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ADAPTATION EFFECTIVENESS INDICATORS FOR AGRICULTURE IN THE GANGETIC BASIN

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Adaptation Effectiveness Indicators for Agriculture in the Gangetic basin
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ABBREVIATIONS

ADS	Agricultural development strategies
BADC	Bangladesh Agricultural Development Corporation
BCAS	Bangladesh Centre for Advanced Studies
BINA	Bangladesh Institute of Nuclear Agriculture
FGD	Focus group discussion
GaIn	Global Adaptation Index
ICIMOD	International Centre for Integrated Mountain Development
IGES	Institute for Global Environmental Strategies
LaIn	Local Adaptation Index
LAPA	Local Adaptation Plan of Action
NAPA	National Adaptation Programs of Action
NARC	Nepal Agricultural Research Council
NGO	Non-governmental organization
PDSI	Palmer Drought Severity Index
PRA	Participatory Rural Appraisal
SC-PDSI	Self-calibrating Palmer Drought Severity Index
SPI	Standardized Precipitation Index
TERI	The Energy and Resources Institute
UPBSN	Uttar Pradesh Bhumi Sudhaar Nigam
UPLDC	Uttar Pradesh Land Development Corporation
VDC	Village Development Committee

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EXECUTIVE SUMMARY

Measuring the effectiveness of adaptation to climate change has assumed significance for the reasons that huge amount of resources are being made available for climate change adaptation and it is important for various stakeholders to direct these resources for achieving adaptation efficiently and avoiding maladaptation. Identifying adaptation effectiveness indicators is the first step to measuring the effectiveness of adaptation actions at the local level. Keeping this in view, the project entitled ‘Identification of win-win adaptation options through adaptation metrics and integrated adaptation decision making frameworks’ was implemented in the Gangetic basin with the collaboration of national level partners Bangladesh Centre for Advanced Studies (BCAS) in Bangladesh, The Energy and Resources Institute (TERI) in India and International Centre for Integrated Mountain Development (ICIMOD) in Nepal. The study was funded by the *Suishinhi* (S8) of the Ministry of Environment through Ibaraki University, Japan.

The study was conducted in the drought-prone areas of Bangladesh, India and Nepal in the Gangetic basin. The approach consisted of identifying local indicators and integrating them into the analytical framework of the Global Adaptation Index (GaIn). The index developed with local indicators has been termed as Local Adaptation Index (LaIn). A broad set of indicators were identified from the literature reviews and regional consultations. These indicators were further put through national and community level consultations for identifying the final set of indicators that can be integrated into the LaIn computation.

The objective of this interim report is to provide results of the community questionnaire surveys conducted in the three study sites for obtaining feedback from wider audience that could be incorporated into the subsequent phases of the study. The report provides detailed methodology envisaged by the study, provides the background of study locations, characterizes drought in terms of intensity and duration using drought indices and discusses the results of community surveys conducted for prioritizing adaptation effectiveness indicators.

The study on identifying adaptation effectiveness indicators in the Gangetic Basin has revealed that the effectiveness indicators could significantly vary with the location and to certain extent depending on who is choosing them and the adaptation practices in question. Hence, incorporating these human and location specific considerations into any adaptation decision making framework is crucial for better connecting the measurement outcome with those benefiting from these adaptation actions. Indicators identified in this report are only a first step in a direction towards developing a robust and organic process of monitoring and evaluating adaptation interventions that evolves with our understanding on climate change and adaptation.

Project Team

Weather records from the weather stations nearest to the survey locations were obtained and the historical drought was characterized by using Standardized Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI). The results have shown clear decadal alternative wetting and drying cycles that is typical in this part of the world (teleconnections of Indian monsoon system with the El Nino and La Nina episodes in the Pacific Ocean). Considering the PDSI, the site in India can be considered relatively more drought prone followed by Nepal and Bangladesh and this observation correlates with that of the long-term average annual rainfall in these sites. The most number of severe droughts were observed in India followed by Nepal and Bangladesh. In general, 3-month SPI values tend to identify more drought events than 12-month SPI values which indicate the presence of more of short-lived droughts than the long-term droughts in the study locations. The 12-month SPI values have resolved more number of extreme drought events than the 3-month SPI values. 12-month SPI values indicated more extreme droughts in Bangladesh followed by India and Nepal.

In Bangladesh, the surveys were conducted in the drought prone area of Chapai Nawabganj district. The repeated droughts in the district have manifested in the form of loss in crop production, increase in pest attack, and perennial water crisis. One of the prominent responses in the region is to drill deep tube wells to supplement the rainfall deficit for crop and household purposes. However, this single intervention has failed to provide an effective remedy to the problem. The field surveys have indicated that options such as adoption of drought tolerant and short duration crop varieties followed by relay cropping are the need of the hour. Subsidies to farmers and establishing farmer field schools were seen as important policy options for adapting to climate change in this region. To evaluate the effectiveness of these options, the respondents have identified several effectiveness indicators which have shown limited statistically significant association with the demographic background of the respondents. Four out of five indicators have shown significant association with the practice group showing the tendency that respondents practicing particular practice or who thinks certain practice is important have tendency to rank certain indicators as important as against other indicators.

In India, the study was carried out in the drought-prone areas of Kanpur Dehat District of Uttar Pradesh. The prominent adaptation option in vogue in the area is construction of water harvesting structures such as check dams and contour bunds. The surveys have revealed that there is a need to introduce improved irrigation systems, improved soil management practices and improved drought forecasting to go hand in hand with the water harvesting being implemented. The respondents felt that the indicators such as increased water availability, duration of water stress, access to and availability of food, percentage of income used for health care and food self-sufficiency will better reflect the effectiveness of the identified adaptation options. The statistical analysis has revealed very few significant associations between top ranked indicators and socio-economic characteristics of the respondents and practice groups.

In Nepal, the study was carried out in the drought-prone areas of Bara and Parsa districts. The repeated droughts in the region have decreased crop yields, were responsible for increase in insect pests, and decreased availability of fresh water. The significant adaptation options identified in the study location were small irrigation systems, irrigation scheduling in the canal, irrigation rationing and community based maintenance of irrigation canals. Most indicators showed significant association with the practice group and very few indicators were influenced by the gender and economic status. This signifies that farmers practicing certain adaptation practice or those who ranked certain adaptation practice as important have tendency to choose and rank high certain indicators against other indicators.

The above identified indicators are being quantified through consulting literature for integrating into the Global Adaptation Index (GaIn) leading to development of Local Adaptation Index (LaIn). The preliminary results have shown a shift in LaIn values after introduction of a certain practice compared to the business as usual (see Appendix 3). However, these calculations are provisional at this stage and hence are not discussed in this report.

In summary, the study was able to identify number of environmental, policy and economic indicators that could help in measuring the effectiveness of adaptation actions at the local level. However, several questions remain to be answered which include the cost of implementing such indicator-rich measurement system for small projects with little funds to spare for monitoring and evaluation, the capacity considerations for various stakeholders and how these indicators work in consistency with the measurements done at the macro level. The community was involved towards the end of the indicator identification and prioritization process and some of the community respondents had difficulty in recognizing, understanding and linking the indicators to their context. Hence, there is a need to conduct a completely bottom-up exercise at the study locations and study to what extent the bottom-up set of indicators differ from the top-down set of indicators that are identified in the first phase of the project. In addition, so far the project has focused only in the drought prone areas of the Gangetic basin and there is a need to carry out similar studies in the flood prone areas as well due to the significance of floods in the basin. The project team aims to answer these questions in the rest of the project phase (2013-2015).

1. INTRODUCTION

So far under international climate change actions the priority has been to measure the effectiveness of mitigation actions. The objective of this measurement has been to monitor the progress made in greenhouse gas mitigation and to plan for future actions. The measurement was made through identifying atmospheric greenhouse gasses, measuring their emissions and establishing an inventory system. This measurement was necessary not only because of high stakes involved in GHG mitigation but also due to huge investments made for mitigation actions. The same analogy applies for measuring the effectiveness of adaptation actions though it is more important than measuring mitigation actions since it directly involves working with social and earth ecosystems. Despite this importance, measuring the effectiveness of adaptation actions has attracted least attention globally to date. The Table 1 provides a comparison of mitigation and adaptation and what made difficult to measure the effectiveness of adaptation actions.

TABLE 1. METRICS: MITIGATION VS ADAPTATION (PRABHAKAR AND SRINIVASAN, 2009)

Mitigation	Adaptation
• Has a protocol (KP) that governs	• No 'protocol' to govern adaptation
• There are GHG reduction targets to meet with coordinated efforts	• There are no 'adaptation targets' to meet
• There are ways and means to measure the impact of collective actions	• No streamlined measurement system for adaptation
• Global actions and global benefits (more organized at global level)	• Mostly local actions and local benefits (with some undeniable global spillover benefits)
• Physical principles that govern mitigation	• At nascent stages: Complex interaction of biophysical and socioeconomic elements

In addition to the above listed differences, adaptation deals with the systems that are at different levels of vulnerability and adaptive capacity making it even more complex to understand and manage. Several adaptation options differ in their effectiveness when applied in different socio-economic and location contexts which is not the case with most mitigation actions.

Measuring adaptation is still a new concept in international negotiations, at national and local levels and even among the research community. Though the Bali Action Plan (BAP) and subsequent negotiation texts under the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) continue to state the need for enhanced actions on adaptation through various means and especially through prioritization of actions, integration of adaptation actions into sectoral and national planning, specific programs and projects, little progress has been made on how to measure, report and verify the effectiveness of adaptation actions at international, national and local levels. Measuring the effectiveness of adaptation actions is important for: the reason that adaptation has higher stakes now since rapid climate change impacts are expected, huge amounts of funds are to be invested in adaptation requiring accountability in how they are spent and how risks are mitigated, prioritizing the adaptation actions according to their potential to reduce climate risks before they are implemented, measuring the progress against an agreed benchmark (e.g. adaptation benchmark or baseline), setting adaptation targets and to avoid maladaptation. Measuring adaptation actions is incentivized when one wants to knowing where to reach (adaptation targets), when time frame for adaptation actions at various levels is agreed, and when accountability and effectiveness are asked for. This is possible only when adaptation framework at global level is designed such a way that it includes the essential elements of adaptation targets and a complementary measurement system. In addition, measurement is also necessary to check if adaptation concerns are 'mainstreamed' into the sectoral and national planning processes.

Keeping the above background in view, the current research project was initiated with the objective of identifying adaptation effectiveness indicators at the local level through a consultative process as indicated in the methodology. For this purpose, the Gangetic basin was identified as study location due to the importance of the Basin for the food security of billions in south Asia and the projected climate impacts on agriculture production and water resources in the basin. Gangetic basin is characterized by diverse socio-economic regions with specific characteristic sub-regions within the basin. The available literature indicate a variety of climate change impacts in the region among which reduced flows of freshwater leading to water shortages on the one extreme and flash floods on the other extreme with possibility of both extremes happening in various parts of the region in the same year. For this reason, the region assumes high importance for climate change adaptation interventions. Identifying adaptation interventions based on their effectiveness even before they are implemented in the field is important for efficiency purposes including for avoiding maladaptation. However, not many approaches are available for measuring progress in adaptation attributable to the practices introduced in agriculture and water sectors.

The study on adaptation effectiveness indicators has been carried out by the Institute for Global Environmental Strategies (IGES) in collaboration with national partners BCAS, ICIMOD and TERI in the Gangetic basin with support from the Strategic Environment Research fund of the Ministry of Environment, Government of Japan (*Suishinhi,* S8). The study follows the approach of identifying local effectiveness indicators in a participatory manner to be integrated into the Global Adaptation Index (GaIn) in order to arrive at Local Adaptation Index (LaIn). A broad set of effectiveness indicators were identified first by conducting literature review followed by a regional consultation workshop and these indicators were further vetted at national level expert consultation meetings where individual indicators were discussed for their relevance to the country and study location specific circumstances (Appendix 1). These indicators were then transformed into structured questionnaires for consultations with farming communities, district administration and non-governmental organizations that engage in implementing adaptation projects (Appendix 2 for questionnaires prior to indicator vetting meetings). The survey data has been statistically analyzed for identifying associations between adaptation options and various socio-economic characteristics (Pearson chi-square test) of the respondents and the indicators and criteria they chose. The indicators are currently been quantified for integration into a form of Local Adaptation Index following the GaIn methodology.

1.1 OBJECTIVES

The project has three objectives namely to identify adaptation effectiveness indicators for agriculture in the Gangetic basin, to quantify these indicators into some form of index (such as Local Adaptation Index) that different stakeholders can use to monitor and evaluate their adaptation interventions, and to assess the existing adaptation decision making frameworks, both in the literature and in vogue among government and non-governmental agencies to provide a meaningful delivery mechanism for the above developed indicator system.

While achieving the above objectives, it was imperative for the study to develop a tool that can help in prioritizing different package of practices (also termed as adaptation options throughout this report) that would accrue a certain amount of progress in adaptation as indicated by Local Adaptation Index (LaIn) when those practices are adopted at any given unit of adoption (a single farmer, community or a village). The Figure 1 indicates Adaptation Decision Making Matrix, which is an expected ultimate outcome of the study. The rows indicate the LaIn levels and the columns indicate the drought severity levels (climatic stimuli). It shows various possible combinations of package of practices that a local administrator or project manager can pick according to different levels of adaptive capacity and drought incidence levels for his location.

LaIn Value	Drought Incidence levels			
	D1	D2	D3	D4…D7
A1	Package a, b, c, d			
A2				
A3		Package b,z,e		
A4			Package d,l,r	
A5				
A6				Package h,y,z
A7				

FIGURE 1. ADAPTATION DECISION MAKING MATRIX

The procedure for estimating drought incidence levels and assessing the effectiveness of adaptation actions is discussed in the methodology section of this report.

1.2 SCOPE OF THE REPORT

This interim report presents the results of the community questionnaire surveys conducted to identify adaptation effectiveness indicators. The aim was to share the results with wider audience for obtaining feedback that could be incorporated in the subsequent years of the study. The report provides a background of the study locations, characterizes the drought in terms of intensity and duration using Standardized Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI) and discusses the results of community surveys conducted for prioritizing adaptation effectiveness indicators.

2. METHODOLOGY

2.1 RESEARCH STEPS

Achieving the previously discussed project objectives required the following steps: characterizing the climatic stimuli and estimation of effectiveness of practices.

Step I: Characterizing the climatic stimuli (columns in Fig. 1)

The climatic stimuli in the form of drought in the study locations were identified using standardized precipitation index (SPI) and Palmer Drought Severity Index (PDSI). For calculating these indices, input data such as precipitation data (monthly), normal precipitation and temperature values for the station in consideration were collected. The partners have procured this data from the respective meteorological agencies and provided for calculating indices from the historical data. This step provided the climatic stimuli context within which the practices and indicators were identified.

Step II: Estimation of effectiveness of a practice (rows in Fig. 1)

This forms the major part of the project. For estimating the effectiveness of adaptation actions, this study heavily borrowed from the Global Adaptation Index (GaIn) (refer to www.gain.globalai.org). Though GaIn was not designed to estimate effectiveness of individual actions but rather to be a generic index of effectiveness of cumulative actions at national level, this study aims to develop what is called Local Adaptation Index (LaIn) by identifying and incorporating indicators that are relevant at the local level where most of adaptation actions are taken up in agriculture and water sectors; and see to what extent the LaIn can be used for estimating the effectiveness of individual practice at the local level (village and group of villages).

For the purpose of this study, the effectiveness of a particular practice can be understood in terms of a change in LaIn value after a practice is introduced. The Figure 2 indicates the concept for estimating the effectiveness of a particular practice.

MEASURING LAIN AT THE LOCAL LEVEL

GaIn is designed as a broad index at the national level.[1] Two sets of indicators are employed for estimating the GaIn, one set is to estimate the vulnerability (24 indicators in total) and the second set is to estimate the readiness (14 indicators in total). The vulnerability indicators were grouped into four components of water, food, health, and infrastructure. The readiness indicators were grouped into three components of economic, governance, and social. Since this study is to measure the effectiveness of climate change adaptation options in agriculture and water sectors at the local level, the GaIn would not be able to achieve this objective due to the

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[1] *The details for estimating GaIn can be found in the paper on 'Global Adaptation Index™ ("GaIn™") Measuring What Matters, Global Adaptation Institute, 2011.*

use of broad set of indicators for which the data is available only at the national level and relevance of these indicators at the practice level. Hence, this study identifies additional indicators that will strengthen the GaIn for to be used at the local level (which we term as LaIn) using a combination of participatory rural appraisal (PRA) and multi-criteria techniques.

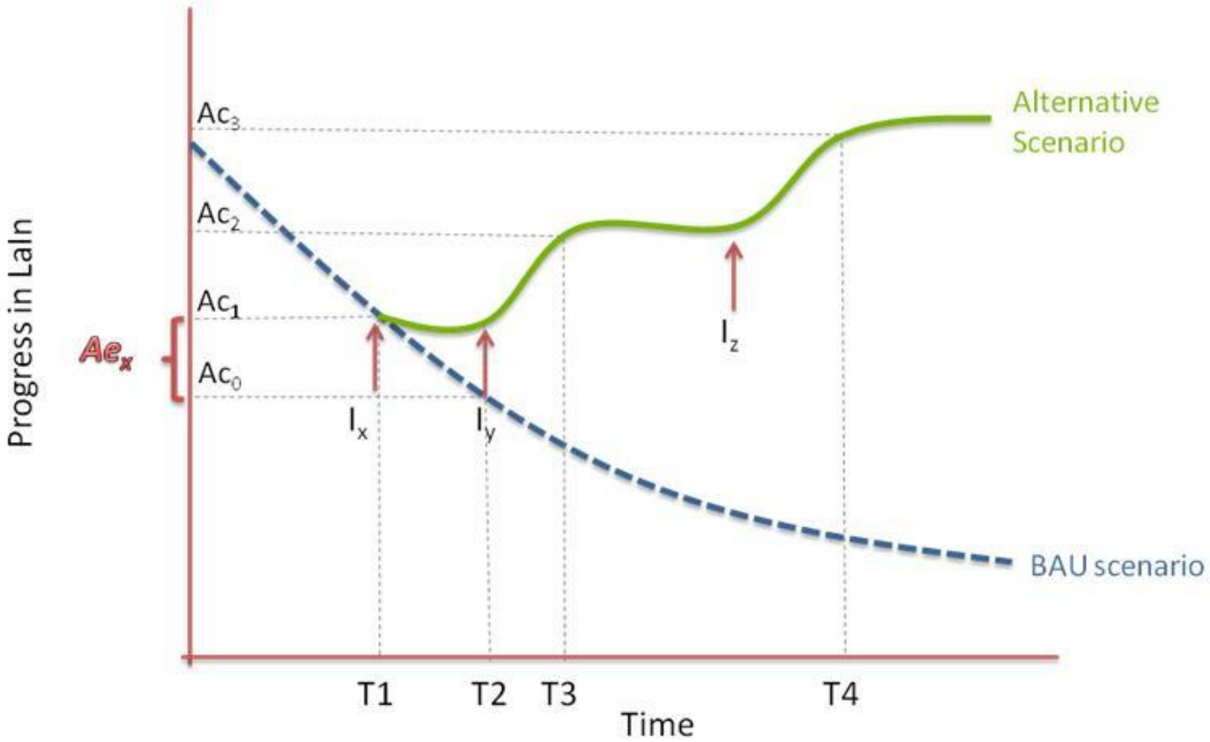


FIGURE 2. MEASURING EFFECTIVENESS OF ADAPTATION ACTIONS USING LAIN

$$Ae_x = Ac_1 - Ac_0$$ ………………………………………………………………..EQUATION 1

Where,

Ae_x: Effectiveness of adaptation action x;

Ac_0, Ac_1: LaIn value at times T1 and T2

Ix, Iy, Iz: Interventions x, y, z

A0 would be the LaIn value of BAU scenario and Ac1 would be the LaIn value for each proposed adaptation action for implementation. The difference between these two LaIn values would give an estimate of the effectiveness of action/practice to be implemented.

2.2 SURVEY METHODOLOGY

The overall survey approach for identifying adaptation effectiveness indicators is shown in Figure 3. Structured questionnaire surveys and PRAs were conducted for identification of additional indicators for various components of GaIn to derive LaIn (Appendix 2). This was done through first conducting regional and national consultations with experts and subsequently focus group discussions (FGDs) and structured questionnaire surveys with local communities in the order shown in Figure 3. Subsequent to prioritizing indicators, the values for these indicators (for the existing ones in the GaIn and for the additional ones identified from the questionnaire survey) were collected from various sources and direct expert judgement for demonstrating the applicability of using LaIn at the local level through calculating LaIn values before and after introduction of a particular adaptation practice (Figure 2, Appendix 3 for mock exercise on LaIn).

The indicators were prioritized in the following survey stages: Stage I: Conduct regional consultation meeting to identify broad institutional, technical and policy barriers to measuring adaptation effectiveness in the Gangetic basin; Stage II: National level consultations to enlist adaptation options, identify detailed list of effectiveness indicators and identify survey locations in Bangladesh, India and Nepal (See Appendix 1); Stage III: Pilot survey for fine-tuning the questionnaires developed from the previous processes (see Appendix 2). During the pilot surveys, the practices were also updated after conducting focus group discussions with farming community; and Stage IV: conducting actual questionnaire surveys.

Survey locations

The survey locations in the Gangetic basin are marked in Figure 4. These locations were identified based on the feedback received during the national consultations carried out with the help of agriculture departments and NGOs who are well verse with the local conditions such as drought prevalence and presence or absence of practices to help alleviate drought impacts. Since the study is on the hazard specific impacts of climate change, the drought prone areas were identified for the survey purposes [The study will also include flood prone areas in the remaining two years of the project (2013-15)]. While surveying in these locations and during the national level consultations, all practices with climate change adaptation benefits being practiced by farmers and promoted by various community based organizations and government departments were enlisted and locations where these practices are being practiced were identified. This practice list has become a base for further discussions for identifying and prioritizing indicators during the community consultation process and to further identify villages these practices are in vogue.

- India: Central Gangetic basin (Uttar Pradesh)
- Nepal: Narayani Basin area of southern Nepal
- Bangladesh: Barind Region of Western Bangladesh

Survey scale and respondents

Surveys were done with three categories of respondents. Questionnaire surveys were done mainly with the farming community at the village level. Other stakeholders such as researchers and district level administration and non-governmental organizations were also included in the questionnaire surveys.

- Local communities: farmers at the village level.
- Local administration: agriculture department personnel in the village, Zila Parishad and district levels.
- Researchers: researchers working on agriculture and water related subjects from universities, research institutes and have sufficient exposure to the issues and the technologies/practices being promoted in the region.

The sample size for the structured questionnaire surveys was determined using the formula:

SAMPLE SIZE (N) = $$\frac{t^2 \times p(1-p)}{m^2}$$ ……………………………………………………….EQUATION 2

Where

t= confidence interval (usually taken 1.96 for 95% of confidence level)

p= estimated prevalence (presence of a particular practice in the population being surveyed)

m= Margin of error (usually given at 5% or 0.05)

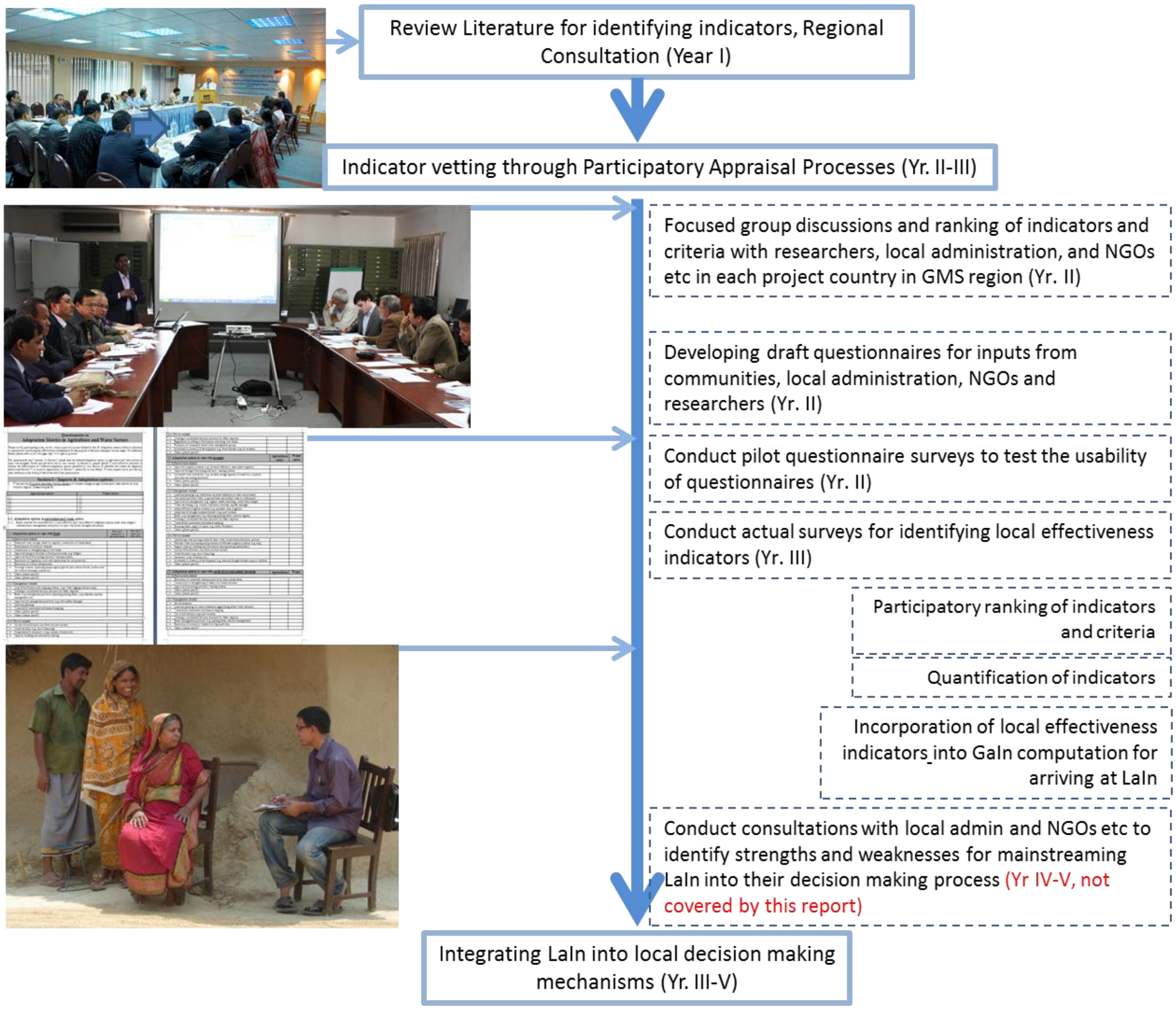


FIGURE 3. THE FLOW OF STEPS INVOLVLED IN THE STUDY

Quantifying indicators

Information for quantifying indicators, those already included in the GaIn and those identified from field surveys, were collected from extensive literature review, by consulting relevant experts and during field surveys. The Table 2 provides sources of data for quantifying indicators that are already included in GaIn. The provisional results from LaIn calculations are presented in Appendix 3.

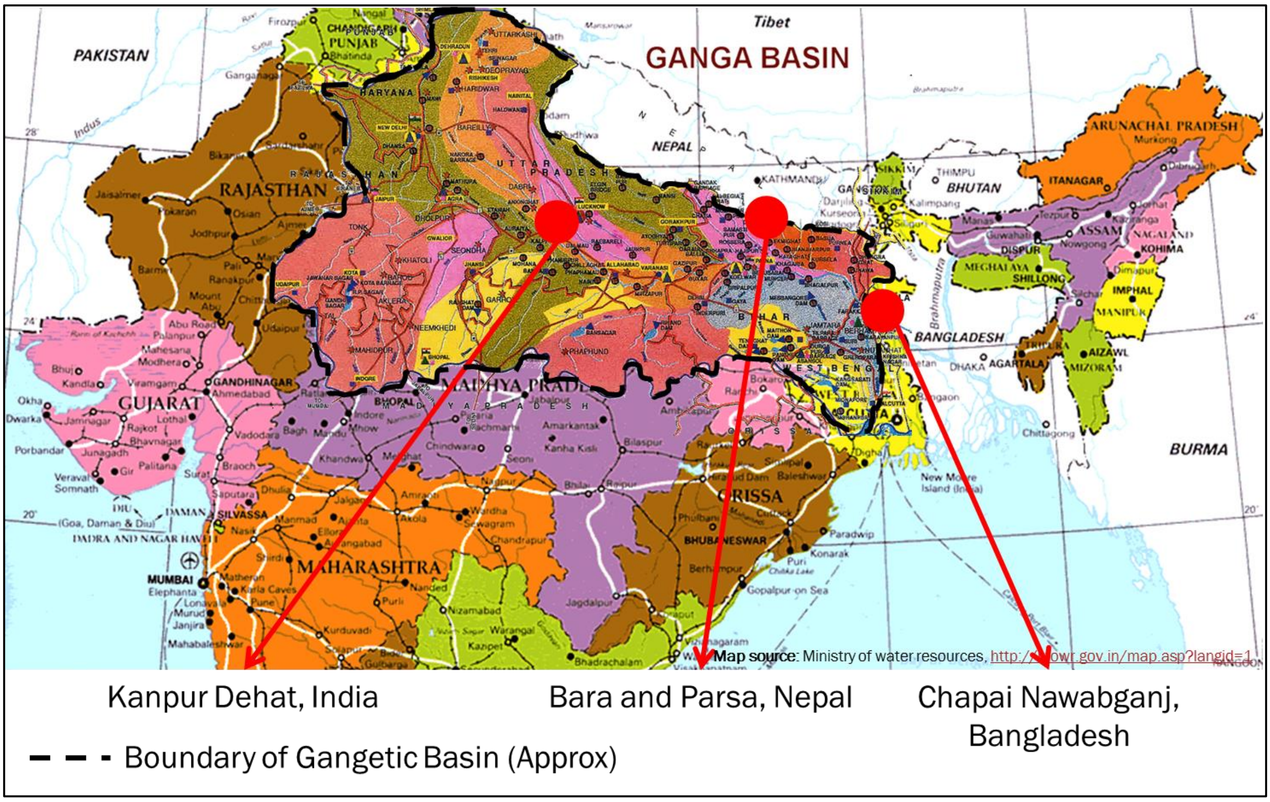


FIGURE 4. STUDY LOCATIONS SHOWN WITH THE BOUNDARY OF THE GANGETIC BASIN

TABLE 2. SOURCE OF DATA FOR INDICATORS INCLUDED IN GAIN

Component	Indicators	Source of data: Survey/local records	Source of data: Published data
	Vulnerability indicators		
Water	• Projected change in precipitation		O
	• Projected change in temperature		O
	• Internal and external freshwater extracted for all uses	O	
	• Population with access to improved water supply	O	
	• Mortality among under 5 yr.-olds due to waterborne diseases	O	
	• Population with access to improved sanitation	O	
Food	• Projected change in agricultural (cereal) yield		O
	• Coefficient of variation in cereal crop yields		O
	• Population living in rural areas	O	

Component	Indicators	Source of data	
	• Food import Dependency	O	
	• Agricultural Capacity	O	
	• Children under 5 suffering from malnutrition	O	
Health	• Estimated impact of future climate change on deaths from disease		O
	• Mortality due to communicable (infectious) Diseases	O	
	• Health workers per capita	O	
	• Health expenditure derived from external resources	O	
	• Longevity	O	
	• Maternal mortality	O	
Infrastructure: Coast	• Land less than 10 m above sea-level	NA	NA
	• Population living less than 10 m above sea-level	NA	NA
Energy	• Population with access to reliable electricity	O	
	• Energy at risk	O	
Transport	• Frequency of floods per unit area	O	
	• Roads paved	O	
	Readiness indicators		
Economic	• Business freedom		
	• Trade freedom		
	• Fiscal Freedom	O	O
	• Government Spending	O	O
	• Monetary Freedom	O	O
	• Investment Freedom	O	O
	• Financial Freedom	O	O
Governance	• Voice & Accountability	O	O
	• Political Stability & Non-Violence	O	O
	• Control of Corruption	O	O
Social	• Mobiles per 100 persons	O	O
	• Labor Freedom	O	O
	• Tertiary Education	O	O
	• Rule of Law	O	O

3. STUDY LOCATIONS

3.1 BANGLADESH

The study was conducted in the Barind tract region of western Bangladesh. The parts of greater Rajshahi, Dinajpur, Rangpur and Bogra District of Bangladesh and the Indian territorial Maldah District of West Bengal are geographically identified as Barind tract (Bangladesh Multipurpose Development Authority, 2013). The Barind Multipurpose Development Authority is working in the main drought-prone area of Bangladesh for water supply and drought risk mitigation. Though Barind tract is the driest region of Bangladesh, land degradation can be found all over Bangladesh. Desertification process is not distinct in Bangladesh (United Nations, 2002). Long dry season (seven months) causes severe drought. Land degradation has been occurring due to over exploitation of soil. Characterized by dry climate with high temperatures (Temperature ranges from 8 degree Celsius to 44 degree Celsius), the region receives a rainfall between 1500 mm to 2000 mm. It has a total cultivable area of 582,750 hectares, out of which 34% is loamy, 10% Sandy, 49% is clayed and 7% others. Out of the total cultivable land, 84% are single cropped, 13% are double cropped and the rest are triple cropped. The cropping intensity in the region is 117%.

Droughts are common in Bangladesh particularly in the Barind tract. They affect water supplies and crop growth leading to loss of production, food shortages and starvation. In comparison with floods and especially cyclones, droughts are slow to manifest and are pervasive in nature. Typically, uncertainty of rainfall during pre-*kharif*, prevalence of dry days and lack of soil moisture during the dry season reduces potential yields of broadcast, *T. aman* and *rabi* crops. Depending on the intensity of drought, estimated yield reduction of different crops varies from 10 percent to 70 percent (Chowdhury, 2006).

Severe droughts affect crop production in about 30 percent of the country, reducing yields by an average 10 percent. Drought normally affects *kharif* crops (e.g., *aus* and *aman*), and sometimes *rabi* crops (e.g., wheat and mustard), as in the case of 1978-80 which affected about 42 percent of the cultivated land and 44 percent of the population (Ericksen et al., 1993). Persistent drought is relatively rare, but has the potential to cause famine. Drought often affects western districts severely, more so when the monsoon is curtailed. Over the years, the massive afforestation through social forestry programmes, river dressing, river restoration and wetland conservation has contributed to these problems and the integrated approaches implemented the Ministry of Agriculture has helped considerably.

Four villages, two each in Nachole and Kasba Unions in Nachole upazila and Chapai Nawabganj district, were identified for conducting questionnaire surveys after consulting relevant government stakeholders and NGOs. These four villages include 1) Shabdalpur, 2) Shonaichondi, 3) Shibpur, 4) Maktapur (Figure 5, the unions surveyed are shown in red mark in the map of Nachole upazila).

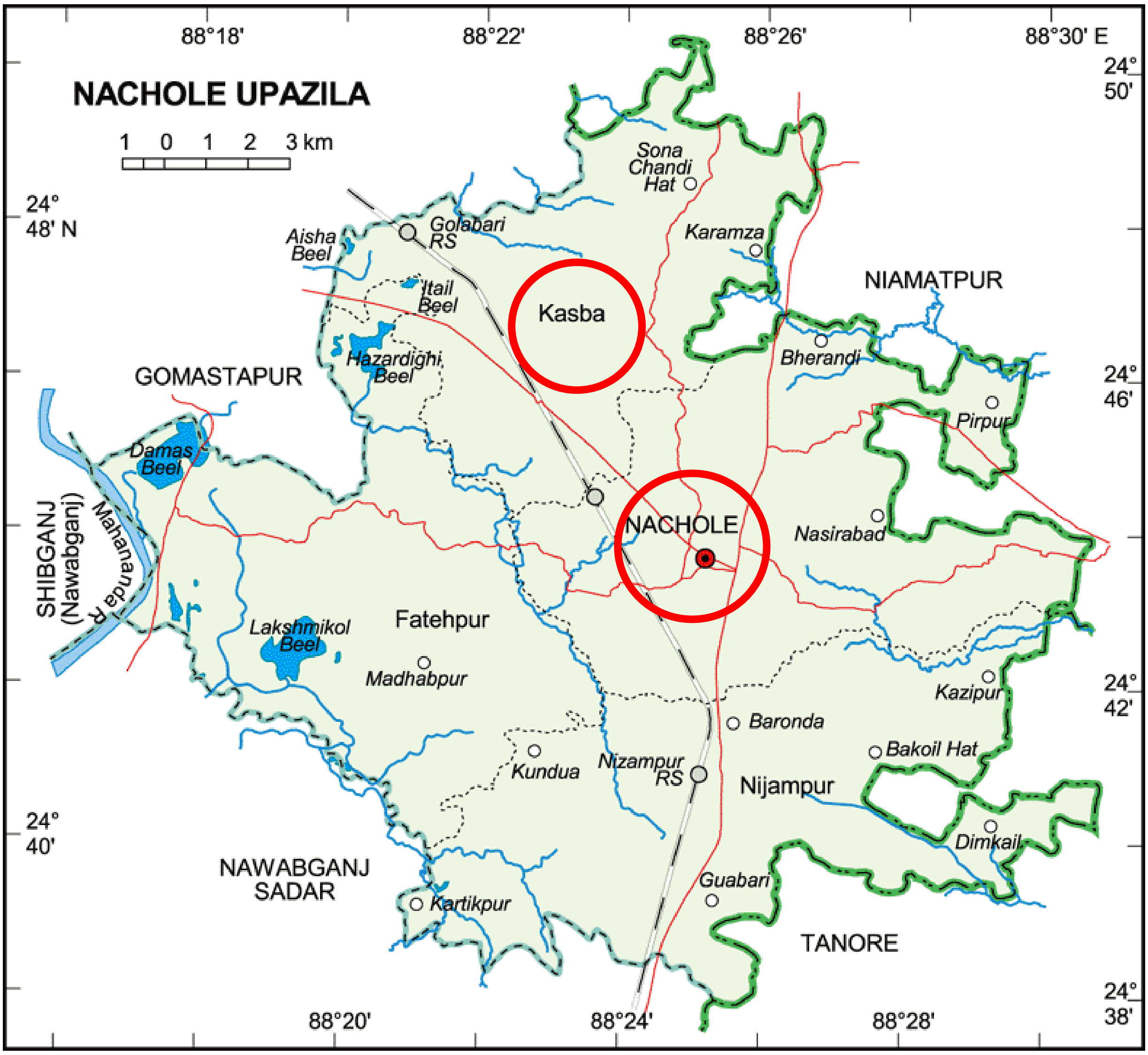


FIGURE 5. NACHOLE UPAZILA (RED CIRCLES INDICATES THE STUDY UNIONS) WITH STUDY LOCATIONS

Nachole upazila is located in the northeastern part of Chapai Nawabganj district in the Barind tract. The upazila has an area of 284 sq km and composed of 4 unions (lowest administrative unit), 220 villages with a population of 1,32,308. Literacy rate of the upazila is 42.2%. 91% of the upazila falls under Barind tract. Average rainfall of this area is approximately 2,044 mm and it's also very much seasonal, almost 77% of rainfall occurs during monsoon. 80% of the population here are farmers and mainly cultivate rice, wheat, maze, sugarcane and mango. Main source of irrigation is ground water through deep tube wells. Over extraction of ground water has led to ground water depletion in this area. According to the community interviewed the groundwater level has decreased by about 15ft in the last 6 years.

For community surveys, the sample size was calculated using the formula given in the methodology section of this report. All the 211 questionnaires out of 211 respondents derived from the formula (138 respondents using deep tube well and 73 respondents using excavation of ponds) were interviewed using the structured questionnaires. In addition, 6 policy makers were also interviewed for obtaining the policy level opinions on the indicator process.

Prior to conducting the final questionnaire survey, two FGD's were conducted in Nachole and Kasba unions on 5th May, 2012 (Figure 6). These discussions were helpful in updating the questionnaire with the practices and indicators suggested by the farming community. During these FGDs, the project team presented the main objectives of the project and indicators (environmental, social and economic) for prioritization. After the FGD's, the team had a discussion with the government agriculture extension workers of Nachole upazila to validate the priority indicators. The administration and community have suggested including indicators such as 'Asset ownership among women and men and Gender equity' as an important indicator under social effectiveness so that the gender equality issue is not excluded. The practices and indicators identified were summarized for updating the questionnaires developed by IGES.

FIGURE 6. FOCUS GROUP DISCUSSION AT VILLAGE LEVEL IN BANGLADESH

3.2 INDIA

The state of Uttar Pradesh, which is situated in the Gangetic basin, is essentially an agriculture based state. Large parts of the state are drought prone and face frequent water shortage which affects the overall productivity and the livelihoods of farmers. The farmers face a number of stressors related to agriculture and water availability. The socio-economic factors of the communities further add to their vulnerability. The poverty ratio in many parts of the state is very high. Climate variability is an added stressor for the farmers as it not only impacts the agriculture and water sector directly but also has secondary impacts. In order to combat the negative impacts of drought and ensure better availability of water, drought alleviation projects are being implemented in the state. Monitoring and evaluation of these projects can help in effective adaptation and avoiding maladaptation practices.

Severe soil erosion has been faced due to water runoff in the ravine lands leading to severe land degradation on the banks of River Yamuna and Sengur in the Gangetic basin. Nearly 83% of the population is largely dependent on agriculture and these agrarian communities are been put at risk of losing their livelihoods due to land degradation. Though there are favorable agro-climatic conditions for growing crops, increased land degradation has made conditions unfavorable for optimum growth of crops. In addition, these blocks have less cultivable area due to uneven or undulating lands and lack of irrigation sources. Farmers face water scarcity due to high water runoff which gives less time for groundwater recharge. As a result, the groundwater level is substantially low at 61 to 76 meters. There has been acute scarcity for green fodder in month of February and most farmers do not get sufficient crop in a year leading to high level of poverty. Migration has become a common coping strategy for the communities in this region.

The criteria for site selection was to choose a suitable site in the Gangetic basin which is drought prone and where some kind of drought alleviation practices were implemented either by the government and other organizations. For this purpose, Kanpur Dehat district (Ramabai Nagar) in the state of Uttar Pradesh (Figure 7) was selected as the survey site for the project because large parts of the district are drought prone. Meetings were carried out with the district officials of Kanpur Dehat District to understand the drought risk reduction initiatives being undertaken in the agriculture and water sector. There were water and soil conservation practices implemented by the Uttar Pradesh State Government as well as local NGOs. The practices were summarized for updating the questionnaire developed by IGES.

Subsequently, villages in Amrodha Block and Malasa block were selected for conducting field surveys where watershed development activities including different types of bunds were constructed. These initiatives were undertaken by *Uttar Pradesh Bhumi Sudhaar Nigam* (UPBSN) which is a UP Government undertaking. Shramik Bharti which is a local NGO based in Kanpur has facilitated in the implementation of this project.

Ravine stabilization work has been undertaken in the selected sites of Ramabainagar by Uttar Pradesh Land Development Corporation (UPLDC) which includes construction of check dams and bunds (contour bunds, peripheral bunds and marginal bunds). Shramik Bharti has been working with the UPLDC for implementation of ravine stabilization work. As a result of these interventions, farmers are now able to grow crops in the degraded fields. The NGO has also undertaken initiatives along with UPLDC to increase the agricultural output and effectively manage water resources. During a span of one year, 654 hectares of land was stabilized benefitting 633 farmers, most of them were small and marginal farmers.

Pilot testing of the questionnaire was done with the communities in Rasulpur Khunda Hamlet, Amrodha Block and Jarsen Village, Malasa Block (Figure 8). The pilot testing was done by organizing focus group discussion with communities (no individual questionnaire survey was implemented but it was organized in a focus group discussion mode using questionnaire as a guide). The FGD in Amrodha Block was attended by 8 male and 2 female farming community representatives. The group included farmers with large, medium and small land holdings. The FGD in Jarsen Village, Malasa Block was attended by 13 male and 4 female farming community representatives. The respondents were given a background on climate change and changing water availability followed by a brief on the purpose of the survey.

The respondents were asked about changes they observed in the climate and related observed impacts on water and agriculture in their village, to prioritize the possible practices related to drought risk reduction and to rank the identified indicators for measuring the effectiveness of practices identified. The context of the practice given to them was of the change which they have observed in their livelihoods due to the interventions made by UPLDC resulting in better water availability and thus higher crop yield. They were asked to judge the effectiveness of this practice with respect to the identified indicators and rank them accordingly. The ranking was done by consensus among the participants.

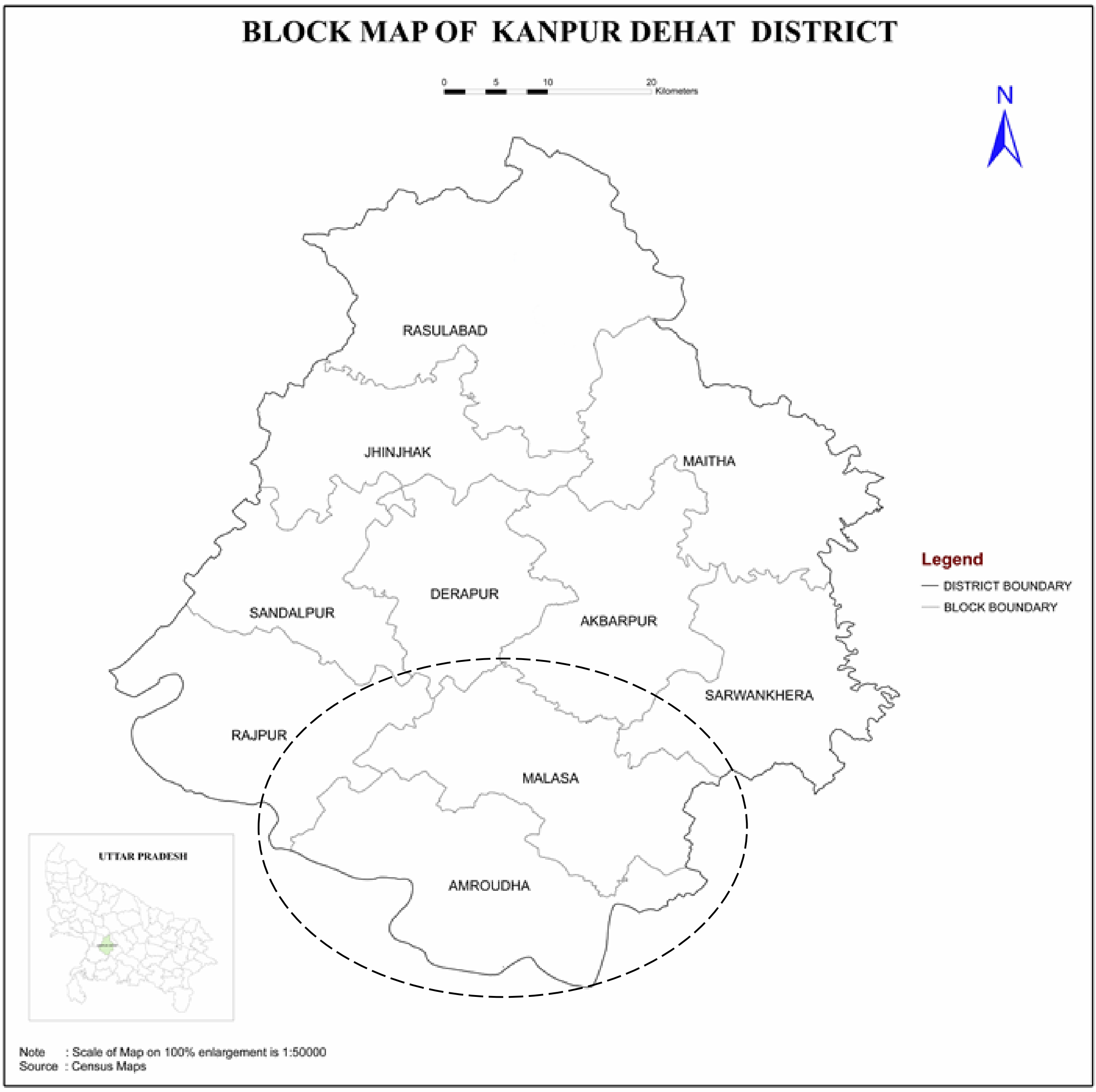


FIGURE 7. KANPUR DEHAT DISTRICT MAP SHOWING STUDY LOCATIONS IN INDIA (SOURCE: WWW.KANPURDEHAT.NIC.IN)

Subsequent to pilot testing the questionnaire, the questionnaire was modified from the pilot experiences and the main survey was conducted with 195 respondents including both males and females (the number was arrived at by using the formula provided in the methodology section). The sample included individuals of both who have benefitted from the drought mitigation interventions and those who were not benefited by these practices (mostly due to distance of their farms from the water harvesting structures). The respondents were chosen from different economic groups by taking into consideration the land holding size. Apart from the community surveys, surveys were also done with researchers, local administration and non-governmental organizations and policymakers.

FIGURE 8. SURVEY PROCESS IN AMRODHA BLOCK, KANPUR DEHAT DISTRICT

3.3 NEPAL

The lowland region of Nepal forms a part of the larger Indo - Gangetic basin and the Gangetic basin in Nepal is classified into three river basins: the Karnali basin (Western Nepal), Narayani basin (Central Nepal) and the Koshi basin (Eastern Nepal). Flows from these river basins join the Ganges river basin in India. The surveys were carried out in two lowland districts, Parsa and Bara in Nepal (Figure 9). This study area was purposively selected because these districts fall in the Central lowland region. The southern part of most of the bordering districts in central lowland regions of Nepal have irrigation canals, due to its border proximity with India, where as the northern parts of the this region have less access to irrigation facilities. These areas are rain-fed and are vulnerable to drought.

The vulnerability analysis shows Parsa district as a suitable study site for this research. Bara district was added since it is adjacent district and is also moderately vulnerable to climate change and drought. The spatial and temporal analysis of drought in Nepal show that the highest probability of long duration drought fall in the northern and southern part of 85ºE to 87°E, i.e. the central lowland and eastern lowland region (Sigdel and Ikeda, 2010). Further to this analysis, the recent NAPA report (Ministry of Environment, 2010a), lists seven districts in the central lowland region (Chitwan, Parsa, Bara, Rautahat, Sarlahi, Mahottari, Dhanusha), as moderate to high vulnerable. Out of these seven districts, four districts, i.e. Parsa, Chitwan, Mahottari, Dhanusha, ranked high on climate change vulnerability (0.787 – 1.000), while the other three districts (Bara, Rautahat, Sarlahi) were moderate in vulnerability ranking (0.356 – 0.600). Bara and Parsa has a total cultivated area of 60,346 and 46,750 ha respectively (ISRC, 2010). Nearly 94 and 77% of the population in Bara and Parsa respectively were affected by droughts in 2008, 2009 and 2012.

Most of the districts in the lowlands receive 80% of the annual rainfall from June to September. The mean annual rainfall ranges between 2000-2100 mm of rainfall annually (DHM, 1995). Farmers in these areas use shallow tube wells and small irrigation infrastructure.[2] The main occupation in the region is agriculture. Around 40% of the areas are cultivated and 50% of the cultivated area i.e. 20.1% of total area is irrigated. The main cereal crops cultivated in the region are rice, wheat, maize, lentil and vegetable crops. Cash crops cultivated were sugarcane and tobacco. Farmers harvest two to three crops in a year and the cropping patterns used in the region are early variety of rice followed by intercropping. Mostly farmers were cultivating early rice (Hardinath-1), Lentil, Tobacco etc. which demand less irrigation.

Since the study aims at identifying adaptation options which farmers are directly practicing in relation to coping with drought, the study area was suitable to conduct surveys to identify options against set of indicators in each categories (environmental, social and economic). Hence, identifying options in drought sensitive and vulnerable areas to develop local adaptation indicators was most suitable in northern areas of Parsa and Bara districts. The cluster of villages of Fattepur and Dumarwana in Bara, and Belwa and Bageshowori in Parsa formed the sampling areas for this study.

The survey sites were chosen purposively. There are few reasons to justify purposively selection of study areas. Stratified random sampling can generally turn out to be expensive, as compared to designing a survey area purposively, provided it meets research criteria. As mentioned before, the challenge in Nepal is that the practices adopted by farmers are few, so stratified random sampling in this case would not be the ideal sampling framework. The samples within two practices selected for the survey were taken into consideration after consultations with local officials from district agriculture development office and agriculture scientists from NARC. Both indicated that these areas are drought prone. Reports and articles on the study area were referred through secondary data, and literature review, which was useful in identifying survey locations and villages. In a nutshell, the reasons to choose Bara and Parsa as study sites are their drought vulnerability, accessibility, limited budget and resources, and the presence of National Agricultural Research Station in Parwanipur, Bara which serves as an information centre in the region. Lastly, the need to involve researchers as potential enumerators to conduct surveys was another reason to have chosen Bara and Parsa as survey sites.

Based on consultation with scientists from Regional agricultural research station, Parwanipur (NARC), and discussions with agriculture officers from District Agriculture Development Offices of Bara and Parsa, and coordination with District Development Committee, and NGOs, the VDCs were ranked as most drought prone areas. Similarly, based on the pre-field visit survey before the final survey, it was also identified as drought prone area. These areas were observed as rain fed and having less access to irrigation.

The initial questionnaires, designed for communities (farmers) and administrators (local district administrators, researchers, NGO's), were provided by IGES which were developed based on the literature review and other related efforts. Subsequently, these questionnaires were updated with location specific information after conducting national level consultation meeting for vetting indicators and focus group discussions at village level to identify additional location specific adaptation options and indicators. Using the formula presented in the methodology section, a

[2] In this report, 'small irrigation' consists of irrigation pump sets for pumping ground and surface water used by individual farmers.

sample size of 269 was derived for Nepal and all the statistically suggested 269 samples were surveyed by the project team in four villages of Fattepur, Dumarwana, Belwa and Bageshwori. In addition, 39 questionnaires were sent to administrators at district level, policy makers and researchers involved in climate change and allied sectors. Local NARC researchers from Bara, Parsa and two agricultural graduates were involved as enumerators to conduct surveys in the study sites. Enumerator's workshop was conducted, which included detailed discussion of questionnaires and a site visit to neighboring VDC to test the questionnaire with farmers.

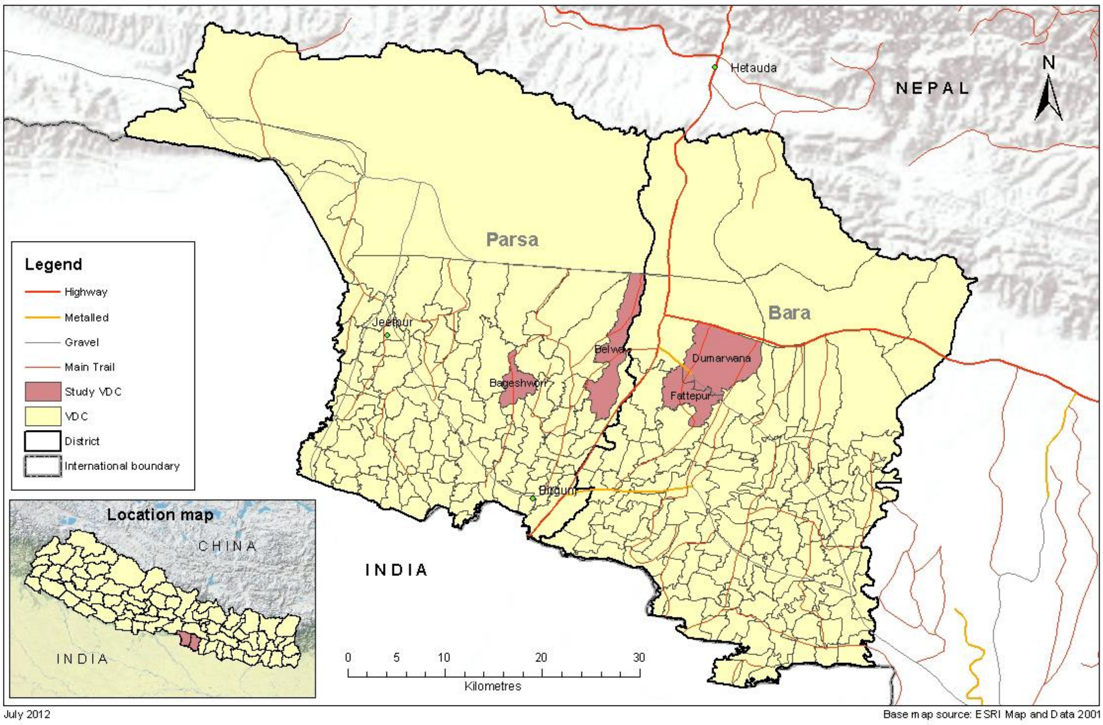


FIGURE 9. BARA AND PARSA DISTRICTS SHOWING STUDY LOCATIONS IN NEPAL

FIGURE 10. FOCUS GROUP DISCUSSION AT ONE OF THE SURVEY LOCATIONS IN NEPAL

4. CHARACTERIZING CLIMATIC STIMULI

4.1 INTRODUCTION

The first three years of the study has considered drought as one of the important climatic stimuli to which various stakeholders respond in the Gangetic basin. In the later stages (Years IV-V), the study will include floods to understand community responses to cope with floods and if there is a need for an additional set of indicators from those identified from the drought prone areas to assess the effectiveness of responses to floods.

The Identification and classification of drought severity are some of the most difficult aspects of drought management. It is difficult due to the fact that drought affects a wide variety of disciplines, varies temporally and spatially, and has a complex series of impacts associated with it. The sooner and better the drought is identified, the sooner and better the governments and other stakeholders can be prepared and respond to the impending drought. However, despite the continuous efforts made globally, limited success has been achieved in getting a universally accepted definition of drought and developing an index that measures it as drought means different for different stakeholders.

The policy level definition of drought is important for activation of different institutional response mechanisms. However, such a definition of drought is not uniform within a country and region. For example, in India, drought is often defined differently at different geographical scales. According to the Indian Meteorological Department, meteorological drought is defined as occurring when the seasonal rainfall received over an area is less than 75% of its long term average value. The drought is moderate when the rainfall deficit exceeds 26-50% and severe drought occurs when the rainfall deficit exceeds 50% of normal. A year is considered a drought year for the country if the area affected by drought covers more than 20% of the total area of the country (Ray, 2000). In order to define agricultural drought, an Aridity Anomaly Index (AI) was developed to monitor the incidence, spread, intensification, and recession of drought. The AI is denoted as a ratio between the moisture deficit, expressed as difference of potential evapotranspiration (PE) and actual evapotranspiration (AE), and potential evapotranspiration (PE) and expressed as percentage (Equation 1 below). Biweekly Aridity Anomaly Indices are prepared for the whole country during the southwest monsoon season and for five meteorological subdivisions during the northwest monsoon season.

$$AI = \frac{PE - AE}{PE} \times 100 \quad \text{.......... EQUATION 3}$$

While simple in concept, the use of the departure from normal approach is disputable. What is normal in one location may not be the norm in other locations and hence cross comparison of the rainfall events across locations using departure from normal is difficult rendering it limited in its scope. Cross-comparison is also difficult due to the fact that rainfall in a time series is far from normal, which means that the average precipitation is often not the same as the median precipitation. For the same reason, drought intensities across the locations cannot be compared using the departure from normal approach. This necessitates identifying a suitable alternative to mean deviation that would help us in making cross-location comparisons of drought intensities.

Some drought indices that have become popular globally are Palmer's PDSI and PHDI Indices (Palmer Drought Severity Index and Palmer Hydrological Drought Index), which is based on antecedent precipitation, moisture supply and moisture demand (Palmer, 1965), and the VCI (e.g. Vegetation Condition Index) based on the satellite imagery of Advanced Very High Resolution Radiometer (AVHRR) (Kogan, 1995). PDSI incorporates precipitation, soil moisture (in the form of available water holding capacity) and moisture demand in the hydrological computations (Dai et al., 2004). The PDSI was subsequently modified into what is called self-calibrating PDSI by Wells et al. (2004) by replacing the empirical constants used in PDSI calculations with the dynamically generated constants depending on the location specific information provided to the SC-PDSI program. In essence, SC-PDSI is nothing but PDSI that is obtained the way Palmer intended it to be but using modern computational facilities available from computers. The SPI and PDSI classifications are given in Table 3 (Zhai et al., 2010).

McKee et al. (1993) developed the Standardized Precipitation Index (SPI) for the purpose of defining and monitoring drought. They defined the Standardized Precipitation Index (SPI) as the difference of precipitation from the mean for a specified time period divided by the standard deviation where the mean and standard deviation are determined from past records. However, as the precipitation will not be normally distributed over the time scale considered, a transformation is applied to the distribution. Hence, the SPI is simply the transformation of the precipitation time series into a standardized normal distribution (z-distribution-like).

TABLE 3: SPI AND PDSI VALUES FOR DROUGHT CLASSIFICATION

SPI value	Class	PDSI value
≥2	Extremely wet	≥4.0
1.5 to 1.99	Severely wet	3 to 3.99
1.0 to 1.49	Moderately wet	2 to 2.99
-0.99 to 0.99	Near normal	-1.99 to 1.99
-1.49 to -1.00	Moderately drought	-2.99 to -2.0
-1.99 to -1.5	Severe drought	-3.99 to -3.0
< -2	Extreme drought	≤ -4.0

The SPI has several advantages which are well documented in the literature (Bordi and Sutera, 2001; Richard, 2002; Guttman, 1999). The SPI is simple to compute, suitable to quantify most types of droughts (Szalai and Szinell, 2000), and its variable time scale computation allows it to describe drought conditions for a range of meteorological, agricultural and hydrological applications; standardization ensures that the frequency of extreme events at any location and on any time scale are consistent. Contrary to the PDSI, the SPI requires only rainfall data which is easy to obtain when compared to soil moisture, evapotranspiration, and other data that are required by some other indices. However, the SPI do have some disadvantages such as the assumption that a suitable theoretical probability distribution can be found to model the raw precipitation data prior to standardization (Hughes and Saunders, 2002) and its limitation for applications to short time scales in those regions having low seasonal precipitation.

4.2 METHODOLOGY

In this study, both the SPI and PDSI are computed to characterize the drought in the study areas. This choice is motivated from the literature review presented in the Introduction. The detailed methodology for computing the SPI can be obtained from Guttman (1999) and McKee et al. (1993) and the methodology for calculating SC-PDSI can be obtained from Wells et al. (2004). Here, only a brief overview is given.

The Standard Precipitation Index is calculated by preparing monthly data sets for the years provided (Table 4). The data sets are averaged over the years into 3-month and 12-month windows to reflect the impact of both agricultural and hydrological droughts respectively. The averages are moving in the sense that each average of 3 months includes the preceding monthly rainfalls. Each of the data sets is fitted to a gamma distribution to define the relationship of probability to precipitation. From this relationship, the probability of observed precipitation is calculated and used along with an estimate of the inverse normal to calculate the precipitation deviation for a normally distributed probability density with a mean of zero and standard deviation of unity. This is done for every month and for every location separately. Hence, the SPI indicates the number of standard deviations that a particular event deviates from normal rainfall value. This makes the SPI normalized in location and time scales. This value is the SPI for the particular precipitation data point. The obtained SPI values were classified into various SPI categories provided by McKee et al. (1993). It should be noted that the SPI value for each month and location has a certain probability value attached to it. For example, moderate droughts (SPI$\leq$ -1) would have a probability of 9.2% and extreme droughts would have a probability of occurrence of 2.3%. Hence, by definition, extreme values will happen with the same frequency, or probability, at all the stations. In this report,

TABLE 4. METEOROLOGICAL STATIONS AND DURATION OF THE DATA SUBJECTED TO SPI AND PDSI CALCULATIONS

Country	Station name	Distance from the study location (km)	Duration of data	Avg. Rainfall (mm)
Bangladesh	Rajshahi	92	1964-2008	1460
India	Kanpur Chakeri	82	1966-1990	837
Nepal	Parwanipur	32	1980-2010	1596

* Source of data: All the data was obtained by the country partners from the respective meteorological departments.

SC-PDSI was calculated by using the compiled program available for download from the Greenleaf Project website of University of Nebraska, Lincoln.[3] The program can be run from dos window of windows operating system. The program needs four input files with monthly temperatures, monthly precipitation, latitude of the weather station, soil available water holding capacity value for the dominant soil type in the area of the weather station and monthly normal temperatures (long-term average of the data under consideration). The program outputs the SC-PDSI data into a dat file that can be read using windows text reader.

The drought analysis was carried out using long-term monthly records of precipitation (SPI and PDSI) and temperature measurements (PDSI). The precipitation data was obtained from the respective meteorological departments by the country partners. The duration of weather data vary from meteorological station to the station due the limited clean data available from the nearest weather station to the study locations. After obtaining the SPI and PDSI values, the values were classified according to the respective classification schemes (Table 3) and the number of droughts were counted and presented in the report.

4.3 RESULTS

As discussed in the methodology, the number of drought incidences was arrived at by classifying the drought events using the SPI and PDSI classification given by Zhai et al. (2010). The results presented in Figure 11 indicate wide variation in number of droughts within and across the study locations.

Number of droughts

PDSI resolved more number of droughts than SPI across the study locations and mostly in extreme and severe dry categories. This behavior of PDSI has already been well recognized in the literature (Willeke et al., 1994). Out of total meteorological events resolved by PDSI, only 8% of them fall under 'dry' category (sum of extreme, severe and moderate droughts) in Bangladesh, 30% in India and 22% in Nepal. By this distinction, the site in India can be considered relatively more drought prone followed by Nepal and Bangladesh. This observation correlates with that of the long-term average annual rainfall in these sites (Table 4) wherein the site in India records least long-term average rainfall followed by Nepal and Bangladesh. The most number of severe droughts were observed in India followed by Nepal and Bangladesh. The PDSI has produced more number of near normal events in Bangladesh (87%) than in other sites.

SPI values were calculated for 3- and 12-month running averages for resolving agricultural and hydrological droughts respectively in the study locations. In general, 3-month SPI values tend to identify more drought events than 12-month SPI values which indicate the presence of more of short-lived droughts than the long-term droughts in the study locations. From the 3-month SPI values, it can be seen that about 17% of spells fall under drought range in Bangladesh and India while it is slightly higher in Nepal (18%). 3-month SPI values are important for better understanding the impact of drought on agricultural and other livelihood activities, which depend on short-term water supplies through precipitation. A similar situation is also observed in the 12-month SPI values. The 3-month SPI identifies less number of extreme, severe and moderate droughts in Bangladesh and India. However, the contrary can be seen in the 12-month SPI

[3] http://greenleaf.unl.edu/

values wherein more extreme droughts can be seen as compared to the 3-month SPI values in all the locations. 12-month SPI values indicated more extreme droughts in Bangladesh followed by India and Nepal. Among the severe drought spells, 12-month SPI reported similar values for both Bangladesh and Nepal. From the 12-month SPI values, it can be deduced that only 7% of total events fall under drought category in India while it is 16% in Bangladesh and 20% in Nepal.

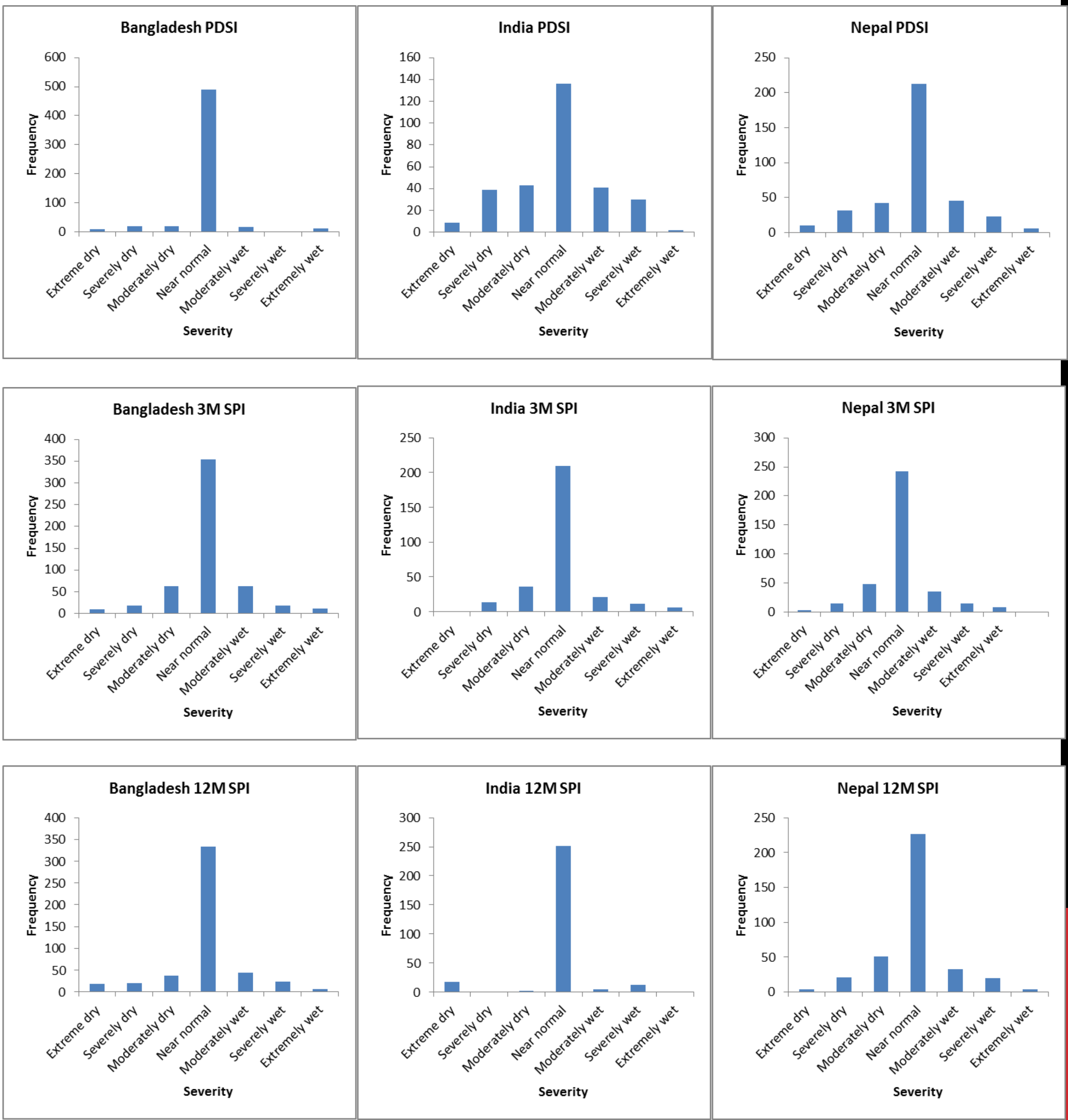


FIGURE 11. FREQUENCY OF DIFFERENT CATEGORIES OF DROUGHTS IN THE STUDY LOCATIONS AS RESOLVED BY PDSI, 3- AND 12-MONTH SPI VALUES

Long-term trend of SPI and PDSI values are plotted in Figure 12. Such graphs provide a comprehensive view on how SPI and PDSI values have changed over the years. An alternating cycle of positive and negative SPI values are conspicuously observed at many locations while other locations show continuous negative SPI values after certain duration (more conspicuously in the case of 12-month SPI values in India). While the 3-month SPI figures are little difficult to read, the 12-month SPI values provide a clear picture of trends in SPI values, mostly on the alternate wet and dry cycles prominent in this part of the world.

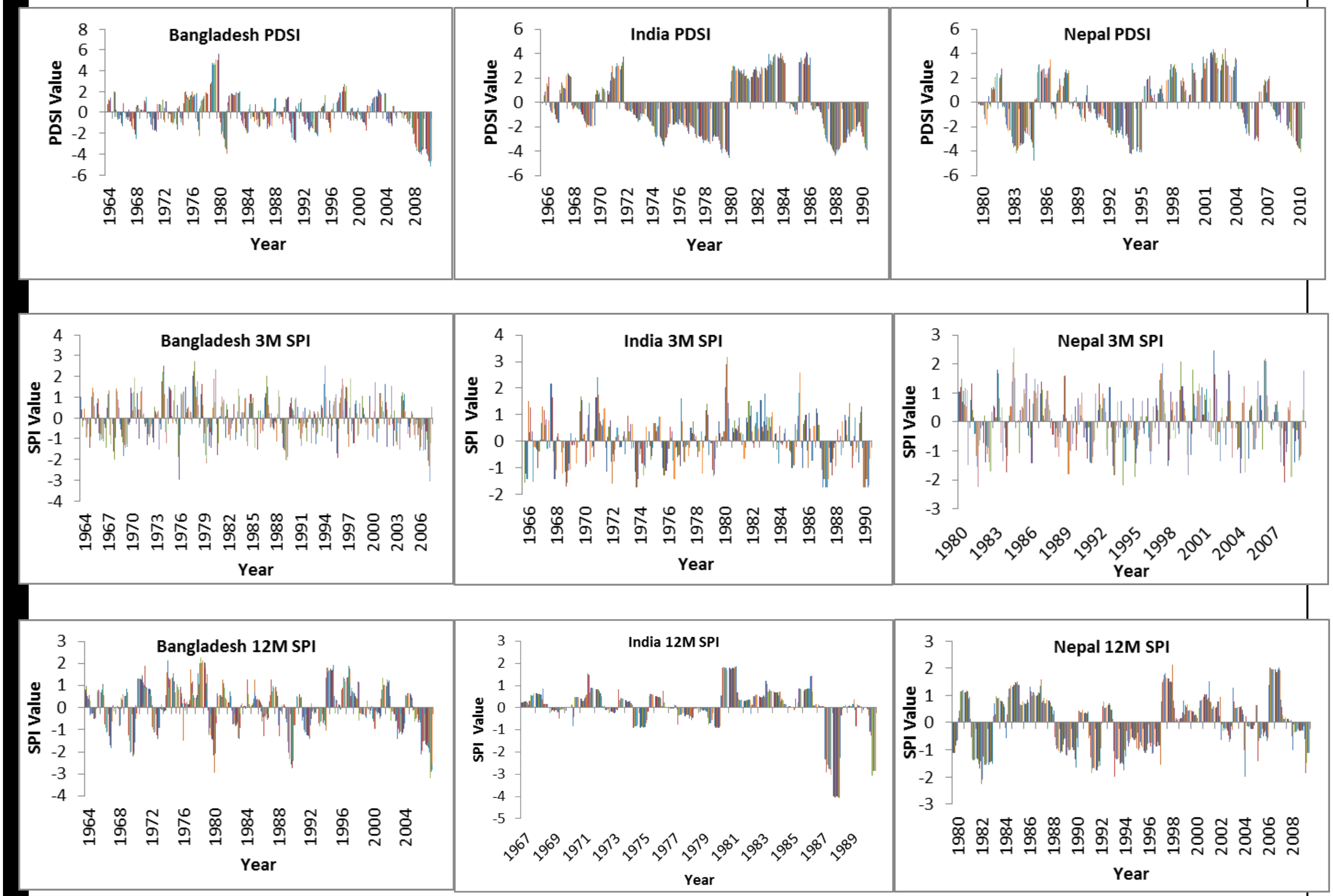


FIGURE 12. LONG-TERM TRENDS IN PDSI (TOP ROW) AND SPI (3- AND 12-MONTH) VALUES IN THE STUDY LOCATIONS

Duration of droughts

Both SPI and PDSI could be used for estimating the duration of drought events. Here, the duration of a drought is defined as the time between consecutive negative index values and ending following a positive index value. Such a definition is highly functional as it is easy to use and helps local irrigation managers to compute the average duration of the drought in a given location for which they should plan ahead in terms of water resources available. This can also help in alerting the water demand sectors on the need to manage available water sources to ward off the impending drought impacts. It should be noted that a less frequent 3-months droughts may also make a region more vulnerable if no appropriate preparedness and mitigation actions are put in place. Hence, the timing of the drought is also important in addition to the duration and intensity. Among both SPI and PDSI, 3- month SPI was able to resolve more number of droughts in the duration of 1-5 months and PDSI in general returned more long-duration droughts (drought spells more than 5 months). Longer drought spells were recorded in Bangladesh followed by India using PDSI. More number of 1-month long droughts were recorded in India and Nepal followed by Bangladesh. In general, Bangladesh recorded more number of longer duration droughts when 3-month SPI values were considered.

4.4 PROJECTED DROUGHT CONDITIONS

This research doesn't project the future drought conditions in the Gangetic basin due to climate change and it is beyond the scope of this report to reproduce the vast amount of literature available on projected climate change in South Asia. However, a brief literature is summarized here to help the reader understand the projected drought conditions for the region and emphasize the importance of continued drought risk reduction for the Basin.

Since the historical drought analysis was conducted using Standardized Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI) in this study, it is worthwhile to look at the future projections of these indices for the Gangetic basin and surrounding regions. The significant related literature comes from the work of Dai (Dai, 2013) who projected the drought conditions globally using PDSI. Though not much discussion was related to Gangetic basin in this paper, the paper indicated the future dryer climate in South Asia with negative SC-PDSI values over the Gangetic basin area (as shown in Figure 2a and 2b in Dai, 2013). However, it was not clear if the Gangetic basin would become drier than the past records since the historical analysis of drought by the same author (Figure 7 in Dai et al., 2004) indicated prevalence of drier conditions in South Asia in general and Gangetic basin in particular for the records analyzed for 1950-2002. In general, this paper indicated a progressively drying climate for the South Asia from 1900 to 2002.

The 4x4 assessment report by the Ministry of Environment, Government of India offers one of the most recent synthesis works on climate change impacts in India in which most parts of the Gangetic basin falls (Ministry of Environment, 2010). The report emphasizes the possibility of reduced flows in river Ganges as a result of retreating glacier Gangotri that feeds the Ganges river significantly impacting the livelihoods of downstream communities. In addition, the report suggests the possible decline in runoff in the river basin, despite increasing precipitation, due to increased evapotranspiration and variation in the distribution patterns of the rainfall. The other factor that could negatively influence the water resources in the region is the possibility of increased sedimentation due to favoring precipitation and land-use change patterns projected in the region. The report also predicts a moderate to extreme drought scenario for the Himalayan region despite the above projected increased rainfall due the above discussed factors. Using the Model for Interdisciplinary Research on Climate (MIROC), research carried out by Hirabayashi et al., (2008) projected the possibilities for both increasing floods and droughts in the Gangetic basin and this is largely due to increase in heavy precipitation.

Using the Soil and Water Assessment Tool, SWAT) the research carried out by Gosain et al (2006) projected the seasonal or regular water stress conditions in the Gangetic basin. These results are further corroborated by similar studies carried by Gosain et al. (2011), the projected PDSI has indicated increase in drought severity from base line to midcentury scenario for the state of Madhya Pradesh which also falls within the Gangetic basin (south to the study location identified in this project). All these studies corroborate the fact that the Gangetic basin has drier future climate with high probability for moderate to intense drought spells in the region.

5. SURVEY FINDINGS

5.1 BANGLADESH

Golam Rabbani and S.S. Haider, BCAS, Bangladesh

In Bangladesh, the structured questionnaire surveys were conducted in four villages of Nachole upazila in the district of Nawabganj. A total of 211 filled questionnaires were obtained among which 73% were male respondents, 41% identified themselves as low income group and 57% of respondents owned land more than 6 ha (or 5 bigha). The results are presented as percentage of respondents and the statistical significance test results are presented using Pearson Chi Square test of independence.

General understanding on climate change

The survey results showed that about 99% of the respondents have observed some changes in drought characteristics (Figure 13). 81% of the male respondents were aware about the climate is changing and main sources of their awarness was from mass media and from their own experience.

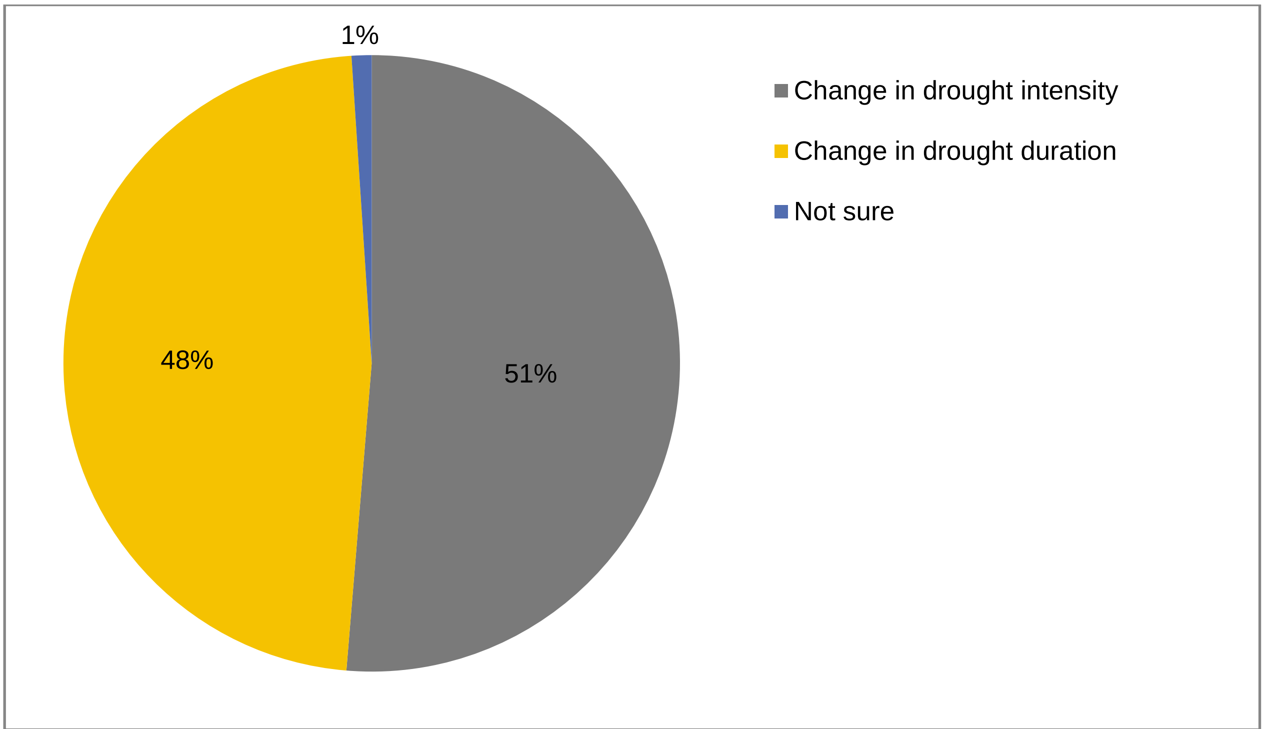


FIGURE 13. CHANGE IN DROUGHT CHARACTERISTICS

Nachole upazila is situated in Barind tract and it is the driest region of Bangladesh. Many of the respondents were 'aware' about climate change and reported about the changing characteristics of the drought in the region (e.g. change in drought intensity and duration). They also reported changes in terms of increasing temperatures, declining rainfall, and intense winters. Main drought impacts identified by the community on agricultural crop were loss of production due to increase pest attack, less water availability for irrigation, increase in crop disease, and loss in production of fruits such mangoes. The responses indicated that the increasing length of droughts is disturbing their traditional agriculture calendar. They opined that the change in drought characteristics was due to changes in weather conditions especially amount of precipitation, changes in human activities such as over extraction of groundwater, changes in cropping pattern, deforestation, and climate change.

Repeated droughts have caused different impacts on agriculture in the study area. Crop losses from pest attack are found to be one of the primary production problems for farmers in this region. Figure 14 shows the impact of climate change on agriculture sector.

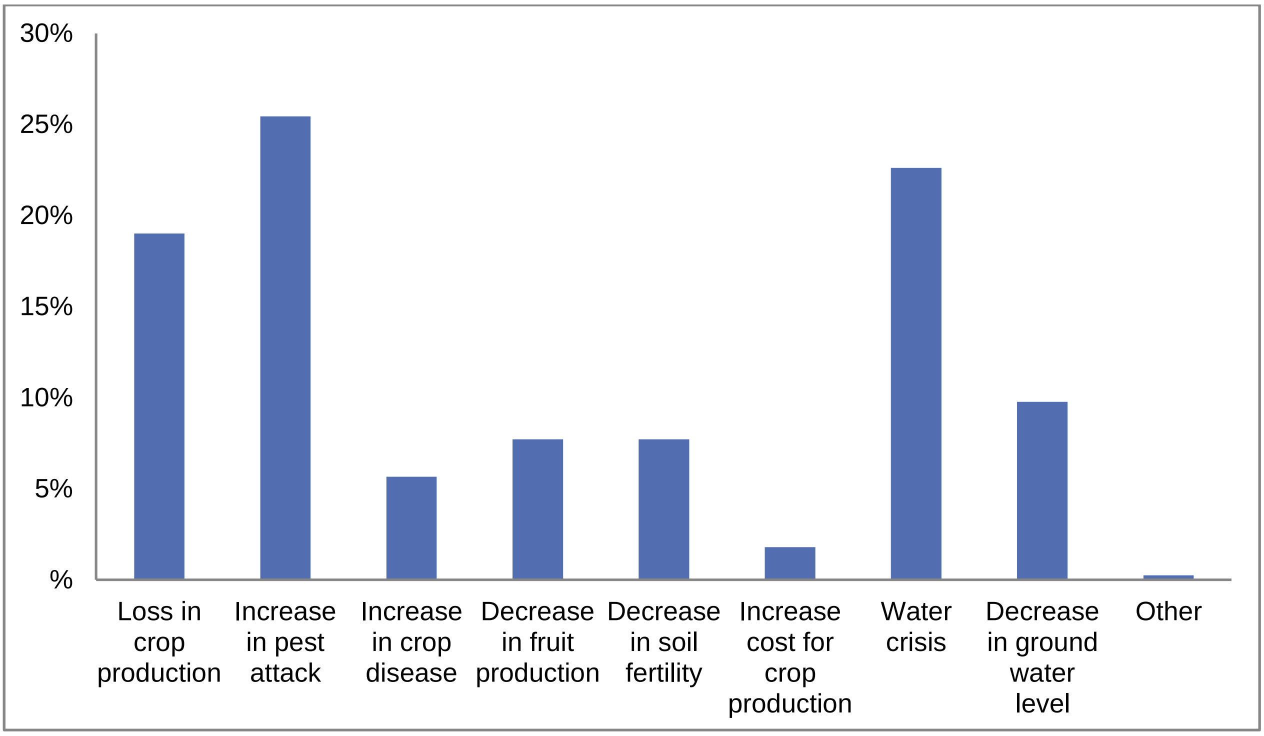


FIGURE 14. IMPACT OF CLIMATE CHANGE ON AGRICULTURE CROP SECTOR

Uncertainty of rainfall during dry period reduces potential yields of broadcast, *T. aman* and *rabi* crops. High yielding *Boro* rice is cultivated in 88% of the cultivable area of the country, grows during this time. A deficit of rainfall during this period causes huge damage to agriculture and to the economy of the country. For example, drought in 1995 has led to a decrease in rice and wheat production to the tune of 3.5 X 10^6 ton in the country (Rahman and Biswas, 1995). In Bangladesh, it is estimated that 10-15% yield losses occur due to insect damage alone. According to the respondents, pest attack is the second most important impact of drought in agriculture sector. Many farmers complained about increasing incidence of '*Morok rog*' a form of dieback disease affecting the paddy crop in the region. Majority of the farmers are using chemical pesticides and increasing pesticide spray is leading to declining natural enemy population and crop profit. Almost all water-bodies in the study area dry up during the dry season and make communities completely dependent on groundwater. The area is also highly prone to droughts because of high rainfall variability (Shahid, 2008; Shahid and Behrawan, 2008). As a result, groundwater becomes the only source of water during dry period in the region. However, groundwater is also deleting fast due to extensive withdrawal for irrigation in the Barind tract. The rapid decline of groundwater in the northwestern region within the operating ranges of shallow and deep tube wells during dry season is increasingly becoming a major problem. According to a recent BADC survey (Bangladesh Agricultural Development Corporation, 2002 as sited by Shahid and Hazarika, 2010), the ratio of surface water and groundwater use for total irrigated agriculture has been changing rapidly in Bangladesh in last two decades. The contribution of groundwater has increased from 41% in 1982/1983 to 75% in 2001/2002 and surface water has declined accordingly (Shahid and Hazarika, 2010).

Adaptation options

Infrastructure related adaptation options followed in the surveyed villages fall under the irrigation category as water scarcity during the drought is the most severe problem for farmers (Figure 15). Existing adaptation options are mainly use of water from deep and mini deep tube well, pumping water from an existing pond, and 3) use of plastic pipe for irrigation. Construction of levies around farms has been practiced in the region since time immemorial.

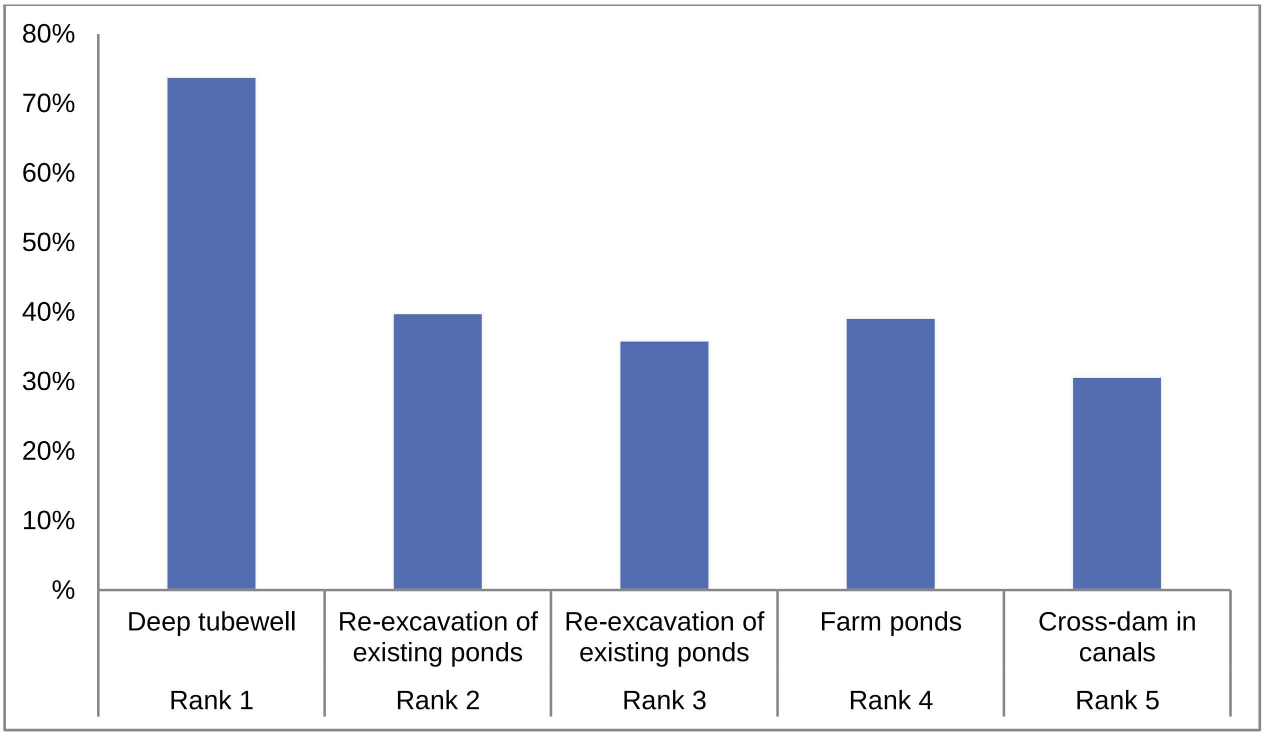
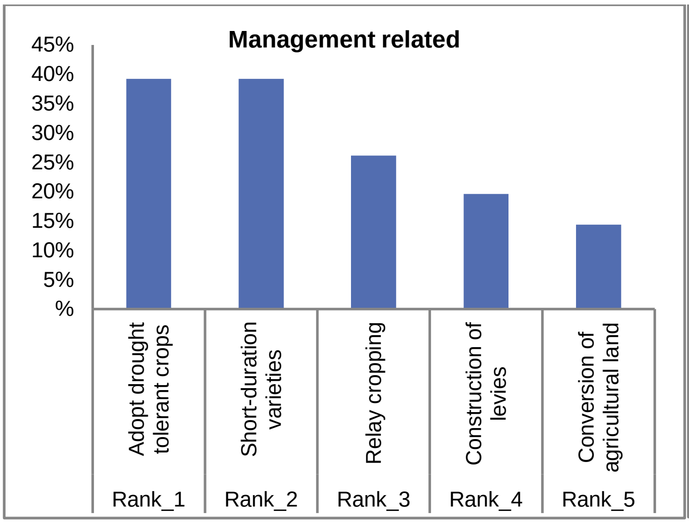


FIGURE 15. FIVE MOST IMPORTANT INFRASTRUCTURE RELATED ADAPTATION OPTIONS

Results show that deep tube wells were ranked as first choice by majority of community respondents as an important infrastructure related adaptation option. The possible reason for this could be its ability to provide water during the dry period to a large area. Though communities believed that this is the first-to-resort option for coping with the drought, the extensive use of deep tube wells has resulted in rapid ground water depletion in the region. The community respondents said that in last six years the groundwater level has decreased by about 5 m. Majority of the farmers are aware of the fact that if they continue to use deep tube well at the current rate in future they will suffer from intensive water scarcity. However, ensuring present day income is their first priority and at present they do not have any other effective measure to replace deep tube well. Several respondents opined that the re-excavation of existing big ponds dug by the government can solve their water crisis to some extent. It is necessary to construct more ponds in the area as for holding large quantity of water s it can reduce the dependency on the ground water and the water can be used for other household purposes. They opined that mini ponds are not suitable for extreme drought prone areas as they can only supply water for a small area of land and for few irrigations.

Drought tolerant and short duration crop varieties were ranked as first and second most important management related adaptation options by the respondents (Figure 16). Both drought resistant and short duration crop varieties allow farmers to minimize their loss from drought. As rice and other crops are gradually becoming susceptible to increasing temperatures and droughts, farmers prefer drought tolerant varieties. For example, BINA Dhan-7 is a drought tolerant paddy variety and provides better yield during drought years. However, as this variety is cultivated only by few farmers, it suffers from severe pest attack. During the focus group discussions, farmers suggested that increasing the area under this variety could reduce the pest attack and related yield loss.



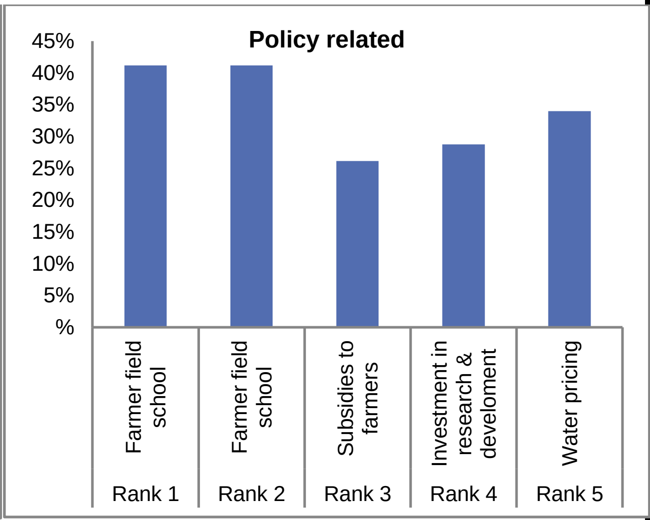


FIGURE 16. FIVE TOP MANAGEMENT AND POLICY RELATED ADAPTATION OPTIONS

Among the policy related (or soft) adaptation options, majority of the farmers reported that they need training in farmer field schools to obtain necessary skills and knowledge to adapt to the changing climate. Farmer field schools were ranked both first and second priority by most respondents (Figure 16).

Adaptation effectiveness indicators

Community respondents were presented with a final set of adaptation effectiveness indicators that were vetted at the national level expert consultation meeting organized in Dhaka. These indicators were categorized into environmental, social and economic effectiveness.

Majority of respondents (76%) identified the period of fresh water availability as the most important environmental indicator reflecting the effectiveness of adaptation actions ranked in the previous section (Figure 17). This was mainly due to the persistent drought and water scarcity in the region. This was followed by the net primary productivity, change in ground water level and nutrient balance in soil and water systems. To monitor the social effectiveness, the following indicators were ranked in the order of importance in measuring the adaptation effectiveness (Figure 17): calorie intake per person (both first and second ranked), rate of employment and % of households having access to safe drinking water. Social capital and equity were one of the most often cited indicators during the individual discussions with the respondents. The community respondents believed that, mostly the women folk, providing diversified income sources to women could reduce their dependency on men for regular home-management and could empower them.

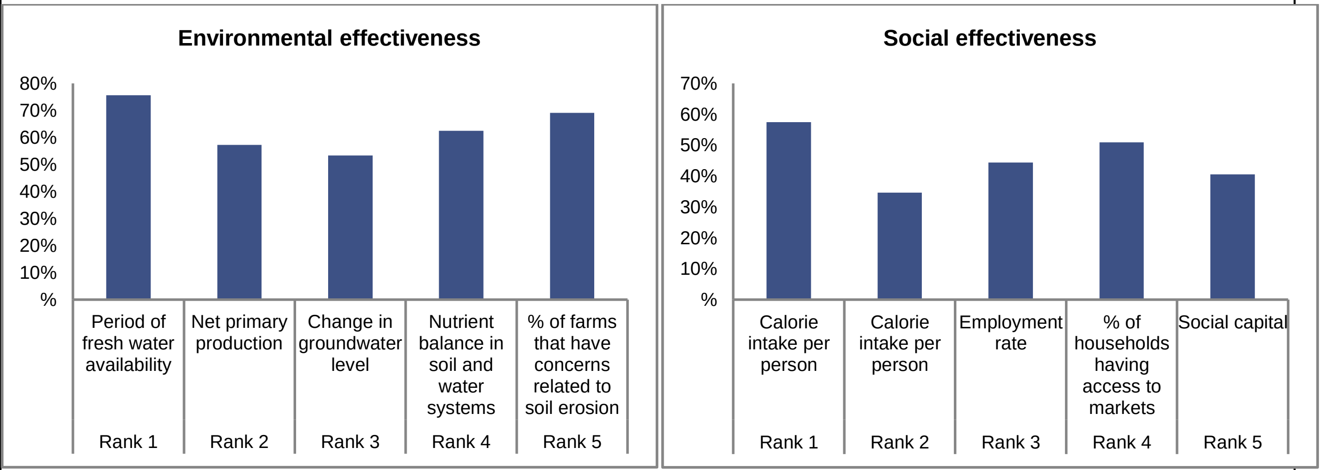


FIGURE 17. INDICATORS FOR MONITORING THE ENVIRONMENTAL AND SOCIAL EFFECTIVENESS

TABLE 5. ASSOCIATION BETWEEN INDICATORS AND OTHER PARAMETERS

Associations	Chi square Value	P value
Options vs indicators		
Crop yield and yield variability	48	0*
Market price of commodities	38	0.002*
Market price of agro inputs	18	0.319
Damage per household/farms due to extreme events	32	0.010*
Number of jobs created	47	0*
Economic status vs indicators		
Calorie intake per person	9	0.323
% of households having access to safe drinking water	9	0.322
Employment rate	14	0.086
Social capital	10	0.143
% of households having access to markets	7	0.485
Gender equity	1	0.662
Gender vs indicators		
Period of fresh water availability	13	0.001*
Net primary production	20	0.001*
Change in ground water level	8	0.097
% farms with erosion concern	1	0.830
Nutrient balance in soil and water	4	0.390

Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association*

During the survey, several farmers mentioned the lack of direct access to the market due to presence of middle men because of which they are not able to sell their produce at profitable prices. Currently, middlemen buy crop at low price from farmers and sell at high prices. Sometimes the farmers have to sell at such a low price that the returns could hardly cover their expenses. Although government has fixed the price for many crops, the farmers are not able to get direct benefit from the fixed price policy of the government due to the presence of middlemen. The farmers' direct participation in the market and transport of farm produce has been weekly developed in the study area. Our discussions have revealed that it is crucial to provide timely and fair agricultural marketing information to help farmers to fetch a fair price. Another issue that came up predominantly was the ownership of assets by women which was found to be one of the main reasons behind lack of empowerment of women in the region. This made them dependent on men for income as a result of which the decision making in the household was predominantly by men. Although women involve in income generation activities such as agriculture, the income generated by women often do not put them at par with men and hence the gender equity (this social indicator was not included in the structured questionnaire survey) was identified an important indicator in this area.

Associations between three sets of parameters were tested using the Pearson Chi Square test. The combination of associations tested was: Indicators vs options, economic status vs indicators and gender vs indicators. The results are tabulated below (Table 5). Five indicators were tested for their association with adaptation options. It was found that other than the market price of agro inputs, all other indicators had significant association with the practice. This implies that all those respondents who identified a particular practice as an important adaptation option have tendency to rank a particular indicator as more important against other indicators. Results of association tests in rest of this report should be read in this manner. For example, those who identified deep tube well as an important adaptation option had a greater tendency of ranking crop yield and yield variability as important indicators against other indicators.

Among the association between indicators and economic status, none of the indicators showed significant association with economic status. This indicates the lack of tendency for different economic groups to rank indicators differently. Although low income respondents relatively gave high rank to social capital than other economic classes and more middle income respondents preferred the indicator of high employment rate, all these differences were only numerical and were statistically not significant. All high income respondents gave relatively low preference to all these indicators. The Pearson Chi Square test of association was conducted between gender and five indicators. The results have indicated the presence of significant association between for two out of five indicators tested and gender. The indicators period of fresh water availability and net primary production were more preferred by male respondents than female respondents. All other indicators did not show any association with the gender.

5.2 INDIA

Divya Mohan and Himany Upadhyay, TERI, India

In India, the main structured questionnaire survey was done in the form of individual interviews for 195 respondents. Most of the respondents were in the age group of 25 to 65 and all of them were primarily farmers. Majority of them had more than ten years of experience in farming and more than 65% of the respondents belonged to middle income group while the rest were from the low and high income group based on area of land owned.

General understanding on climate change

A few questions were asked in the beginning of the questionnaire to get insights on respondents' understanding of issues related to climate change and its impact on their livelihoods. Almost all the respondents informed that they are aware about changing climate. When asked about the source of their awareness, more than 75% of them said that it is based on their direct observation. They themselves have observed changes in the rainfall and temperature patterns. Some of them responded that they came to know about the changing climate through their friends. Most of them said they have observed changes in the drought characteristics in their region. 60% of the respondents said that the change has been primarily observed in the duration of drought (increasingly longer droughts) while the rest of the respondents observed changes in drought intensity.

Adaptation options

The respondents were asked to rank the likely adaptation options relevant for their region in order to cope with the climatic hazards such as droughts keeping in view their past observations of the trends in drought intensity and duration (Figure 18).

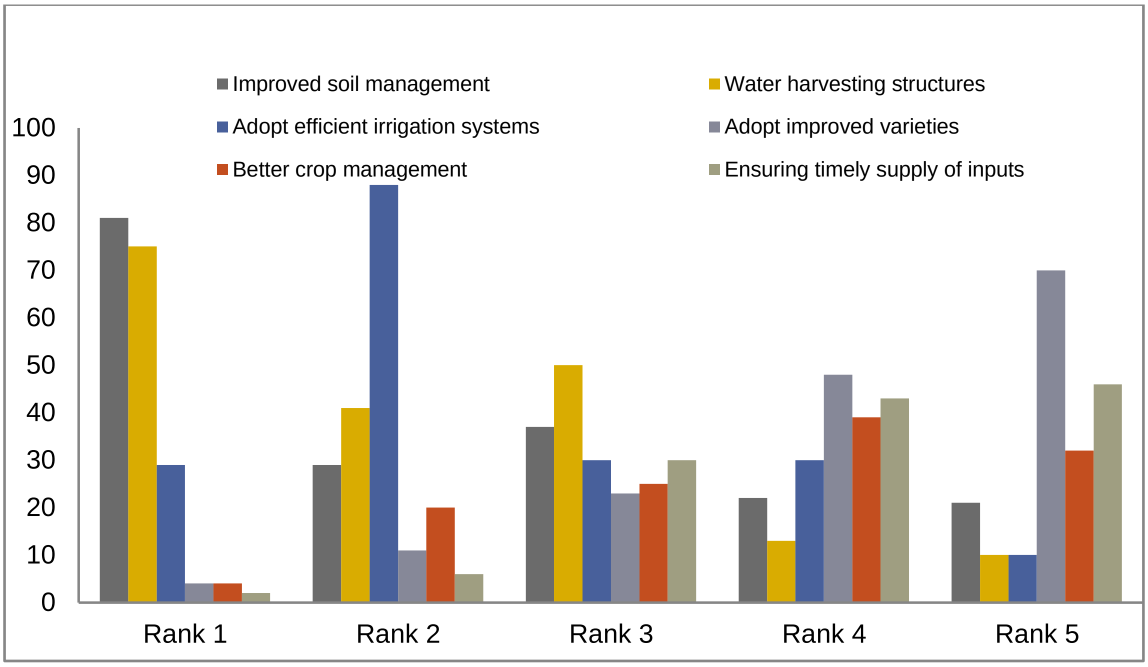


FIGURE 18. TOP RANKED INFRASTRUCTURE AND MANAGEMENT ADAPTATION OPTIONS

FIGURE 19. SOIL CONSERVATION PRACTICES IN VOGUE IN KANPUR DEHAT DISTRICT, INDIA

As seen in Figure 18, most of the respondents have chosen improved soil management as the top ranked management adaptation option while infrastructure options such as water harvesting structures that increase the water availability were chosen as second most preferred option. Hence, here the management options were preferred the most to the infrastructure options. This could be due to the reason that there is already a heavy emphasis on infrastructure related drought mitigation in the region (see Figure 19). Adoption of heat and drought tolerant crop varieties was ranked 4 and 5. For the policy related adaptation options, the respondents preferred water conservation policies followed by policies for promotion of efficient irrigation systems and credit facilities.

Adaptation effectiveness indicators and associations

Ranking of indicators for monitoring the effectiveness of adaptation options was done with respect to the infrastructure interventions of construction of bunds and check dams implemented in the study site by the local organization (refer to the description of the study location). A total of nine environmental effectiveness indicators related to water, soil and crop productivity were included in the questionnaire. The data shows that most number of respondents (nearly 60%) consider increased water availability for irrigation as the top most important indicator to monitor environmental effectiveness of adaptation options (Table 6). The second most often chosen indicator for rank 1 is duration of water stress period followed by change in groundwater level.

As seen in Table 6, indicators related to water stress period and change in groundwater level was most chosen indicators by the respondents for second and third rank respectively. For the 4^{th} rank, soil productivity has been most often chosen indicator while for the 5^{th} rank it was percentage of farms having concerns on soil erosion. The major indicators for social effectiveness were related to food availability, health care, and access to safe drinking water (Table 7). As evident from Table 7, food self-sufficiency along with the access to and availability of food was most frequently chosen indicators to monitor social effectiveness of adaptation options. Most of the respondents felt that food availability is the most important factor for them. The next most often chosen indicator was percentage of income used for health care and number of children going to school. The most often chosen indicator for rank 2 was the number of children going to school and for rank 3 it was percentage of income spent on health care. Figure 20 shows the responses on indicators related to economic impact of adaptation options.

TABLE 6. RESPONSES FOR INDICATORS OF ENVIRONMENTAL EFFECTIVENESS

Indicators	Rank 1	2	3	4	5
Increased water availability for irrigation	115	40	20	7	1
Duration of water stress period	37	71	20	27	12
Vegetative cover	9	29	17	15	17
Total biomass produced	3	11	14	20	24
Change in groundwater level	17	25	68	25	20
Percentage of farms soil erosion concerns	2	3	23	22	42
Soil Productivity	10	15		38	34
Input use efficiency	0	0		35	31
Crop diversification	2	1		6	13

TABLE 7. RESPONSES FOR INDICATORS OF SOCIAL EFFECTIVENESS

Indicators	Rank 1	2	3	4	5
Access to and availability of food	57	43	22	16	35
Percentage of income used for health care	24	45	51	43	21
Food self sufficiency	70	22	31	29	27
Children under the age of five with symptoms of malnutrition	3	6	8	10	20
Access to safe drinking water	15	13	20	27	35
Number of children going to school	23	59	37	25	27
Social capital	4	8	27	46	28

Figure 20 shows total farm income as the most preferred economic effectiveness indicator to monitor economic effectiveness of adaptation options. This was followed by the increase in assets and disposable income as second and third most preferred indicators. The other most preferred indicators include inter-annual stability of household income, damage per household due to drought and share of non-agriculture income. During the focus group discussions, most respondents reported the need for the diversified income opportunities that would make them less dependent on agriculture income during drought years (this option was not included in the structured questionnaires).

ANALYSIS OF ASSOCIATIONS

The response were analyzed for associations in four main categories: association between gender vs top ranked indicators, economic status vs top ranked indicators, highest ranked criteria vs indicators and practice group vs top ranked indicators. Such an analysis of associations provides useful insights into what influences the choices made by the respondents. For this, the Pearson chi square test was performed.

i. Gender vs top ranked indicators

Gender is one of the key factors considered for understanding the pattern of ranking indicators by respondents. A comparison was done between gender wise distribution of respondents and their respective ranking of indicators to monitor effectiveness of adaptation options. Table 8 summarizes the results. The null hypothesis in this case was that gender and ranking of indicators are independent of each other and there is no association between these two.

The p values show that there is no association between the two variables, for all the top five ranked indicators in all the three categories of effectiveness, the p values obtained are above the significance level and thus inferring that the indicators of effectiveness of adaptation options is independent of gender influence.

ii. Economic status vs top ranked indicators

In this test of association, economic status was taken as one of the factors for selecting the respondents of this survey (Table 9). The respondents were from three main economic groups – low, medium and high based on the area of land owned by the farmer. The null hypothesis for this was the economic status of the individual and their responses on ranking of indicators are independent of each other.

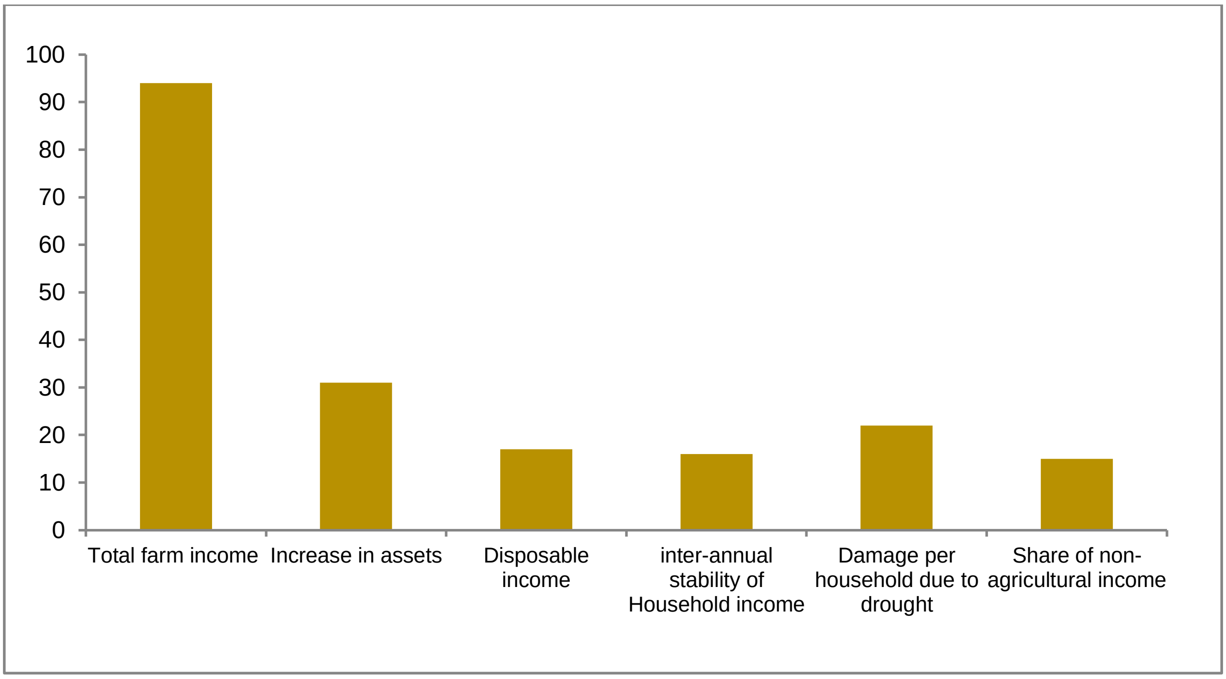


FIGURE 20. TOP RANKED ECONOMIC EFFECTIVENESS INDICATORS

TABLE 8. ASSOCIATION BETWEEN GENDER AND ADAPTATION EFFECTIVENESS INDICATORS

	Pearson chi-square	P value
Gender vs. Indicators of Environmental effectiveness		
Rank 1 indicator	4.477	0.723
Rank 2 indicator	1.447	0.984
Rank 3 indicator	12.781	0.120*
Rank 4 indicator	7.742	0.459
Rank 5 indicator	3.386	0.908
Gender vs. Indicators of Social effectiveness		
Rank 1 indicator	4.115	0.661
Rank 2 indicator	4.715	0.581
Rank 3 indicator	4.126	0.660
Rank 4 indicator	6.222	0.399
Rank 5 indicator	0.687	0.995
Gender vs. Indicators of Economic effectiveness		
Rank 1 indicator	8.275	0.142*
Rank 2 indicator	1.032	0.960
Rank 3 indicator	3.988	0.551
Rank 4 indicator	4.754	0.576
Rank 5 indicator	3.208	0.668

Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association*

TABLE 9. ASSOCIATION BETWEEN ECONOMIC STATUS AND ADAPTATION EFFECTIVENESS INDICATORS

	Pearson chi-square	P value
Economic Status vs. Indicators of Environmental effectiveness		
Rank 1 indicator	16.839	0.265
Rank 2 indicator	26.291	0.024*
Rank 3 indicator	34.758	0.004*
Rank 4 indicator	17.600	0.348
Rank 5 indicator	19.019	0.268
Economic Status vs. Indicators of Social effectiveness		
Rank 1 indicator	15.276	0.227
Rank 2 indicator	14.153	0.291
Rank 3 indicator	18.308	0.107*
Rank 4 indicator	9.613	0.650
Rank 5 indicator	6.559	0.885

	Pearson chi-square	P value
Economic Status vs. Indicators of Economic effectiveness		
Rank 1 indicator	9.033	0.529
Rank 2 indicator	15.771	0.106*
Rank 3 indicator	10.750	0.377
Rank 4 indicator	5.563	0.937
Rank 5 indicator	3.166	0.977
Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association*		

The p-values showed a mixed picture for environmental indicators. For rank 1, the p value obtained was higher than the significance level (0.05) indicating no significant association between these two. On the other hand, for the 2nd and the 3rd ranked indicators, the p value obtained was less than the significance value and thus suggesting the presence of association between these indicators and the economic status. For rest of the indicators of environmental effectiveness (4th and 5th), again the p values were higher than the significance values showing their independence. For the other two categories of indicators, i.e., social and economic, all the p values were more than the significance values indicating no association. In summary, for the comparison between economic status and indicators to monitor effectiveness of adaptation options, it can be said that in most of the cases no association could be found between these two variables. It can be inferred that to a large extent economic status does not affect the ranking of indicators of effectiveness of adaptation options.

iii. Practice group vs top ranked indicators

Two sets of respondents were included in the survey–those who have benefited from the adaptation options and those were following traditional practice and not benefited from the adaptation options. A comparison was done between the responses on the ranking of indicators for environmental, social and economic effectiveness obtained by these two practice groups. The null hypotheses for the statistical analysis between practice group and top 5 ranked indicators of environmental, social and economic effectiveness was that the two are independent of each other and there is no association between them.

TABLE 10. ASSOCIATION BETWEEN PRACTICE GROUP AND ADAPTATION EFFECTIVENESS

	Pearson chi-square	P value
Practice vs. Indicators of Environmental effectiveness		
Rank 1 indicator	12.030	0.100
Rank 2 indicator	12.885	0.075
Rank 3 indicator	4.520	0.807
Rank 4 indicator	18.823	0.016*
Rank 5 indicator	3.451	0.903
Practice vs. Indicators of Social effectiveness		
Rank 1 indicator	2.747	0.840
Rank 2 indicator	6.609	0.359
Rank 3 indicator	5.714	0.456

	Pearson chi-square	P value
Rank 4 indicator	4.254	0.642
Rank 5 indicator	6.087	0.414
Practice vs. Indicators of Economic effectiveness		
Rank 1 indicator	0.864	0.973
Rank 2 indicator	2.371	0.796
Rank 3 indicator	5.611	0.346
Rank 4 indicator	3.950	0.683
Rank 5 indicator	1.795	0.877

Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association*

The p values obtained from the Pearson chi-square test showed non-significant association between the practice group and most indicators. This suggests that the respondents tend to identify similar indicators irrespective of whether they were practicing a particular practice or not which is an interesting and useful outcome for project implementers at the ground level who often tend to prioritize and implement projects based on direct and random observations from other areas where these practices are implemented.

iv. Highest ranked criteria vs indicators

A qualitative assessment has was done for understanding the correlation between highest ranked criteria and top ranked indicators for monitoring environmental, social and economic effectiveness of adaptation options (Table 11). The numbers obtained for the choice of the top ranked criteria shows that social acceptability was the most often chosen criteria for both the top and second rank. For the third rank, the responses showed that communicability is the most frequently chosen criteria for prioritizing effectiveness indicators.

Analysis of the pattern of ranking of indicators to monitor the effectiveness of adaptation options by individuals who have chosen social acceptability as 1st rank, social acceptability as 2nd rank and communicability as 3rd rank was done. For the indicators of environmental effectiveness it was found that irrespective of the criteria chosen, the responses for the top 3 ranked indicators are same. Increased water availability for irrigation was most frequently chosen indicator for the top rank by all these three sets of individuals. Duration of water stress period was the second most often chosen indicator while change in groundwater level was the third most frequently chosen indicator. For the 4th and 5th ranks, the responses differ to some extent. However, the indicators most often chosen by the individuals for these ranks were total biomass produced, vegetative cover and soil productivity. Overall, these sets of individuals have considered indicators related to water availability as most important followed by indicators related to biomass production and soil.

For the top three ranks of indicators of social effectiveness, response of the three sets of individuals show that the responses are similar although not exactly same. Access to and availability of food, food self-sufficiency and percentage of income spent on health care are the most often chosen indicators for top three ranks. Thus, for these sets of individuals, food availability and health care are the most chosen indicators for social effectiveness. Number of children going to school and social capital are the most often chosen indicators for the 4th and the 5th rank. The responses for indicators of economic effectiveness also showed that irrespective of criteria people have most frequently chosen gross household income and increase in assets as most important indicators (1 & 2). Disposable income and inter-annual stability of household income were the next most often chosen indicators. This analysis indicates that the most indicators tend to be the same in the top three ranks irrespective of the criteria applied by the respondent. This provides an interesting insight for the possibility of existence of few indicators that could be applied for measuring adaptation effectiveness in a wide variety of situations, practices and possibly climate change impacts.

TABLE 11. INTERACTION BETWEEN MOST OFTEN CHOSEN CRITERIA AND TOP RANKED INDICATORS

Most often chosen criteria	Top 5 environmental indicators					Top 5 social Indicators					Top 5 economic indicators					
Rank 1: Social Acceptability	1	2	5	7	7	1	1	3	6	7	1	2	3	4	6	Most occurring indicator
	26	13	15	12	9	17	12	10	11	8	24	16	12	14	14	Frequency of occurrence
Rank 2: Social acceptability	1	2	5	4	9	3	2	2	5	6	1	2	2	4	2	Most occurring indicator
	16	7	10	7	6	12	9	7	6	7	9	9	8	9	8	Frequency of occurrence
Rank 3: Communicability	1	2	5	8	8	2	1	2	2	7	1	2	2	3	5	Most occurring indicator
	20	14	12	6	9	9	11	13	8	8	12	10	12	9	9	Frequency of occurrence

Where,

Top 5 environmental indicators are: 1=Increased water availability for irrigation 2=Duration of water stress period 3=Green cover 4=Total biomass produced 5=Change in groundwater level 6=% of farms that have concerns related to soil erosion 7=Soil Productivity 8= Input use efficiency 9=crop diversification 10=Vegetative Cover.

Top 5 social indicators are: 1=Access to and availability of food 2=% of income used for health care 3=Food self-sufficiency 4= Children under the age of five with symptoms of malnutrition 5= Access to safe drinking water 6= Number of children going to school 7= Social capital 8=Access to sanitation facilities 9=Access to market 10 =Access to information

Top 5 economic indicators are: 1=Gross household income 2=Increase in assets 3=Disposable income 4=inter-annual stability of Household income 5=Damage per household due to drought 6=Share of non-agricultural income 7=Access to credit

5.3 NEPAL

Nawraj Pradhan, Rajan Kotru and Anju Pandit, ICIMOD, Nepal

In Nepal, a total of 269 structured questionnaires were implemented in four villages of Bara and Parsa districts (the number was derived using the statistical sampling formula presented in the methodology section). 53% of respondents were female, 52% literate and 59% of respondents owned land less than 0.7 ha followed by 30% of respondents owning a land in the range of 0.7-2 ha. Most respondents were farmers (97%) and majority (90%) was farming for more than 10 years. Most respondents work in the service sector as a secondary occupation followed by farm labor and merchandizing.

General understanding on climate change

The survey revealed that all the respondents were aware of climate change, 68% of them reported 'direct observation of changes' (Figure 21), 29% learned about it from multiple sources, 2% from mass media and the rest from friends. 51% of the respondents experienced 'change in drought duration' and 21% felt there was 'change in drought intensity' during recent years (Figure 21).

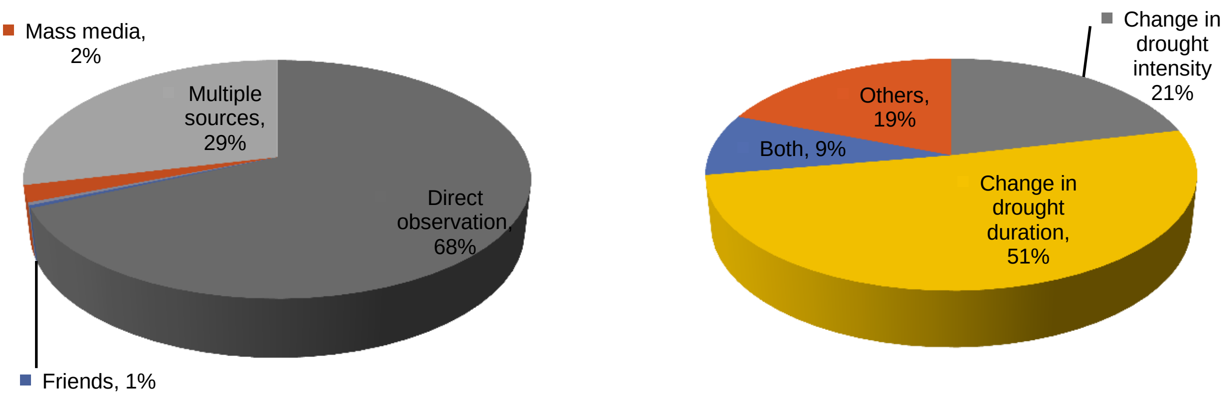


FIGURE 21. CLIMATE CHANGE AWARENESS AND VIEWS ON TRENDS IN DROUGHT

Analysis from the survey showed that 19% of the male respondents and 18 % of the female respondents mentioned about 'decreased production/yield' as an impact of climate change on agriculture (Figure 22). The second major impact of climate change on agriculture was mentioned as 'increase in pest attack' (17% male and 15% female respondents) and the third major impact mentioned was 'degradation of soil quality and decreased fertility'. The respondents from Parsa district ranked both 'decreased production / yield' and 'increase in pest attack' higher than the respondents from Bara. The policy makers have ranked the 'shift in cropping' as the major impact of climate change on agriculture followed by 'degradation in soil quality', and 'pest and insect attack'.

Adaptation options

Three categories of adaptation options were ranked by communities and policy makers: Infrastructure, management and policy.

Infrastructure: The study has shown ‘small irrigation systems’ and ‘canal management through irrigation scheduling in canals’ as most important infrastructure related adaptation option for farmers (Figure 23). Similar responses were obtained from both male and female respondents. Similar findings were obtained from policy makers and administrators.

Management: There was a difference in opinion among male and female respondents in ranking the management related adaptation options. The male respondents gave highest rank to ‘cropping systems’ (intercropping, mixed and early variety rice) whereas female respondents preferred ‘composting and green manuring’. These differences persisted for the second ranked adaptation options for both sexes (Figure 24). Similar findings were obtained from policy makers and administrators.

Policy: There was a common understanding in this region amongst farmers (both male and female respondents) and local administrators in ranking ‘cooperatives’ as a top rank for policy related adaptation option. The other ranks were a mix of ‘microcredit programs’ and ‘micro enterprise development’ (Figure 25). This is understandable for the reason that the farmers often use irrigation infrastructure such as pump sets and groundwater tube wells for irrigating their fields and there is an informal economy devleoped around this practice in the region where in cooperatives were instrumental in perpetuating the irrigation infrastructure among communities.

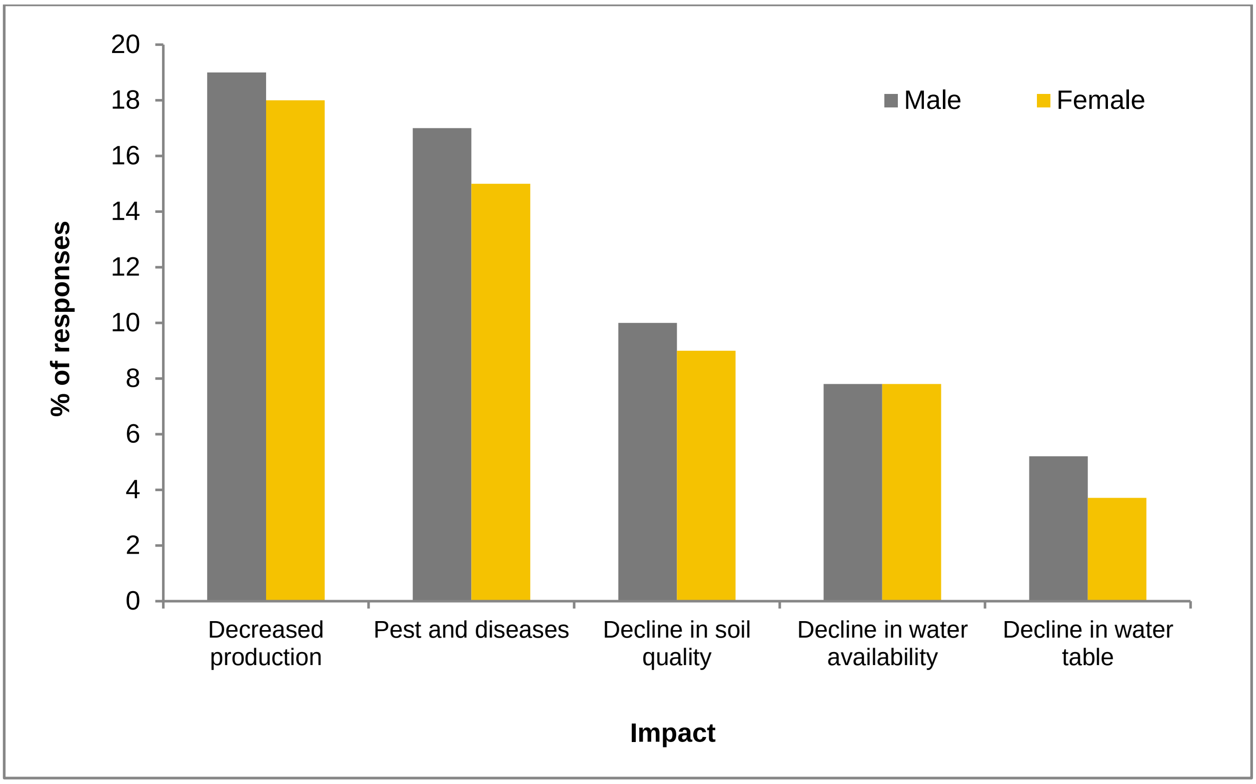


FIGURE 22. COMMUNITY RESPONSES ON IMPACT OF CLIMATE CHANGE

Criteria Ranking: Communities were asked to rank the criteria based on which they identified certain indicators as important against other indicators (Figure 26). Though this could have been done for each indicator ranked, it was tedious for each respondent to identify based on what criteria the respondent gave a particular rank to each indicator. Since most respondents will have a certain ‘world view’ of what is important for them, the respondents were asked to provide an overview criteria he or she had in mind while ranking the indicators throughout filling a questionnaire. Most community respondents ranked ‘simplicity’ and ‘measurability’ as top criteria based on which they expressed their opinion on indicators. In comparison, policy makers chose ‘vertical scalability / applicability’, ‘cost effectiveness’ and ‘scientific basis’ as top ranked criteria for ranking adaptation effectiveness indicators (not shown in the figure).

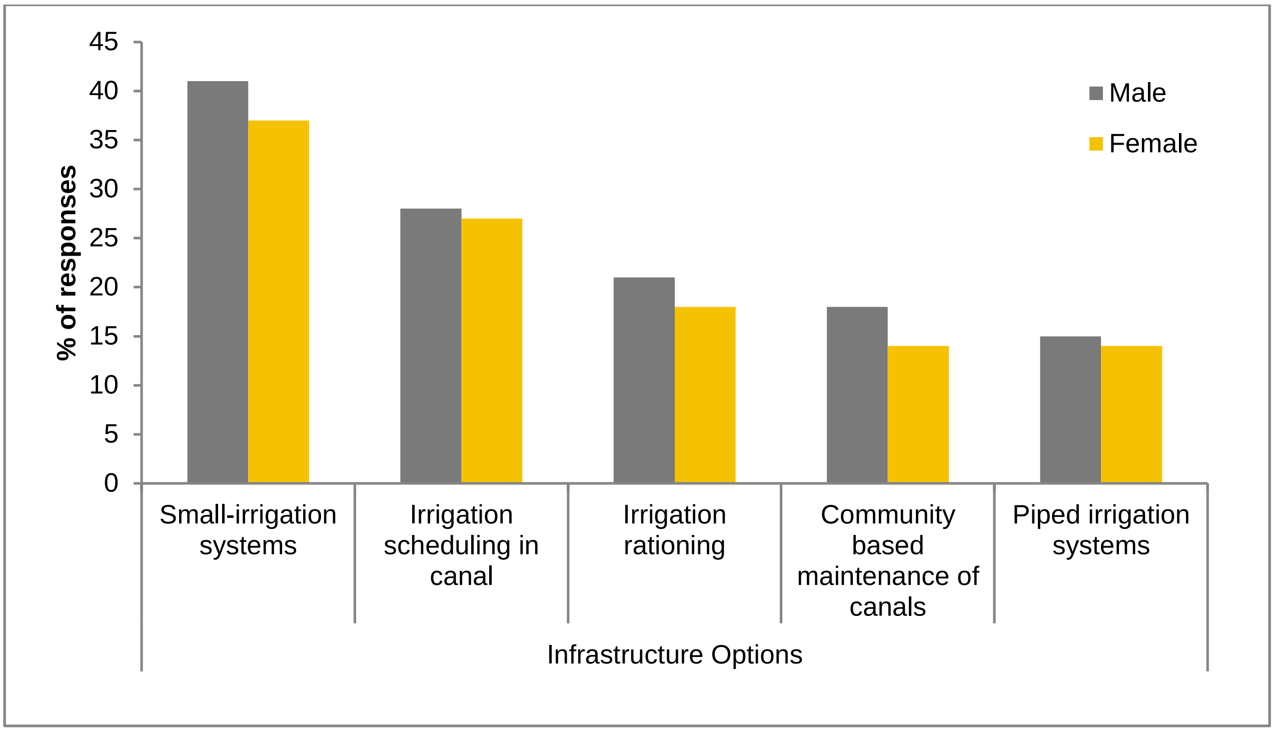


FIGURE 23. RANKING OF INFRASTRUCTURE RELATED ADAPTATION OPTIONS (COMMUNITIES)

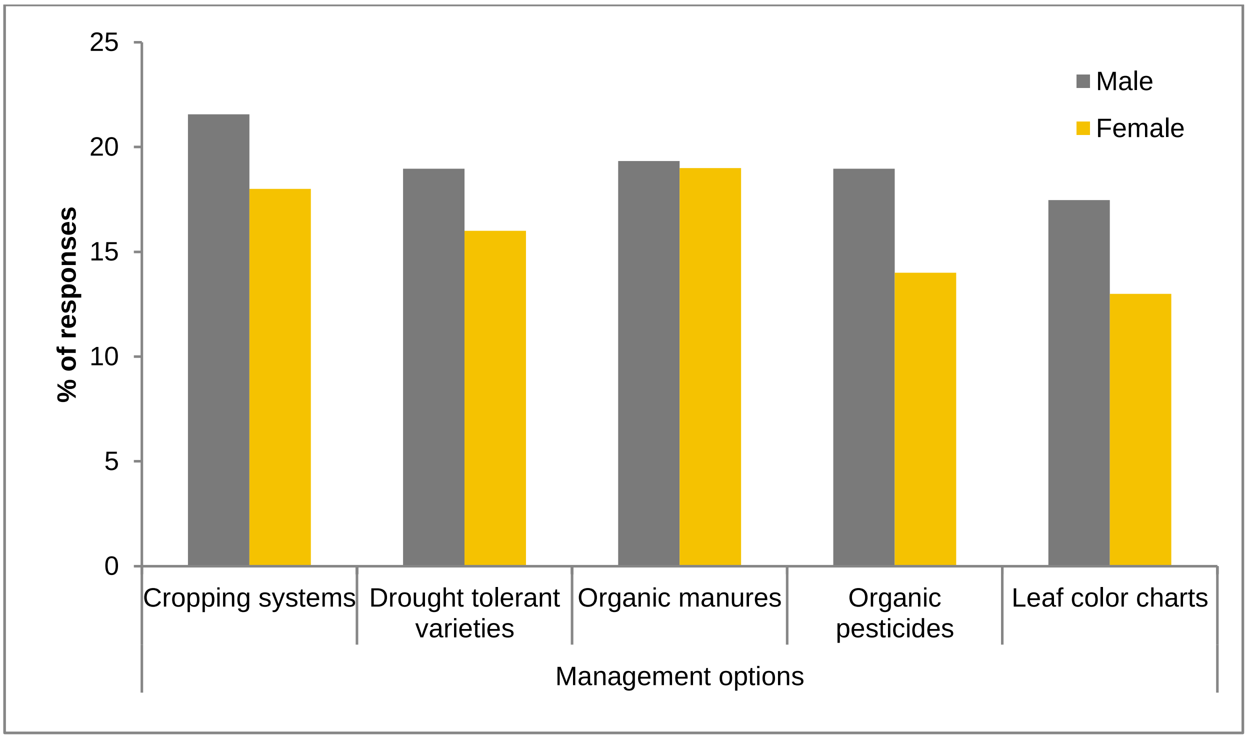


FIGURE 24. RANKING OF MANAGEMENT RELATED ADAPTATION OPTIONS (COMMUNITIES)

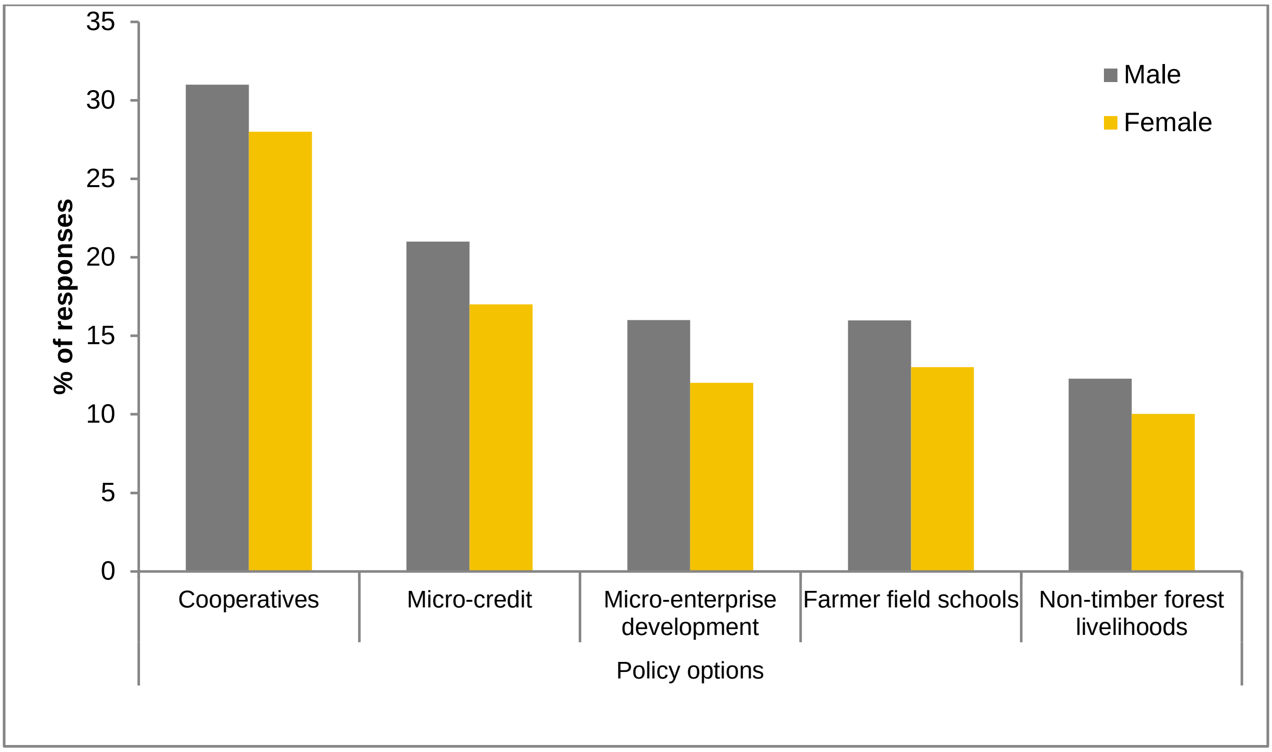


FIGURE 25. RANKING OF POLICY RELATED ADAPTATION OPTIONS (COMMUNITIES)

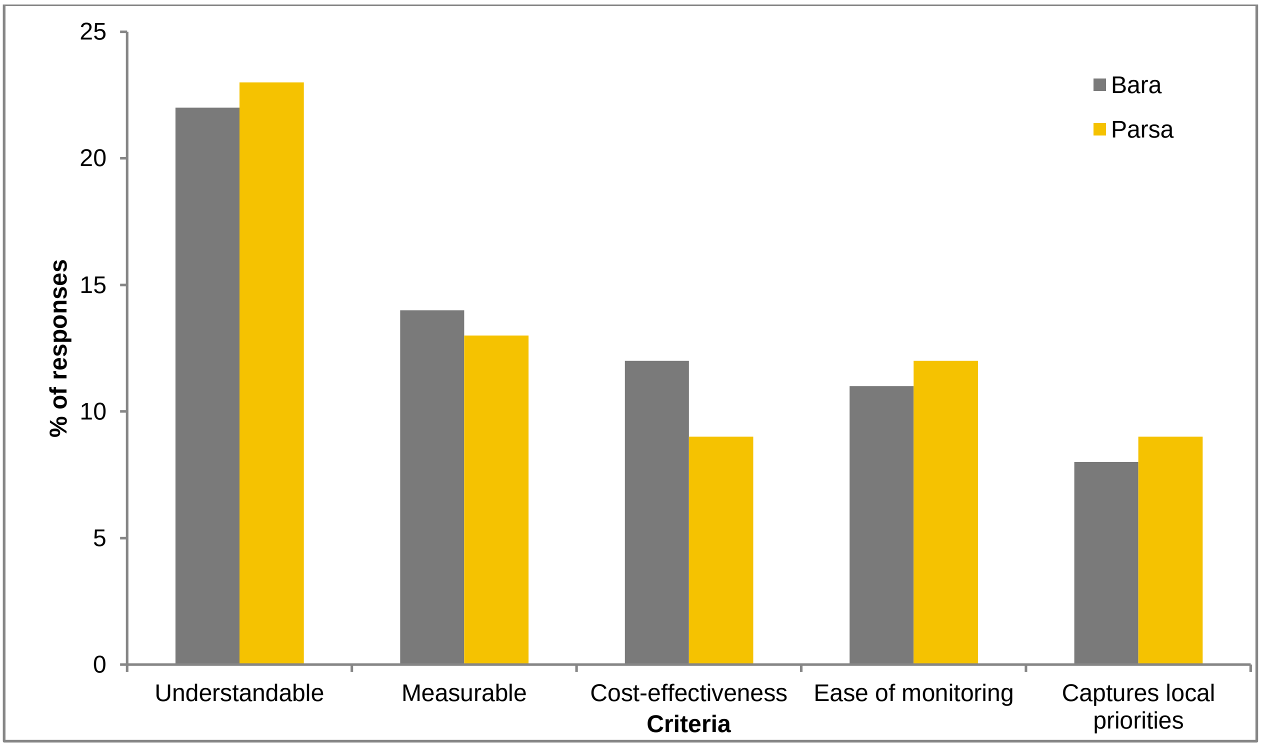


FIGURE 26. HIGHEST RANKED CRITERIA FOR RANKING ADAPTATION EFFECTIVENESS INDICATORS (COMMUNITIES)

Association between indicators, options and criteria

The presence or absence of association between different options, criteria and indicators was tested using Pearson Chi Square test as mentioned in methodology (Tables 12-17). The association was tested between indicators and options (small irrigation, intercropping) and between criteria and indicators. For associations between indicators and options, associations were tested for both combined and individual options.

TABLE 12. ASSOCIATION BETWEEN COMBINED OPTIONS AND TOP FIVE INDICATORS (COMMUNITIES AND POLICY MAKERS)

Indicators		Practice	
		Community	Policy makers
Environmental effectiveness	% of area that have concerns related to drought	0*	0.016*
	Period of fresh water availability		
	Number of droughts	0*	0.030*
	Duration of soil cover	0*	0.103
	Soil cover extent (% land covered)		
	Net primary productivity	0.064	0.012*
	Rise in groundwater level		
	% of farms that have concerns related to soil erosion		
	Organic matter content in the soil	0*	0.040*
	Biodiversity (change in species such as bees, natural enemies of pests, birds, frogs etc)		
Social effectiveness	No of farmers with concerns related drought	0*	0.001*
	Calorie intake per person		
	Quality of food/Nutritional diversity	0*	0.197
	Access/availability (Number of months of food sufficiency)	0*	0.005*
	Affordability to health care		
	Work load on women (Number of hours spent on labour work)	0*	0.431
	% of households having access to safe drinking water		
	% of households having access to markets	0.001*	0.636
Economic effectiveness	% of household income from non-agriculture practices	0.012*	0.363
	Change in household savings/assets	0.164	0.705
	Crop yield change (economic terms)	0.416	0.523
	Inter-annual variability of household income	0.001*	0.006*
	% of households having access to credit (Formal sector)		
	Crop loss per household due to droughts (in economic terms)	0.498	0.391

Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association. Empty cells: association not tested, only top 5 ranked indicators were tested for association.*

Among the associations between combined options and indicators, there was significant association between environmental effectiveness indicators and options in responses from both communities and policy makers. Indicators such as ‘percentage of area that have concerns related to drought’ and ‘period of fresh water availability’ tend to be different depending on which practice the respondent had ranked high. Similarly, there was association between all social effectiveness indicators and options for communities (Table 12).

The Tables 13-17 show statistical analysis of significance between options (small irrigation and intercropping) and indicators from community and policy responses. In general, there was no significant association between most indicators and characteristics. However, there was significant association between education status and ‘access and availability (number of months of food sufficiency)’ and between economic status and ‘crop yield change (economic indicators)’ among those who identified small irrigation systems as an important adaptation option (Table 13). Rest of the associations were insignificant. This indicates that the farmers who are practicing small irrigation systems have greater tendency to choose indicators such as access and availability of food and change in crop yield as important indicators for assessing the effectiveness of the adaptation option.

TABLE 13. ASSOCIATION BETWEEN CHARACTERISTICS AND INDICATORS (SMALL IRRIGATION PRACTICE, COMMUNITIES)

Indicators		Characteristics			
		Highest ranked criteria	Gender	Education status	Economic status
Indicators to monitor environmental effectiveness	% of area that have concerns related to Drought	0.879	0.602	0.828	0.314
	Period of fresh water availability	0.578			
	Number of droughts	0.710	0.394	0.467	0.943
	Duration of soil cover	0.928			
	Net primary productivity	0.142	0.776	0.745	0.914
	Organic matter content in the soil		0.145	0.126	0.343
	Biodiversity (change in species such as bees, natural enemies of pests, birds, frogs etc)		0.162	0.232	0.282
Indicators to monitor social effectiveness	Number/No. of farmers with concerns related drought	0.879	0.523	0.384	0.619
	Quality of food/Nutritional diversity	0.792	0.632	0.208	0.490
	Access/availability (Number of months of food sufficiency)	0.684	0.167	0.036*	0.485
	Affordability to health care				
	Work load on women (Number of hours spent on labour work)	0.862	0.442	0.716	0.155
	% of households having access to safe drinking water	0.791			
	% of households having access to markets		0.942	0.231	0.828
Indicators to monitor	% of household income from non-agriculture practices	0.240			

Indicators		Characteristics			
economic effectiveness	Change in household savings/assets	0.499	0.301	0.796	0.211
	Crop yield change (economic terms)	0.977	0.721	0.259	0.049*
	Inter-annual variability of household income		0.999	0.570	0.660
	% of households having access to credit (Formal sector)	0.996	0.794	0.307	0.591
	Crop loss per household due to droughts (in economic terms)	0.95	0.811	0.171	0.562

Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association. Empty cells: association not tested, only top 5 ranked indicators were tested for association.*

Among those responses which identified intercropping as an important adaptation option, there was significant association between education status and the tendency to choose indicators such as ‘rise in groundwater level’ and ‘% of farms that have concerns related to soil erosion’ (Table 14). There was also an association between ‘education’, and ‘percentage of household income from non-agriculture sources’. The data revealed high preference for non-farm sources of income among well educated than those less educated or uneducated.

TABLE 14. ASSOCIATION BETWEEN VARIABLES AND INDICATOR (INTERCROPPING, COMMUNITIES)

Indicators		Characteristics			
		Highest ranked criteria	Gender	Education status	Economic status
Indicators to monitor Environmental effectiveness	% of area that have concerns related to Drought	0.376	0.147	0.634	0.353
	Period of fresh water availability				
	Number of droughts	0.416			
	Duration of soil cover	0.963	0.334	0.072	0.870
	Soil cover extent (% land covered)	0.515			
	Rise in groundwater level		0.283	0.047*	0.139
	% of farms that have concerns related to soil erosion		0.572	0.034*	0.645
	Organic matter content in the soil	0.401	0.710	0.164	0.094
	Biodiversity (change in species such as bees, natural enemies of pests, birds, frogs etc.)				
Indicators to monitor Social effectiveness	Number of farmers with concerns related drought				
	Calorie intake per person	0.1764	0.1618	0.147	0.570
	Quality of food/Nutritional diversity	0.598	0.376	0.323	0.544
	Access/availability (Number of months of food sufficiency)	0.218	0.500	0.180	0.161
	Affordability to health care	0.539	0.535	0.883	0.871
	% of households having access to markets	0.626	0.428	0.481	0.971

Indicators		Characteristics			
Indicators to monitor	% of household income from non-agriculture sources	0.879	0.035	0.014*	0.314
Economic	Change in household savings/assets	0.244	0.127	0.098	0.919
effectiveness	Crop yield change (economic terms)	0.666	0.78	0.188	0.270
	Inter-annual variability of household income	0.704	0.630	0.282	0.170
	Crop loss per household due to droughts (in economic terms)	0.999	0.078	0.585	0.940

Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association. Empty cells: association not tested, only top 5 ranked indicators were tested for association.*

Similar to community respondents, there were no significant association observed between options, most indicators and characteristics of policy makers (Table 15). Education status had influenced the tendency to choose indicators such as number of farms with drought concerns and field of specialization influenced the tendency to choose % area with drought concerns as an important adaptation effectiveness indicator.

Associations between indicators and criteria: among those respondents who chose small irrigation practice as an important adaptation option and those who chose simplicity as important criteria had a tendency to rank indicators such as % of area that have drought concern and crop yield change against other indicators (Table 16). Similarly, respondents who chose intercropping as an important adaptation option and chose simplicity as an important criteria had tendency to rank organic matter content in soil as an important environmental indicator and change in crop yield as an important economic indicator (Table 17).

TABLE 15. ASSOCIATION BETWEEN OPTIONS AND INDICATORS (TOP FIVE INDICATORS, POLICY MAKERS)

Indicators		Practice 1:Small irrigation			Practice 2: Intercropping		
		Specialization	Experience	Educational status	Specialization	Experience	Educational status
Environmental effectiveness	% of area that with drought concerns	0.373	0.603	0.717	0.014*	0.771	0.045*
	Period of fresh water availability	0.191	0.416	0.517	0.265		0.265
	Duration of soil cover		0.286	0.427			0.401
	Soil cover extent (% land covered)	0.346	0.475	0.795			
	Net primary productivity	0.260	0.676	0.171	0.322	0.544	0.255
	Organic matter content in the soil				0.813	0.841	0.746
Social effectiveness	Number of farmers with drought concerns	0.176	0.587	0.038*	0.821	0.763	0.522
	Calorie intake per person				0.446	0.519	0.965

Indicators		Practice 1:Small irrigation			Practice 2: Intercropping		
	Quality of food/Nutritional diversity	0.835	0.380	0.794	0.406	0.769	0.656
	Access/availability (Number of months of food sufficiency)	0.132	0.404	0.743			
	Affordability to health care						
	Work load on women (Number of hours spent on labour work)				0.600	0.610	0.209
Economic effectiveness	% of household income from non-agriculture practices	0.673	0.308	0.450	0.179	0.506	0.710
	Change in household savings/assets	0.927	0.221	0.822	0.620	0.279	0.782
	Crop yield change (economic terms)	0.655	0.882	0.516			
	Inter-annual variability of household income		0.862	0.547	0.058	0.152	0.693
	% of households having access to credit (Formal sector)	0.749					
	Crop loss per household due to droughts (in economic terms)	0.110	0.693	0.362	0.196	0.822	0.716

Note: *Ho : variable and indicators are independent, Ha: variable and indicators are significantly associated * implies significant association. Empty cells: association not tested, only top 5 ranked indicators were tested for association.*

TABLE 16. ASSOCIATION BETWEEN TOP INDICATORS AND CRITERIA (SMALL IRRIGATION PRACTICE)

Highest Ranked Criteria	Indicators : (Practice One: Small irrigation)		
	Environmental Effectiveness	Social effectiveness	Economic effectiveness
1. Simplicity	% of area that have concerns related to Drought	Number of farmers with concerns related drought	Crop yield change (economic terms)
2. Measurability	Period of fresh water availability	Number of farmers with concerns related drought	Crop yield change (economic terms)
3. Cost Effectiveness	% of area that have concerns related to Drought	Number of farmers with concerns related drought	Crop yield change (economic terms)

Barriers in assessing the effectiveness of adaptation options

The policy makers and district administration personnel were asked to evaluate the important barriers in assessing the effectiveness of adaptation options before, during and after the adaptation options are identified and implemented in the form of projects. Most perceived barrier to measuring the adaptation effectiveness was reported to be lack of financial resources for evaluating the effectiveness before the practices are implemented. This was followed by lack of technical staff, diversity in stakeholder perceptions and lack of good indicators to choose from. During the implementation of adaptation options, the most important barrier was the lack of financial resources while lack of technical staff was reported to be the major barrier for measuring the effectiveness after the implementation of adaptation options.

TABLE 17. TOP RANKING INDICATORS UNDER HIGHEST RANKING CRITERIA (INTERCROPPING)

Highest Ranked Criteria	**Indicators : (Practice Two: Intercropping)**		
	Environmental Effectiveness	Social effectiveness	Economic effectiveness
1. Simplicity	Organic matter content in the soil	Access/availability (Number of months of food sufficiency)	Crop yield change (economic terms)
2. Measurability	Organic matter content in the soil	Access/availability (Number of months of food sufficiency)	Crop yield change (economic terms)
3. Cost Effectiveness	Organic matter content in the soil	Access/availability (Number of months of food sufficiency)	Crop yield change (economic terms)

6. CONCLUSIONS

The study has provided useful experiences and important observations on how communities perceive and measure the effectiveness of adaptation options. Characterizing the historical drought was helped in identifying and characterizing the drought prone areas in the Gangetic basin. Analysis of historical drought events using Standardized Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI) has revealed that these indices can provide important means of characterizing drought in terms of intensity and duration in the Gangetic basin. While the results from both SPI and PDSI varied, the 12-month SPI values and PDSI were the closest. Such an objective comparison and classification of drought prone areas would be helpful for the governments in planning and implementing various developmental programs more effectively. Since the SPI can be calculated for various time scales, it is possible, depending on the availability of quality data, to calculate shorter duration SPI values and see the probability of occurrence of such droughts. PDSI can use the location specific information such as soil water holding capacity and hence can help in bringing out location specific results. This brings us to propose an index-based drought monitoring system in the basin. Utilizing the strength of the individual drought indices, the proposed drought monitoring system should be able to help release monthly drought bulletins with interpretation of what it signifies for different stakeholders in the monitored area. These computations could be made available widely to the general public and other water supply and user groups associations, including city water supply boards and rural irrigation infrastructure machinery in using them for better drought preparedness and operational use. The bulletin could consist of outlooks for the week or even the month, along with spatial maps showing the distribution of precipitation in terms of SPI values, and possible suggestions or guide rules for water managers. To a certain extent, continued monitoring of progress in indices could help in anticipating drought conditions and help in taking precursor measures. As the Gangetic basin has thriving agriculture economy, it is important that such bulletins are made available widely in rural areas through the regional and district meteorological networks managed by the central government and state level governments. These indices can also be used in combination with other drought monitoring tools including remote sensing. Development of a composite drought monitoring index with these indices as a component can also be attempted to. In addition, these indices could be used to cross compare with the other drought monitoring tools thus acting as a check.

The structured questionnaire surveys were conducted with communities (n=675, community responses) in 11 villages in the drought-prone areas of Bangladesh, India and Nepal. The findings of these surveys helped in getting insights on the kind of adaptation options preferred by the communities in drought prone regions and on the indicators chosen by them to measure the effectiveness of adaptation options. These results can contribute in designing an adaptation decision making framework based on effective adaptation strategies which can facilitate planned adaptation. Knowing the possible impacts of adaptation options beforehand can help in achieving effective and efficient adaptation. A broad set of indicators were identified to monitor the effectiveness of adaptation options and these can help in understanding the possible impact of adaptation options on the adaptive capacity of communities.

In Bangladesh, the surveys were conducted in the drought prone Barind region where farmers heavily rely on ground water for regular irrigations. Despite the declining water table, communities still preferred ground water tube wells as a main drought alleviation practice. In Bangladesh, most respondents elicited the changing drought duration and intensity and attributed these to the global climate change. They opined that these trends are the reason behind increasing crop losses, pest attacks and declining water resources in their vicinity. The farmers have chosen the deep tube wells as an important adaptation strategy followed by re-excavation of existing farm ponds or construction of new ones to adapt to the reported climate change impacts. Among the management related adaptation options, the communities have ranked high the drought tolerant and short duration crop varieties and they thought that the soft options such as farmer fields schools, water pricing enhanced investment in research and development as important.

To assess the adaptation effectiveness, the respondents in Bangladesh chose indicators such as period of fresh water availability and net primary production as important environmental indicators. Among social indicators, the calorie intake per person was found to be most the most important indicator followed by employment rate and percent of households having access to markets. These responses were very little influenced by the demographic background of the respondent (economic status and gender) and other criteria (e.g. picking a particular practice as important against others). However, it was found that the tendency to choose indicators such as crop yield and yield variability, market price of commodities, damage per household and number of jobs created tend to be influenced by the practice a particular farmer has ranked as important or has been practicing. Economic status of the respondent didn’t influence the way the respondents have ranked the indicators and gender of the respondent tend to influence picking indicators such as period of fresh water availability and net primary production.

In India, the results have shown that the communities had tendency to prefer adaptation options that can help in ensuring and increasing water availability. Interventions which can help in improving irrigation systems (infrastructure related), facilitate adoption of efficient irrigation systems such as drip and sprinkler (management related) and introduction of water conservation policies (policy related) were preferred more compared to strategies related to crop and soil management. This is reasonable as agriculture in the survey area was essentially rain fed and there are hardly any irrigation options available to farmers. Since it is a drought prone and ravine area, where water and soil runoff is high, ensuring water availability is the key to enhance the adaptive capacity of the communities and increase their resilience towards current as well as future vulnerabilities to climate change.

The indicators were ranked by the communities to monitor the effectiveness of adaptation options with respect to construction of bunds and check dams. For the indicators of environmental effectiveness, preference was given to indicators related to water such as increased fresh water availability, and change in groundwater level. Indicators related to soil and crop productivity were ranked next to these water related indicators. For the indicators of social effectiveness, the responses showed that food availability is the primary requirement followed by healthcare and education. Thus, adaptation options which can help in improving access to and availability of food and which can help in increasing their access to healthcare and education were considered more effective in improving social well-being of communities. For economic effectiveness, the most important indicator was increase in farm income in terms of investment and income from the sale of farm produce because an increase in income improves their purchasing power.

The comparisons done between different variables of respondents profile such as gender and economic status, and their respective ranking of indicators provided some understanding on their implication for monitoring and evaluation of adaptation projects. In this study, for most of the comparisons done, no significant association was found between several variables and indicators. No association was found between gender and ranking of indicators to measure effectiveness of adaptation options. Similarly, adaptation options were not associated with the indicators signifying that the effectiveness of several adaptation options could be measured by a common set of indicators instead of the need for specific indicators for specific type of adaptation options. However, some degree of association was found between economic status and ranking of indicators. It can be said that in some cases, economic status was found to be influencing the choices made for indicators. The resultant comparison showed that for this particular region, factors such as gender or practice group might not substantially influence adaptation decisions at local level. However, economic status might be an influencing factor in monitoring effectiveness of adaptation options by the communities. This is an important observation since most adaptation options are identified and prioritized relatively at higher administrative levels.

In Nepal, options and indicators are limited due to poor technological transfer, inadequate extension service, lack of adaptation to climate change interventions and small scale agricultural practices. The result of the study shows that there are barriers in accessing the effectiveness of adaptation during an intervention as noted by administrators, practitioners and researchers. The five most important of them are: 1. lack of financial resources, 2. lack of technical staff, 3. diversity of stakeholder perceptions, 4. lack of good indicators that capture the effectiveness of an option, and 5. lack of relevant data or information for decision making. As mentioned earlier, any adaptation intervention must understand and build upon the existing farmer strategies and related institutional local capacity. Our analysis also show that small and poor farmers cannot afford small irrigation systems and have to rely on cooperatives; this has also been reflected through the survey by practitioners from this region. The study indicates that for farmers the top rankings criteria's for prioritizing indicators are: 1. Simplicity - which is easily understandable locally; 2. Measurability – readily measurable and 3. Cost effectiveness. Local and national policies should consider issues faced by marginal groups and then design adaptation strategies accordingly.

In Nepal, the practices adopted by farmers are very few, so a larger sample area covering districts that are vulnerable to drought would help in addressing this issue. This broad survey data would bring learning from vulnerable lowlands to develop local strategies, and then integrate these into national strategies for drought preparedness for both short and long term. Despite list of applied indicators being comprehensive, it does not necessarily reflect the effectiveness of options for the entire Gangetic basin of Nepal.

In view of the Government's current initiative to implement local adaptation strategies (LAPA's), and blueprint of agricultural development strategies (ADS), there are major institutional gaps and deficiencies that need to be incorporated. For instance, addressing vulnerable rain-fed lowland areas of Nepal need to be included in development plans and strategies. The current ADS draft, the new blueprint on agricultural development however does mention about strategies in value chains, irrigation and agro entrepreneurship. Short term issues also need to be considered such as micro – irrigation programs, rain water harvesting schemes and forming water user association to run small irrigation systems that participate in the management of larger systems.

There are cost related factors for adopting small irrigation systems. Depending on the depth of ground water table, material and other costs range from $120 - $ 800. For those who cannot afford, they pay farmers with ground water tube wells in the range of $4 - $6 an hour to irrigate their fields. This has led to development of a thriving ground water market in the region. This was also the reason why most farmers ranked 'cooperative' as an important mechanism since cooperatives have made access to ground water affordable. The farming community is already forming informal cooperatives and sharing irrigation pumps. Forming water user association to run small irrigation systems is an important management practice in this region. Most of the communities use intercropping due to uncertainty of weather and drought conditions. Farmers harvest three crops per year that are drought tolerant and early maturing varieties. This system decreases the risk of total loss or failure of one crop and also helps them adapt to changing rainfall conditions.

This study was undertaken with the larger objective of finding means of facilitating adaptation decision making at the local context. The surveys have helped to get an understanding of the perspective of the local communities on their preference on adaptation options related to drought. It gave an indication of what can be the indicators preferred by the communities to monitor effectiveness of adaptation options. This can be a useful input for adaptation decision making at the local level. Usually adaptation decisions are taken and strategies are implemented at different scales. However, there are no proper mechanisms in place to measure the impacts of these adaptation strategies in terms of enhancing the adaptive capacity of the target groups. Even during the course of implementation of an adaptation project, it becomes important to track and review the progress of the goals under the project. Since climate change is a dynamic process and there are a number of uncertainties associated with it, it becomes very important to have a mechanism for monitoring and evaluation of adaptation projects. This can help in making timely adjustments in projects, if necessary and can contribute in achieving the objectives of the adaptation intervention and in avoiding maladaptation.

An indicator based approach can be a useful tool in monitoring and evaluation of adaptation interventions. There are a number of challenges in following this approach as adaptation applies at a local context and a particular set of indicators might not be applicable for every given region as became evident from this study. However, the emphasis was to identify a broad and robust set of indicators that captures the commonalities of diverse sub-regions in the Gangetic basin is possible but challenging. In addition, there are a number of factors influencing the effective implementation of adaptation interventions which cannot be assessed using indicators. However, an indicator based approach provides a mechanism to understand the impact of adaptation intervention in quantitative or qualitative terms (though this study gave more preference to quantitative indicators for the reason to integrate them with the already existing global adaptation index (GaIn). Based on the findings of this study, a broad set of indicators can be identified which can be applicable at a local level for measuring the effectiveness of adaptation options.

From limitations to way forward

This study is not without limitations. The information for developing effective local indicators for measuring adaptation would require investment of time, resources and possibly permanent sampling plots representing practices. Similarly, to analyze traditional practices and coping strategies, a participatory approach involving local farmers, service delivery line agencies, local NGO's and researchers over a reasonable period of time of 2 to 3 growing seasons is required. The consultative workshop held during the initial stages did not target farmers, local researchers and NGO's and therefore this study may not have identified number of local issues. In the first phase of this research, to begin with, the study has focused on drought while repeated floods are also common in the Gangetic basin. Due to the limited focus of the study to drought prone areas, there was no way to identify if the indicators would differ between areas with different hazard profiles. Secondly, the indicators were identified prior to consulting communities and hence it did not give sufficient opportunity to fully incorporate preferences of communities and local institutions. Thirdly, the community responses were based on the past experiences of and trends in drought and no efforts were made to educate them on the future projections before raking practices and indicators. Hence, the practices and indicator identified and ranked are retrospective in nature rather than prospective.

Taking these gaps into consideration, the subsequent phases of the research will focus on flood prone areas of the Gangetic basin with a complete bottom up approach. This means that the indicators would be identified first by the communities and they will be subsequently compared with the top down approach adopted by the first phase of the project. Notwithstanding the title of the report, this study was done in few distantly located clusters of villages in the vast Gangetic basin and hence the findings should not be treated as generic to the entire Gangetic basin. This calls for a comprehensive bottom up studies in each distinct agro-ecological region of the Gangetic basin to see if there are real differences in indicators as influenced by demographic and agro-climatic contexts.

APPENDIX

APPENDIX 1: REGIONAL AND NATIONAL LEVEL CONSULTATION MEETINGS

The project has heavily depended on accessing various stakeholders through consultative process at the regional, national and local levels. At the regional level, a regional consultation meeting was organized on ‘Adaptation Metrics and Policy Frameworks for Adaptation Governance in the Gangetic Basin’ on 5-6 March 2011 in Dhaka, Bangladesh (Figure A1-1). This meeting was attended by 30 researchers and policy makers engaged in climate change adaptation in the Gangetic basin countries and have discussed the current state of understanding on the subject of adaptation metrics and adaptation governance. The meeting was instrumental in setting the specific direction that the project should take.

FIGURE A1-1. REGIONAL CONSULTATION MEETING IN DHAKA, BANGLADESH

Subsequent to the regional consultation meeting, indicators identified from literature review and previous efforts of the Institute for Global Environmental Strategies (questionnaire can be seen in Appendix 2) were further vetted through national level consultation meetings organized in

Bangladesh, India and Nepal (Figure A1-2). These meetings have helped in localizing the generic questionnaire developed to the national and local circumstances such as presence of adaptation options and including fine-tuned indicators and criteria. In addition, these meetings were also helpful in developing two sets of questionnaires, one for the farming community and the other for policy makers, administrators and researchers. National level experts in agriculture, water and socioeconomics domains have participated in these meetings. The main objectives of these meeting were to identify a list of adaptation options being practiced in the study region, to identify and prioritize criteria based on which these indicators could be ranked and to discuss and prioritize environmental, social and economic that should be included in the structured questionnaire surveys with communities and other stakeholders. The results of these national level consultations are briefly discussed here.

FIGURE A1-2. NATIONAL LEVEL INDICATORS VETTING MEETING AT ICIMOD, KATHMANDU

Following were the major changes made in the questionnaires after national level consultation meetings:

- Develop two sets of questionnaires, one for farming community and the other for policy, administrative and research communities.
- Focus the survey on drought as climatic stimuli and implement the survey with focus in drought prone areas.
- Update the questionnaire with specific adaptation options found in the survey locations
- Update and modify the indicators and criteria in terms of standardization of terminology, removing redundant and irrelevant indicators, identifying proxy indicators for those indicators difficult to convey and for which data may not be available widely, and reduce the overall number of indicators and criteria as much as possible.

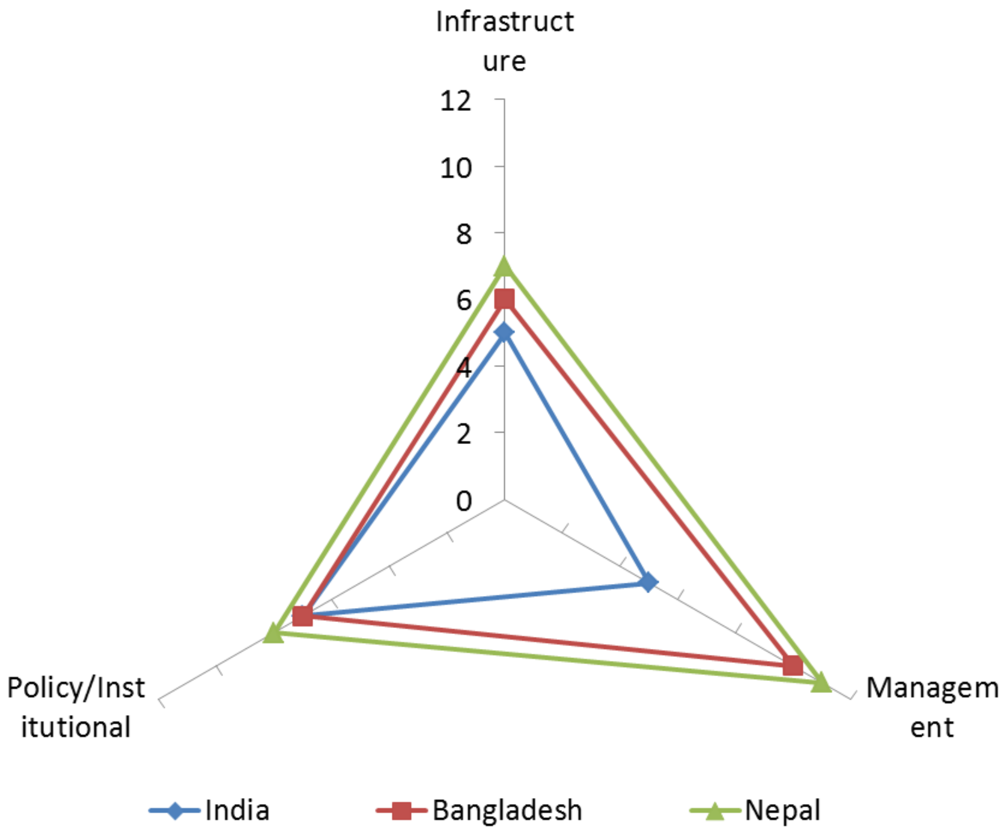


FIGURE A1-3: NUMBER OF ADAPTATION OPTIONS IDENTIFIED IN THE THREE INDICATOR VETTING MEETINGS

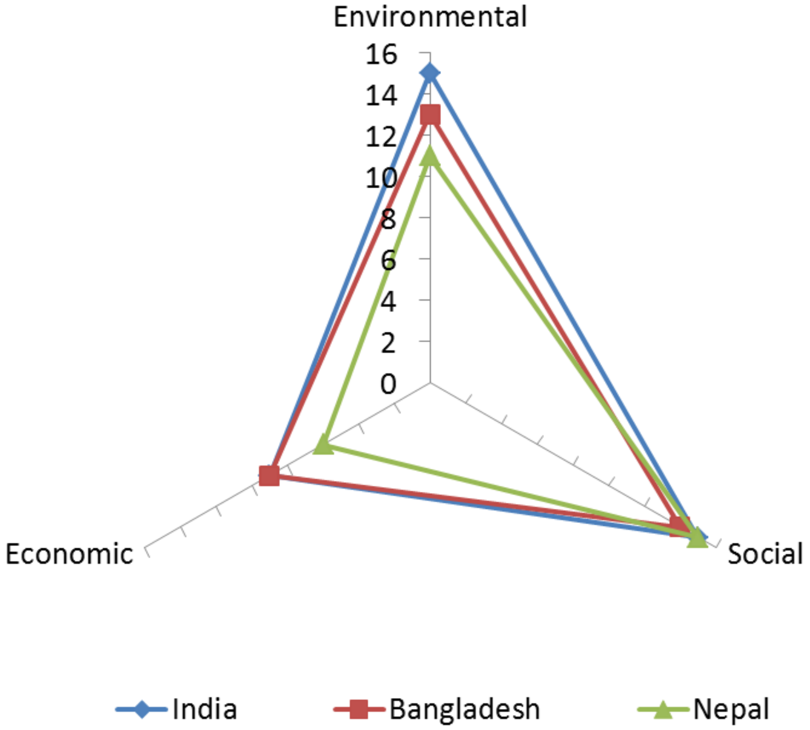


FIGURE A1-4. ENVIRONMENTAL, SOCIAL AND ECONOMIC INDICATORS BY THE END OF EACH NATIONAL MEETING FOR INCLUSION IN THE STRUCTURED QUESTIONNAIRE SURVEYS

Adaptation options

Considering drought as a climatic stimuli in the study locations of the project, three FGDs were organized to identify options that alleviate the drought in three study countries which was participated by the local district administration, researchers and national level administration involved in agriculture and water sectors. This listing has helped the participants to think indicators as something that is affected by the options they have listed. The number of adaptation options identified in each project location is shown in Figure A1-3.

Effectiveness indicators

Upon identifying the specific adaptation options, the FGDs were focused on identifying indicators that reflect the effectiveness of these options. The indicators were grouped into environmental, social and economic categories since these three aspects are considered the pillars of sustainable development. The Figure A1-4 compares the number of indicators identified in each country at the end of national consultations.

Some general observations from this vetting process are: a) perfect negative Pearson Rank Correlation between number of options and number of effectiveness indicators (p= -1.0). More analysis is required to explain this interesting observation, it could be better explained by analyzing associations between each category of options and indicators; b) relatively more policy emphasis in India when compared to other interventions and in other countries; c) an agreement among all countries that social indicators are more important than economic or environmental indicators.

Criteria for prioritizing indicators

Several criteria underline the decision making while identifying indicators of effectiveness and most often the criteria differs from the stakeholder involved. Hence, discussing indicators independent from criteria would make little sense in adaptation decision making. The research has ranked several criteria that underlined the identification of indicators. The most important criteria in Bangladesh and Nepal were found to be policy relevance of indicators while in India it was measurability of an indicator.

Multi-criteria ranking of indicators

Subsequent to ranking the indicators and criteria, all the indicators were individually ranked by all the participants of the meetings for each criteria. The objective was to see if applying specific criteria affects the ranking of the indicator. The output of this exercise has determined which indicators will ultimately find place in the structured questionnaire surveys. Those indicators which stood most criteria (more than 5) were chosen to include in the questionnaire surveys.

APPENDIX 2: GENERIC QUESTIONNAIRE PRIOR TO CONSULTATIONS[4]

Section I – Impacts & Adaptation options

1.1 What are the five most important impacts of climate change on agriculture sector in your location?

1. ______________ 2. ___________ 3. ____________ 4. _____________ 5.____________

1.2 Adaptation options

Please rank the five most effective (1 for most effective, and 5 for less effective) adaptation options under each category (infrastructure, management, and policy) to cope with top impact listed above.

(1.2.1) Adaptation options to cope with floods	Rank top 5
(i) Infrastructure related	
• Enhanced water storage (reservoir capacity, construction of check dams)	
• Establishment of artificial wetlands	
• Construction or strengthening of river banks	
• Improved transport facilities in flood-prone areas (e.g. bridges)	
• Improved flood forecasting and early warning systems	
• Restoration of vegetation cover and replant trees for soil protection	
• Relocation of critical infrastructure	
• Drainage systems (siphoning pumps against glacial lake outburst floods, surface and sub-surface drainage systems etc)	
• Others (please specify)	
• Others (please specify)	
(ii) Management related	
• Crop diversification and cropping systems (e.g. water logging tolerant crops)	
• Creating a coordinated decision structure for better response	
• Better crop management practices (adjusting planting dates, crop calendar, nutrient management, etc)	
• Zero and reduced tillage options	
• Improved soil management practices (e.g. sub-surface drainage)	
• Land use planning	
• Vulnerability assessment and hazard mapping	
• Others (please specify)	
• Others (please specify)	

[4] This questionnaire was modified after conducting country level consultation meetings and community level FGDs and two separate questionnaires were prepared for policy and community levels for each country. These questionnaires were not provided in the report due to page limitation and can be obtained by writing to the author. Adopted from the following source. Srinivasan, A. and S.V.R.K. Prabhakar. 2009. Measures of adaptation to climatic change and variability (Adaptation metrics). Hayama, Japan: The World Bank and Institute for Global Environmental Strategies.

(1.2.1) Adaptation options to cope with floods — Rank top 5

(iii) Policy related

- Income diversification (non-farm income sources)
- Credit facilities (e.g. micro-financing)
- Comprehensive insurance (crops, houses, livestock etc)
- Capacity building and information sharing
- Creating a coordinated decision structure for better response
- Regulations on settling in flood plains and along river banks
- Formation of community based water management groups
- Investment in research & development (e.g. flood tolerant crops & varieties)
- Others (please specify)

(1.2.2) Adaptation options to cope with droughts — Rank top 5

(i) Infrastructure related

- Improved irrigation systems (e.g. increase efficiency, area under irrigation)
- Improved drought forecasting and early warning systems
- Increased water availability (e.g. increase storage capacity of reservoirs, construct rainwater harvesting structures)
- Others (please specify)
- Others (please specify)

(ii) Management related

- Land use planning (e.g. restrictions on some industries in water scarce areas)
- Use saline and fresh water; or groundwater and surface water in combination
- Improved soil management (e.g. organic matter/mulching, conservation tillage)
- Water harvesting (e.g. contour cultivation, trenches, aquifer recharge)
- Adopt efficient irrigation systems (e.g. sprinkler, drip irrigation)
- Adopt heat & drought resistant/tolerant crops and varieties
- Better crop management (e.g. adjusting planting dates, nutrient regime)
- Creating a coordinated decision structure for better response
- Vulnerability assessment and hazard mapping
- Ensuring timely supply of inputs (e.g. seeds, fertilizers)
- Others (please specify)

(iii) Policy related

- Introducing water pricing system & other water conservation/allocation policies
- National water accounting and promotion of efficient irrigation systems (e.g. drip)
- Support capacity building and information sharing among stakeholders
- Income diversification (non-farm income sources)
- Credit facilities (e.g. micro-financing)
- Insurance (crop, livestock, etc.)
- Investment in research & development (e.g. heat and drought tolerant crops or

(1.2.1) Adaptation options to cope with floods — Rank top 5

varieties)

Section II – Adaptation metrics

2.1. Adaptation metrics in agriculture and water sectors

Identify three most important adaptation options (covering any of infrastructure, management, and policy aspects) to cope with impacts of climate change. Then, identify five most important indicators (1 most important and 5 less important) in each category (environmental, social and economic) for monitoring the effectiveness of selected option. If an option is strictly applicable to only one sector, you do not need to rank the indicators for the other sector.

(2.1.1) Adaptation option 1: (Please fill in…………………………..………………..) — Rank top 5

(i) Indicators to monitor environmental (including ecological) effectiveness

- % of farms that have concerns related to salt intrusion
- % of households at risk due to sea-level rise
- Period of fresh water availability
- Number of floods or droughts
- Soil cover (duration and extent)
- Net primary productivity
- Rise in groundwater level
- % of farms that have concerns related to soil erosion
- Carbon storage in soil and vegetation

(ii) Indicators to monitor social effectiveness

- Calorie intake per person (indicator of access to and availability of food)
- % of households having access to health care
- % of households having access to sanitation facilities
- % of households having access to information
- % of children under the age of five with symptoms of malnutrition
- % of households having access to safe drinking water
- Employment rate

(iii) Indicators to monitor economic effectiveness

- Crop yield and yield variability
- Gross domestic product
- Cost-benefit ratio and internal rate of return of adaptation options
- Household income and its inter-annual stability
- % of households having access to credit
- Damage per household/farms due to extreme events (e.g., floods, drought)

(2.1.2) Adaptation option 2: (Please fill in……………………………..……) — Rank top 5

(i) Indicators to monitor environmental (including ecological) effectiveness

- Soil erosion and sedimentation
- Biodiversity
- Nutrient balance in soil and water systems

(2.1.2) Adaptation option 2: (Please fill in……………………….…….) Rank top 5

- Fresh water availability period
- % of farms with concerns related to soil erosion
- % of farms with concerns related to salt intrusion
- % of households at risk due to sea-level rise
- Carbon storage in soil and vegetation
- Number of floods or droughts
- Soil cover (duration and extent)
- Net primary productivity
- Groundwater level

(ii) Indicators to monitor social effectiveness

- Literacy rate
- Social capital (social networks)
- % of households having access to markets
- % of children under the age of five with symptoms of malnutrition
- Calorie intake per person (indicator of access to and availability of food)
- % of households having access to safe drinking water
- % of households having access to health care

(iii) Indicators that measure economic aspect

- Economic loss per household/farms due to extreme climate events
- Gross domestic product
- Cost-benefit ratio and internal rate of returns of adaptation options
- Crop yield and yield variability
- Household income and its inter-annual stability
- % of household that have access to credit

(3) Adaptation option 3: Rank top 5

(i) Indicators to monitor environmental (including ecological) effectiveness

- Number of floods or droughts
- Soil cover (duration and extent)
- Net primary productivity
- Groundwater level
- Fresh water availability period
- % of farms with concerns related to soil erosion
- % of farms with concerns related to salt intrusion
- % of household at risk due to sea-level rise
- Carbon storage in soil and vegetation

(ii) Indicators to monitor social effectiveness

- % of households having access to safe drinking water
- % of households having access to health care
- % of households having access to sanitation facilities

(3) Adaptation option 3:	Rank top 5
• % of households having access to information	
• % of children under the age of five with symptoms of malnutrition	
• Calorie intake per person (indicator of access to and availability of food)	
• Employment rate	
• Literacy rate	
• Social capital (social networks)	
• % of households having access to markets	
(iii) Indicators to monitor economic effectiveness	
• Household income and its inter-annual stability	
• % of households with access to credit	
• Damage per household/farms due to extreme events (e.g., floods, drought)	
• Gross domestic product	
• Cost-benefit ratio and internal rate of return of adaptation options	
• Crop yield and yield variability	

Section III – Methodological Issues

3-1. Please rank 5 most important criteria (1 most important, and 5 less important) for your ranking of above indicators.

Criteria	Rank
• Policy relevance (policy design or implementation)	
• Spatial scalability (applicability at local, regional, national and/or global scales)	
• Cost-effectiveness	
• Measurability (Readily measurable/computable)	
• Simplicity (Easily understandable)	
• Comparability (across projects, sectors and geographical areas)	
• Responsiveness (Sensitive to changes in the extent of effectiveness of adaptation)	
• Communicability (in a simple concise manner)	
• Comprehensiveness (system-wide metrics versus discrete metrics)	
• Temporal reliability (for short, medium and long durations)	
• Scientific basis	
• Ability to capture important local data	
• Transferability	
• Flexibility (ease of monitoring) and adaptability to local conditions	
• Transparency	
• Objectivity	
• Others (please specify)	

3-2. Which approach is the most effective for development of adaptation metrics?
☐ Inductive (data-driven) ☐ Deductive (theory-driven) ☐ Mix of both

3-3. Should adaptation metrics be direct indicators or proxy indicators?
☐ Direct indicators ☐ Proxy indicators ☐ Mix of both

3-4. Should adaptation metrics be qualitative or quantitative or both?
☐ Qualitative ☐ Quantitative (reliable numbers)

☐ Mix of both

3-5. Should all metrics be treated equally? ☐ Yes ☐ No

3-6. Should metrics be comprehensive? ☐ Yes ☐ No

Section IV –Policy applications

4-1 At what stage(s) are adaptation metrics useful?
☐ Policy design ☐ Screen projects for funding ☐ Ex-ante evaluation
☐ Ex-post evaluation ☐ Others ☐ Others

4-2 Is developing protocols for application of adaptation metrics useful at policy level?
☐ Yes ☐ No

4-3 Are measurable "adaptation targets" (e.g. number of vulnerable people to a given climatic stress) necessary for application of adaptation metrics?
☐ Yes ☐ No

4-4. Please rank five important (1 most important, 5 less important) barriers in assessing the effectiveness of an adaptation option before, during and after its implementation?

Barrier	Stage of implementation		
	Before	During	After
• Lack of financial resources			
• Lack of technical staff			
• Lack of relevant data/information for decision making			
• Lack of appropriate adaptation options themselves			
• Lack of good indicators that captures the effectives of an option			
• Lack of protocols to apply indicators			
• Diversity of stakeholder perceptions			
• Others (please specify)			

Section V – Your profile

5-1. Country/Region of expertise:

5-2. Area of specialization (select only one option):

☐ Agriculture
☐ Water management
☐ Engineering
☐ CC mitigation (Specify):____________________
☐ CC (Specify):___________________________
☐ Biodiversity
☐ Disaster management
☐ Climate change (CC) modelling
☐ CC adaptation

5-3. Length of experience in the above area:

☐ 0-5 years ☐ 6-10 years ☐ More than 10 years

5-4. Type of expertise in climate change adaptation (Multiple choices possible):

☐ Research
☐ Funding
☐ Consulting
☐ Planning adaptation projects
☐ Implementing adaptation projects
☐ Others (please specify)

5-5. Type of your organization (Multiple options possible):

☐ Research
☐ Development Agency
☐ Government
☐ Other (please specify)
☐ Nongovernmental Organization
☐ Intergovernmental Organization
☐ Private sector

APPENDIX 3: PROVISIONAL RESULTS FROM LAIN

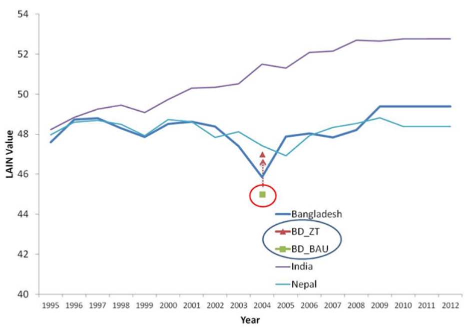
Only provisional results from local adaptation index (LaIn) calculations are available by the time this report was drafted and hence very few details are provided for a quick glance of the reader. These results are being further refined and the full results will be published along with the final project report. The quantification of indicators and related weighing done in the calculations shown below are based on mock desk exercise and hence does not represent the actual values reported it the literature or real world scenario. A shift in LaIn can be seen from before and after implementing a particular practice. The long-term trend lines in the figures plotted are GaIn values. The LaIn values are represented by dots.

Prioritized

	Indicators (Bangladesh, based on pilot survey)
Vulnerability	• % farms with soil degradation (exposure) • % soil cover (exposure) • Period of fresh water availability (exposure) • Area under high water use crops (sensitivity) • Area under arable farming (sensitivity) • Soil organic matter content (capacity) • Area under reduced tillage (capacity)
Readiness	• % of households having access to credit (economic) • % of households having access to markets (economic)

Quantified

	Indicators (Bangladesh, based on pilot survey)	Value	Range (Min Max)	Score	Weight
Vuln.	% Soil degradation	5	5-30	0.17	0.11
	% soil cover	70	10-70	1.00	0.11
	Period of water availability (days)	180	50-200	0.90	0.11
	Water int. crops (ha)	30	40-60	0.50	0.11
	Arable farming (ha)	80	40-90	0.89	0.11
	Soil OM content (%)	0.75	0.25-1	0.75	0.11
	Reduced tillage (ha)	40	5-60	0.67	0.11
Read.	Households credit access (%)	50	10-80	0.63	0.33
	Farmers access to markets (%)	60	20-80	0.75	0.33



$$\mathbf{LaIn} = \left[\left(\sum_{i}^{Read.} \frac{Index_i - Mean_{all}(Index_i)}{Stdev_{all}(Index_i)} * Weight_{Index}\right) / Max(Score)_{all}\right]_{Read.} * 60 -$$
$$\left[\left(\sum_{i}^{Vuln.} \frac{Index_i - Mean_{all}(Index_i)}{Stdev_{all}(Index_i)} * Weight_{Index}\right) / Max(Score)_{all}\right]_{Vuln.} * 40$$

Integrated as LaIn

FIGURE A3-1: QUANTIFYING INDICATORS for LaIn (Prabhakar et al., 2012)

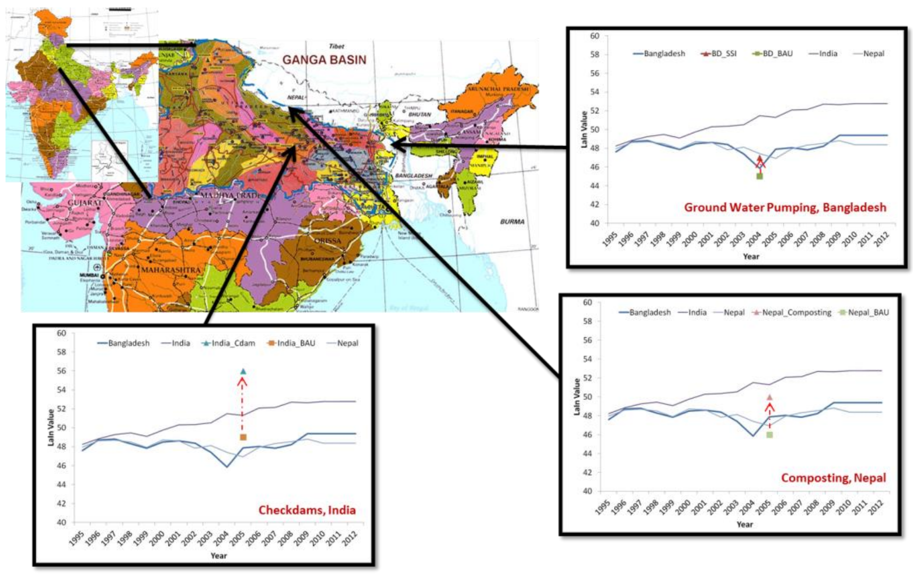


FIGURE A3-2. SHIFT IN LAIN VALUES IN DIFFERENT STUDY LOCATIONS BASED ON PROVISIONAL CALCULATIONS (Prabhakar et al., 2012)

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