthening and making it efficient. Policy usage in seeds market. Role of financial institutions (credit and insurance to address risk). Developing evidence based theory of change on how to evolve efficient value-chains
Target decision makers	State and central governments; solar aggregators; NABARD (financial institutions), MNRE;	Private corporations; farmer groups; state government officials, KVKs, financial institutions
How to communicate?	Share field examples; action research findings; use of success stories Share success stories around use of water to increase crop yields and cropping intensity	
Scale	Macro-scale study on existing schemes; farmer level studies on pump sizing and efficiency; community level/enterprise level studies on business models of group pumps	Emphasize diversification of agriculture into high value crops and allied activities

Nepal

	Research Focus		
Themes	Solar pumps and Gender	FWE system synthesis and gender relationships (food focus)	Food value chains, commercialization, take of innovation
Sequencing	Do CBA, go to private sectors, go to banks for credit, simultaneously government raises awareness, go to innovative farmers, at the local level, private sector should provide training, maintenance and repair services, provide evidence to implementers; solar technology testing center, alternative energy promotion center (AEPC)	Bring evidence to 7 food-deficient districts in the Terai; 7 out of 19 districts are food deficient	
Existing evidence	Studies on solar pumps in India; business model for service provision CBA on solar pumps, sunflower pumps (replacement for treadle pumps)	Study on vulnerability in the IGB; ISET study, cross scale; ethnographic study of food systems in the Terai of Nepal; Studies on gender, CC and migration Trans boundary water—political economy focused Koshi basin study; existing studies on livestock, tree, horticulture, trees—farming system research	
Where is the evidence	INGOs (for eg: ICIMOD, IWMI, ACIAR,) NGOs, Government, Independent researchers	INGOs, NGOs, Government, Independent researches; Articles from Oxford/Erickson/Ingram, Olivia / CCAFS; IWMI.	Single commodity focused value chain work, work on women's' groups – dynamics,
Gaps	CBA compared to electric pumps, distributional impacts; risk of groundwater depletion and degradation; BGS – IGB-arsenic, depletion, pollution; cost fluctuations, forward and backward linkages, market	Insufficient FEW foci (most often water or food, but not energy); a lot of work is old, need updates;	

	service chain-support service; technology imperatives of solar water pump in the spectrum of agriculture pumping compared with other pumping		
Target decision makers	Extension agents, district officers. Government organizations. NGOs and INGOs: CIPRED, SWAPROS, NARC, CIMMYT Media Chamber of Commerce, World Bank PACT		
How to communicate?			
Scale			

11.5 Summary

The Foresight Workshop and Dialogue in Kathmandu, Nepal on Friday 17 March 2017 on Sustainability and Resilience in the Eastern Gangetic Plains (Bangladesh, India and Nepal) provided a rich set of insights on the many challenges and opportunities for sustainably increasing agriculture and food security in the EGP region of South Asia.

The afternoon dialogues focused on elements of the proposed vision on Improved Food-Energy-Water Knowledge Systems to support sustainable development and inclusive growth, with a particular focus on women and girls in the Eastern Gangetic Plains. The first set of dialogues focused on FEW knowledge and evidence needed in terms of: (1) agricultural diversification; (2) agricultural service economy; and (3) sustainable energy and water management in the EGP. Key barriers to advances in these three areas relate to land tenure and land size, lack of technological innovations, and challenges regarding the quantity and quality of labor in agriculture. Bangladesh also identified water constraints as a key barrier. To address these challenges, participants identified a range of policy areas focused on the enabling environment of agriculture as well as on a better understanding of the natural resource base around energy, water and food and how these relate to agricultural production systems.

A second set of dialogues focused on opportunities and the steps and sequencing to deliver policy important knowledge based on the topic identified in the first set of dialogues, specifically: lack of technological advancement with a focus on solar pumps, commercialization and value chains, and issues related to feminization of agriculture, again by country in the EGP.

Research gaps identified around solar pumps are similar across the three EGP countries and include: 1) lack of economic analysis of adoption of solar pumps by smallholders and 2) Policies/incentives for solar irrigation; 3) cost-benefit analysis of solar pumps; and 4) institutional and financial arrangements for such pumps as well as learning across boundaries on lessons from solar pump use, and 5) what is the risk of arsenic and pollution? Research gaps identified for commercialization and value chains include 1) how can smallholders be integrated into local value chains; 2) what are drivers of commercialization, 3) what are impacts of commercialization of agriculture on women and men and 4) what is the role of cooperatives for uptake of associated technologies?, 5) what is the role of market emergence and financial institutions? For the topic of feminization of agriculture, key identified research gaps include 1) what are impacts on nutrition and health? and 2) and the role of education and technologies

These priorities will be taken forward by the ACIAR project team with the intent to develop a larger proposal around FEW knowledge systems for sustainable development and inclusive growth in the EGP.

11.6 Acronyms

ACIAR: Australian Centre for International Agricultural Research

ANU: The Australian National University

BIDS: Bangladesh Institute of Development Studies

BARC: Bangladesh Agricultural Research Council

CASI: Conservation Agriculture for Sustainable Intensification

CBA: Cost Benefit Analysis

CIMMYT: International Maize and Wheat Improvement Center

CSIRO: The Commonwealth Scientific and Industrial Research Organization

DFAT: Australian Department of Foreign Affairs and Trade

FEW: Food, Energy and Water

ICIMOD: International Centre for Integrated Mountain Development

IFAD: International Fund for Agricultural Development

IFC: International Finance Corporation

IFPRI: International Food Policy Research Institute

INGOs: International Non-Governmental Organization

MUS: Multiple Water Use System

NGOs: Non- Governmental Organization

SAARC: South Asian Association for Regional Cooperation

SAWI: South Asia Water Initiative

SDIP II: Sustainable Development Investment Portfolio II

SRFSI: Sustainable and Resilient Farming Systems Intensification

UNIDO: United Nations Industrial Development Organization

USAID: United States Agency for International Development

WaRM: Water Resource Management

WEAI: Women’s Empowerment in Agriculture Index

WLE: Water, Land and Ecosystems

11.7 Appendices

11.7.1 Appendix 11.1: Workshop Agenda

FORESIGHT WORKSHOP 17th March 2017, Hotel Yak & Yeti, Durbar Marg, Kathmandu **8:30-9:00** TEA AND COFFEE

9:00 - 9:30 Introductions (Grafton)

RC Srivastava (Vice Chancellor, Dr. Rajendra Prasad Central Agricultural University)

Madhab Karki (Executive Director, Centre for Green Economy Development, Nepal)

Raj Paroda (Executive Secretary, APAARI)

- 9:00-9:05 Welcome and overview of workshop and objectives (Grafton)

- 9:05-9:30 Introductions from participants

- 9:30-9:40 Overview of SDIP II (Julie Delforce) and SRFSI (Dixon and Qureshi)

9:40-9:55 Presentation of Highlights of Bangladesh Study (Neelormi)

9:55-10:10 Presentation of Highlights of India Study (Kishore)

10:10-10:25 Presentation of Highlights of Nepal Study (Shukla)

10:25-10:45 Dialogue on Country Presentations

10:45- 11:00 MORNING TEA

11:00-11:20 Presentation on Highlights off Institutional Mapping (Fanaian)

11:20-11:30 Discussion on Institutional Mapping

11:30-11:50 Presentation on Gender Challenges in Eastern Gangetic Plains (Sugden)

11:50-12:00 Discussion on Gender Challenges in Eastern Gangetic Plains

12:00-12:45 Presentation on High Priority SRFSI innovation platform and CASI (Gathala)

12:45-1:15 Facilitated Discussion on Barriers to Adoption and Transformational Opportunities (Williams)

1:15-2:00 LUNCH

2:00-2:30 Overview of Afternoon Dialogue including vision, context, purpose, participation required, and outcomes. (Fanaian, Grafton, Kishore, Ringler and Williams)

2:30-3:30 Breakout Groups (Bangladesh, India and Nepal) on FEW knowledge and evidence needed in terms of: (1) agricultural diversification; (2) agricultural service economy; and (3) sustainable energy and water management in EGP (facilitated by Fanaian, Grafton, Kishore, Ratna, Ringler and Williams)

3:30-3:45 Plenary findings and dialogue on knowledge and evidence needed (Fanaian, Grafton and Kishore)

3:45-4:00 AFTERNOON TEA

4:00-4:30 Breakout Groups (Bangladesh, India and Nepal) on opportunities and the steps and sequencing to deliver policy important knowledge in terms of: (1) agricultural diversification; (2) agricultural service economy; and (3) sustainable energy and water management in EGP. (facilitated by Fanaian, Grafton, Kishore, Ratna, Ringler and Williams)

4:30-6:00 Plenary findings and dialogue on next steps and actions (Fanaian, Grafton, and Kishore)

11.7.2 Appendix 11.2: Biographies and Presenters and Facilitators

John Dixon

Principal Adviser – Research and Program Manager cropping Systems and Economics, ACIAR

Email: John.dixon@aciar.gov.au

John is Principal Adviser, Research, and Program Manager, Cropping Systems and Economics, at the Australian Centre for International Agricultural Research (ACIAR), Canberra, Australia with particular interests in farming systems, systems agronomy, conservation-agricultural based sustainability, innovation systems and agricultural policy. He has worked on South Asian questions for more than 30 years, notably with FAO and CIMMYT.

Quentin Grafton, FASSA

Professor of Economics, Crawford School of Public Policy, The Australian National University

Email: Quentin.grafton@anu.edu.au

Quentin is a Fellow of the Academy of Social Sciences in Australia, UNESCO Chair in Water Economics and Transboundary Governance and President (2017-18) of the Australasian Agricultural and Resource Economics Society. He is the Project Leader on the Small Research and Development Activity, funded by the Australian Centre for International Agricultural Research, on Improving policies and institutions for sustainable intensification of agriculture and resilient food systems in the Eastern Indo-Gangetic Plains

Madhab Karki, CGED Nepal

Madhab Karki is a Natural Resources Management and Climate Change Adaptation Specialist. He is the Executive Director of the Centre for Green Economy Development, Nepal (CGED-Nepal) and the Advisor (Natural Resources Management and Climate Change) of the Integrated Development Society, Nepal (IDS-Nepal). He is also the South Asia Chair of the IUCN Commission on Ecosystem Management (CEM). He holds Ph.D. and Masters' degrees in Forestry and Natural Resources Management from the US. He was the Deputy Director General (DDG) – Programs of the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu.

Avinash Kishore, IFPRI

Research Fellow, International Food Policy Research Institute (IFPRI)

Email: a.kishore@cgiar.org

Avinash is a Research Fellow at IFPRI. He is interested in agriculture, environment, and development economics. His research focuses on understanding the adoption of sustainable agricultural technologies and practices in Asia and the role of public policies in promoting sustainable agriculture. Avinash studied at IRMA and worked for four years with International Water Management Institute (IWMI). He has a PhD in Public Policy from Harvard University Masters in Public Affairs from Princeton University.

Sharmind Neelormi, Jahangirnagar University, Bangladesh

Email: neelormi1@yahoo.com

Apart from teaching, Neelormi has been intensely involved in research and advocacy. Her research interest entails climate change, food security, gender in relation to development discourse of a developing economy. She regularly represents Bangladesh in climate change negotiation led by UNFCCC and contributes in the IPCC process. Also takes keen interest to influence policy makers on issues related to her research interest.

Raj Paroda

Scientist, research administrator and development practitioner

Email:

Raj Paroda, who served as director general of the Indian Council of Agricultural Research (ICAR) and as secretary of India's Department of Agricultural Research and Education, is an accomplished scientist, research administrator and development practitioner. Dr. Paroda is known for modernizing and strengthening the national agricultural research system in India and other countries. The government of India recognized his contributions to the advancement of agriculture by awarding him the Padma Bhushan Award. Dr. Paroda was founding chairman of the Global Forum on Agricultural Research, and was president of the Indian Science Congress Association and India's National Academy of Agricultural Sciences.

Ejaz Qureshi

Research Program Manager, Agricultural Development Policy, ACIAR

Email: Ejaz.Qureshi@aciar.gov.au

Ejaz is Program Manager of the Agricultural Development Policy program of ACIAR, Canberra, Australia and currently has 10 projects in about a dozen countries in the Indo-Pacific region. A key component of the policy program is understanding how policies can influence adoption and further the outcomes of technical research.

Nazmun N. Ratna

Senior Lecturer in Economics, Faculty of Agribusiness and Commerce, Lincoln University

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Nazmun is a development economist specializing on food security, institutions, diversity and gender. After trained as an economist at Dhaka University, she obtained her Masters in Economics of Development and Ph.D. degrees from the ANU. She gained comprehensive experience in providing policy guidelines in poverty alleviation, infrastructure development, and women empowerment, through working with various national and international development partners in Bangladesh.

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Claudia's research focuses on water resources management and agricultural and natural resource policies for developing countries. Over the last 12 years she has also undertaken research on the impacts of climate change on developing country agriculture and on appropriate adaptation and mitigation options. She has more than 100 publications in these areas.

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Dr. RC Srivastava is an agricultural engineer. He obtained Master's and Ph.D degrees in Soil & Water Conservation Engineering from Indian Institute of Technology, Kharagpur. During his service career of about 39 years in the Indian Council of Agricultural Research (ICAR), he held several prestigious positions and won many prestigious awards. He is widely published and he has vast experience in establishing linkages with Public and Private, National and International Institutions for effective implementation and conduct of the ongoing programmes. His views on various aspects can be viewed at http://concernedindianviews.blogspot.in

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Ashutosh Shukla had his academic training in land and water resources engineering. Prior to joining ISET-Nepal, he was professor at Institute of Agriculture and Animal Science and Institute of Engineering under Tribhuvan University in Nepal. His research-knowledge-outreach involvement relates to land and water issues involving interdisciplinary perspectives. At ISET-Nepal he leads training and capacity building division.

Fraser Sugden

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Fraser is a development geographer by training, specializing in the political economy of agriculture, water management and resilience. He is the country representative for IWMI Nepal, and the Gender, Youth and Inclusion theme leader for the CGIAR program on Water, Land and Ecosystems. His research interests are in rural class and gender relations and their role in mediating access to water and other land resources – particularly in the context of out-migration and climate stress. He has worked extensively in the eastern Gangetic plains for a decade, with a focus on the Tarai-Madhesh of Nepal, Bihar, and West Bengal, although has also has extensive fieldwork and research experience from the Eastern Himalayas, as well as China, Vietnam and Bangladesh. He is presently leading participatory action research with farmers in North India and Nepal on farmer collectives. Fraser is also the convener of IWMI's emerging research programme on migration and agrarian change.

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John is a Fellow of the Australian Academy of Technological Sciences and Engineering, a founding member of the Wentworth Group of Concerned Scientists, and holds the prestigious Farrer Memorial Medal for achievement and excellence in agricultural science. He is one of Australia's most respected and trusted scientists, with extensive experience in providing national and international thought-leadership in natural-resource management, particularly in agricultural production and its environmental footprint.

11.7.3 Appendix 11.3: Workshop Participants

Name	Affiliation
Quentin Grafton	The Australian National University
Claudia Ringler	International Food Policy Research Institute (IFPRI)
Safa Fanaian	SaciWATERs
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Ejaz Qureshi	Australian Centre for International Agricultural Research (ACIAR)
John Dixon	Australian Centre for International Agricultural Research (ACIAR)
Kuhu Chatterjee	Australian Centre for International Agricultural Research (ACIAR)
Jim Woodhill	
Julie Delforce	Department of Foreign Affairs and Trade
Andrew McDonald	Consultative Group for International Agricultural Research (CGIAR)
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Byjesh Kattarkandi	SaciWATERs
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Fraser Sugden	International Water Management Institute (IMWI) - Nepal

Pranita Udas	International Centre for Integrated Mountain Development (ICIMOD)
Raj Paroda	Chairman, Trust for Advancement of Agricultural Sciences (TAAS), India
Suvarna Chandrappagari	
Hari K Upadhyaya	Executive Chairperson, CEAPRED, Nepal
Tapan Chowdhury	
Prachanda Pradhan	Farmers Managed Irrigation System Promotion Trust (FMIST), Nepal
KM Singh	
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12 Conclusions and recommendations

12.1 Conclusions

The key findings of the SRA indicate that the major impediments to increasing agricultural output and farmer prosperity in the EGP are not simply the lack of access to new technologies, but rather the lack of an enabling environment from a policy, institutional and financial perspective, and mechanisms that facilitate the scaling out of innovative technologies. Importantly, donors can support such an enabling environment and be catalyst of change.

While differences in the nature of these impediments vary between countries, there is a clear need for stronger extension services in all three countries. Access to extension services also has to be complemented by policies that aim to promote agricultural output, albeit by better access to water and access to appropriate machinery. Further, extension services need to promulgate more information about problems of over fertilisation, and practices that support the sustainable use of natural resources.

The small size of land holdings in all three countries indicates that policies that facilitate increasing the size of individually farmed areas, possibly through co-operative farming and machinery sharing, need to be considered.

Additional investments in irrigation and other agricultural technologies, such as plant breeding, appear to offer valuable opportunities in terms of growing rural livelihoods and support for food security. Irrigation intensive and dependent crops, like rice, would benefit from increased investments in improved water practices and technologies while wheat and maize production would benefit from further plant breeding and extension efforts. Lack of investment in these key staple crops, as evidenced by very low and declining investments in national agricultural R&D, contribute to food insecurity in the region.

In terms of the SRSFI project, the SRA findings suggest that estimated yield increases via the implementation of CASI technologies require a much more detailed economic analysis to substantiate the potential economic benefits to farmers. Similarly, more attention is required to ensure that where greater use of groundwater is proposed, there is a clear understanding of risks associated with arsenic and fluoride, and related solutes, that might arise in terms of contamination of the food chain, people and the environment. The SRA workshop dialogues (New Delhi and Kathmandu) also highlight the priority of a more proactive approach to understanding the dynamics and impediments to more gender inclusive agricultural systems and gender mainstreaming within existing institutional structures.

12.2 Recommendations

Here, we highlight future research and policy priorities for ACIAR and DFAT based on dialogues around the food-energy-water nexus undertaken by the SRA project team. These priorities include a better understanding of the impediments to:

1. Agricultural diversification;
2. Agricultural service economy, especially in terms of mechanisation; and
3. Sustainable energy and water management in agriculture within the EGP.

Key barriers to advances in these three critical areas relate to land tenure and land size, lack of technological innovations, a lack of gender mainstreaming, and challenges regarding the quantity and quality of labour in agriculture.

To address these challenges, a series of policy actions should support an ‘enabling environment’ for agriculture coupled with a much better understanding of the natural

resource base around energy, water and food, and how these relate to agricultural production systems. In particular, a much better understanding, at a local level, is required about the effects of increased water use on water availability and water quality before practices are recommended that result in greater water extractions.

A series of expert and stakeholder dialogues focused on specific opportunities within the three broad themes listed below within the EGP is highly recommended. Possible priority topics include:

1. **Economic costs and benefits of solar pumps.**

Key questions and research gaps identified by stakeholders engaged with the SRA team around solar pumps include: 1) lack of economic analysis of adoption of solar pumps by smallholders and 2) Policies/incentives for solar irrigation; 3) cost-benefit analysis of solar pumps; and 4) institutional and financial arrangements for such pumps as well as learning across boundaries on lessons from solar pump use, and 5) what is the risk of arsenic and fluoride contamination and pollution?

2. **Effects of the mechanisation of agriculture on vulnerable agricultural households.**

Key questions and research gaps identified for mechanisation of agriculture include: 1) how can smallholders be integrated into local value chains; 2) what are drivers of mechanisation, 3) what are the differential effects of mechanisation of agriculture on women and men, 4) what is the role of co-operatives for uptake of associated technologies?, and 5) what is the role of market emergence and financial institutions?

3. **Migration and the feminisation of agriculture.**

Key questions and research gaps identified for the feminization of agriculture include: 1) what are impacts on nutrition and health, especially women and children? and 2) what gender-centred education and technologies are needed in support of vulnerable households?

CASI provides a science/technology base for increasing productivity and profitability, as well as the need for improved economic analysis of its benefits. Nevertheless, we strongly advocate that it will only reach its greatest potential if the underpinning social, political, environmental and policy frameworks are delivered in the region.