Understanding Climate Change Adaptation for Smallholders/Marginal Farmers and Quantifying its Impact on Agri-allied Value Chains in Indo-Gangetic Plains

Some of the information referred to in this report consists of forecasts and projections. Future-oriented financial information referred to in this report was prepared by the management based on estimates and assumptions.

The underlying assumptions and estimates are materially dependent on the feedback received from stakeholder interviews. Readers are cautioned that, since these projections and other estimates and conclusions are based upon assumptions about future events and conditions, the actual results will vary from the projections, even if the assumptions materialize, and the variations could be significant.

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List of Abbreviations and Acronyms

ATMA	Agricultural Technology Management Agency
C	centigrade
CO2	carbon-dioxide
CSA	climate-smart agriculture
DAP	District Agriculture Plan
DORB	de-oiled rice bran
EWS	early warning system
FCI	Food Corporation of India
FMCG	fast moving commercial goods
FPC	Farmer Producing Company
FPO	Farmer Producer Organization
GDP	gross domestic product
GHG	greenhouse gas
ha	hectare
HYV	high yielding varieties
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agriculture Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	information and communication technologies
IGP	Indo Gangetic Plain
IMD	Indian Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
KCC	Kisan Credit Card
kg	kilogram
KVK	Krishi Vigyan Kendra
MIC	micronaire
Mm	millimetre
MMT	million metric tonne
MSP	Minimum Support Price
MT	metric tonne
NABARD	National Bank for Agriculture and Rural Development
NICRA	National Innovation on Climate Resilient Agriculture
NITI	National Institution for Transforming India
NMSA	National Mission on Sustainable Agriculture
NRLM	National Rural Livelihoods Mission
PACS	Primary Agricultural Credit Society
PDS	Public Distribution System
PMKVY	Pradhan Mantri Kaushal Vikas Yojana
PMU	Project Management Unit
PSC	Project Steering Committee
OMSS	Open Market Sales Scheme
RAFTAAR	Remunerative Approaches for Agriculture and Allied Sectors Rejuvenation
RKVY	Rashtriya Krishi Vikas Yojana
SAAPCC	State Adaptation Action Plan on Climate Change
SAP	District Agriculture Plan
SC	Scheduled Caste
SHG	self-help group
SMAC	Social, Mobile, Analytic and Cloud
SRI	System for Rice Intensification
SRLM	State Rural Livelihoods Mission
ST	Scheduled Tribe
UNDP	United Nations Development Programme
VO	Village Organization

Executive Summary

The current study titled *"Understanding Climate Change Adaptation for Smallholders /Marginal Farmers and Quantifying its Impact on Agri-allied Value Chains in the Indo-Gangetic Plains (IGP)"* has explored the impacts of climate change on value chains of identified agri-commodities, and adaptation costs as well as losses borne by value chain agents.

The importance of the study lies in the fact that the **Indo Gangetic Plain (IGP)** which faces frequent incidence of climate extremes covers five states (Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal) occupying nearly 15 percent of the total geographical area and housing approximately 38 percent of the population of the country.

Importance of the IGP region

- **Covers five states of India: Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal**
- **Occupies nearly 15 percent of the total geographical area and is inhabited by 38 percent of the total population of India**
- **Produces half of the total food production in India**
- **Collectively produces 90 percent of the total wheat production in India**
- **Produces 35 percent of the total rice production in India**

The importance of sustainable agriculture for the region can also be understood from the fact that, out of the total 610 administrative blocks in India, 185 blocks are from the IGP region. It produces around 50 percent of the total food. The highest wheat producing states such as Uttar Pradesh, Bihar and Punjab which, along with Madhya Pradesh and Rajasthan, collectively contribute around 90 percent of the total wheat production in the country, are from the IGP region. In the case of rice too, the leading rice producing states of Uttar Pradesh, Punjab and West Bengal are from the IGP region that together produces close to 35 percent of the total rice production in the country. Major crops grown in this area are rice, wheat, maize, chickpea, lentil, mustard, potato, sugarcane and vegetables. The sustainability of agriculture in IGP is important as the region provides food security and agriculture-based livelihoods for millions of people in India. However in recent times, the region is facing climate extremes with increased frequency. The risk of climate change on agriculture is very significant for this region not only due to its high dependency on rainfall but also as IGP is strongly connected to the tectonics and climate of the Himalaya. Climate change is impacting the region’s value chain of crops and affecting not only growers but also those involved in aggregation and collection, transportation, storage and food processing and are considered value chain actors who add value through different sets of activities. Climate change impacts will occur at all levels of the value chain and individual adaptive responses at each level will either enhance or reduce overall performance in terms of efficiency, continuity and product attributes. The review of available literature shows that most studies done so far largely focused on the impact of climate change on agriculture with very little attention paid to study the impact of climate change on post-harvest value chain agents, their adaptations and adaptation costs. There are some studies that focused on adaptation measures of some key value agents but, again, the entire value chain focus is missing. This study, therefore, aims not only to understand the impact of climate change on the value chains of identified crops and climate adaptations undertaken by these actors but also tries to explore the effect of these climate adaptations across the value chains. Through this study, an attempt is being made to bring together various climate change-related issues which affect the agriculture value chains in IGP with a specific focus on the states of Uttar Pradesh and Bihar.

Among the five states that are constituted by IGP, Bihar and Uttar Pradesh were selected for this study. From these two states, the study focuses on districts that were identified from the top 37 vulnerable districts in Bihar and Uttar Pradesh by the National Innovations on Climate Resilient Agriculture (NICRA). The list of most vulnerable districts was further matched with the list of 'aspirational districts' identified by the National Institution for Transforming India (NITI) known as NITI Aayog (commission) of the Government of India. In order to identify two districts each from these two lists, districts with high agriculture centrality and higher proportion of a rural population to the total population were selected for the study.

Table ES1: Districts and crops identified for the study

After the identification of these districts, based on the highest production, the top two or three crops were selected from both cereal and horticulture categories in these districts. Accordingly paddy, wheat, maize, tomato, potato and chilli crops were identified for this study from

Identified States/ Districts for the Study	Identified Agro Value Chains for the Study
• Bihar: Katihar and Samastipur • Uttar Pradesh: Bahraich and Sonbhadra	• Paddy, wheat , maize, tomato and potato

the four districts of Bihar and Uttar Pradesh. The value chain agents of the identified agriculture commodities were interviewed to understand the impact of climate change, adaptation and adaptation costs borne by these actors. The study also tried to understand the impact of climate adaptations by value chain agents across the value chain. Information collected about the primacy of crops from farmers was also cross-checked with agriculture traders, grain merchants, representatives of district chambers of commerce from each district as well as government officials. The district officials from the National Bank for Agriculture and Rural Development (NABARD) and district Krishi Vigyan Kendra (KVKs or agriculture science centres) initiated by the Indian Council of Agricultural Research (ICAR) initiated district were consulted to establish the validity of the collected information.

The productivity of most crops in this region is near their yield potential due to the presence of favourable agro-climatic conditions, i.e., productive alluvial soil, maximum irrigated land, sub-tropical climate, etc. Agriculture practices adopted by farmers are highly input-intensive with higher usage of resources such as fertilizer and water that are contributing to greenhouse gas (GHG) emissions as well.

Table ES2: Value chain losses in the IGP region

An increase in temperature, higher number of dry and hot days with a decrease in rainfall, changing patterns of rainfall, increase in temperature extremities, shifting of seasons, and long spells of high temperature and humidity are some recurring climate changes that the region is facing.

Commodity	Total Value Chain Losses
Paddy	3,492-3,823 Million INR
Maize	900-1,410 Million INR
Wheat	800-830 Million INR
Potato	6,220 – 9,010 Million INR
Tomato	1,110- 1,130 Million INR
Overall	12,740 Million INR

The number of rainy days is constantly decreasing in most areas across IGP. On the other hand, instances of rainfall with increased intensity of rainfall are also on the rise. Furthermore, incidences of drought and floods are becoming more frequent. These climate extremes are reported to impact the pre- and post-harvest value chains of crops identified for this study. Loss in production, quality deterioration, increasing unreliability of production and increase in agriculture cost due to higher pest and disease infestation are some of the climate change impacts reported by the farmers. Value chain agents, on the other hand, are affected by irregular and low quality supply of raw material, rising procurement and electricity costs and compulsion to make investment in new machinery and equipment to stay in the business. The total value chain loss due to the impact of climate change is INR 12,740 million.

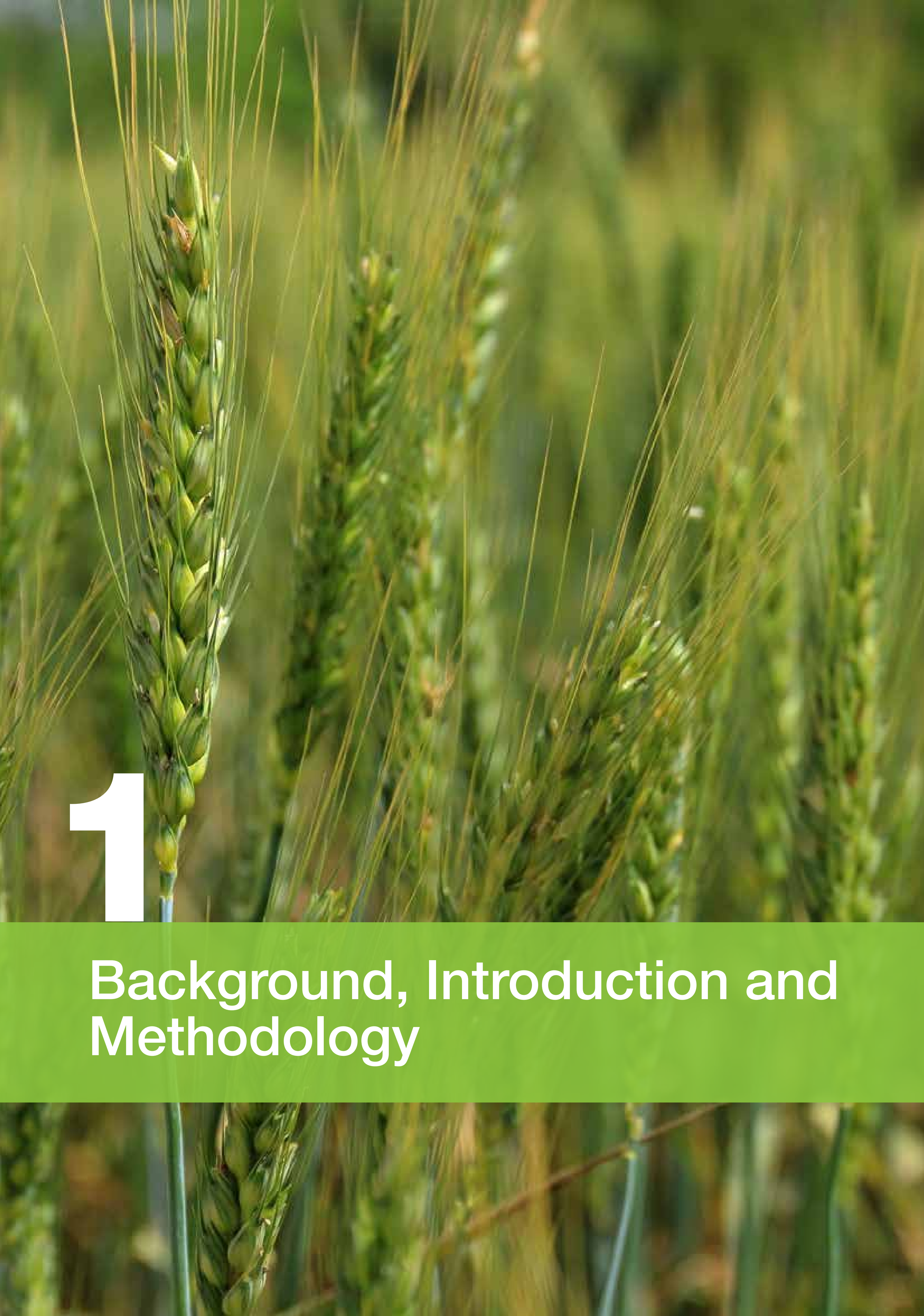
Table ES3: Commodity-wise value chain losses due to climate change (in INR million)

These lossess will increase as climate extremes are occurring more regularly and with increased intensity every time. IGP is a source of food security and livelihoods for millions of people from the states in the study. Since climate extremes are not consequences of local environmental imbalances, efforts have to be made at the macro as well as the micro level. Coordination

Value Chain	Storage Loss	Quality Loss	Processing Loss	Transportation Loss	Total
Rice	990	2,250	250	NA	3,820
Maize	100	840	470	NA	900-1,410
Wheat	90	120	620	NA	830
Potato	3,240	2,800	180	NA	6,220-9,010
Tomato	NA	NA	NA	1,300	1,300

among all stakeholders along the value chains is required. Better focused research, capacity building of the stakeholders and joint consultations are some of the measures that need to be initiated immediately.

The government and private players can join hands to provide climate-specific business development services to micro, small and medium value chain agents.



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Background, Introduction and Methodology

1.1 Background and Rationale

The Indo Gangetic Plain (IGP) which covers five states (Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal) occupies nearly 15 percent of the total geographical area and houses approximately 38 percent of the population of the country that resides in 185 out of a total of 610 administrative blocks in India. It is one of the most intensely farmed areas and is popularly known as food bowl of India due to its high contribution in production of cereal crops, especially rice and wheat. It produces around 50 percent of the total food production of which lentil production is close to 70 percent of the total production in the country. Wheat producing states such as Uttar Pradesh, Bihar and Punjab, which along with Madhya Pradesh and Rajasthan, collectively contribute around 90 percent of total wheat production in the country are from the IGP region. The leading rice producing states, Uttar Pradesh, Punjab and West Bengal, are from the IGP region and together produce close to 35 percent of the total rice production in the country.

NITI Aayog has, on the basis of agro-climatic zones, divided this area into four major sub regions: trans Gangetic plain; upper Gangetic plain; middle Gangetic plain; and lower Gangetic plain.

The present study has focused on districts from upper-Gangetic plains and middleGangetic plains. Both regions are known for fertile soils, favourable climate and generally abundant supply of water. The concentration of small and marginal farmers with small land holdings is very high in these regions.

The major crops grown in this area are rice, wheat,

Figure 1: IGP regions

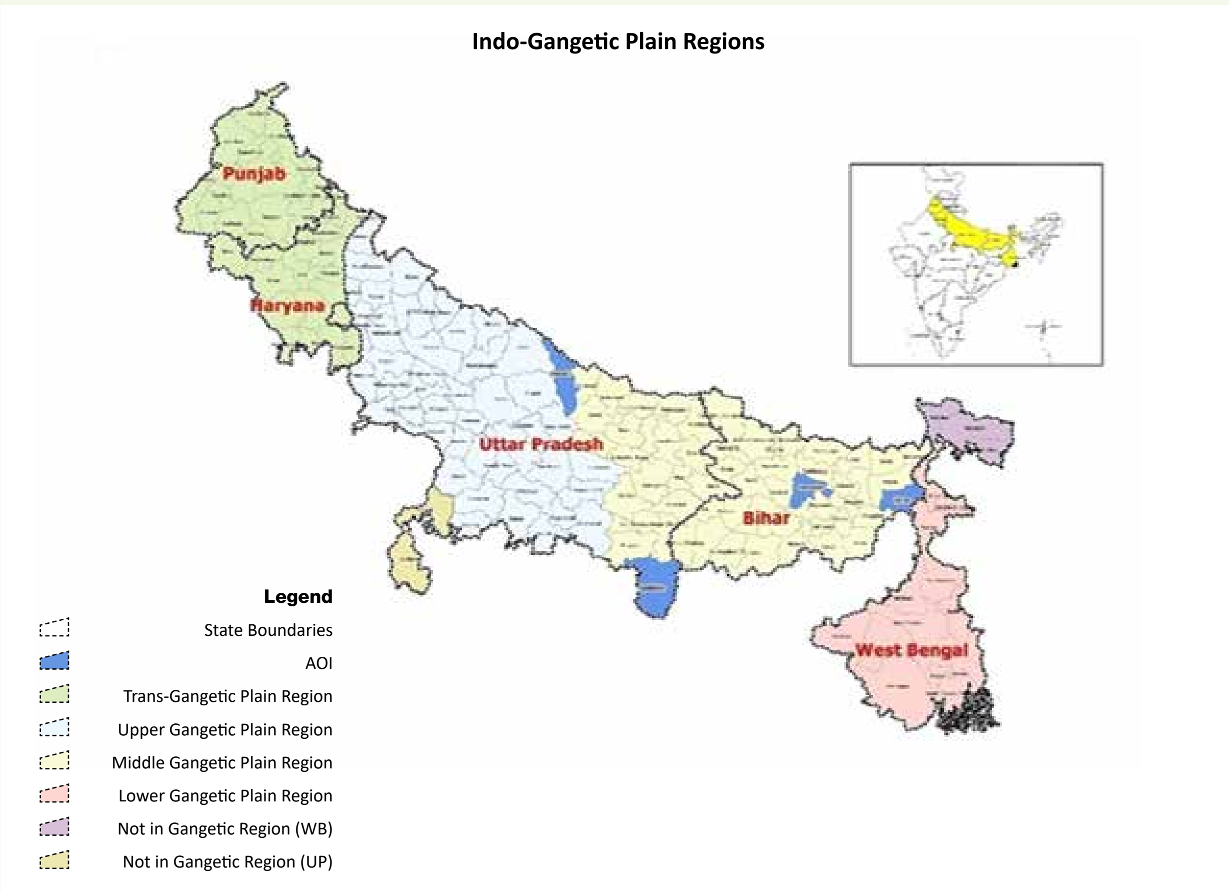
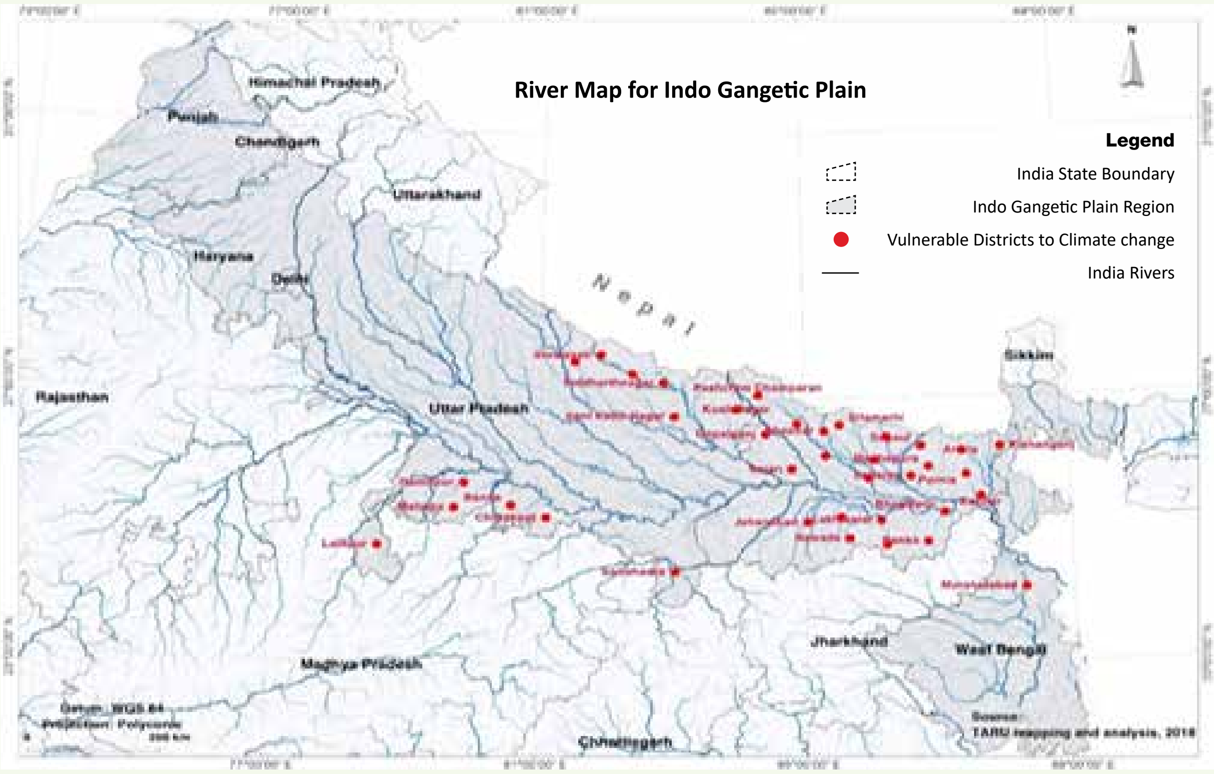


Figure 2: River map of IGP



maize, chickpea, lentil, mustard, potato, sugarcane and vegetables. Rice- and wheat-based cropping systems cover most of the area from these two regions which can be attributed to climate suitability, better adaptability, availability of high yielding varieties and increasing mechanization of both crops. The productivity of most crops in this region is close to their yield potential due to the presence of favourable agro-climatic conditions including productive alluvial soil, maximum irrigated land, sub-tropical climate, etc. Agricultural practices adopted by farmers are highly input intensive with higher usage of resources such as fertilizer and water which contribute to greenhouse gas (GHG) emissions as well. IGP is significant from the point of production of major food grain crops. Characterized by a favourable climate, fertile soils and abundant water supply, IGP is seen as the "bread basket" of South Asia, providing food and livelihood security for hundreds of millions of its inhabitants[3]. It is also known as India's "bowl of food grains" because it contributes 48.4 percent of rice and 74.7 percent of wheat of the total Indian production of these two major food grains crops.

Most areas of these plains have two to three crops in a year. Wheat, potato and mustard are the major crops of the spring (Rabi) season and paddy is grown in autumn (Kharif) season[4]. The climatic trends of IGP show that the temperature of this region is increasing year by year. According to a weather trend variability analysis done for the IGP region, the average temperature of this region has increased by 0.2°centigrade (C) per decade from the year 1960. The range of possible temperature increase for IGP is 0.6-2.7°C, 0.5-3.1°C and 1.0-5.4°C above the 1070-1999 mean for the 2030s, 2050s and 2090s, respectively. In general, temperatures in the monsoon period increase less than in the dry seasons[5]. The research indicates that though average precipitation of the plains is static, the timing of precipitation is changing[6].

3 Erenstein, Olaf, 2010. A comparative analysis of rice–wheat systems in Indian Haryana and Pakistan Punjab. *Land Use Policy,* Vol. 27 Issue 3 pp 869-879.

4 Koshal , A. K., 2014. Changing Current Scenario of Rice-Wheat System in Indo-Gangetic Plains Region of India. *International Journal of Scientific and Research Publications,* (4) (3).

5 New, M., Rahiz, M. and Karmacharya, J., 2012. Climate Change in Indo-Gangetic Agriculture: Recent Trends, Current Projections, Crop-Climate Suitability and Prospects for Improved Climate Model Information. CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS).

6 Kumar, Anuj, 2018. Economic Analysis of the Impact, Adaptation and Mitigation of Climate Change in the Dominant Cropping System of Indo-Gangetic Plains of India.

A study was conducted by the Centre for Environment Science and Climate Resilient Agriculture on assessment of impacts on rice and wheat in IGP[7] using the climatic data based on the PRECIS regional climate model developed by the Hadley Centre, United Kingdom, in nine representative locations of IGP. The study suggested the occurrence of extreme temperature events which could cause yield reduction, particularly if these events coincide with sensitive stages of crop growth. Apart from differential growth and yield responses of crop species to high thermal stress, the study also suggested differential response to high temperature stress during various growth phases[8]. The results indicated that an increase in temperatures adversely influences crop performance and these negative impacts of temperature are not compensated enough by elevated carbon-dioxide (CO2) concentrations as is evident from a reduction in overall projected yields. Results also project occurrence of low yielding years more frequently due to climate change.

IGP is an environmentally sensitive, socially significant and economically strategic domain of India where landscape, hydrology and fertility are threatened by climate warming and anthropogenic pressure. A decline in food production will be the major problem. In order to assess environmental changes, concerted efforts should be initiated to understand the geological past and model the future[9]. Even a rise in temperature by 2^0C can lead to a fall in farm production between 4 and 34 percent (IPCC, 2007)[10].

The soil salinity, already prevalent in the plains of Haryana, Punjab and western Uttar Pradesh, is bound to extend over the marginally saline areas, reducing the availability of agricultural land. This will place additional stress on the already declining water table. Groundwater exploitation is likely to be intensified and consequently water stressed areas will become water scarce. According to another study on the current rice-wheat system scenario in IGP, a good correlation is indicated between rainfall and rice yield as shown by statistical and remote sensing data analysis.

The study's findings mention that the current scenario of climate changes, i.e., global warming, rising temperatures, irregular pattern of rainfall, excess use of fertilizers and irregular pattern of irrigation significantly contribute to a decline in the fertility of lands[11]. The risk of climate change to agriculture is very significant in IGP due to its high dependency on rainfall and its connections to the tectonics and climate of the Himalaya. Thus, any change in these factors will have an adverse effect on the hydrology, soil fertility, food production and settlement patterns of IGP.

Incidence of pest and diseases would be most severe in tropical regions due to favourable climate/weather conditions, multiple cropping patterns and availability of alternate pests throughout the year. Climate change is likely to cause a spread of tropical and subtropical weed species into temperate areas and to increase the numbers of many temperate weed species currently limited by the low temperature at high latitudes.

India is the third highest GHG emitter. Agriculture and livestock together account for 18 percent of the gross national emissions. It is the third highest emitter after the energy and industry sectors. The growing population necessitates continuous increase in food production while ensuring low carbon footprints of agriculture and livestock. Incidentally, Uttar Pradesh, a prominent state from the IGP region, is also a top agricultural and livestock GHG emitter[12]. This underscores the importance of climate aligned sustainable agricultural practices.

Climate change can have a huge impact across the food processing industry due to its immense dependency on agriculture produce as a raw material. With weather becoming unpredictable, it becomes difficult to foresee industry needs. Climate change and agriculture produce are directly related to the cost of production and hence any risk involved in acquiring agriculture produce will have serious implications on profitability and sustainability of food-based enterprises. Apart from the growers, actors involved in aggregation and collection, transportation and storage, food processors are considered as the value chain actors who add value through a different set of activities. Climate change impacts will occur at all levels of the value chain and individual adaptive responses at each level will either enhance or reduce overall performance in terms of efficiency, continuity and product attributes. This study aims to explore adaptations of small holder farmers with special attention on climate implications and adaptive strategies to value chain actors.

7 Zacharias, Manju, Kumar , S. Naresh, Singh, S.D., Swaroopa Rani, D.N. and Aggarwal, P.K., 2014. Assessment of impacts of climate change on rice and wheat in the Indo-Gangetic plains. *Journal of Agrometeorology* 16 (1) : 9-17 June.

8 Cheng, W., Sakai, H., Yagi, K., and Hasegawa, T.,2009. Interactions of elevated [CO2] and night temperature on rice growth and yield. *Agril. For. Meteorol.,* 149(1): 51-58.

9 Saini, H.S., 2008. Climate Change and its Future Impact on the Indo Gangetic Plain (IGP). e-Journal *Earth Science India,* Vol. I (III), 2008, pp. 138-147.

10 Inter-Governmental Panel on Climate Change (IPCC), 2007. Fourth assessment Report.

11 Koshal , A. K.,2014.Changing Current Scenario of Rice-Wheat System in Indo-Gangetic Plains Region of India. *International Journal of Scientific and Research Publications,* (4) (3).

12 https://scroll.in/article/914085/agriculture-is-a-big-contributor-to-greenhouse-gas-in-india-a-study-finds-a-way-to-fix-that

1.2 Methodology Adopted for Selection of Districts and Crops

Among the five states that come under IGP, Bihar and Uttar Pradesh were selected for this study.

The study focused on districts that were identified from among the top 37 vulnerable districts from the states of Bihar and Uttar Pradesh by the National Innovations on Climate Resilient Agriculture (NICRA). The vulnerability of the districts and their ranking were determined based on three components. These three components of vulnerability are sensitivity, exposure and adaptive capacity, identified based on the extent and intensity of the possible climate impact.

This study considered climatic, physical and socio-economic factors together to arrive at the vulnerability rating. Eight indicators using gridded meteorological data for the period 1951-2009 were used for computing exposure while sensitivity was computed from six indicators based on crop and soil characteristics. Computation of adaptive capacity has been based on socio-economic indicators of agricultural technology, infrastructure and human development. These spatial datasets of the key indicators contributing to agricultural vulnerability have been generated for the 161 districts in IGP. The study also found that the districts located in the eastern and southern parts of Uttar Pradesh and Bihar were more vulnerable, whereas districts in Punjab and Haryana have low vulnerability due to their higher adaptive capacity to recover from climatic stresses. Hence it was decided to select districts from Uttar Pradesh and Bihar which are also priority states for the United Nations Development Programme (UNDP). This list included 36 districts from Bihar and Uttar Pradesh. It was also proposed to select districts that are in the list of 'aspirational districts' as identified by NITI Aayog of the Government of India. A total of 115 districts were

Figure 3: District selection framework for the study

District Selection

STEP **01**

Selection of Vulnerable Districts (IGP) & Aspirational Districts

The Study focused on the common districts which were identified from the top 36 vulnerable districts from the states of Bihar and Uttar Pardesh by National Innovation on Climate Resilient Agriculture (NICRA) and the 21 aspirational districts from Bihar and UP as classified by NITI AYOG. A total of 14 districts which were identified were common to both.

14 Districts Selected

STEP **02**

Selection of Districts from Agro-Climatic Zones

Bihar has been classified into 3 distinct Agro-climatic Zones while UP has been into 9 Agro-climatic Zones. For both the states it was decided that 1 district needs to be selected from each Agro Climatic Zone.

4 Different Agro-Climatic Zone

STEP **03**

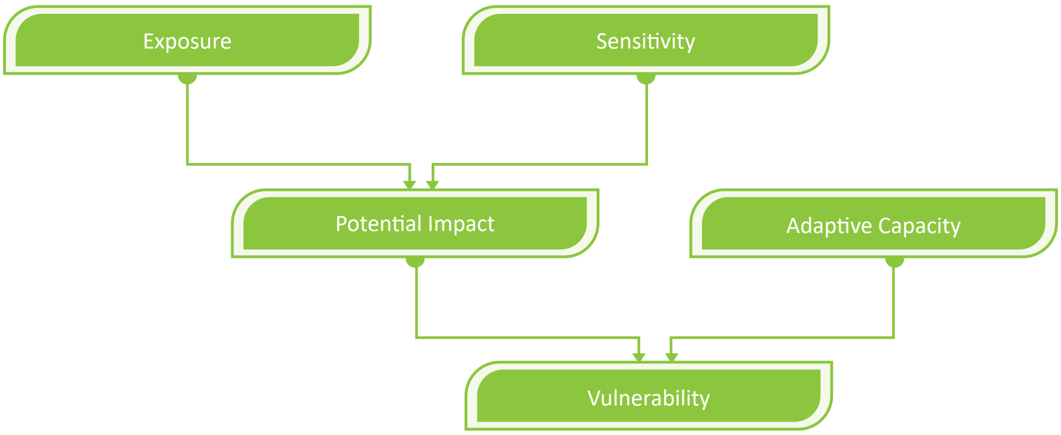
Finalization of Districts on the basis of Agriculture & Value Chain Centrality

Final List of Districts were identified by ranking the districts on the basis of Indicators developed for Agriculture and Value Chain Centrality.

4 Districts Selected

Figure 4: Conceptual framework of assessing the vulnerability of agriculture to climate change

Conceptual Framework of Assessing the Vulnerability of Agriculture to Climate change



Source: Reproduced from the document Vulnerability of Agriculture to Climate Change: District Level Assessment in the Indo-Gangetic Plains, Indian Agricultural Research Institute, Indian Council of Agricultural Research, New Delhi.

identified from 28 states with the criteria of at least one from each of the states. The selection of districts was made in a transparent manner by a committee of senior officers of the Government of India in consultation with state officials, using a composite index of key data sets that included deprivation enumerated under the Socio-Economic Caste Census, key health and education sector performance and state of basic infrastructure indicator. Twenty-one of the total 115 districts were from Bihar and Uttar Pradesh. Based on these two selection criteria, a total of 14 districts were identified (nine from Bihar and five from Uttar Pradesh). The scope of study suggested that two districts each from Bihar and Uttar Pradesh should be included. In the interest of a broader perspective and representation from diversified agro-climatic conditions, it was also decided to select districts from two different agro-climatic zones. Districts common to these two lists were further evaluated based on a framework comprising parameters such as centrality of agriculture, meaning the importance of agriculture as a source of livelihood for the district.

Agriculture centrality

Agriculture centrality could be further unpacked as how central it is to the population of the district and how central it is to the geography of the district. Taking a cue from these two leading questions, it is further subdivided into three specific indicators:

- What percentage of population is dependent on agriculture as their first livelihood option? In the absence of reliable data on this parameter, rural population was taken as a proxy indicator;
- What percentage of the total geographical area of the district is under agriculture? and
- What is the crop intensity of the district?

The last two questions led us to understand whether the dependent population is factually dependent or agriculture is another form of drudgery in the absence of

Table 1: Scoring criteria

Criterion	1	2	3	4	5
% area under agriculture	>20%	21-40%	41-60%	61-80%	81-100%
Crop intensity	<1.2	1.21-1.4	1.41-1.6	1.61-1.8	>1.81
% rural population	<90%	90.1%-92%	92.01%- 94%	94.01%-96%	96.01-98%
Value addition potential (INR Cr.)	<100	101-200	201-300	301-400	>400

other livelihood options. For all these three indicators, data from the secondary source were used for all districts and a score of different scales ranging from 1 to 5 and a comparative score were assigned to each of the 14 districts which were shortlisted from the above-mentioned criteria.

Value chain centrality

From the objective of assignment, it became essential to add the districts that had large value addition potential due to production of certain crops. To calculate the value chain centrality, end usage of the commodities produced in the districts were identified. The difference between the value of the commodity produced and its price as raw material and its value after being converted into a consumable product gave us an idea of the value chain possibility within the district.

As an example, in the case of wheat, district-wise production of wheat was multiplied by the price of wheat which we took as the Minimum Support Price (MSP) declared for the commodity. Based on secondary research, the final usage of wheat was assessed which could be wheat flour, fine flour, rava (suji) and wheat bran. The wholesale price for each of the commodities was multiplied with the proportion of wheat produced in the districts. Through this exercise, the value chain possibilities for all the main crops were identified.

Table 2: Value chain intensity

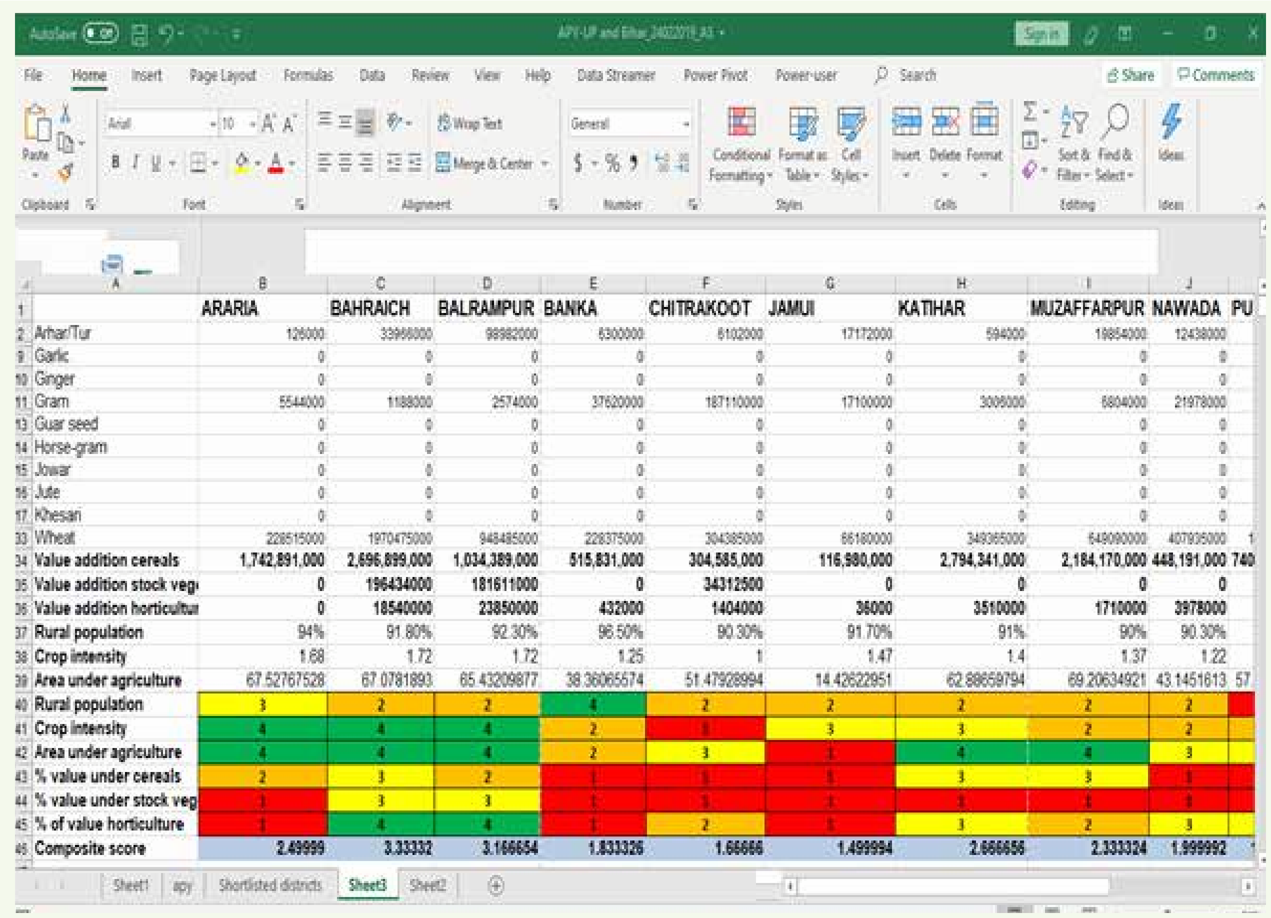
Agricultural centrality (50%)				
Parameters	**Weighted Percentage**	**Particular**	**Score**	**Weighted Score**
% area under agriculture	17%	45%	3	0.5
Crop intensity	17%	35.00	0	0
% rural population	17%	60%	4	0.67
Total	50%			1.17
Value chain centrality (50%)				
Parameters	**Weighted Percentage**	**Particular**	**Score**	**Weighted Score**
% proportion of high value addition crops	50%	23%	2	1
Total	50%			1
Total Score			2.17	

Agro-climatic zones

An agro-climatic zone can be defined as the land unit expressed in terms of major climatic conditions suitable for a certain range of crops. Some of these conditions are temperature, rainfall, altitude and soil characteristics. The first two plays an important role in defining the agro-climatic zones. India is classified under 15 agro-climatic zones and 73 sub zones. However, ICAR has delineated India into 127 zones. In addition to the agriculture and value chain centrality, representation of agro-climatic zones in different states was also considered as an important criterion. Out of the two states identified for this study, Bihar, with a total geographical area of 9,360,000 hectare (ha), has three important agro-climatic zones. These zones are known as North-West, North-East, and South. Similarly under the National Agricultural Research Project undertaken by the erstwhile Planning Commission (presently known as NITI Aayog) nine agro-climatic zones have been recognized in the state which are Tarai, Western Plain , Mid-Western Plain, South-Western Semi-Dry Plain, Mid Plain, Bundelkhand, North-Eastern Plain, Eastern Plain and ninth as Vindhyan. Table 3 shows the demarcation of the 14 districts as per the agro-climatic zones.

These multiple contextual filters finally helped to identify Sonebhadra and Bahraich districts from Uttar Pradesh

Figure 5: District selection framework



	ARARIA	BAHRAICH	BALRAMPUR	BANKA	CHITRAKOOT	JAMUI	KATIHAR	MUZAFFARPUR	NAWADA
Arhar/Tur	126000	33966000	99982000	6300000	6102000	17172000	594000	19854000	12438000
Garlic	0	0	0	0	0	0	0	0	0
Ginger	0	0	0	0	0	0	0	0	0
Gram	5544000	1188000	2574000	37620000	187110000	17100000	3006000	6804000	21978000
Guar seed	0	0	0	0	0	0	0	0	0
Horse-gram	0	0	0	0	0	0	0	0	0
Jowar	0	0	0	0	0	0	0	0	0
Jute	0	0	0	0	0	0	0	0	0
Khesari	0	0	0	0	0	0	0	0	0
Wheat	228515000	1970475000	948485000	228375000	304385000	66180000	349365000	649090000	407935000
Value addition cereals	**1,742,891,000**	**2,696,899,000**	**1,034,389,000**	**515,831,000**	**304,585,000**	**116,980,000**	**2,794,341,000**	**2,184,170,000**	**448,191,000**
Value addition stock veg	**0**	**196434000**	**181611000**	**0**	**34312500**	**0**	**0**	**0**	**0**
Value addition horticultur	**0**	**18540000**	**23850000**	**432000**	**1404000**	**36000**	**3510000**	**1710000**	**3978000**
Rural population	94%	91.80%	92.30%	96.50%	90.30%	91.70%	91%	90%	90.30%
Crop intensity	1.68	1.72	1.72	1.25	1	1.47	1.4	1.37	1.22
Area under agriculture	67.52767528	67.0781893	65.43209877	38.36065574	51.47928994	14.42622951	62.88659794	69.20634921	43.1451613
Rural population	3	2	2	4	2	2	2	2	2
Crop intensity	4	4	4	2	1	3	3	2	2
Area under agriculture	4	4	4	2	3	1	4	4	3
% value under cereals	2	3	2	1	1	1	3	3	1
% value under stock veg	1	3	3	1	1	1	1	1	1
% of value horticulture	1	4	4	1	2	1	3	2	3
Composite score	**2.49999**	**3.33332**	**3.166654**	**1.833326**	**1.66666**	**1.499994**	**2.666656**	**2.333324**	**1.999992**

Table 3: Classification of districts as per agro-climatic zones

District	State	Agro-climate zone
Araria	Bihar	North East Alluvial
Banka	Bihar	South Bihar Alluvial
Jamui	Bihar	South Bihar Alluvial
Katihar	Bihar	North East Alluvial
Muzaffarpur	Bihar	North West Alluvial Plain
Nawada	Bihar	South Bihar Alluvial
Purnia	Bihar	North East Alluvial
Samastipur	Bihar	North West Alluvial Plain
Sitamarhi	Bihar	North West Alluvial Plain
Bahraich	UP	North Easterly Plain
Balrampur	UP	North Easterly Plain
Chitrakoot	UP	Bundelkhand
Shravasti	UP	North Easterly Plain
Siddharth Nagar	UP	North Easterly Plain
Sonbhadra	UP	Vindhayachal

Table 4: Final scores

District	State	Rural population	Crop intensity	Area under agriculture	% of value crops	Composite score
Araria	Bihar	4	4	4	4	3.999992
Bahraich	UP	2	4	4	5	4.16666
Balrampur	UP	3	4	4	4	3.833326
Banka	Bihar	5	2	2	4	3.499994
Chitrakoot	UP	2	1	3	1	1.499996
Jamui	Bihar	2	3	1	1	1.499996
Katihar	Bihar	2	3	4	5	3.999994
Muzaffarpur	Bihar	2	2	4	5	3.833328
Nawada	Bihar	2	2	3	3	2.666662
Purnia	Bihar	1	2	3	3	2.499996
Samastipur	Bihar	5	3	4	4	3.999992
Shravasti	UP	5	2	4	3	3.333326
Siddharth Nagar	UP	3	4	4	5	4.333326
Sitamarhi	Bihar	4	4	4	2	2.999992
Sonbhadra	UP	1	2	2	2	1.83333

Note: Sonbhadra was selected despite having a lower score than Shravasthi so as to ensure that both districts were from different agro-climatic zones.

and Katihar and Samstipur districts from Bihar. After the identification of these districts, based on the highest production, the top two or three crops were selected from both cereals and horticulture. All districts were thus scored. Two top districts from each state were shortlisted.

The final shortlisted districts included Katihar, Araria and Samastipur from Bihar whereas Siddharthnagar and Bahraich from Uttar Pradesh. The districts Araria and Samastipur had the same score and hence secondary research was further carried out in the context of connectivity, diversity of crops and available infrastructure. It was found that Samastipur district had more diversity in terms of crop production, better infrastructure and connectivity, thus demonstrating its capability for value creation. It was therefore decided to include Samastipur in the study. As mentioned above, in case of Uttar Pradesh, three districts were shortlisted. These districts were Siddharthnagar, Bahraich and Sonbhadra. However, after applying the criteria of representation of different agro-climatic zone, it was found that Siddarthnagar and Bahraich represented the same North-Eastern plain agro-climatic zone. Therefore, in order to have different agro-climatic zone represented, Sonbhadra district that falls in Bindhya zone was finalized.

Accordingly, the final districts shortlisted for the study were:

1. Samastipur and Katihar from Bihar; and
2. Sonbhadra and Bahraich from Uttar Pradesh.

Based on an assessment, important crops from the category of food crops and horticulture which have prominence in the district were selected for the value chain study. The selected crops included paddy, wheat and maize from the group of cereals and potato and tomato from the horticulture group. All crops selected for the study are prominent crops in the states and make significant contributions to the national-level production.

1.3 Methodology Adopted for the Study

Developing research tools for stakeholders

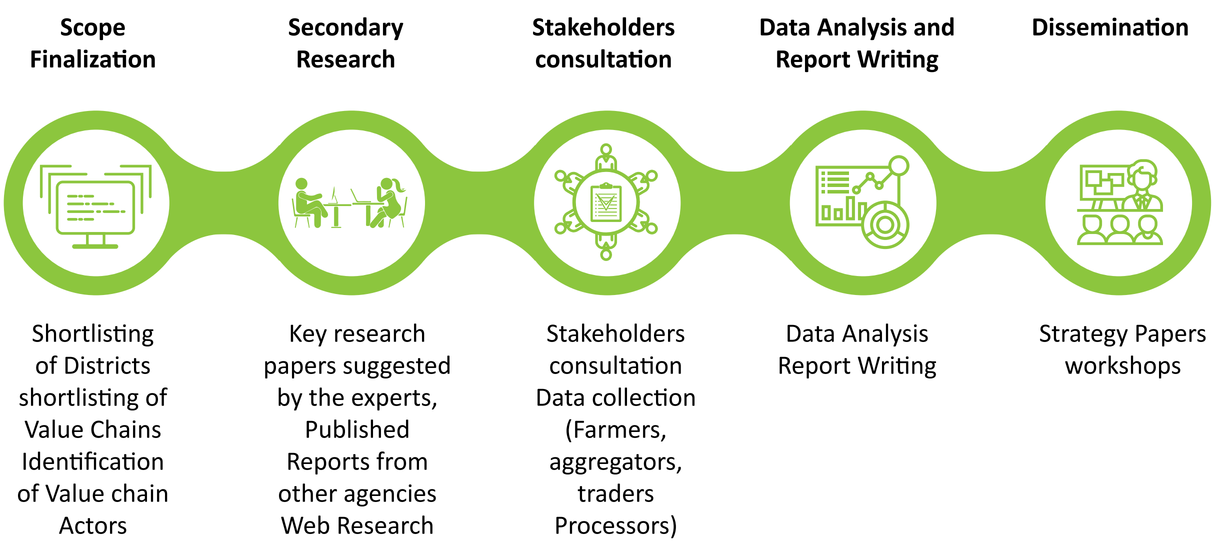
To understand the impact of climate change on small and marginal farmers, farmers were first asked to identify the climate change impacts which they perceived had impact on select crops for this study with pre-structuredtested questionnaire. Capturing qualitative information to access quantitative impacts is a known challenge, more so when the impact varies from individual to individual. In order to address this problem, the research team designed a five-point scale to capture qualitative information under this study. The scale so designed was discussed with the farmers.

They were asked to assign 1-5 numbers to the climate change impact based on the intensity of the impact. Accordingly, 1 was assigned to climate impacts where there was no loss of production, while score 2 meant noticeable loss in production due to climate change. Going up on the scale, a partial loss in production due to climate impact was assigned the number 3. The number 4 represents significant loss in production due to climate change and number 5 was assigned to complete loss of production due to climate change. Once the climate change impacts for different crops were identified then the research team discussed different types of adaptations, by small and marginal farmers. To understand the extent of adaptations, farmers rated key adaptations on the 5-point scale. For a calculation of value chain losses this study has focused on the losses due to climate change during the process of storage and processing. Losses incurred during transportation have been excluded for cereals and potato, as the losses incurred during the process were not observed to be directly linked with climate change.

All stakeholders in the value chain were further interviewed with the structured questionnaire and, wherever possible, group discussions with representatives of each value chain were also conducted. To quantify the value chain losses, we have used production figures for the 36 districts from Uttar Pradesh and Bihar from the most vulnerable districts identified by NICRA. For the calculations of value chain losses, production numbers from area and production statistics maintained by the Ministry of Agriculture and Farmer Welfare[13] were used. For estimating losses across the value chain, the average of the range quoted by stakeholders during personal interviews was used. The regulated value chain which involves procurement and distribution by government-nominated agencies/ Food Corporation of India (FCI) has been excluded while estimating losses. For estimating losses of produce, the MSP declared for year 2018-19 by the government was used.

Information collected from farmers about primacy of crops was also cross-checked with agriculture traders, grain merchants, representatives of the district chambers of commerce from each district as well as government officials. District officials from the National Bank for Agriculture and Rural Development (NABARD) and Krishi Vigyan Kendras (KVK) (Agriculture Science Centres), initiated by Indian Council of Agricultural Research (ICAR), were consulted to establish the validity of the collected information. Finally, the team visited wholesale agriculture mandis (trading centres) to validate the data collected for various crops and the level of value addition in the select value chains. Post this, all the key value agents -- right from farmers to processing units and

Figure 6: Methodology of the study



13 https://aps.dac.gov.in/Home.aspx?ReturnUrl=%2f

finally the logistic agents of the identified value chains -- were interviewed with the help of the specifically structured questionnaire (see Annexure V) to understand the climate change impact and adaptation measures (see Annexure VI for the detailed methodology).

1.4 Limitations and Key Challenges

One of the key challenges that we faced in this study was a lack of understanding among stakeholders regarding the differences between climate change and climate variability. Most stakeholders treat climatic variability as the only impact of climate change. Similar was lack of understanding with respect to adaptations among farmers. For farmers, it was difficult to differentiate between adoption of good practices to increase production vis-à-vis adaptations to mitigate the impact of climate change.

This lack of understanding was also evident in other value chain actors such as aggregators, traders, warehouse owners and processors. Stakeholders in the value chain, including farmers, treat adaptations in the same way as alterations, modifications or even adjustments which were even minor in nature in their value addition process. It was difficult to differentiate between losses due to inefficient value chain/production system.

The other limitation was with respect to attributing the impacts faced by farmers and other stakeholders in the value chain entirely to the climate change. Most previous studies on the impact of climate change on agriculture were focused on production and productivity with no or limited focus on value chain participants and value chain losses.

2

Review of Literature

This section presents a review of literature on global best practices on climate change in the agri-value chain. The agri-value chain for the study focused on a range of activities from post-harvest to further processing of commodities. The section presents the literature review of the available documents, reports and research articles. The literature review has also identified the research gap in the form of the scant number of available case studies in the agri-value chain adaptation to climate change. Based on an analysis and literature gap, the areas of enquiry in the present study have been identified.

Climate change can have significant impacts on economic activity and agri-value chains in two ways. First, in order to preserve their production capabilities, growers must adapt to changing conditions by means of incremental changes to their production systems and use of resources. Second, climate change may alter production capabilities more deeply, as the value created by agents diminishes or become obsolete in a new environment. Overall, these changes will affect economic profitability and competitiveness, livelihoods, sources of growth and employment and socioeconomic outcomes. In the context of climate change, resilience is the ability of a system or community to rebound following a shock such as a natural disaster. Building resilience requires not only a recognition of potential hazards such as extreme weather events, but also an understanding the underlying vulnerabilities that may affect recovery from them[14].

Almost every institution in the form of businesses, non-profits, governments or communities has acknowledged climate change and understood that its impact is being felt in day-to-day operations. Changing climate would also result in changes in agriculture systems and their value chains. For the value chains to be climate resilient, adaptations to mitigate hazards of climate change at various levels of the chain in a coordinated manner would be required to minimize the impact, innovate in terms of processes to deliver more value and quickly recover in case of uncertain climate events.

A series of articles in peer reviewed journals obtained from public and private domains were reviewed to identify successful measures undertaken to adapt value chains to mitigate the impact of climate change. Efforts were made to identify climate resilient practices adopted by various actors in the value chain, coordinated or uncoordinated along the value chain. The reviewed documents have been grouped under four categories:

1. Impact of climate change on the value chain;
2. Adaptive measures in the value chain to mitigate climate risks/hazards;
3. Adaptive measures to overcome climate change in farming systems; and
4. Impact of climate change on farming/production.

Substantive articles and research on the "impact of climate change on agriculture production or farming practices" have been conducted at the micro and macro level across the globe. A similar body of research on adaptive measures undertaken to mitigate the impact of climate change are documented in various articles. However, there are few references on adaptive measures in the value chain to mitigate climate risks/hazard. Out of the reviewed documents, very few articles discuss the value chain in agriculture or allied areas; however, these discussions are not completely centred around the value chain actors along the chain and thus represent adaptive measures in isolation in the chain. Documents pertaining to coffee, sugarcane and food value chains such as mangoes, wine and potato chips present details of climate risks to value chains, various value chain actors and the mitigation or adaptive measures being practiced. A detailed synopsis of the reviewed documents is presented in Table 5, which is followed by the case studies of select value chains.

14 https://aps.dac.gov.in/Home.aspx?ReturnUrl=%2f https://www.bsr.org/en/topics/climate-resilience

Table 5: A synopsis of the reviewed documents

Sr.No	Title of the Paper/Author / Institution/Journal / Year of Publication	Key points
Adaptive measures in the value chain to mitigate climate risks/hazards		
1	Thorpe, J. and Fennell, S., 2012. Climate Change Risks and Supply Chain Responsibility: How should companies respond when extreme weather affects small-scale producers in their supply chain?. *Oxfam Policy and Practice: Private Sector, 9* (1), pp.39-62.	The study is based on climate change adaptation by companies, the key component in the value chain. The study is a compilation of climate adaptive measures undertaken by different companies.
2	Batool, Samavia and Saeed, Fahad, 2016. Cotton Value Chain in Pakistan: A Preliminary Assessment of its Climate Vulnerabilities.	The paper highlights the importance of cotton in the national economy of Pakistan and in export earnings. It is based on a field study of cotton farmers in Pakistan and captures the climate adaptive measures undertaken by different components of the cotton value chain.
3	Fleming, A., Hobday, A.J., Farmery, A., van Putten, E.I., Pecl, G.T., Green, B.S. and Lim-Camacho, L., 2014. Climate change risks and adaptation options across Australian seafood supply chains–A preliminary assessment. *Climate Risk Management,* 1, pp.39-50.	The study is based on a case study of adaptation measures undertaken by different Australian seafood supply chains. It highlights the impact of climate change on the seafood industries and the measures adopted by them. It further explains how the impact is felt across all components of seafood supply chains.
4	Surminski, S., 2013. Private-sector adaptation to climate risk. *Nature Climate Change,* 3(11), p.943.	The paper is one among the very few studies that are available on private sector adaptation of climate change. The study is based on a field study of three companies. It further examines the adaptive measures undertaken by different small holders involved in coffee production.
5	Sloan, K., Teague, E., Talsma, T., Daniels, S., Bunn, C., Jassogne, L. and Lundy, M., 2019. One Size Does Not Fit All: Private Sector Perspectives on Climate Change, Agriculture and Adaptation. In *The Climate-Smart Agriculture Papers* (pp. 227-233). Springer, Cham.	This study highlights the need for differential solutions to the climate change problem. It further captures the perception of the private sector in adapting to climate change. The focus of the paper is on key components of the value chain, but intermediate components are missing from the discussion.
6	Mwongera, C., Nowak, A., Notenbaert, A.M., Grey, S., Osiemo, J., Kinyua, I., Lizarazo, M. and Girvetz, E., 2019. Climate-Smart Agricultural Value Chains: Risks and Perspectives. In *The Climate-Smart Agriculture Papers* (pp. 235-245).	The book is a compilation of papers on climate smart agricultural practices. It discusses the causes of climate change, its impact and adaptation measures by different components of the value chain. The book was found to be very relevant for the study under consideration.
7	Ruben, R., Wattel, C. and Van Asseldonk, M., 2019. Rural Finance to Support Climate Change Adaptation: Experiences, Lessons and Policy Perspectives. In *The Climate-Smart Agriculture Papers* (pp. 301-313). Springer, Cham.	The paper explores the role of the finance sector in climate adaptation. It discusses how adaptive capacities of farmers to adopt climate adaptive measures is affected due to the absence of finance. The study indirectly deals with the agriculture value chain.

Sr.No	Title of the Paper/Author / Institution/Journal / Year of Publication	Key points
8	Rojas-Downing, M.M., Nejadhashemi, A.P., Harrigan, T. and Woznicki, S.A., 2017. Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management,* 16, pp.145-163.	The study investigates the relationship between climate change and its impact on the livestock industry. It presents the mismatch between increasing global demand for dairy products and climate impacted reduction in supply of dairy products. Livestock is an allied value chain and thus the paper helps in improving an understanding of the possibilities of integrating allied value chains for building collective adaptive capacities.
9	Joshi, S.R., Rasul, G. and Shrestha, A.J., 2016. Pro-poor and climate resilient value chain development: operational guidelines for the Hindu Kush Himalayas. *ICIMOD Working Paper,* (2016/1).	This paper is a welcome deviation from the present literature on climate chain analysis. It emphasizes the need for a bottom-top approach in understanding and developing climate resilient measures.
10	Hecht, S.B., 2007. Climate change and the transformation of risk: Insurance matters. *UCLA L. Rev., 55,* p.1559.	The paper enquires into the role of insurance in developing climate adaptation strategies. It further delves into changing patterns in the insurance sector and makes a case for index-based agriculture insurance. The paper is very important to agriculture value-chain analysis.
11	Amado, J.C. and Adams, P., 2012. Value chain climate resilience: a guide to managing climate impacts in companies and communities. *Report prepared for Partnership for Resilience and Environmental Preparedness, Montreal, 11 July.*	The study investigates how companies and communities can deal with the changing climate. It further collects evidences of climate change impacts on businesses. The paper presents an integrated solution to climate change problems faced by companies and communities.
12	Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G., ... and Nelson, R. (2016). *Adaptive value chain approaches: Understanding adaptation in food value chains.*	The study defines the value chain and proposes a theoretical context by literature review of supply chain management, sustainability and adaptation for supply/value chains. It further defines value chain analysis. Three case studies with respect to value chain adaptation have also been documented and presented as part of this study.
13	Batool, Samavia and Saeed, Fahad, 2018. Towards a climate resilient cotton value chain in Pakistan: Understanding key risks, vulnerabilities and adaptive capacities.	The case study is designed with a value chain analysis that is proposed for a more integrated approach to climate adaptation. It documents findings and learnings from an initiative on climate-resilient coffee value chains which was piloted in Uganda.
14	Dekens, J. and Bagamba, F. 2014. Promoting an Integrated Approach to Climate Adaptation: Lessons from the coffee value chain in Uganda. International Institute for Sustainable Development.	This is a study to identify climate risks facing cotton value chain actors in Pakistan based on various climate indicators, including temperature, rainfall and climate extremes. This working paper has been produced by Sustainable Development Policy Institute, Pakistan.

Sr.No	Title of the Paper/Author / Institution/Journal / Year of Publication	Key points
	Impact of climate change on value chain	
15	Trienekens, J.H., 2011. Agricultural value chains in developing countries: a framework for analysis. *International Food and Agri-business Management Review, 14* (1030-2016-82778), p.51.	The paper presents a framework for developing country value chain analysis made up of three components. It investigates the theoretical framework of value chain analysis and further presents an in-depth analysis of value chains in agriculture.
16	Zhao, D. and Li, Y.R., 2015. Climate change and sugarcane production: potential impact and mitigation strategies. *International Journal of Agronomy, 2015.*	The paper briefly reviews the sugarcane response to climate change events, sugarcane production in several different countries, and challenges for sugarcane production in climate change. It further discusses measures for improving resilience of sugarcane production. There are various actors involved in the sugarcane value chain and they adapt to climate change differently. The focus of this paper is, however, on the production side only and it remotely touches the post-harvest value chain in sugarcane.
17	Laderach, P., Lundy, M., Jarvis, A., Ramirez, J., Portilla, E.P., Schepp, K. and Eitzinger, A., 2011. Predicted impact of climate change on coffee supply chains. In T*he economic, social and political elements of climate change* (pp. 703-723). Springer, Berlin, Heidelberg.	The study, on the impact of climate change, poses a very grim picture of climate in the future. Climate change would impact food security as well as the livelihoods. It would also impact products that are more dependent on stable climatic conditions. The paper presents the case study of climate change impact on coffee production in general and its quality in particular. This a product- and country-centric study and deals with the coffee supply chain with a limited focus on post-harvest actors in the coffee value chain.
18	Kumar, S. and Sharma, A., 2016. Agricultural value chains in India: prospects and challenges. *Retrieved from http://www. cuts-citee.* *org/pdf/Agricultural_Value_Chains_in_India_ Prospects_ and_Challenges. pdf.*	The paper presents an analysis of agriculture value chains In India. It highlights the importance of these value chains in reducing poverty and taking care of food security. It does not address the climate change component.
19	Rhiney, K. and Ajayi, O.C., 2018. Economic impacts of climate change on priority value chains in the Caribbean: Implications for private-sector investment and scaling-up of climate-smart agriculture in the region, Technical Centre for Agricultural and Rural Cooperation	This report is informed by a detailed desktop review of available literature on current and potential climate change impacts on fruit and vegetable and root and tuber value chains in the Caribbean.
	Impact of climate change on farming/production	
20	Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the national academy of sciences, 104*(50), pp.19680-19685.	This paper deals with how smallholders or subsistence farmers are more vulnerable to climate change and also brings out the problems associated with predicting these impacts for different reasons. The paper concentrates on only the primary actors involved in the value chain.

Sr.No	Title of the Paper/Author / Institution/Journal / Year of Publication	Key points
21	Kaur, J., 2017. Impact of Climate Change on Agricultural Productivity and Food Security Resulting in Poverty in India (Bachelor's thesis, Università Ca'Foscari Venezia).	The paper examines the impact of climate change on poverty and development in developing countries with special reference to India. It also highlights the role of multiple stakeholders in improving climate change mitigation
22	Verma, R.R., Srivastava, T.K. and Singh, P., 2019. Climate change impacts on rainfall and temperature in sugarcane growing Upper Gangetic Plains of India. *Theoretical and Applied Climatology, 135*(1-2), pp.279-292.	The paper refers to the metrological data of the last five decades of rainfall and temperature in the Gangetic plains and their impact on sugarcane production in the region. It further suggests specific adaptation and mitigation measures.
23	Nguyen, Hung, Marquez, Leorey and Talebian, Masoud, 2016. Increasing the resiliency of Vietnam's rice supply chain: a simulation approach.	The paper discusses the importance of the rice value chain in Vietnam's economy. It further explains the different climatic vulnerabilities associated with this crop with a simulation modelling approach.
24	Thuy, N.N. and Anh, H.H., 2015. Vulnerability of rice production in Mekong River delta under impacts from floods, salinity and climate change. *International Journal on Advanced Science, Engineering and Information Technology, 5*(4), pp.272-279.	This study tries to estimate the climate specific indexes for the rice farming provinces in Mekong River delta. The study , with the help of a simulation model, tries to quantify the impact of climate change on rice production.
	Adaptive measures for climate change in farming systems	
25	Abid, M.E.A., Scheffran, J., Schneider, U.A. and Ashfaq, M., 2015. Farmers' perceptions of and adaptation strategies to climate change and their determinants: the case of Punjab province, Pakistan. *Earth System Dynamics, 6*(1), pp.225-243.	The paper talks about the impact of climate change on agriculture in Pakistan and also adaptation measures undertaken by farmers in Pakistan. It lists out the constraints faced by farmers in such adaptations. Considering the dearth of literature on adaptive measures undertaken by different components of the value chain, this paper is an important resource for the study under consideration.
26	Ford, J.D., Berrang-Ford, L., Bunce, A., McKay, C., Irwin, M. and Pearce, T., 2015. The status of climate change adaptation in Africa and Asia. *Regional Environmental Change, 15*(5), pp.801-814.	This paper highlights the need for documenting adaptive measures carried out in different parts of the world. It has reviewed a large number of studies available. Results indicate a significant increase in reported adaptations since 2006. Adaptations are primarily being reported from African and low-income countries, particularly those nations receiving adaptation funds. The study, though it covers different geographies, has its focus on pre-harvest stages of the value chain only.
27	Baethgen, W.E., Meinke, H. and Gimene, A., 2003, November. Adaptation of agricultural production systems to climate variability and climate change: lessons learned and proposed research approach. In Climate Adaptation. net conference *"Insights and Tools for Adaptation: Learning from Climate Variability* (pp. 18-20).	This paper talks about how agriculture institutions can initiate adaptive practices and also of the various determining factors for better adaptation. The paper doesn't throw much light on agriculture value-chain analysis.

Sr.No	Title of the Paper/Author / Institution/Journal / Year of Publication	Key points
28	Bizikova, L., Parry, J.E., Karami, J. and Echeverria, D., 2015. Review of key initiatives and approaches to adaptation planning at the national level in semi-arid areas. *Regional Environmental Change, 15*(5), pp.837-850.	This paper deals with climate change adaptation initiatives by international agencies in semi-arid areas and how they influence the national strategies for climate change adaptation. The paper has its usefulness for policy level adaptation measures and not agriculture value analysis.
29	Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K. and Hottle, R., 2014. Climate-smart agriculture for food security. *Nature climate change, 4*(12), p.1068.	The paper talks about the climate smart agriculture and its need to deal with climate change. It explains the climate smart agriculture concept in details and discusses how its more comprehensive than the business as usual approach.
30	Scialabba, N.E.H. and Müller-Lindenlauf, M., 2010. Organic agriculture and climate change. *Renewable Agriculture and Food Systems, 25*(2), pp.158-169.	This article discusses the importance of organic agricultural systems and climate adaptation with specific reference to developing countries.
31	Ramirez-Villegas, J., Salazar, M., Jarvis, A. and Navarro-Racines, C.E., 2012. A way forward on adaptation to climate change in Colombian agriculture: perspectives towards 2050. *Climatic Change, 115*(3-4), pp.611-628.	This is a country-specific case study of Colombia. The study talks about the impact of climate change on agriculture in Colombia and underlines the need for policy measures and sectoral integration.
32	Harvey, C.A., Chacón, M., Donatti, C.I., Garen, E., Hannah, L., Andrade, A., Bede, L., Brown, D., Calle, A., Chara, J. and Clement, C., 2014. Climate-smart landscapes: opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. *Conservation Letters, 7*(2), pp.77-90.	The article brings out the need for coordination between adaptation and mitigation to improve the resilience of the agriculture sector to deal with climate change. It highlights the relative benefits of the landscape approach in dealing with climate change.
33	Smit, B. and Skinner, M.W., 2002. Adaptation options in agriculture to climate change: a typology. *Mitigation and adaptation strategies for global change, 7*(1), pp.85-114.	The paper discusses the typology of adaptation to classify with reference to Canada, the existing adaptation measures in agriculture.
34	Abid, M., Schilling, J., Scheffran, J. and Zulfiqar, F., 2016. Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. *Science of the Total Environment, 547,* pp.447-460.	This paper builds the case for documenting the farm level impact and adaptation to climate change. The paper is based on the data generated from a large sample of farmers of Punjab from Pakistan. The paper examines and documents the adaptive measures undertaken by farmers only and doesn't cover the other components of the agriculture value chain.
35	Cairns, J.E., Sonder, K., Zaidi, P.H., Verhulst, N., Mahuku, G., Babu, R., Nair, S.K., Das, B., Govaerts, B., Vinayan, M.T. and Rashid, Z., 2012. Maize production in a changing climate: impacts, adaptation, and mitigation strategies. I*n Advances in agronomy* (Vol. 114, pp. 1-58). Academic Press.	The paper discusses the role of climate resilient seeds and agriculture management practices in maize production. It also stresses the need to develop germplasm that accelerates its adoption by farmers.

Sr.No	Title of the Paper/Author / Institution/Journal / Year of Publication	Key points
36	Satapathy, S., Porsche, I., Kunkel, N., Manasfi, N. and Kalisch, A., 2011. Adaptation to Climate Change with a Focus on Rural Areas and India. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, India. Project on Climate Change Adaptation in Rural Areas of India.	The report is the outcome of joint consultations of the agriculture department and other international agencies. It shares the prevailing practises of climate adaption in rural India.
37	Sadiq, M.A., Kuwornu, J.K., Al-Hassan, R.M. and Alhassan, S.I., 2019. Assessing Maize Farmers' Adaptation Strategies to Climate Change and Variability in Ghana. *Agriculture, 9*(5), p.90.	The study is based on maize farmers in Ghana. It examines the adaptation practices used by farmers in Ghana. It further suggests specific adaptation and mitigation measures.
38	Janowiak, M.K., Dostie, D.N., Wilson, M.A., Kucera, M.J., Skinner, H.R., Hatfield, J.L. and Swanston, C.W., 2016. *Adaptation Resources for Agriculture: Responding to Climate Variability and Change in the Midwest and Northeast.* United States Department of Agriculture.	The workbook is a compilation of suggestive measures to be undertaken by the different stakeholders dealing with climate change. It presents an array of site solutions farmers across theUS.
39	Müller, A., 2009. Benefits of organic agriculture as a climate change adaptation and mitigation strategy in developing countries.	The paper explores the option of organic agriculture as an adaptive measure and its dynamics. It highlights the sustainability aspects of organic agriculture and emphasizes its importance as an adaptive measure. The study presents organic agriculture as an option but has limited relevance to the value chain study.
40	Nyong, A., Adesina, F. and Elasha, B.O., 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. Mitigation and Adaptation Strategies for Global Change, 12(5), pp.787-797.	This study is based on exploring the suitability as well as limitations of indigenous knowledge in dealing with climate change. The paper tries to look at how social capital of communities gained overtime in dealing with climate change can be moulded into modern management practices. The absence of value chain analysis in this paper makes it less relevant for this study.
41	Shrestha, S., Deb, P. and Bui, T.T.T., 2016. Adaptation strategies for rice cultivation under climate change in Central Vietnam. *Mitigation and Adaptation Strategies for Global Change, 21*(1), pp.15-37.	The report is based on a case study of rice cultivation in Vietnam, climate change impact and the prevailing adaptation measures. The paper majorly concentrates on the production stage of the value chain.
42	Winters, P., Murgai, R., Sadoulet, E., De Janvry, A. and Frisvold, G., 1998. Economic and welfare impacts of climate change on developing countries. *Environmental and Resource Economics, 12*(1), pp.1-24.	The paper explores the economic and welfare impact of climate change on developing countries. It takes an overview of the adaptive and mitigation measures in these countries. The climate specific vulnerabilities of the smallholders are documented but the analysis of adaptive measures is limited to one component of the value chain, i.e., farmers, only.

Sr.No	Title of the Paper/Author / Institution/Journal / Year of Publication	Key points
43	Franzel, S., Kiptot, E. and Degrande, A., 2019. Farmer-to-farmer Extension: A Low-cost Approach for Promoting Climate-smart Agriculture. In *The Climate-smart Agriculture Papers* (pp. 277-288). Springer, Cham.	The paper emphasizes the importance of agriculture extension services to improve the climate resiliency of farmers. It further discusses an innovative case of farmers to farmers' agriculture extension medium being practised by farmers.
44	Hammond, J., van Wijk, M., Pagella, T., Carpena, P., Skirrow, T. and Dauncey, V., 2019. Shea Butter: A Pro-poor, Pro-female Route to Increased Income. In *The Climate-smart Agriculture Papers* (pp. 215-226). Springer, Cham.	This paper builds the case for the need of looking at how smallholders adapt to climate change. It explains the case of how smallholders and women collect and trade shea butter to ensure livelihoods and food security as a climate adaptation strategy.
45	Ortiz, R., Sayre, K.D., Govaerts, B., Gupta, R., Subbarao, G.V., Ban, T., Hodson, D., Dixon, J.M., Ortiz-Monasterio, J.I. and Reynolds, M., 2008. Climate change: can wheat beat the heat? *Agriculture, Ecosystems & Environment, 126*(1-2), pp.46-58.	This article reviews some of the approaches for addressing the expected effects that climate change may likely inflict on wheat in some of the most important wheat growing areas, namely germplasm adaptation, system management, and mitigation. The analysis presented in the paper is product centric and doesn't provide many inputs for value chain analysis.
46	Meza, F.J. and Silva, D., 2009. Dynamic adaptation of maize and wheat production to climate change. *Climatic Change,* 94(1-2), pp.143-156.	The focus of this study is to document the impacts of climate change on maize and wheat yields in Chile as well as to describe the dynamics of adaptation. Like many other studies this too is a product centric study and adopted a narrow approach of value chain analysis
47	Ertiro, B.T., Azmach, G., Keno, T., Chibsa, T., Abebe, B., Demissie, G., Wegary, D., Wolde, L., Teklewold, A. and Worku, M., 2019. Fast-tracking the Development and Dissemination of a Drought-tolerant Maize Variety in Ethiopia in Response to the Risks of Climate Change. In *The Climate-smart Agriculture Papers* (pp. 79-86). Springer, Cham.	The literature on climate smart agriculture highlights the need for developing climate adaptive seed varieties. The focus of the paper is on understanding the processes of dissemination of a drought-tolerant maize variety in Ethiopia in response to the risks of climate change.

2.1 Case Studies

(I) Cotton Value Chain in Pakistan

The working paper titled "Towards a climate resilient cotton value chain in Pakistan: Understanding key risks, vulnerabilities and adaptive capacities" is based on a study to identify climate risks facing cotton value chain actors in Pakistan based on various climate indicators, including temperature, rainfall, and climate extremes. This working paper has been produced by the Sustainable Development Policy Institute, Pakistan. This paper presents the findings of the study which helped identify climate risks that helped understand comparative vulnerabilities depending on different landholdings, geographic locations and gender, by using a mix of qualitative and quantitative methods. The study also examines current adaptation practices at the farm-level, drivers of adaptation decision-making, opportunities for public-private partnerships to support farm-level adaptation, and potential ways to increase the resilience of cotton value chain in semi-arid regions of the country.

This research work followed a VC-ARID methodology outlined in Carabine and Simonet (2017) and is a continuation of the background review done in Batool and Saeed (2017). VC-ARID is a three-step systematic approach to map the value chain, and identify climate risks, adaptation options and opportunities for investment[15]. The study was carried out in in three Union Councils of Dera Ghazi Khan and Faisalabad districts.

Impact of Climate Change on Cotton Value Chain

Moving up the value chain (towards the processing sector), the study states that the level of vulnerability declines as reliance on raw cotton imports increases, and climate impacts become more and more indirect (fewer impacts are transferred down the value chain as each actor undertakes adaptive measures). Key informant interviews and focus group discussions conducted in the Dera Ghazi Khan and Faisalabad districts with cotton value chain actors focused on their perceptions of climate change, the factors that make them vulnerable to impacts of climate, climate risks on their firm/industry and adaptation practices. Interviews with industrialists, processors, representatives of pesticide and seed companies, agriculture research institutes and local agriculture departments all concluded that there was a high level of awareness about climate impacts among the respondents. Processors viewed climate change as most threatening to the cotton production stage and further stressed importance of educating farmers about climate risks and their management.

Factors Causing Vulnerability to Climate Change

The study identified the following factors causing vulnerability due to climate change.

Climate Change Risks

No physical climate change risks have been found in the study but the working paper emphasizes that there are indirect impacts of climate change on the textile industry which may disrupt business operations. Three major risks identified for the cotton textile industry due to direct impacts of climate change at farm level are[16]:

a) Competitive risk: the product loses value in the international market;

b) Reputational risk: international buyers start procuring from others whose supply is reliable, both in terms of quality and quantity; and

c) Revenue risk: results from both competitive and reputational risk and causes a rise in the cost of production at the industry-level.

At the local level, ginning, spinning and weaver units in the supply chain have been facing problems due to a decrease in the quality of the domestic cotton:

a) Changes in the micronaire (MIC)[17] of the cotton ball due to a changing rainfall pattern has affected the spinning of cotton ball into fine yarn. The quantity of MIC is found to be very high;

b) Spinners have to invest more in cleaning cotton due to increased moisture which attracts more trash content in case of excessive rainfall;

Table 6: Factors causing vulnerability due to climate change

Sr.No	Factor	Description
1	Size	Small firms were found to be more vulnerable to climate shocks compared to the larger ones
2	Type of final product	Firms that produce hosiery-based products as compared to home textile are more susceptible to raw material supply shortage affected by climate change
3	Type of market targeted	Firms that target local markets rely on local raw material suppliers and can be easily affected, whereas those targeting international markets can chose to import the raw material to mitigate the supply demand gap
4	Type of industry	Secondary industries such as cottonseed oil units are affected by production While small sized industries have attempted to source raw material from other cities, large firms have adapted by stocking the cottonseed throughout the year.
5	Formality or informality of the firm	Informal textile industry suffers more as it lacks the capacity to buffer input supplies and has limited access to finances thus affecting women and poor labourers working with it the most.

15 Batool, Samavia and Saeed, Fahad, 2018. Towards a climate resilient cotton value chain in Pakistan: Understanding key risks, vulnerabilities and adaptive capacities, pp. 19.

16 Batool, Samavia and Saeed, Fahad, 2018. Towards a climate resilient cotton value chain in Pakistan: Understanding key risks, vulnerabilities and adaptive capacities, pp. 52.

17 MIC is a measure of the air permeability of compressed cotton fibres. It is often used as an indication of fibre fineness and maturity (Cotton Inc. 2017).

c) The other problems that have been reported include decline of fibre strength due to early maturity of the produce, pest and disease outbreaks because of high temperature impacting the colour and strength of cotton ball and rapid changes in season have shrunk the operational period of sock industries by two months. The study highlights that the shrunk operational period of the sock industry has resulted into an opportunity for product innovation and sock industries are moving away from pure cotton-based socks to other lighter material socks that are wearable in mid-season;

d) At the weaving units, labour conditions have further worsened due to heat emitted by machines combined with increased outdoor heat. This requires more rest hours and provision of water at the work place. High temperatures affect efficiency of workers; and

e) Printing and dying units are susceptible to water scarcity in the future though not currently.

Current Adaptation Practices

The study has noted that current practices of adaptation to climate risk are more unit-specific and not inclusive of other value chain actors. These adaptation practices pertain to covering the supply gaps in the domestic cotton markets, to sustain business operations and profit margins. Current adaptation practices include:

1. Large firms resort to buying imported cotton whereas small firms, solely dependent on local production, bear the brunt of the decrease in supply. Small firms purchase cotton from large ones from their stock in case of a decrease in supply of domestic cotton. Medium sized firms have also started to import cotton. These practices are reactive adaptation practices;
2. Large manufacturing units have attempted to mix cotton with nylon, polyester, etc., to meet supply demands. However, this strategy is very limited because it is determined by demand (i.e., manufacturers cannot mix other materials if the buyers demand 100 percent cotton); and
3. As an adaptation strategy, a large number of export-oriented textile firms have started to target the domestic market. As these firms were unable to remain competitive abroad, they have entered the local textile markets to sustain profit margins.

The study also proposed the following targeted policy actions for cotton value chain:

- Linking ginners with global markets;
- Public-private partnerships to support adaptation at the farm-level; and
- Awareness raising on climate change issues.

(ii) Coffee Value Chain in Uganda

Climate resilient value chains and food systems briefing note series from February 2014 presents the case study of the coffee value chain in Uganda[18]. The case study is designed with value chain analysis that is proposed for a more integrated approach to climate adaptation. It documents findings and learnings from the initiative on climate-resilient coffee value chains which was piloted in Uganda.

Coffee being a climate sensitive crop, negative impacts of climate change have been predicted globally through various studies. In Uganda, the negative impacts have been predicted especially for the Arabica coffee. The climate risk analysis for the coffee value chain was conducted using multi-stakeholder dialogues along the coffee value chain.

Key findings presented in the case study are:

Impact of climate hazards: Impacts of climate hazards are felt across the entire coffee value chain from production to export. The perceived impact of climate change has been associated with drought, floods and changing rainfall patterns. The impact of climate change can be seen at various stages of the coffee value chain. The direct impact has been seen on reduction of coffee yield, disruption of the bean drying process, and the destruction of inputs and infrastructure for processing and transportation. Indirect impacts have been noted in terms of a decrease in income due to reduced business activities and services, an increase in costs directly at three levels – production, transformation (e.g., increased breakdown of processing equipment and machinery due to high moisture content of beans resulting from heavy rainfall), and distribution (e.g., increased vehicle repair costs due to road deterioration from heavy rainfall). While the case study discusses the limitations of not being able to generalize the differences between value chain actors in terms of the level of vulnerability and exposure to climate hazards, it clearly states that coffee farmers and processors generally tend to be more vulnerable to the impacts of climate hazards than traders, middlemen and exporters. The pilot revealed that the vulnerability tends to be more concentrated at the production end of the coffee value chain.

Adaptations or efforts to minimize the impact: The actors in the value chain seem to be making efforts

18 Dekens, J., and Bagamba, F., 2014. Promoting an Integrated Approach to Climate Adaptation: Lessons from the coffee value chain in Uganda. International Institute for Sustainable Development

to minimize the impact but not all responses are sustainable. Most responses along the chain are oriented toward loss prevention, sharing with or transferring the losses to other actors along the chain (input suppliers transmit risks to the farmers by selling improper inputs; exporters transfer the risk to actors in the lower stages by off¬ering lower prices for lower quality coff¬ee; insurers increase premiums), and to a lesser extent on capacity building and awareness raising (some exporters support the adoption of good agricultural practices among farmers and the development of drought-resistant coff¬ee varieties in partnership with research institutes). These responses happen in isolation or an uncoordinated manner among the value chain actors.

What hampers climate change adaptation? The case study highlights that a lack of communication, exchange of information and trust between and among actors along the value chain hampers climate adaptation. Participating actors at different levels of the chain do not know about each other. The chain is fragmented with many intermediaries between farmers and exporters.

(iii) Caste Study: Impact of Climate Change on Soy, Sesame and Pigeon Pea Value Chains in Mozambique

This case study is based in Mozambique, a country that is predominantly agrarian with close to 80 percent of the total workforce employed in agriculture which contributes around 25 percent to the gross domestic product (GDP). A majority of the farmers are engaged in subsistence farming. Agriculture is the main occupation for most rural households. Climatic risks for agriculture are high as much of the agriculture is rainfed with cropping cycles defined by the onset of the rains. Farmers use traditional modes of farming. In spite of the promotion of the modern methods of farming such as the use of certified seeds, farmers prefer to use conventional methods which reflect low adaptation. This affects their resilience capacity and makes them vulnerable to ongoing as well future climate extremes. Climate changes that reflect in frequent weather extremes and the projected climate changes for the country are indicative enough that these changes are going to further intensify the country's existing poverty. The study identified the value chain of three commodities, namely, soy, pigeon pea and sesame, to understand regional climate risks. These crops were selected based on their economic importance as well as their priority in the United States Agency for International Development's projects in Mozambique. The study identified the following climate related concerns:

1. Shifts in growing seasons; and
2. Increases in extreme events, including high temperatures and intense rainfall events or longer dry periods.

Climate projections for Mozambique are presented under rainfall and temperature categories. These projections highlight the increased climatic risks for Mozambique in the future. The rainfall projections indicate large uncertainties in the total duration of the rainy season, start and end of the rainy season and intensity of rainfall. Similarly, both minimum and maximum temperatures in Mozambique are projected to continue to be warmer across all seasons.

The report further presents the climate sensitivities of identified key value chains which are soy, pigeon pea and sesame. The analysis is summarized in Table 7.

Table 7: Impact of climate change on identified value chains on production systems in Mozambique

Identified Commodity	Uses	Weather Extremes and their Impact on Production		Climate Threat Level
		Temperature	Rainfall	
Soy	Used for animal feed. Supply meets only 40% of the demand. Potential to increase production	Climate projections suggest a greater number of days when temperatures exceed the 35°C threshold. This will lead to poor germination. Moderate droughts will affect the soy yield but extreme droughts may lead to complete crop failure. Drought could lead to a nationwide soy shortage but be especially devastating to northern and central Mozambique	Delayed start of the rainy season will affect soy yield. Further an altered rainfall regime, with more dry spells during the growing season, is likely to decrease yields. Floods that cause prolonged waterlogging and submergence can reduce yield by 17 to 45%at the vegetative stage and 50 to 56% at the reproductive stage. Flooding has the potential to decrease availability of soy on the domestic market, which will force some farmers to find alternative feed for livestock	**High**

Identified Commodity	Uses	Weather Extremes and their Impact on Production		Climate Threat Level
		Temperature	Rainfall	
Pigeon pea	An important crop for small farmers. The crop has high potential for improving incomes. It is a rich source of protein, dietary fibre, vitamins and minerals. Pigeon pea offers significant nutritional benefits	Higher temperature of more than 40°C will affect germination. Heat waves will affect yield. There are projections of high temperature and increased humidity. During storage, the combination of high humidity and high temperature increases the risks of aflatoxin and other fungi to seeds	Weather extremes such as excessive and intense rains may lead to plant mortality. Overall increased rainfall in Mozambique will likely increase plant growth. Pigeon pea is very sensitive to flooding and water logging, making it susceptible to increased frequency of intense rainfall events. Drought, particularly low soil moisture content during planting, could lead to low germination rates and poor seed development	**Low**
Sesame	Mostly grown by small farmers. Earns foreign exchange for the country as 98% of the total production is exported. There is potential to double the production. Tolerance is high for moderate climate variations	Sesame is known to have better adaptive capacity to temperature as it is native to tropical and subtropical regions where temperature is usually warmer. Higher temperature is going to have a unnoticeable impact on production	Delayed onset of monsoon or prolonged dry spells will affect the yield. The crop is sensitive to drought during the germination stage, and soil moisture deficits negatively impact growth. The crop is very sensitive to waterlogging. More than 50% of yield could be lost when plants are waterlogged even for shorter periods.	**Medium**

The analysis categorizes the value chains of the identified crops for this study based on the severity of climate change impact as high, medium and low. Accordingly, the climate change threat for the soy value chain is considered as high whereas it is low and medium for pigeon pea and sesame, respectively. The uniqueness of this study lies in its coverage of climate change impact on post-harvest value chain agents such as transportation and storage termed as 'cross-cutting risks' of climate change in this study. The study has also made recommendations to improve the resilience of the value chain involving these value chain actors. The analysis is presented in Table 8.

The study identified information gaps in climate change impact studies on the value chain. The major gap of the entire focus on documenting/studying the impact on production by a large number of studies is identified by this study as well. The study further underscores the need for a full value chain approach to identify areas for priority investment. It identifies the lack of studies on climate change impact on storage in sufficient details. It further highlights the need for additional research on the impact of increased CO_2 in the atmosphere on plant growth and nutrition.

The study has also shortlisted areas for priority investment to improve the resilience capacity of value chains of identified crops in Mozambique. It underscores the need for the right type of weather information for farmers to develop their resilience capacity and recommends provision of climate-smart agriculture

Table 8: Climate change impacts on transportation and storage

Value Chains Actors of Soy, Pigeon Pea and Sesame	Impact of Climate Change	Recommendation to Improve Resilience
Transportation	Road conditions in Mozambique are poor in rural area. This makes them vulnerable to climate extremes such as floods and intense rainfall. The roads became inaccessible during recent floods in 2015 that damaged road infrastructure severely	Investments in building road infrastructure
Seed storage	Seeds are more susceptible to fungi and pathogens in the event of weather extremes such as high temperatures and humidity	Promotion of proper drying and storage techniques to mitigate storage risks associated with temperature and humidity

services termed as 'climate services' in the study. It, however, falls short in its full value chain approach in recommendations which are more or less limited to production only.

2.2 Adaptations in Food Value Chains

The study titled 'Adaptive value-chain approaches: Understanding adaptation in food value chains' is aimed at helping agri-food companies to systematically identify, assess, prioritize and act against risks and to seize opportunities that extreme weather and a changing climate might offer to their chains using a value chain approach.

The study defines the value chain and proposes a theoretical context by literature review of supply chain management, sustainability and adaptation for supply/value chains. It further defines value chain analysis. Three case studies with respect to value chain adaptation have been documented as part of this study.

i. Smith's Potato Chips

Smith's Snackfood Company is a Pepsico business unit and offers a range of brands such as Smith's Chips, Doritos Corn Chips and Sunbites Grain Waves, among others. The climate related vulnerability in Smith's chain is highest at the farming stage. It indirectly affects other activities in the chain, especially processing. Smith's chain has undertaken adaptations at the farming stage which has resulted in direct benefits to efficiencies and performance of multiple stages further down the chain, including logistics, manufacturing and retail performance. The case study documents that, although the adaptations are predominant at farming stage, there are evidences of adaptation across multiple activities along the chain. These include changes in loading systems to reduce lead times for processing, use of new oil blends to mitigate low supply of local oils, implementation of climate control systems to avoid transport delays, changes in the receiving system in order to mitigate penalties for not meeting orders and volume contracts. The Smith's value chain case study considers implications of risks and thus initiated multiple activities across the chain by building on management strength. The adaptation and mitigation strategies have been embedded in existing company competitive strategies, creating win-win opportunities.

ii. Calypso™ Mangoes

The Harvest Markets Pty. Ltd. Calypso™ mango chain is the longest value chain in Australia which produces and supplies premium varieties of mangoes via the rail and road network. The climate and weather risks are associated at the mango growing stage which is exposed most to the natural environment in this chain. Indirect climate impacts are felt across the chain. As a fast-moving fresh product, any impact felt at the farming end is likely to translate into deterioration in quality at the consumer end[19]. The case study states that current adaptation strategies are not necessarily designed to address a climate risk directly. They are autonomous along the chain. However, such adaptation action addressing risk at one stage of the chain could pose challenges to another if not considered from a holistic chain perspective. Climate risks associated with this chain include increased lead times, transport delays that results in ripening fruit, reduction in product quality in the store, and thus poor consumer experience. Mitigation strategies have included changing the in-production schedule, harvesting at night, improving site cooling facilities, and changes in loading systems, delivery schedules and receiving systems. The case study proposes that development of adaptation strategies based on a greater understanding of the interplay of climate impacts and adaptation strategies across the chain would result in Harvest Markets achieving a more competitive position.

iii. Treasury Wine Estates wine

Treasury Wine Estates, one of the world's largest wine companies, has a multiplicity of brands and products sold in over 70 countries across the world. It has a complex value chain system, and therefore it is involved in all levels of the value chain including owning and managing vineyards, winemaking, bottling and distribution functions. Changing harvesting periods have affected scheduling of logistics and receivables at wineries. As a result, the company carries a significant amount of risk in terms of asset exposure to climate change impacts[20]. The adaptation carried out is about ensuring its value chain assets remain flexible and agile when needed. The adaptive strategies have included early release of vintages and modification of wine-making styles, review of vineyard management, change in glass bottle formulation, water and carbon accounting for the whole chain, and subsequent changes in marketing strategies. This case study demonstrates how interdependent value chain activities are reinforcing the importance of considering the whole value chain when understanding the impacts of climate change on a business. It also demonstrates how supply chain management strategies are utilized as an approach to adaptation. Lastly, this example illustrates the nexus between adaptation and mitigation. In business, these lines blur with the potential to be addressed hand-in-hand to harness the competitive merit of a strategy[21].

2.3 Analysis and Research Gap

The key findings of the literature review and case studies presented above can be summed up as:

1. The available literature highlights the climate risks associated with various commodities as well as few actors of the value chain. The literature focuses on the climate risks such as increasing temperature, uneven rainfall, floods, drought, etc., and its impact on agriculture production systems;
2. The literature also focuses on mitigation measures undertaken by farmers or companies/businesses at the production stage as most of the direct climate risks and exposure to vulnerability are more evident at the pre-harvest stage. The deterioration at this stage results in an indirect impact up the value chain;
3. There have been a few studies which explain commodities such as maize, rice, wheat, etc., but fail to highlight the impact of climate change on different actors along the chain; and
4. Available studies that have highlighted the impact on value chains and adaptive measures reveal that, in most cases, the measures are reactionary and undertaken in isolation by actors. Thus, they remain too unit specific and uncoordinated to be able to create risk mitigation along the entire value chain. There are very few documented evidences of post-harvest adaptations in value chains.

It is in this context that the present study "Understanding climate change adaptation for smallholders/marginal farmers and quantifying its impact on agri-allied value chains in Indo-Gangetic Plains (IGP)" is of significance in exploring the gaps identified in the studies reviewed above. The present study aims at focusing on the post-harvest adaptations to climate change as we move up the value chain.

The review of the available literature shows that most studies, done so far, largely focused on the impact of climate change on agriculture with very little attention given to studying the impact of climate change on post-harvest value chain agents, their adaptations and adaptation costs. There are some studies that focused on the adaptation measures of some key post-harvest value agents but again the entire value chain focus was missing from these studies. This study, therefore, aims not only to understand the impact of climate change on the value chain of identified crops, climate adaptations by the actors but also tried to explore the effect of climate adaptations on actors across the value chain. Through this study, an attempt is being made to bring together various climate change-related issues which affect the agriculture value chains in IGP with specific focus on the states of Uttar Pradesh and Bihar.

19 Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G. and Nelson, R., 2016. Adaptive value chain approaches: Understanding adaptation in food value chains, pp. 13.
20 ibid, pp. 15.
21 Ibid, pp 16.

3

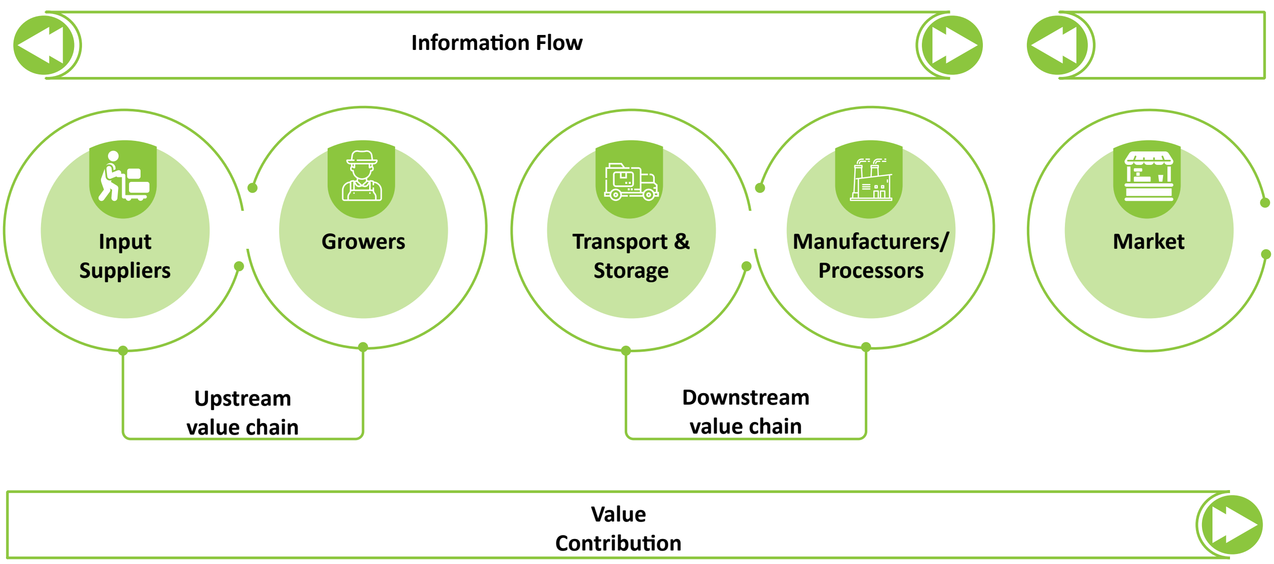
Understanding Impact of Climate Change on Agriculture Value Chains

Climate change is increasingly seen as a major threat to the food security and sustainability of agriculture. Its impact on agriculture could result in threatening the livelihoods of a large number of households who are dependent on agriculture and allied activities. Agricultural productivity is affected by climate change in two ways: first, directly, due to changes in temperature, precipitation and/or CO_2 levels and, second, indirectly, through changes in soil, distribution and frequency of infestation by pests, insects, diseases or weeds. Climate change symptoms such as water deficit conditions combined with thermal stress could adversely affect important food crops like wheat and rice productivity. Climate change can affect crop yields and, in extreme case, the types of crops that can be grown in certain areas by impacting agricultural inputs such as water for irrigation, amounts of solar radiation as well as the prevalence of pests.

The Indian Agricultural Research Institute (IARI) examined the vulnerability of agricultural production to climate change, with the objective of determining differences in climate change impacts on agriculture by region and by crops. The study found that increases in temperature (by about 2°C) reduced potential grain yields in most places. Climate change is also predicted to lead to boundary changes in areas suitable for growing certain crops. Reductions in yields as a result of climate change are predicted to be more pronounced for rain-fed crops (as opposed to irrigated crops) and under limited water supply situations because there are no coping mechanisms for rainfall variability. In sub-tropical environments, the decrease in potential wheat yields ranged from 1.5 to 5.8 percent while in tropical areas the decrease was relatively higher, suggesting that warmer regions can expect greater crop losses. Overall, temperature increases are predicted to reduce rice yields. An increase of 2-4°C is predicted to result in a reduction in yields. Eastern regions are predicted to be most impacted by increased temperatures and decreased radiation, resulting in relatively fewer grains and shorter grain filling durations[22].

A value chain is simply defined as the path or system which adds value to the product or service offered. In the case of agri value chains, this path has different actors and varying value contribution happens at different levels. Value contribution is a function of the relationships between these actors, information sharing and use, and handling of processes efficiently.

Figure 7: Value chain



22 Key sheet 6 Climate Change Impacts on Agriculture in India, The Indian Agricultural Research Institute http://www.indiaenvironmentportal.org.in/files/Defra-india-cc-agri.pdf

Growth and development of agricultural value chains is a powerful tool for economic empowerment particularly for small and marginal farmers.

The analytical framework for this assignment treats the value chain as a sequence of value addition activities, from production of agriculture produce to making it fit for consumption in various forms, through activities such as transportation, storage and processing. Generally, value chain approaches focus on activities from production to final consumption but, for this study, we have limited the scope to the final processing only. Value chain actors such as wholesalers and retailers stated that, due to the nature of their business and the multiplicity of products in which they deal, it would be difficult to differentiate between supply chain inefficiency-related loss and climate change-related loss. For most commodities grown in IGP, increased focus is being observed in activities such as storage, processing and trading with a higher degree of coordination amongst farmers, warehouse/cold storage owners and processors in the value chain. Due to changes in consumption patterns, the demand for value-added food products is increasing.

Climate change impacts are not limited to farmers only. It affects the entire chain from producer to final consumer. Although the primary impact of climate change is on the very production and quality of the crop, the effects are faced by all value chain agents. Substantial value addition has been done by these value agents by the time the final produce reaches to the ultimate consumers. Climate change not only has a bearing on the quantity and quality of supplies of raw material that these post-harvest value chain agents receive, but also on the various value additions as well. In spite of this close correlation, the climate impact studies appear to have focused more on studying the pre-harvest impacts.

Figure 8: Climate change impact on the value chain

Impact on Raw Material Supply

- Supply of farm produce not meeting quality specifications
- Inadequate supply from regular procurement area /fluctuating supply
- Working capital management issues due to disruptive procurement (credit/ payments/cash purchase, etc.)

Impact on Supply Chain

- High cost of storage in warehouses due to increased expense on fumigation, capacity unde-rutilizatiion
- Quality deterioration risks of both raw material as well finished products

Impact on Logistics

- Increased cost of transportaion due to production loss in the natural procurement area
- Higher spending on transportation to maintain quality standards
- Increased risk in supplying finished products

Impact on Production/Processing

- Quality of final product
- Low shelf life of final product
- Additional investment in machinery

In order to preserve their value-addition capabilities, value chain actors need to adapt to changing conditions by means of incremental changes to their production systems and use of resources. In extreme cases, it may even affect their business continuity by making the existing economic structures obsolete. Overall, these changes will affect economic opportunities, profitability and competitiveness, livelihoods, sources of growth and employment and socio-economic outcomes.

Consideration of the effects of climate change on value chains is a relatively new, yet-to-be explored area of research with the majority of agricultural adaptation research focused on the impact of climate change on farming. Limited attention is given to the whole system that creates and delivers value (the value chain) and implications that climate change and the resulting actions have on other actors in a value chain. Climate change impacts value chains in many ways. It affects the quality and yield of agriculture commodities and, hence, in order to maintain the quality of final products value chain agents need to adapt by making changes into their supply chain and production systems which require additional resources. The change in climate sometimes adversely impacts production in their procurement areas and they need to make alternate arrangements for procurement, leading to higher procurement and transportation cost. Climate change can also have an impact on the quality of the final products as well the shelf life.

Adopting a value chain perspective makes it possible not only to identify the direct effect of climate change on private sector/firms' constraints and behaviour but also to consider an indirect effect of climate change through its impact on upstream (supply) and downstream (demand) sectors, as well as on transversal sectors such as infrastructure and logistics which are essential for value chain operations to take place.

The impact of climate change is also leading to an increased tendency on the part of value chain agents to relax the quality norms for procuring paddy/ wheat from farmers due to their long-term relations and interdependency. Changes in climatic conditions increase the cost of operations for warehouse/cold storage owners due to an increase in electricity charges, fumigation expenses and lower capacity utilization. The impact of climate change affects the small business more than the big business as small businesses lack resources for adequate planning and preparedness.

The vulnerability of small businesses is also higher due to lack of financial resources to endure even a small rupture in the supply chain which may be caused, for instance, by an extreme weather event. As the flow of raw materials starts from the farmers' end, the adverse impact at the farmer level affects all actors in the value chain. The adoption of short duration high yielding varieties (HYV) by farmers as an adaptation in monsoon crops affects the business of traders, warehouse owners, transporters as well the final processors. Similarly, an increase in moisture content of the raw material affects the conversion ratio during processing, increases the cost of production and leads to higher investments for the purchase of new equipment and machines. Climate change alters the capabilities of value chain participants, as the value created by value chain agents diminishes.

These changes affect economic profitability, competitiveness, livelihoods and employment growth as well. Value chain actors, other than farmers, try to mitigate the risks of climate change by adopting various strategies which include procurement of produce from alternate sources, improvement of the supply chain, changes in processes, investment in plants and machineries, etc. Though adoption of these measures helps value chain actors in minimizing the operational risks, it increases their financial risks by raising the cost of production. They also face threats from competitors as barriers to entry are quite low in the agriculture value chain.

The available literature presents a skewed information picture. It is mostly on the impact of climate change on agriculture. The studies have documented quantitative and qualitative impacts of climate change on agriculture. Based on the results and recommendation of these studies, there have been efforts by governments and civil societies to design the required policy response. However, as reported by the post-harvest value chain agents of the identified commodities from the IGP region, not much policy response is seen to develop the climate resilience capacity of the post-harvest value chain agents. Among other reasons, this could also be attributed to the absence of sufficient relevant studies leading to limited policy inputs on climate change impacts of the post-harvest value chain. Through this study, an attempt is being made to bring together various climate change-related issues which affect the post-harvest agriculture value chains in IGP with specific focus to states of Uttar Pradesh and Bihar.

4

Climate Change Impacts on Paddy Cultivation, Paddy Value Chain and Adaptations by Various Stakeholders

The rice-based cropping system of the IGP region is one of the most important cropping patterns for food security. Apart from the food security, it also provides employment and livelihoods to millions of rural households. The crop is grown during the warm, sub-humid monsoon summer months with the cropping season starting from June and concluding around November-December. The crop is grown mostly in a rainfed-based ecosystem.

Most small and marginal farmers grow rice for their household consumption and there is little marketable surplus. India's paddy production has shown an increase of over 150 percent. Yield improvement contributed 84 percent to this increase while area expansion contributed only 16 percent (Janaiah and Faming, 2010)[23].

Both production and productivity have increased since the early 1970s, after the introduction of HYV and their widespread adoption by farmers. In the rice production ecosystem, there has been significant improvement in total factor productivity which may be attributed to the development and large-scale adoption of newer varieties and vertical integration of value chain actors.
The number of rainy days is constantly decreasing in most areas across IGP leading to increased intensity of rainfall whenever it rains. Furthermore, the incidence of weather extremes, duration and frequencies of drought and floods is becoming more frequent which may significantly impact the yields of rice in the region.

IARI examined the vulnerability of agricultural production to climate change, with the objective of determining differences in climate change impacts on agriculture. Overall, temperature increases are predicted to reduce rice yields. An increase of 2-4ºC of temperature is predicted to result in a significant reduction in yield of paddy. The same study also suggests that increased temperatures and decreased radiation will result in relatively fewer grains and shorter grain filling durations[24] (Key sheet 6-Climate Change Impacts on Agriculture in India, Indian Agriculture Research Institute).

At the producer level, nearly 75 percent of rice production is considered as marketable surplus. Of this 75 percent marketable surplus, between 40 to 50 percent is procured by FCI or the supporting state government agencies and the remaining is available for the private sector.

In terms of consumption, 88-90 percent of the paddy grown in IGP states is consumed in the form of rice while

23 http://www.fftc.agnet.org
24 http://www.indiaenvironmentportal.org.in/files/Defra-india-cc-agri.pdf

10 to 12 percent is used as other value-added products such as *poha-chura* (flattened rice) and *murhi* (puffed rice) with concentration of such units being higher in Bihar than in Uttar Pradesh.

4.1 Climate Change Impacts on Paddy Crop

The farmers' group narrated three types of impacts of climate change on paddy cultivation. The first in terms of production and productivity; second, quality of produce; and, third, increased cost of production to minimize the impact of climate change. In extreme situation (flood/ severe drought), there is also risk of the complete loss of production.

Paddy, a water dependent crop, is prone to extreme weather conditions. Excessive heat, humidity and erratic rainfall affects the growth of paddy and the incidences of pest infestation. An increase in temperature leads to reduction in crop growth duration, increase in pollen sterility, reduced seed set and number of grains, and reduced grain weight which cause yield reduction. Farmers reported that, in recent years, climatic conditions have been very unpredictable. Unexplainable delay in rains, insufficient and untimely rains resulting in excessive humidity and prolonged periods of high temperature are resulting in increased incidences of pest attacks on the paddy crop. Farmers have also reported that peak temperature is soaring high every year recently. They further communicated that, due to prolonged periods of heat, the moisture level in soil is decreasing as is the immunity level making the crops more susceptible to diseases. The key impacts perceived by farmers, intensity of the impacts and how they affects the paddy production ecosystem are discussed below.

4.2 Adaptation Measures

Climate change adaptation involves taking action to adjust to, or respond to, the effects of changes in climate. Adaptations to climate change exist at the various levels during the growth cycle of paddy. Types of adaptation ranges from change in variety, more application of inputs, change in planting and harvest dates, tillage and rotation practices, substitution of crop varieties, increased fertilizer or pesticide applications, and improved irrigation and drainage systems. Farmers reported that in recent years, their traditional wisdom, their predictions based on certain traditional pre-monsoon indicators have proved wrong and they are not always sure about planning their farm practices.

The most important characteristics of climate change observed by farmers are disproportionate, short duration, untimely and delayed rains. To mitigate the effect of rainfall variations, farmers have started adaptations with nursery preparation in phased manners. Planting of HYV/hybrids and application of agro-chemicals is increasingly becoming a common pratice to mitigate the negative impact of changes in the monsoon. Due to delayed and insufficient rains, farmers using short duration and low water requirement types of seed varieties which not only affect the cost of production but also varietal diversity which was a unique characteristic rice cultivation.

In addition to this, there has been adaptation of System of Rice Intensification (SRI) by farmers in IGP. This adaptation has largely been driven by the government and non-government organizations. Farmers as well the researchers stated that under changing climatic conditions, it helps them in optimizing water resources and reducing usage of insecticides/pesticides. Farmers

24 http://www.indiaenvironmentportal.org.in/files/Defra-india-cc-agri.pdf

also said that adaptation of SRI had helped them in increasing the rice yield over the traditional method of flooded rice cultivation.

As the impacts of climate change perceived by farmers are non-uniform, adaptations by the small and marginal farmers have also been erratic. Typically, paddy transplantation happens after 20-25 days of nursery preparation. Farmers now prepare the nursery in phases as well as maintain additional stock of seedlings. This strategy helps them in minimizing the risks of delayed rainfall. We also came across cases where farmers are selling seedlings to other farmers who do not have seedlings available at the time of transplantations.

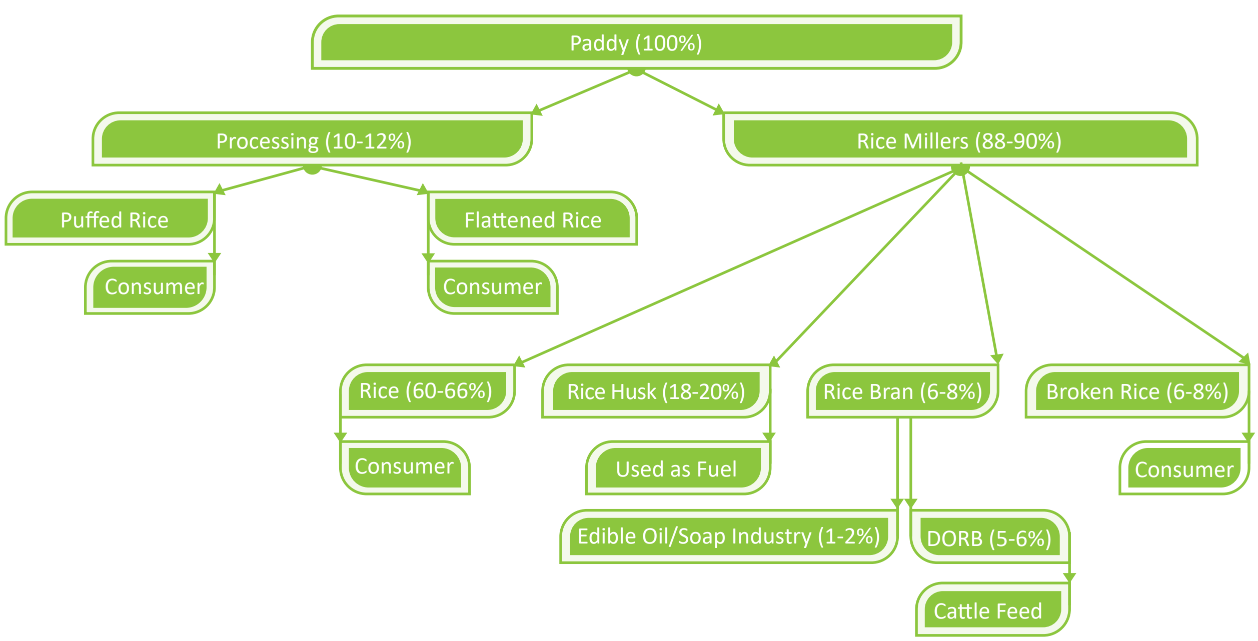
Farmers undertake adaptation measures which help them in minimizing yield losses; nevertheless the quality of paddy is affected. The crop sometimes loses its natural shine and the weight of grain is affected. The frequency of un-ripe paddy is also on rise. The millers complain about the decreasing conversion rate of paddy to rice and thus offer either low rates or reduce the weight of the total paddy sold by 2-3 percent of the total weight supplied by the farmers. In case of paddy, the incidences of hollow or semi-hollow shells have been increasing. Farmers further said that, in recent years, seed companies have introduced short varieties with lower duration which has helped in mitigating the climate change impact to some extent. Farmers have observed that these new varieties are more prone to diseases and therefore they are constantly under pressure to match production by increasing the doses of inputs to maintain production and avoid incidences of pest attack.

Table 9: Impact of climate change and adaptations for paddy

Perceived Impact of Climate Change	Key Adaptations by Small Holder/Marginal Farmers
• Loss of crops due to flood/flood-like situation • Loss of crops due to drought /long period of no rains • Late rainfall affecting nursery preparation • Long drought periods leading to increase in weeds/ pest infestation • Quality reduction of paddy with the presence of more foreign particles • More empty grains due to uneven grain feeling	• Change in seed variety • Nursery preparation in phased manner • Increased intercultural operations • More usage of fertilizer • More usage of chemical Insecticides/pesticides/ herbicides • More number of flood irrigations • Rescheduling of harvesting • Increased mechanization at the time of harvesting

4.3 Impact of Climate Change on the Value Chain

Figure 9: Paddy value chain



The effect of climate change on value chain participants is of two types. The first one is related to the quality of paddy received at various levels of the value chain and second is with respect to receiving an adequate amount of paddy so that production facilities can run at optimal level. These issues become important as the cost of mitigations by various value chain participants involves extra cost either in the form of capital investment or increased cost of operations. At the producer level, nearly 75 percent of rice production is considered as marketable surplus. Of this 75 percent marketable surplus, between 45 to 50 percent is procured by FCI or supporting state government agencies and the remaining is available for the private sector.

Table 10 presents a summary of products and by-products of the paddy value chain.

Based on the geographical distance between the producer and end consumer and the number of intermediaries involved in the process between them, we have tried to classify the value chain of paddy under four categories. The impact of climate change depends upon the type of value chain.

Traditional rice value chain: This value chain consists of the local supply chain of paddy grown by the farmer which is de-husked in a local village mill and consumed by farmer households; the remaining is sold in the local village market for local consumption. In this value chain, the impact of climate change is mostly borne by the end consumer. This value chain is affected due to inferior quality of paddy which often leads to a high percentage of broken rice and impurities. The impact is minimized as broken rice also is consumed either in the form of broken rice or in the form of rice flour. No tangible value chain losses happen on paddy processed through this value chain.

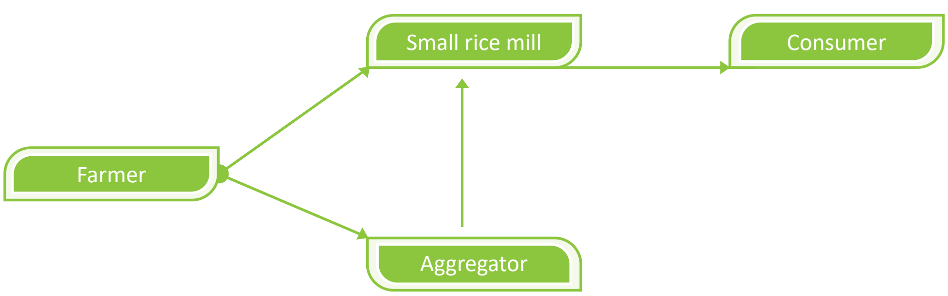
Transitional rice value chain (intra-state/inter-district trade): The transitional rice value chain is one of the most prevalent value chains in IGP after the regulated value chain. Farmers sell paddy to village-based aggregators who then sell it to urban markets from where it is procured by rice millers. Millers also have agents who purchase directly from the farmers or through village-based aggregators. They generally procure in the initial months after harvesting and store it on their premises. Rice millers sell the rice to the city-based whole sellers from where it reaches the consumers through retailers.

Table 10: Processing profile of paddy

Products	Percentage Extraction from Paddy	Processing Point	End Consumer/Consumption
Rice	60 to 66%	Rice mill	Consumers
Broken rice	6 to 9 %	Rice mill	Consumers
Husk	18 to 20%	Rice mill	Processing units
Rice bran	6 to 8%	Rice mill	Solvent units
Rice Bran oil	16 to 18% of rice brain	Solvent unit	Cooking oil/soap industry
De-oiled rice bran	82 to 84% rice	Solvent unit	Cattle feed manufacturer
Other products			
Flatten rice	65 to 67%	Flatten rice mill	Consumer
Puffed rice	85 to 90%	Puffed rice mill	Consumer

Source: Interaction with stakeholders

Figure 10: Traditional rice value chain



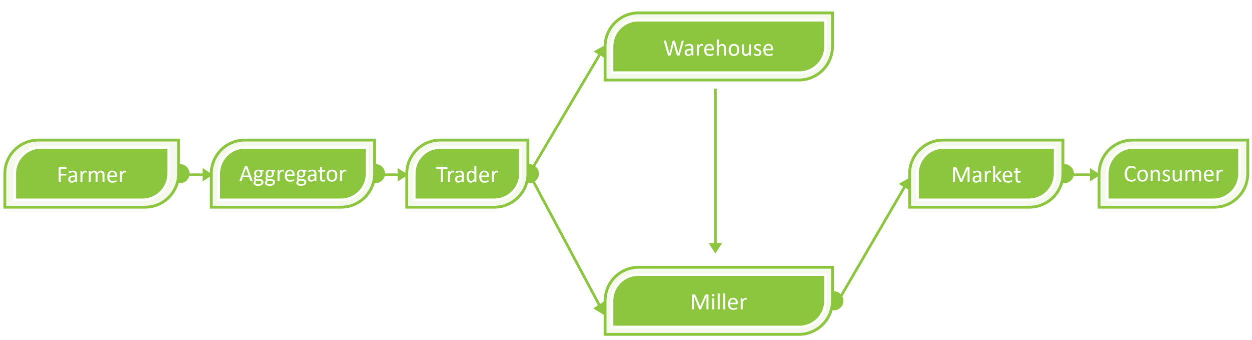
These rice millers generally operate and function at the state level with most of the trade happening at inter-district/intra-state level. During storage at mills, losses for rice range between 4 and 5 percent which happens due to quality standards not met during procurement and moisture losses. Rice millers observed that earlier this percentage used to be around 2 to 3 percent. As they have regular suppliers with whom they maintain long-term relationships, it becomes difficult for them to return the produce.

In recent years, most mill owners have adopted rubber roll shellers which have reduced the percentage of broken rice. Another adaptation strategy is to shift to parboiling as the rice becomes harder and results in higher milling yield with lesser breakage and more oil content in the bran. However, it requires additional capital and an increase in operating costs due to higher energy consumption

Long Value Chains (Inter-State Trade):
This value chain has a large number of intermediaries/

Figure 11: Transitional rice value chain

Figure 12: Long value chain



actors. Due to the significant time lag between the production of paddy and consumption of the product, it faces the highest risks of climate change impacts. Generally, rice millers with large capacity operate in this value chain. They operate throughout the year and have continuous procurement. They store bulk paddy in private warehouses. Climate change impact occurs both due to quality-related issues as well due to fluctuation of the preferred price. The colour of rice is affected if there is rain at the time of harvesting and the paddy has not been dried properly. Sometimes due to adverse climatic conditions at the time of grain filling, the brittleness of the paddy increases which leads to more breakage of rice. The impact of quality-related challenges is highest for such millers as they must meet quality standards.

Regulated Value Chain

This value chain accounts for the maximum percentage of rice produced in the IGP states, particularly in Bihar and Uttar Pradesh. Under this arrangement, milled rice is manufactured by milling paddy procured by the state governments/agencies and FCI. Paddy is procured by agencies nominated by the state government. Paddy procured thus is then supplied to rice millers who, in turn, deliver it back to the nominated agencies of FCI. This value chain is not impacted much due to liberal quality standards. This value chain faces a moderate level of impact of climate change as quality norms are relaxed, both at the time of procurement as well as during supply of rice. Millers observed that they were finding it difficult to meet the conversion percentage fixed by FCI's authorized agencies.

Figure 13: Regulated value chain

Table 11: Quality specifications for the regulated value chain (fixed by FCI)

Quality Specifications during Procurement		Quality Specification for Custom Milled Rice	
Indicators	**Maximum Permissible Limit**	**Indicators**	**Maximum Permissible Limit**
Foreign matter organic	1%	Broken rice (raw)	25%
Foreign matter inorganic	1%	Broken rice Parboiled/single parboiled	16%
Immature, shrunken and shrivelled grains	5%	Foreign matters	0.5%
Admixture of Lower Class	6%	Damaged grains	3 to 4%
Moisture Content	17%	Discoloured	5%
		Red grains	3%
		De-husked grains	13%
		Moisture	14%

Source: http://www.fci.gov.in/app/webroot/upload/Kharif%20Plan%2018-19.pdf

4.3.1 Impact of Climate Change on Commercial Warehousing

It was observed that both large traders and millers procure paddy from various sources after harvest and store it for three or four months. A gap of a minimum of 1 metre is left between and around the stacks with a 1.5 metre clearance between the top of the stack and roof. Arrival of paddy starts from December onwards and the average storage period is around three to four months. One impact is that during storage at the warehouse, the moisture level needs to be constantly maintained below 14 percent and proper safeguards undertaken to ensure that it does not imbibe moisture from the surrounding air.

The other impact is higher fumigation costs. Increased temperature and humidity are favourable for storage insects/pests which can multiply faster in such conditions. To maintain quality, grains stacked in gunny bags needs to be periodically fumigated. In such circumstances warehouses need more cycles of fumigation which results in increased cost of warehouse maintenance.

Though it cannot entirely be attributed to climate change but expansion of commercial warehousing has led to the creation of additional warehouse space. Due to the loss of varietal diversity of paddy crops, almost all farmers grow the same variety which is harvested at the same time. In case of warehouses where farmers themselves store the paddy, the duration becomes shorter while traders' warehouses face tough competition in getting paddy to fully utilize the space.

Table 12: Climate change impact on warehousing

Climate Change Risks	Implications	Impact
Risks of pests infestation due to increase in temperature and humidity	Increased operating costs due to more cycles of fumigations required	Earlier the fumigation cycle was of 40-45 days; it has now reduced to 30-35 days
Risk of moisture increase in grains	Risk of grains getting spoiled	If quality standards are not strictly maintained, there is a minimum of 2 to 3%of production loss
Inward risks	Under-utilization of space in large warehouses	Leasing of warehouses is gaining currency over construction of new warehouse. Short-term leases are preferred

Value Chain Losses in Paddy Warehousing

Total losses
INR 418 million

High temperatures associated weight loss of the stored paddy and increased fumigation expenses result in reduced shelf life and increased humidity

4.3.2 Impact of Climate Change on Rice Milling

All participants in the paddy value chain are completely dependent on the supply of raw material. Millers get their raw material (paddy) from different channels such as farmers, traders and FCI authorized centres. Rice mills that have an agreement with FCI for processing of paddy and supplying rice to FCI again, get paddy from FCI. However, they do mill for private traders as well.

For millers who do not have such an agreement with FCI get around 20-25 percent of their total requirement of paddy from farmers while traders from the local *mandis* supply the rest (75-80 percent) of the total requirement.

Most rice millers pointed out that high adoption of short duration hybrid rice has had an adverse effect on the milling of rice. They also stated that long duration paddy has more flowering days during the crop cycle which increases both the yield and quality of rice.

Rice millers define good quality as paddy that has:

- Low moisture levels;
- Minimum percentage of foreign materials; and
- Small percentage of empty shells, etc.

Prolonged periods of high temperature are considered an important manifestation of climate change. Millers observed that high temperature impacts the paddy crop during the ripening stage in the following ways:

- Decrease in grain weight;
- Reduced grain filling; and
- Higher percentage of white chalky and milky white rice.

Regular increases in temperature and prolonged periods of drought-like situations in the midst of the rainy season affect the moisture content in the paddy which leads to a higher percentage of broken rice. Millers reported that, in recent years, the percentage of broken rice has increased by 2 to 3 percent. They also pointed out that short duration paddy has lower conversion rates to the extent of 1 to 2 percent than the traditional variety. The short duration variety paddy is relatively more brittle, so the percentage of broken rice is high. Millers associated with FCI pointed out that the existing fixed conversion rate (67 percent) is not possible with these new varieties. Millers who have arrangements with FCI/ State Food Corporations for custom rice milling are still in the business due to relatively easier quality control norms, benefits of by-products and lower requirement of working capital.

Rice millers foresee a shift towards rice parboiling, as it helps in eliminating chalkiness in milled rice grains. The process of steaming and drying reduces grain breakage during the milling process and increases grain translucency. It also increases grain hardness and manages to reduce grain breakage as a result of the swelling of the starchy endosperm during gelatinizing. Millers reported that, though this process is effective in minimizing broken rice, shifting to steam-based plants is expensive and small and medium entrepreneurs cannot always afford the cost of technology upgradation as well.

Value Chain Losses in Rice-puffed-flattened Millers

INR 460-481 million

Discoloration of grains, increasing percentage of dead paddy, moisture loss, decreasing conversion rate, broken rice, increasing impurities

Another adaption has been in terms of a shift to rubber roll sheller as this leads to a smaller percentage of rice breakage.

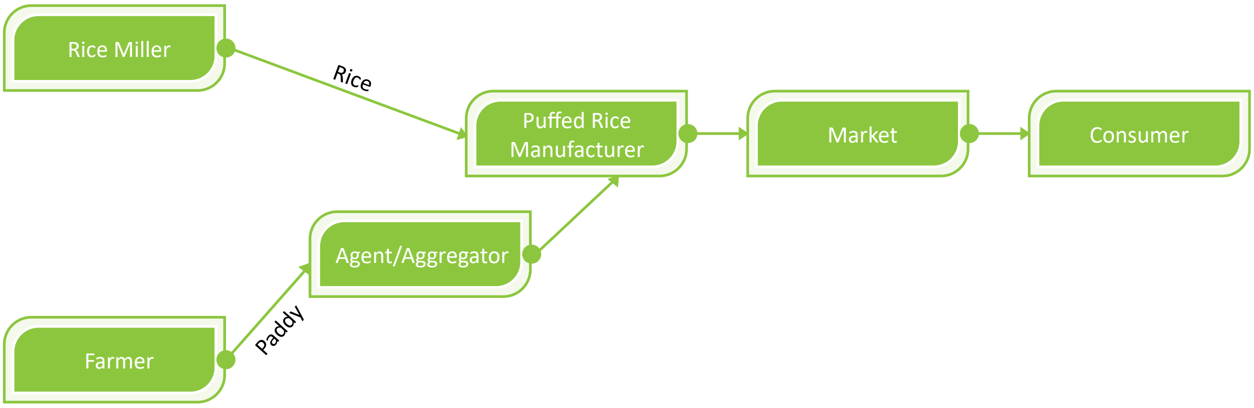
Millers in Bihar have observed a high incidence of impurities in supplies of the paddy which they procure from outside the state. Millers have also reported that a proportion of under-ripe paddy has increased and is now 1 to 2 percentage of the total paddy that they receive. Millers also said that incidences of *indrajou (a kind of weed)* have increased in recent times. To mitigate the impact of this, mill owners have to incur additional labour charges in cleaning or invest in cleaning machinery.

Millers think that they have limited control over the situation but increased competition is forcing them to accept inferior quality of paddy in the process. Consequently, millers are investing in graders and sorters with high configurations as well as pre-cleaners. This amounts to an additional investment of around INR 5 million to 10 million per mill for a commercial large-sized mill. Of late, millers are also thinking of entering into contracts with paddy farmers where farmers can be supplied with the right inputs, training and weather information in lieu of an assured supply of quality paddy.

4.3.3 Climate Change Impact on the Puffed Rice Industry

Puffed rice *(murmura/murhi)* and rice flakes or flattened rice *(poha)* are an important value addition in the paddy value chain. Puffed rice is a product made from rice, which is lightweight crisp and ready to eat. As the name suggests, puffed rice is made by a process involving high pressure heating of the grains. Traditionally, the production of puffed rice in India was largely limited to the village level but now it has gradually emerged as a mechanized industry. The puffing method traditionally followed in India is sand-roasting. Getting good quality of rice is of utmost importance to puffed rice processing units. For the preparation of puffed rice, some units procure paddy directly from the farmers while some unit

Figure 16: Puffed rice value chain



owners procure and process parboiled rice to obtain puffed rice.

In units where parboiled rice is the raw material, rice is gently heated on the furnace without sand to reduce the moisture content slightly. It is then mixed with a salt solution and again roasted on the furnace in small batches with sand on a strong fire for a few seconds to produce the expanded rice. These processors face a limited impact of climate change on the quality of raw material except for the rise in prices when the supply reduces due to low production of paddy. They face some problems in maintaining the crispiness of puffed rice if there are prolonged periods of rains.

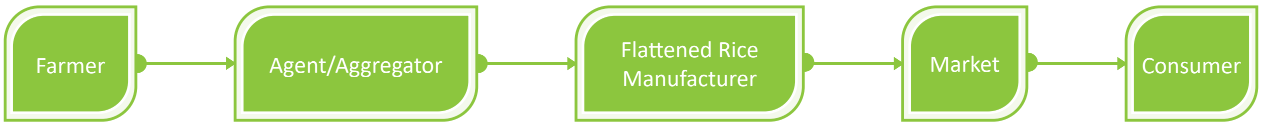
Processors reported that, in recent years, due to changing climate conditions, incidences of high moisture, higher percentage of broken and black rice and greater percentage of impurities in the rice are on the rise, affecting the quality and cost of the processing. This leads to 2 to 3 percent of loss of the finished product leading to a production loss of INR 90-100 per quintal of puffed rice produced.

Due to the high moisture content in the raw material, processors have to invest in drying the rice, resulting in use of extra driers and an additional cost of INR 10 per quintal. However, as suggested by the representative of one of the largest units, drying rice in natural light is a must to ensure better quality of puffed rice. However, in recent years, since the rains have become unpredictable, processors have to be more vigilant while drying paddy in sunlight. Many mills have also invested in blowers costing about INR 200,000 to remove impurities from the paddy. Other processors of puffed rice are also facing the same problem due to the diminishing quality of paddy and are adapting by increasing investment in relevant machinery such as dryers and blowers.

4.3.4 Climate Change Impact on Beaten Rice/Flattened Rice

Flattened rice is another important value chain agent in the paddy value chain. Traditionally, it is prepared from soaked paddy, after heat treatment and immediate

Figure 17: Flattened rice value chain



flattening using a flaking machine (an edge runner). Paddy is soaked in water for two or three days to soften the kernel followed by boiling in water for a few minutes and draining the water off. The paddy is heated in a shallow earthen vessel or sand in an iron pan till the husks break open. It is pounded by a wooden pestle which flattens the kernel and removes the husk. The husk is separated by winnowing. Flaked rice is thin and papery and of white colour.

Processors of flattened rice complained about the higher percentage of broken rice and of low-quality paddy post paddy processing and of low-quality paddy. For the flattened rice industry, a whole and healthy grain of paddy is important so as to make good flaked rice. However, processors have been unable to get good quality supplies of late. Even the percentage of empty shells is higher by 2-3 percent. The firms are constantly identifying newer geographies for raw material supply. However, this increases the transportation cost leading to an increase of 1-2 percentage of the procurement price. Processors reported that earlier they would keep the stock for two or three days only as the supply was regular; however, in recent years, there is stiff competition among the traders and millers to get good quality of paddy and many firms now maintain eight to10 days of stock. As a result, interest cost has increased. Processors also mentioned that labour costs in cleaning and transportation have increased. Firms have also reported that they have had to invest INR 200,000 to 250,000 in purchasing sievers to minimize the impurities

4.3.5 Climate Change Impact on Solvent Plants

Rice bran is the most valuable by-product in the paddy value chain. Rice bran contains about 18-20 percent rice bran oil which is the raw material for the solvent extraction unit. In the solvent extraction facility, rice bran oil is extracted as the chief product; de-oiled rice bran (DORB) is the by-product, a rich source of protein and used as a chief ingredient in cattle feed preparation. Solvent plants collect this rice bran from rice millers and after due process produce crude rice bran oil. On an average, 20 percent is the extraction rate for the rice bran industry. These industries are primarily concentrated around rice producing geographies. Due to the very nature of this supply arrangement, solvent plants procure their raw material from multiple local rice millers as well as those from outside. Extractability of oil depends on a good milling process and supply of rice bran which should be ideally within four to six days after its recovery from the milling process. Solvent extraction plants check for the extractability percentage before accepting the bran lot.

Other than supply-related issues due to fluctuating production, no climate change impact was observed on solvent plants.

4.3.6 Climate Change Impact on Cattle Feed Producers

For cattle feed producers, the moisture level in DORB is an important parameter to judge the quality of raw material. DORB with a moisture level of 11 percent is considered good quality raw material. Most cattle feed industries procure their raw material from Punjab, Bihar and Uttar Pradesh. High demand for cattle feed has boosted the demand for DORB but the present supply is unable to meet demand. The industry does not face any major direct impact of climate change. Extreme weather, humidity, etc., reduce the shelf life of DORB therefore stock has to be maintained at an optimum level. Industry experts have observed that climate change has also affected the feed requirement of livestock so there is a fluctuation in the demand for feed as well. Producers are unsure of regular supply and maintain raw material stock. This has increased the lock-in-period of capital as well as interest cost.

Table 13: Summary of climate change impacts on the paddy value chain

Products	Climate Change Impact	Mitigation Strategy	Investment	Impact on Operating Costs	Value Chain Losses
Rice milling	Increasing percentage of broken rice leading to reduced conversion rate of paddy to rice	Shift towards rice parboiling and steaming process as it helps in reducing breakage and improves conversion rate	Parboiling Unit additional INR 4.5 million Steaming INR 3 to 3.5 million	Increase in electricity cost by 10 to 15%	Increase in rejection of 2 to 3% of paddy
	Increase in weeds, soil, empty and yellow paddy shells	Pre-cleaning machines	INR 500,000 for pre cleaning machine of 4-tonne capacity		
	Increase in de-coloured grains	Installation of sorting machinery	Sortex machine for INR 3.5 million per 4 tonne	Increase in finance cost and operating costs	Incremental rejection of 0.5 to 1%
	Increase in percentage of broken rice	Advanced graders to separate broken, half and head rice	INR 250,000 to 275,000 for single grader of 4-tonne capacity		
Flattened rice	Increase in percentage of broken rice	Advanced graders/sieve to separate broken, half and head rice	Investment in chala/sieve costing between INR 25,000 to 250,000	More labour charges around 40-50 per quintal	Rejection on finished products to the extent of 2 to 3%(60-70 per quintal)
Puffed rice	Increased moisture level and foreign material	Investment in blower and drier	Additional investment of INR 350,000	Additional drying cost of INR 10 per quintal	Loss of 2 to 3%of finished products (100-120 per quintal)
Solvent units			No Such impact		
Cattle feed manufacturers	Increased moisture level	Moisture controller machine	The machine is supplied by the supplier at no charge. Purchasing medicine is compulsory		INR 15 per quintal

Table 14: Estimation of value chain losses in the paddy value chain

	Total Paddy Production in MMTs (2015-16)	Total Value of Production in INR Millions*	Stage of Value Chain	Share of Total Production Involved in Stage	Remarks
Bihar	4.636	₹ 110,972	Rice milling (30% of total paddy)	90%	90% of the paddy produced is consumed in the form of rice and 30% of the total paddy produced goes into milling
Uttar Pradesh	1.705,267	₹ 81,130	Processing (puffed rice/ flattened rice)	10%	10% of the paddy gets converted into murhi and chura
Total	6.341267	₹ 29,842	Warehousing/ storage	16%	Approximately, 15-17% of the paddy produced reaches private warehouse. We have excluded paddy which is stored by FCI. This storage includes storage by all value chain participants

*Prices calculated are based on inputs received from interviews of value chain actors:

Paddy MSP 2018-19 @ INR 17,500/million tonne (MT)

Rice @ 26,000/MT

Broken rice @ 23,000/MT

Murhi @ INR 35,000/MT

Flattened rice @ INR 27,000/MT

MMT=million metric tonne

Assumptions: *Losses attributable to climate change subsequent to harvest have only been considered for calculation purposes. For the present study, this has been done primarily using the feedback received from the various actors by comparing normal conditions prior to observable climate change impacts and by assessing the potential impacts as perceived by the participants; in between has been documented in the absence of a baseline figure. In order to maintain uniformity in calculation of prices of the various commodities, MSPs as determined by the Government of India for the financial year 2018-19 have been utilized for the calculation of overall impacts on the value chain. The losses are borne by actors involved at the various stages of the processing as detailed in the table above in the value chains mentioned. The majority of losses happen in the rice milling value chain which roughly translate to around 69 percent of the overall monetary impact on the value chain. This is primarily because of the fact that 90 percent of the paddy produced in the region goes through this section of the value chain. A detailed view of the rice milling stage of the value chain reveals that over 50 percent of the total negative monetary impact on the value chain can be directly attributed to the negative impacts on the quality of yield due to climatic vagaries. No significant monetary impacts were observed on the transportation stage or at the solvent unit stage of the value chain.*

Table 15: Quantification of value chain losses in the paddy value chain

Processing Stage		Key Reasons	Under Normal Situation		Under Climate Change Induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in Millions INR	
Rice miller value chain (90% of paddy)			Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
	Paddy to Rice conversion	Use of short duration hybrid variety by farmers	63%	65%	60%	63%	-3%	-2%	₹-1,335	₹-890
	Broken rice	Use of short duration hybrid variety by farmers	6%	8%	8%	9%	2%	1%	₹ 788	₹ 394
	Impurities	Weeds, farmers want to cut the crop as soon as possible as they apprehend adverse climatic conditions.	3%	5%	6%	7%	-3%	-2%	₹-899	₹-599
	Increase in discoloration of grain	Untimely rains	1%	2%	3%	4%	-2%	-2%	₹-599	₹-599
	Dead paddy	Insufficient rains and lack of uniform maturity of grains	1%	2%	3%	4%	-2%	-2%	₹-599	₹-599
	Moisture loss	Loss of weight of produce from loss of moisture from the time of harvesting (moisture at time of milling is around 14-16%)	1%	2%	2%	3%	-1%	-1%	₹-300	₹-300
Paddy processing	Puffed rice-high moisture 5% with impurities at 60% extraction	Normal conversion of quality murhi is 90% of rice while with climate change the percentage of quality murhi goes down by 3-5%	90%	92%	86%	89%	-4%	-3%	₹-260	₹-195
		Cost of drying and blower @ INR 10/quintal							₹-29	₹-29

Processing Stage		Key Reasons	Under Normal Situation		Under Climate Change Induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in Millions INR	
	Flattened rice-broken rice 5%		62%	65%	60%	62%	-2%	-3%	₹-171	₹-257
Warehousing excluding FCI	Fumigation expenses*	Shelf life has gone down. Excessive humidity.	Fumigation rounds of 45 Days		Fumigation rounds of 30 days		Additional cost of fumigation for 1.3333 rounds during the storage period		₹-19	₹-19
	Loss of weight	High temperature	1%	2%	3%	4%	-2%	-2%	₹-399	₹-399
Total Impact on Paddy Value Chain									**₹ 3,823**	**₹ 3,492**
Transportation cost	No significant climate change impact observed on the value chain									
Solvent unit	No significant climate change impact observed on the value chain									
	Total climate change impact on paddy value chain in the IGP districts is in the range of INR 3.492 billion to INR 3.823 billion									

5

Climate Change Impacts on Maize Cultivation, Maize Value Chain and Adaptations by Various Stakeholders

Maize is an important crop after wheat and rice in IGP. In Uttar Pradesh, maize is grown primarily in the kharif (monsoon) season while in Bihar it is grown in both rabi (winter) and kharif (monsoon). In comparison to other competing cereals, maize, due to its photo- insensitive nature has wider adaptability and hence can be grown in all cropping seasons. Kharif or early summer season maize is short duration while rabi season maize is of a little longer duration. Rabi maize is also considered to have superior transpiration efficiency, lower usage of water per unit of production and high versatile usage which makes it easily marketable.

The proportion of cropped areas under rabi maize is increasing in Bihar. The development of different varieties of seeds with varying maturity period also makes it an attractive crop for cultivators. Both the area and the production of maize are increasing especially in the central IGP. Average grain yield during kharif season varies between 2 to 2.5 MT per ha while in rabi it is more than 4 MT per ha. Favourable agro-climatic conditions, low infestation of insects, pests and diseases, slow growth of weeds and almost no risks from extreme events such as floods or droughts makes maize an attractive crop in the rabi season. Cultivation of maize is also less resource (water, fertilizer, etc.) intensive, when compared to paddy or wheat in IGP. Even though the growth in crop area in the last 20 years has been limited, there has been significant increase in production due to an increase in productivity. The arrival of rabi maize produced in Bihar starts in April and continues till June, depending on the duration of winter. The kharif maize is grown between the months of June to October and arrives in the market from late October to early December.

Around 85-90 percent of the maize produced in both Bihar and Uttar Pradesh is marketable surplus. Due to its wide usage, maize has a very long value chain. In general, maize is known to have around 67-72 percent of starch, 12-15 percent of moisture, 8-12 percent of protein, 2-4 percent of fat, 2-3 percent of fibre and around 1.5 percent minerals. Most maize produced in India is used in the poultry feed industry. The poultry industry is heavily dependent on maize as it covers 50 to 60 percent of the input required for broiler feed and around 25-35 percent of the input required for layer feed. Maize is preferred by the poultry value chain against other substitutes due to its easy availability, higher energy content and price economics. Around 14-15 percent of the total maize produced goes into the cattle feed industry and another 10-15 percent into the starch industry where it is processed further to produce key ingredients for the confectionery, toothpaste and pharmaceutical industries. The recovery of starch from maize is around 60-65 per cent. Due to the wide commercial usage of starch produced from maize, the starch value chain's share is showing continuous increase. Since weather conditions are favourable for winter maize, it has started showing signs of gradually replacing wheat in some districts of Bihar. Farmers who don't have their own irrigation facilities prefer to grow maize rather than wheat.

Adverse climatic conditions affect the quantity and quality of maize and have a cascading effect on the entire value chain albeit with varying degrees. Most value chain agents use maize grain rather than some of its by-products. This peculiarity of the maize value chain makes it susceptible to any adverse climatic impact on quantity and quality of maize production.

5.1 Climate Change Impacts on Maize Crop

In the areas of study, maize is grown in both kharif and rabi seasons. Factors such as low incidence of insects, pests and diseases and easier weed management, coupled with higher yield and limited threat of climate change have contributed to its high-level acceptance by farmers especially in Bihar during the rabi season.

In comparison to rice and wheat, the maize crop is less impacted by climatic vagaries. Prolonged high temperature and moisture affects the yield of the maize due to hastened crop phenology, reduced photosynthesis, increased pollen sterility and poor grain filing with decreasing grain number. Kharif maize growing famers also recognize that erratic rainfall has high potential to damage pre-flowering stalks. Additionally, increased temperature and humidity raise the level of infection or infestation by various diseases and insects/ pests resulting in lower yields.

The extreme temperature has a strong bearing on the productivity and overall production of the maize crop. Maize (rabi) production reported losses in 2018 due to a long spell of cold waves during the grain filling period which not only affected the grains but also the cob colour.

5.2 Adaptation Measures by Small Framers

A seemingly right adaptation strategy based on 2018's adverse experiences might turn out be maladaptation as it forced many farmers to drop maize and opt for other crops. However, seeing the bumper maize crop in 2019, many farmers are found to have been regretting the decision of not cultivating maize. The inability of the farmers to decide on the right adaptation strategy makes them very vulnerable. Changes in sowing dates and variety of crop have been the key adaptation practices reported by farmers. Delay in sowing provides the opportunity for the crop to experience relatively lower temperatures during the grain filling period. Across the region, preference for short duration varieties of seeds is increasing. The agriculture value chains are closely connected.

Table 16: Impact of climate change and adaptations for maize

Perceived Impact of Climate Change	Key Adaptations by Small Holder/Marginal Farmers
• Loss of crops due to drought/long period of no rains in kharif maize • Damage of pre-flowering stalks due to unseasonal rains (rabi maize) • Increase in pest/weed infestation • Increased pollen sterility and poor grain filing with decrease in number of grains • Prolonged high temperature and moisture affects the yield due to hastened crop phenology • Presence of additional impurities such as foreign particles, damaged grains	• Change in seed varieties (rabi maize is almost entirely hybrid variety) • Late sowing by 15-20 days in kharif season and 10-15 days in rabi • Increased intercultural operations • More usage of insecticides /pesticides/herbicides • Rescheduling of harvesting time • More days of sun drying after harvesting

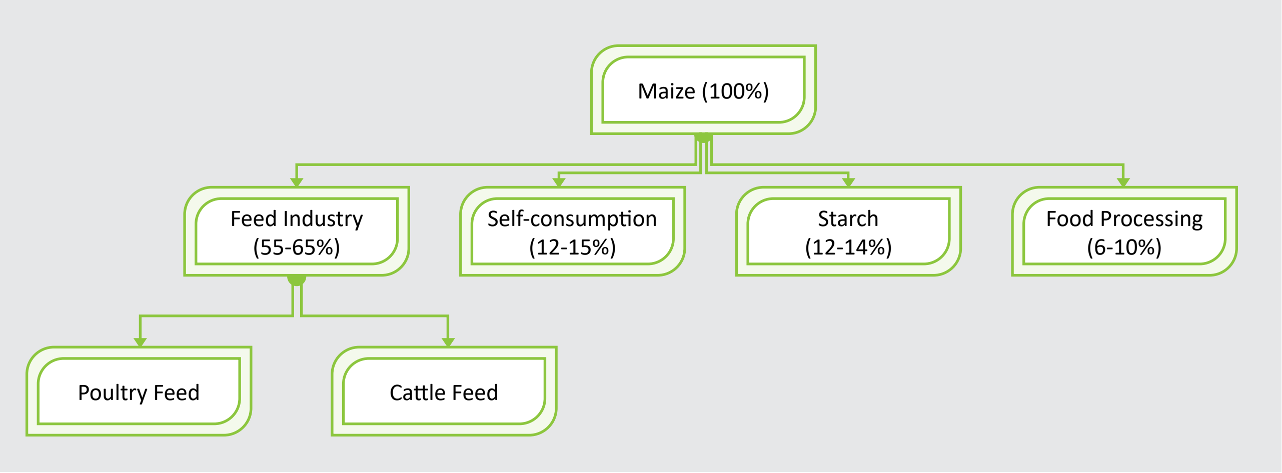
The adaptation measures by one value chain agent have impact on other value chain agent as well. The change in sowing dates and use of climate resistant seeds (short duration seeds) are usual adaptation measures undertaken by farmers. These measures affect the timing of availability of the final produce as well as the quality of the final produce at the farmers' end. Due to these factors, post-harvest value chain agents have been observed to change their production schedules as well. Many post-harvest value agents pointed out that short duration maize was prone to infestation. This necessitates the scientific storage of maize unlike the earlier general practices of storage. Similarly, short duration maize is also reported to have lower percentage of derivatives such as starch, etc. All this has cost implications for post-harvest value chain agents.

5.3 Impact of Climate Change on Value Chain Participants

The harvesting of maize is done manually. After extracting from cobs, grains are sun-dried for some days and then packed in gunny bags and stored.

In addition to consumption in poultry and animals feed, it serves as raw material for starch-based industries; starch in turn is used in the textile, pharmaceutical and cosmetic industries. Maize corn oil, protein, alcoholic beverages and food sweeteners are the other uses of maize. Farmers treat maize as *peela-sona* (yellow gold) due to its high value addition potential and wide usage of derivatives.

Figure 18: Maize value chain



Around 85 to 90 percent of the maize produced in Bihar and Uttar Pradesh is marketable surplus. Unlike paddy and wheat, it is not procured by the government directly. To protect the interests of farmers, the government declares the MSP which was INR 1,760 per quintal in 2019-20. From time to time, the government intervenes by facilitating procurement through designated marketing agencies.

Table 17 presents a short summary of products and by-products of the maize value chain.

The most prevalent value chain for maize is as presented in Figure 19.

This chain accounts for more than 80 percent of the marketed surplus. The supply chain of maize output begins from the farmer level and ends at the processing industry level. Other channels also follow a similar line with elimination or addition of one more agent between the trader or processor. In Bihar, maize is also traded on the commodity exchange in spot as well as derivatives markets. Gulabbagh Mandi (Purnea district of Bihar) is a major trading hub of rabi maize.

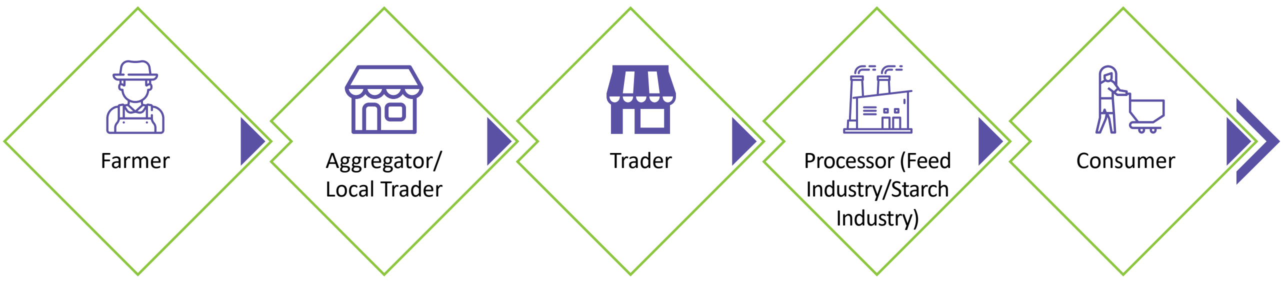
5.3.1 Impact of Climate Change on Storage

Farmers mentioned that the impact of climate change during the production phase was observed to be low in comparison to other crops. At the time of harvesting, adverse climatic conditions affect colour and taste

Table 17: Consumption pattern for maize

Products	Percentage Usage	Processing Point	End Consumer
Self-consumption	12-15%		
Poultry	45-50%	Poultry feed industry	Poultry industry
Cattle feed	10-13%	Cattle feed industry	Consumer
Starch	12-14%	Starch industry	Processing units
Food processed industry	6-10%	Food processing industry	

Figure 19: Maize's most prevalent value chain



Value Chain Losses: Maize Storage

INR 10 million

Increased susceptibility to fungus and deterioration in quality, aggressive fumigation because of which fumigation expenses increased by 8-12 percent

(contamination with toxins). Maize with moisture content of around 13 percent is stored for a longer duration. Maize with higher moisture content is further dried to improve storage quality. Maize is harvested at maturity when the husk is dried and has turned pale brown. Farmers harvest and store the kernel even when it is at a high moisture level. In Bihar, rabi maize is stored mostly by traders to sell their stocks from July to Sept.

Warehouses reportedly engage in short-term lease agreements with famers, traders and product processers as opposed to long-term leases of the past. Short-term lease agreements are preferred because of the burden of fixed rent combined with unpredictable crop produce.

The cost of storage of maize comes to around INR 10-15 per square foot for bulk space booking which is done mostly by traders. However, the storage cost for farmers varies from around INR 9 to 12 per quintal per month. Being a commercial crop, storage rates of maize also depend on the plinth height (higher plinth height costs more to store), location of the warehouse and road connectivity.

The risk of incidences of storage pest/fungus on stored grain has increased which is attributed to climate change by warehouse owners. This affects the extraction percentage and quality of different derivatives of maize. They also suggested that there is slightly more increased occurrence of mycotoxin and aflatoxin levels in the stored maize in recent years which they attribute to an increased humidity level. Storage of maize grain takes place at two major points in the supply chain: first at the farm level for few weeks and then by feed millers or starch manufacturers for four to six months.

There is an increasing trend among farmers to store maize but this is very small proportion of the total maize production. Traders involved in the supply chain stock the grains in gunny bags at flatbed storehoues for a few days which also increases the risk of moisture content and of developing myco-toxins upstream of the chain. Like most other commodities referred to in this study, the impact of climate change on the warehousing business is limited to an increased cost of fumigation and risk of underutilization if production falls below the normal level.

5.3.2 Impact of Climate Change on the Poultry Feed Industry

Maize forms 50-60 percent of the input required for broiler feed and 25-35 percent of the input required for layer feed. In general, the major raw materials used as ingredients for preparing feeds include maize, bajra, soybean oil cakes, rice bran, groundnut, other oilseed cakes, etc. For both broilers and layers, two to three types of feed are used (starter, finisher, etc., for broilers and chick mash, grower mash, layer mash, etc., for layers). In terms of production, 80 percent of the poultry feed is produced in pellet form and the balance 20 percent in mash form. Maize is the main source of energy in poultry feeds and soybean contributes to the protein element. One of the reasons for the preference for yellow coloured maize in poultry feed is that it is a rich source of β-carotenes and xanthophylls. The presence of xanthophylls helps in coloration of egg yolk.

Maize constitutes about 60 to 65 percent of the raw materials in terms of volume and about 50 percent in terms of value of the raw materials used in cattle feed. The price of raw materials accounts for a major share in the overall cost of production of different animal feeds and varies from time-to-time depending on production, agro-climatic situations, import export regulations. Hence any adverse impact on production of maize affects the manufacturers of poultry feed in a significant way as they operate on low margins. Even a 5 percent increase in the price of maize affects the cost of poultry price by more than 2 to 3 percent.

Maize with 14 percent or less moisture levels is used in both pellet and mash feed by storing for less than one month while maize of normal appearance and quality with 15-16 percent moisture content is used for pellet feed. Maize with moisture content around 17 percent or above is not considered fit for poultry feed. The feed industry maintains bulk stock of maize grains for four to six months.

Depending upon the storage capacity available, poultry feed manufacturers store maize either at the warehouse or on their premises. Quality parameters for maize which affect the poultry feed value chain are moisture, heat damaged kernels, foreign materials, mycotoxins and mould damage. Moisture content plays a significant role in the storage of grain; when grain has more moisture, it heats up and can have mould spoilage. Generally, the higher the moisture content, the more susceptible the maize grain is to mould and insect deterioration. Poultry feed manufacturers have to use machines for drying purposes.

The poultry feed firms in Northern India procure their requirement from Bihar and other neighbouring states. The industry is affected due to variations in regular supply of maize. Fluctuations in supply pushed the maize prices upward drastically in 2018. The estimated loss of maize due to the presence of extra dust particles is in the range of about 1 percent. Under normal circumstances, the dust particle is around 0.5 to 1 percent which increases to 1 to 2 percent if climate conditions are not favourable during harvesting or storage. It also affects additional impurities such as foreign particles and damaged grains; the impact ranges between 2 to 4 percent in the case of adverse climatic variations which is generally between 1 to 2 percent. Cattle feed manufacturers observed that the incidences of damaged maize are also on the rise along with an increase in corn dust. Poultry feed manufacturers have to use dryer for drying the maize as well as pellets with higher moisture content which increases the electricity charges.

Experts pointed out that faulty farm practices and unseasonable rains are responsible for the increasing incidence of damaged maize grains. Poultry feed manufacturers also said that feed prepared by using high

Value Chain Losses: Poultry Feed Industry

INR 800-1,200 million

Increasing presence of dust, impurities, moisture content, deterioration in quality, increasing labour cost moisture maize has an effect on the shelf life of maize; it starts smelling within a very short period and so such stocks need to be supplied to the market on priority.

5.3.3 Impact of Climate Change on the Cattle Feed Industry

Maize is recognized as the main constituent of feed ingredients. It is a primary source of energy supplement, contributes 30 percent protein, 60 percent energy and 90 percent starch in animal diet. These contents of maize have increased its utility in the livestock feed industries.

Commonly used ingredients in cattle feed include grains, bran, protein meals/cakes, *chunnies*, agro-industrial by-products, added minerals and vitamins. In comparison to poultry feed, the quantity of maize required for producing cattle feed per unit of production is much lower.

The industry is experiencing erratic and low quality of maize supply in recent years due to adverse weather conditions. Weather extremities impact the shelf life of in-factory storage of maize thereby the stock-keeping cost increases by 10-15 percent. Feed producers are unsure of regular supply and maintain larger stocks of raw material. This has increased the lock-in period of capital.

Feed industries also hire the services of drying units to reduce the moisture level in maize. Moisture levels are brought down from 15-16 percent to 12-13 percent by drying units to meet the feed industry's requirement. Drying firms anticipate an increase in business by 10-12 percent due to the high moisture contents of maize observed in the recent past; they foresee an additional capital investment in advanced dryer technologies. Cattle feed manufacturers also shared that, despite using dryers, a minimum of 2 percentage of maize procured by them is wastage as it is beyond the acceptable limit of quality standards at the time of processing.

Value Chain Losses: Cattle Feed industry

INR 120-170 million

Increase in moisture, increasing use of dryers, decreasing maize quality, rejections due to excessive moisture contents

5.3.4 Impact of Climate Change on the Starch Industry

Maize kernel consists of four primary structures: endosperm, germ, pericarp and tip cap, making up 83 percent, 11 percent, 5 percent, and 1 percent of the kernel, respectively. The endosperm is primarily composed of starch and is surrounded by a protein matrix. At present, about 15 percent of the total maize production in India is consumed by the starch industry.

In India, maize from Bihar is popular due to the higher percentage of starch, gluten, germ and oil content found in it. The conversion ratio of maize to starch is 70 percent. Industrial sources mentioned that, in recent years, due to the use of hybrid seeds, there has been an increase in productivity of maize by 30-40 percent. Maize is the main raw material for the starch industry although other products such as rice, potato and tapioca are also used in the starch industry. Starch and other maize derivatives are primarily used by the textile, paper, construction and pharmaceutical industries. The starch industry is one of the top five processing industries in India.

Volatility in the supply of raw material is considered a major impediment to the growth of the starch industry. Bihar is a hub of winter maize supplies to maize processing industries in India. However, the recent weather extremes in Bihar (low temperature in 2018 and floods in 2019) for two consecutive years affected the production and supply of maize to maize-based processing industries. According to the processors, the price of maize has fluctuated from INR 12 per kg to INR 24 in the last two years. So, while the cost of production has gone up drastically, the prices of starch and starch derivatives have not kept up accordingly. The collective effect, as reported by industry experts, is seen in 30-40 percent underutilization of plant capacities. The consequent effect of volatility of supply of raw material results in processors maintaining a high inventory. This has affected the liquidity of the firms and increased the cost of production. The shelf life of maize has reduced due to untimely rains and increased humidity. These days maize becomes infested more often which severely reduces the key contents in maize. The risk of incidence of storage pest/fungus on stored maize is increasing.

Table 18: Summary of climate change on maize value chain

Type of Value Chain Agent	Climate Change Impact	Mitigation Strategy	Change in Costs/Value Chain Loss
Warehouse	Increased susceptibility to fungus and deterioration in quality	Aggressive fumigation	Fumigation expenses increased by 8-12%
Poultry feed	Presence of high impurities and dust	Rejection of procured grains at the time of processing	Approximately there is additional loss of 2 to 3% of maize which alone increases the cost of raw material by 1 to 1.5%
			Around 2% of maize is wasted due to sudden deterioration in the quality of maize
	Presence of inferior quality maize	Rejection due to moisture	1 to 2% of rejections due to excessive moisture
		Extra drying cost	Increased labour cost to the tune of 20 to 25 per bag (50 kg)
Cattle feed	Presence of impurities	Rejection of procured grains at the time of processing	Around 1 to 2% of maize is wasted due to sudden deterioration in the quality of maize (moisture and presence of foreign particles)
	Wet grains	Drying cost	Around 15 to 20 per bag of cattle feed
Starch industry	Irregular supply	Exploring newer sources of maize supply and maintaining additional stock	Increase in operating cost
	Higher prices of maize	Have reduced the production scale	Underutilization of the plant capacity

Table 19: Estimation of value chain losses in the maize value chain

	Total Maize Production in MT	Total Value of Production in INR (00,000)*	Stage of Value Chain	Share of Total Production Involved in Stage	Stage of Value Chain	Share of Total Production Involved in Stage
Total	2.054747	34,931	Self-consumption	15%	Starch	14%
Bihar	18.88987	32,113	Poultry	48%	Food processing industry	10%
Uttar Pradesh	0.164877	280	Cattle feed	13%	Storage	30%

**Prices calculated are based on inputs received from interviews of value chain actors: maize MSP 2018-19 @ INR 170,00/MT*

Table 20: Estimation of value chain losses in the maize value chain

Processing Stage		Reasons	Under Normal Situation		Under Climate Change-induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
			Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Poultry feed		Presence of dust	0.5%	1.0%	1.0%	2.0%	-0.5%	-1.0%	-84	-168
		Presence of foreign matters/ impurities	1.0%	2.0%	2.0%	4.0%	-1.0%	-2.0%	-168	-335
		Rejections due to excessive moisture/ quality	0.0%	0.0%	1.0%	2.0%	-1.0%	-2.0%	-168	-335
		Drying cost/ increased labour charges			INR 40/quintal				-395	-395
Cattle feed		Drying cost			INR 30/quintal				-80	-80
		Rejections due to excessive moisture/ quality	0.0%	0.0%	1.0%	2.0%	-1.0%	-2.0%	-45	-91
Industrial processing	Starch	No such loss								
Food processing	Processed foods				No such loss					
	Fumigation		Fumigation rounds of 45 days		Fumigation rounds of 30 days		Additional cost of fumigation for 1 to 1.5 rounds during the storage period		-9	-9
									948	1,413
Total climate change impact on maize value chain in the IGP districts is in the range of INR 900 to INR 1,410 million										

Assumptions: *Losses attributable to climate change subsequent to harvest have only been considered for calculation purposes. For the present study, calculation has been done primarily using the feedback received from various actors and by comparing normal conditions prior to observable climate change impacts and by assessing potential impacts as perceived by the participants; the in between has been documented in the absence of a baseline figure. In order to maintain uniformity in calculation of prices of the various commodities, MSP as determined by the Government of India for the financial year 2018-19 has been utilized for the calculation of overall impacts on the value chain.*

The monetary impact of climate change variation is observed to be maximum at the poultry feed level value chain which accounts for almost over 90 percent of the total negative monetary impact of climate change on the maize value chain. These losses occur primarily due to the adverse impact of climate change on the quality of the produce and its resultant impact. At the cattle feed stage of the value chain, the total negative impact on the value chain ranges from INR 120-170 million and these losses too primarily can be attributed to the adherence of quality parameters in the industry which result in higher operations costs for the industry. An increase in fumigation expenses has also been documented during the study to the tune of almost INR 10 million.

6

Climate Change Impacts on Wheat Cultivation, Wheat Value Chain and Adaptations by Various Stakeholders

Wheat is the second most important crop in IGP. Apart from its importance in food security, it also provides employment and livelihoods to millions of rural households. The sowing of the crop starts in November and the crop is harvested by the early April. Production of wheat in India during 2016-17 was estimated to be around 98.38 MMT in the crop area of 30.6 million ha with an average productivity of 3.2 MT per ha. Wheat cultivation in IGP is irrigation dependent and farmers who have irrigated land grow wheat for self-consumption and marketable surplus.

The series of interventions during the period of the Green Revolution has transformed the production of wheat in the country. The transformation, particularly in IGP, has been phenomenal due to the acceptance of high-yielding varieties and adoption of other modern agricultural practices. Because of favourable climatic conditions, most of the major wheat growing states in India are located within IGP, including states such as Uttar Pradesh, Punjab Haryana, Bihar, etc. The region provides favourable conditions with cool and moist weather during the winter which facilitates the growth of the plant and dry and warm weather from late February onwards that enables the grain to ripen properly. During the cropping season, this area provides the ideal germination temperature for wheat. The soil type of this region is also conducive for wheat cultivation. The other advantage of wheat cultivation is that, unlike rice, chances of complete failure of wheat crop in IGP are minimal. In IGP, the coping mechanism for climatic variability and rainfall variability is higher for wheat than the rice crop. Wheat cultivation starts under retreating monsoon conditions. Farmers apply two to three rounds of irrigations, followed by application of fertilizer.

It is expected that climate change will lead to a rise in the maximum temperatures in winter as well as a reduction in the number of days with low temperatures. This may affect the wheat grown especially in middle part of IGP. As wheat uses the residual moisture in the field from paddy cultivation, a good monsoon also leads to better growth and yield in the wheat crop.

6.1 Climate Change Impacts and Adaptations by Small and Marginal farmers

Wheat grows well in cooler temperatures, with sowing in early winter and harvesting at the beginning of the summer.

Temperature is a major factor which influences the yield. As wheat is grown as a winter-irrigated crop, the influence of rainfall is insignificant on the yield but any rains at the time of harvesting can do serious damage to the wheat crop.

Farmers pointed out that if the rain falls between 20 to 75 days after sowing, it helps the crops and saves irrigation costs. Variations in wheat yield in IGP also depend on sowing dates, soil moisture, etc. Amongst these, wheat is most sensitive to high temperatures, especially during the reproductive stage as it increases the levels of water stress in the plant cell. Temperatures rising towards the end of its growth, especially during the grain-filling stage of development (early arrival of summer), affect the yield of wheat. Farmers were of the opinion that increased temperature in winters is a climate changes trend that they have witnessed lately. They said that, in recent years, temperature is relatively higher in the months of November and December than it used to be earlier. Farmers are adapting to this by sowing late, but this increases the risk of more than adequate heat exposure at the time of harvesting. Wheat is a thermo-sensitive crop and both its growth and productivity depend on the temperature during the cropping phase.

Late sown wheat exposes pre-anthesis phenological events to high temperature which influence grain development and ultimately the yield. Farmers stated that if the temperature range deviates from the normal during flowering phases, it may affect the productivity of wheat. They also said that rainfall or cloudy weather may lead to a rust attack in the wheat crop. Higher temperature at the time of maturity also leads to forced maturity resulting in yield loss. Farmers also mentioned that, during the ripening season, the fear of rains or unfavourable conditions forces them to opt for harvesting, even when the crop grains have not fully matured. This early harvesting leads to low recovery of grain, with a higher proportion of immature seeds or broken and poor quality grains. Such grains are more susceptible to disease during storage.

6.2 Adaptation Measures by Small Farmers

Climate change adaptation involves taking action to adjust to, or respond to, the effects of changes in climate.

Types of adaptation in wheat range from usage of newer seeds, more application of inputs, change in planting and harvest dates, increased fertilizer or pesticide applications, etc. One of most common adaptation at the farmer level is experimenting with sowing dates to

minimize the effect of temperature or residual moisture. Farmers also shared that the frequency of seed replacement has also increased. If sowing is delayed due to climatic variations, farmers also increase the seed rate by reducing the spacing between plants.

Usage of better-quality seeds, application of agro-chemicals and increased usage of fertilizer is helping farmers to mitigate the risks of climate change to a certain level. Increased mechanization during the harvesting period has been one of the greatest adaptation strategies by farmers.

Apart from being used to overcome labour shortage, combine harvesters are also increasingly used to reduce climatic risks by shortening the harvesting window after ripening of the wheat. Though it is helping farmers to reduce the exposure of crops, it is also leading to events such as residual burning which is a contributor to adverse climatic conditions.

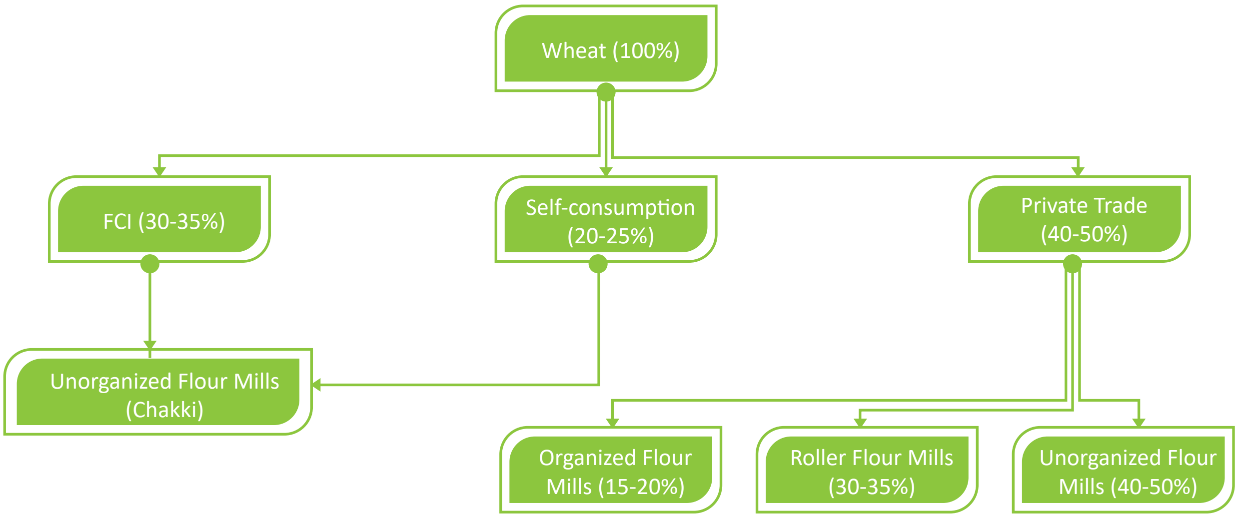
6.3 Impact of Climate Change on Value Chain Participants

Most stakeholders reported that overall growing conditions have been favourable for wheat in 2019. The extended winter conditions also helped to harvest a better yield. Even the government's preliminary estimate (Second Advance Estimate of 28 February 2019) for the year expected a production of around 99.1 MMT. The value chain participants confirmed that they had more

Table 21: Impact of climate change and adaptations for wheat

Perceived Impact of Climate Change	Key Adaptations by Small Holder/ Marginal Farmers
• Late arrival of winter results in late sowing • Less than expected decline in temperature in winter • Unseasonal rain or cloudy weather in winter leads to rust attack • Early arrival of summer leads to forced maturity resulting in yield loss • Increase in pest infestation • Increased presence of foreign matter • Early harvesting leads to low recovery of grain with higher proportion of immature, broken and poor-quality grains • Grains are more susceptible to disease if stored at home	• Change in seed with high seed replacement rates • 120-day seed variety is being preferred • Change in sowing time by either advancing or delaying with a reduced window for sowing • Increased intercultural operations • Adoption of alternate crops, particularly of maize, is also increasing • More usage of fertilizer and pesticides/herbicides • Increased mechanization by high usage of combine threshers; it also leads to incidence of residual burning

Figure 20: Wheat value chain



production in 2019. FCI, along with the state agencies, procured more than 35 MMT of wheat in the 2018-19 marketing year (April-March) on the back of a bumper crop.

Around 30 to 35 percent of the wheat produced by the farmers is used for self-consumption; around 5 percent is stored for seed while the remaining produce is marketable surplus. Sudden rains, hailstorms or heavy winds sometimes destroy or damage the wheat crop so much that such a crop is used for animal feed only. Beside this, the by-product from wheat milling (wheat bran-*chokar*) is also used for cattle feed. Three types of value chains exist for the wheat crop. The first is the regulated value chain which mainly covers wheat procured by FCI/nominated agencies and supplied back for distribution under the Public Distribution System (PDS). The second is the organized value chain which caters to the organized roller flourmills and flourmills. The third is an unorganized value chain that caters mainly to direct customers and small traders. This has wider reach and, in terms of the volume of wheat handled, this is the largest value chain among wheat value chains.

Table 22 shows the various existing value chains for wheat.

More than 75 percent of the remaining wheat is consumed in the form of flour *(atta)* while the rest is processed in roller flourmills that process around 13-14 MMT of wheat to produce various products such as *maida, suji/rava/semolina* and other bakery flours. Processing of flour *(atta)* is mainly done in the *chakki* (grinding stone) mills. In terms of the value chain, the value chain for roller flourmills is more organized while, barring few large players, the value chain for *atta* is largely unorganized.

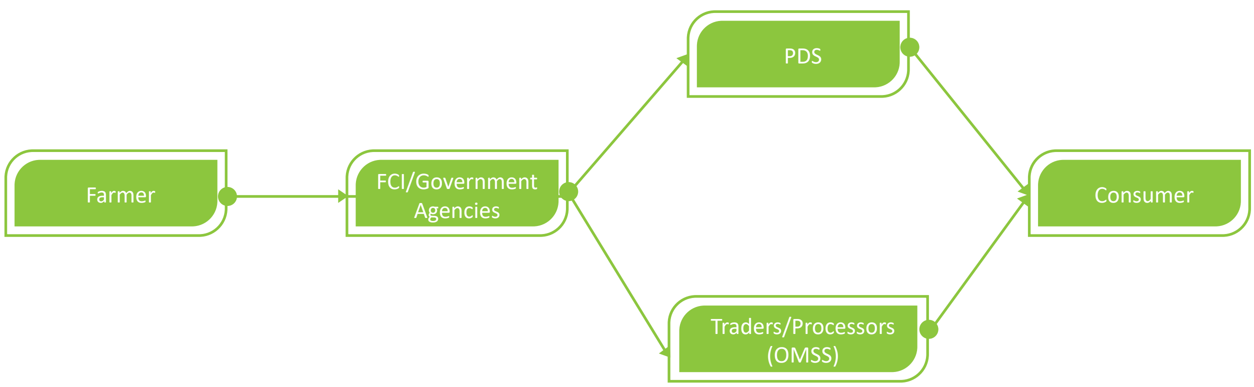
Table 22: Existing value chains for wheat

	Channels	Proportion of Wheat
	Under MSP	
Regulated value chain	Farmers - (FCI, state government agencies) - PDS - customer	30 to 35%
	Farmers - (FCI, state government agencies) -traders/ processors (Open Market Sales Scheme (OMSS))	
Private trade		
Organized value chain	Farmer - aggregator - wholesaler - roller miller - retailer - consumer	10-15%
	Farmer - aggregator - wholesaler - *chakki* mill - retailer - consumer	4-5%
Unorganized value chain	Unorganized value chain (processed through *chakki* mills)	45-50%

Regulated Value Chain

FCI procures wheat on behalf of the Government of India from farmers through state-level cooperatives and/or nominated agencies. This procurement takes place at a pre-declared price under MSP. Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Rajasthan are the major contributors of wheat to the government procurement system. The data for the last few years also suggest that more than 30 percent of the wheat produced is procured by government agencies, especially in Uttar Pradesh. The wheat procured through FCI/nominated agencies is allocated to various state governments for distribution through PDS at a subsidized price. In years of enough surplus procurement and stocks, the government also sells wheat in the open market to the private trade to stabilize OMSS. The wheat distributed through this system is consumed in the form of flour *(atta)* and is processed through unorganized flourmills. The impact of climate change is not significant on this value chain due to non-stringent quality norms, at the time of procurement, distribution and processing. Whatever the impact of climate change, it is largely borne by the end consumer.

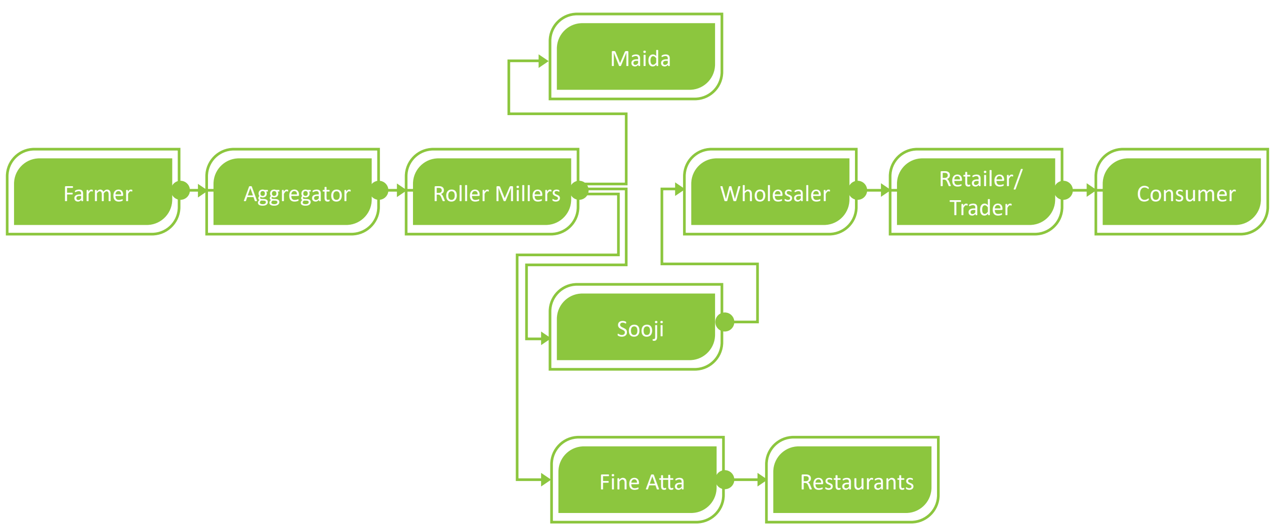
Figure 21: Regulated value chain of wheat



Organized Value Chain (Roller Flourmills/Flourmills)

In this value chain, wheat is procured by organized private millers either directly or through agents from farmers as well from *mandis.* In Bihar, wheat trading is largely driven through private traders where traders supply wheat to roller flourmills. In Uttar Pradesh, farmers also directly supply to wheat mills. This value chain caters largely to large units of roller mills. The organized roller flourmill is an old value chain while the organized flourmill is new and is undergoing transformation. Wheat is used by roller flourmills with a conversion rate of around 97 percent. In this process, 60 to 65 percent of the final product is fine flour *(maida)*, 20 to 25 percent is semolina *(rawa-suji)*, 7-8 percent is residual flour and the remaining is recovered as bran

Figure 22: Organized value chain of wheat



which is used as/in cattle feed. The flour produced through this process is finer in compare to *chakki* flour. The end customers of this refined flour are restaurants and hotels who use it to make various items. Most of these roller mills have capacities varying between 20 to 50 MT per day and operate at 60-70 percent of their capacity.

Organized flourmills are in the business of branded flour. These flourmills grind and sell wheat flour under their own brand name. Many such units also do contract grinding where they process for branded flour manufacturers. Wheat is supplied by the companies to the miller which is milled into whole flour *(atta)* as per the specified quality norms fixed by the companies. This value chain is highly impacted by climate change. The millers have to maintain high quality of the final produce and therefore any climate-affected impurities in wheat have to be cleared before processing. The millers are able to command 20-30 higher prices due to their higher quality/branding over unorganized players. This also works as the main incentive for these millers to invest in high-end machinery such as dryers and sorters to mitigate the climate change impact and stay ahead in the business.

Unorganized Value Chain

Wheat flour is the form in which wheat is largely consumed in India. This value chain consists of famers, small aggregators and small millers. Most of these mills do custom milling for farmers/small traders or consumers who procure wheat from farmers or small aggregators. Production of flour from wheat is done by milling with grinding stone (chakki). This technology is still used due to the unique aroma and texture of the flour which is preferred for household consumption.

These chakki mills are generally small units with a processing capacity starting from 2 to 3 quintal per hour. The impact of climate change on this value chain is lower as its participants rarely engage in activities such as storage and branding. The only impact of climate change is on the increased cost of milling due to use of additional labour in manual cleaning and washing of wheat.

6.3.1 Impact of Climate Change on Warehousing

The arrival of wheat in both Bihar and Uttar Pradesh starts in the month of April and it continues till early June. The primary aim of storage activity is to prevent deterioration of the quality of grain. This is done through control of moisture and aeration and by saving the wheat grain from attack from microorganisms, insects and rodents. The practice of storage has also increased due to the facility of availing credits based on warehouse receipts.

Generally, wheat is stored for four to six months by farmers, in anticipation that it may lead to higher price realization. At the time of harvesting, grain normally contains 20 percent moisture. For safe storage, maintenance of around 12-14 percent grain moisture content is recommended. An increase in moisture may lead to musty odour, discoloration and lower flour yield. It is therefore necessary that an equilibrium moisture content for wheat around 13 at 70 percent relative humidity is maintained during storage. The storage of wheat starts in early summer and it continues till the rainy season. During this storage period, both temperature and humidity increase which is favourable for the growth of storage insect pests. In a hot and

humid climate, they can multiply faster. Sometimes due to an early harvest, wheat grains have higher moisture content which increases the risks of quality deterioration. To maintain quality, grains stacked in gunny bags need to be periodically fumigated; warehouses therefore need to apply more cycles of fumigation which results in increased cost of storage.

6.3.2 Impact of Climate Change on Wheat Milling

Production of wheat has been consistent in the last few years and hence value chain participants do not get affected by production fluctuations (one of the key impacts of climate change).

To mitigate the quality-related impact of climate change, traders and millers are adopting stringent quality parameters at the time of procurement. Most millers have now invested in developing inbuilt facilities for drying (both sun/machine) of wheat. Large roller mills/ flourmills are now impacted by climate change due to increased cost of drying or rejections of wheat at the time of milling due to inferior quality or presence of foreign matters in the wheat.

Wheat with low moisture content, high on shining, heavy and uniform grain and low impurities are considered as good raw material. However, in recent years, due to increased humidity, the moisture level is increasing in wheat. Millers attribute the formation of small wheat grain *(muniyadana)* to climate change. Due to their small size, wheat grains get mixed with filtered impurities. Millers suffer production losses of around 2-3 percent due to this. Similarly, early onset of summer also affects the quality of wheat grain. This effect is magnified at the grain filling stage which leads to reduced grain size. Untimely rain before/at time of the harvest results in discoloured wheat. Recent experience of untimely rain during harvest months compelled farmers to harvest crop produce before maturity in haste. Millers observed that such incidences increase the impurities by 1-1.5 percent. Millers reported that wheat with higher moisture content tended to consume more energy during processing. Although it is difficult to quantify an exact correlation, a pattern of higher energy consumption is being observed. Millers stated that use of drying units was not very common earlier. Now as they have started using them, electricity consumption has gone up by roughly 10-15 percent. Roller millers stated that the extraction proportion for different products such as *maida/sooji* also depends upon the moisture content of wheat. The quality of *maida* is affected by high moisture content in wheat. The cost of processing has increased to match the quality requirement due to investment in advanced machineries such as sievers, grinders and driers.

Value Chain Losses: Wheat Milling

INR 8,320 million

Increased humidity and moisture loss, increasing impurities -increasing labour charges - increasing electricity consumption

Table 23: Summary of climate change on wheat value chain

Type of Value Chain Agent	Climate Change Impact	Mitigation Strategy	Capital Cost Incurred (INR)	Change in Operating Costs
Warehouse	Increased susceptibility to fungus and deterioration in quality	Aggressive fumigation	NIL	Fumigation expenses increased by 8-12% on an annual basis
Unorganized *chakki mill*	Increased percentage of stones, soil and leftover of other crops	Increased manual cleaning and washing	NIL	Labour cost increased by 15-20%
Whole flourmill (organized)	Increased percentage of stones, soil and leftover of other crops	Pre-cleaning machinery	750,000 -1,000,000	Cost of electricity consumption and labour goes up by 5-10%
	Increasing humidity and moisture level in wheat	Increased use of dryers and additional hours of milling	1,000,000 onwards	Cost of electricity consumption and labour goes up by 10-15%
Roller mill	Increased percentage of stones, soil and leftover of other crops	Pre-cleaning machinery	750,000 -1,000,000	Cost of electricity consumption and labour goes up by 5-10%
	Increasing humidity and moisture level in wheat	Increased use of dryers and additional hours of milling	1,000,000 onwards	Cost of electricity consumption and labour goes up by 15-20%

Table 24: Estimation of value chain losses in the wheat value chain

	Total Wheat Production in MT (2015-16)	Stage of Value Chain	Share of Total Production Involved in Stage	Stage of Value Chain	Share of Total Production Involved in Stage
Total	4.290581	Organized roller mill	15%	Regulated value chain	30 to 35%
				Organized value chain roller mills	10-15%
Bihar	1.834646	Organized chakki mill	5%	Organized value chain chakki mills	4-5%
Uttar Pradesh	2.455935	Storage	15%	Unorganized value chain	45-50%

**Prices calculated are based on inputs received from interviews with value chain actors: wheat MSP 2018-19 @ INR 18,500/MT*

Table 25: Estimation of value chain losses in the wheat value chain

Processing Stage	Reasons	Under Normal Situation		Under Climate Change-induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
		Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Organized flourmills	Increased impurities resulting in cleaning charges	Labour charges @INR 400/MT						-86	-86
	Increased impurities resulting in loss of grains	2.0%	1.0%	2.5%	1.5%	-0.5%	-0.5%	-20	-20
	Increased humidity and moisture in wheat resulting in drying charges	Incremental electricity costs and sun drying charges @INR 165/MT						-35	-35
	Increased humidity and moisture in wheat resulting in weight loss	2.0%	1.0%	2.5%	1.5%	-0.5%	-0.5%	-20	-20
Organized roller flourmills	Increased impurities resulting in cleaning charges	Labour charges @INR 400/MT						-257	-257
	Increased impurities resulting in loss of grains	2.5%	1.5%	3.5%	2.5%	-1.0%	-1.0%	-119	-119
	Increased humidity and moisture in wheat resulting in drying charges	Incremental electricity costs and sun drying charges @INR 350/MT						-225	-225
	Increased humidity and moisture in wheat resulting in weight loss	2.0%	1.0%	2.5%	1.5%	-0.5%	-0.5%	-60	-60
Warehouse	Fumigation charges	Fumigation rounds of 45 days		Fumigation rounds of 30 days		Additional cost of fumigation		-10	-10
	Total impact of climate change on wheat value chain							832	832
Total climate change impact on wheat value chain in the IGP districts is around INR 8,300 million									

Assumptions: *Losses attributable to climate change subsequent to harvest have only been considered for calculation purposes. For the present study, calculation has been done primarily using the feedback received from various actors and by comparing normal conditions prior to observable climate change impacts and by assessing potential impacts as perceived by the participants; the in between has been documented in the absence of a baseline figure. In order to maintain uniformity in calculation of prices of the various commodities, MSP as determined by the Government of India for the financial year 2018-19 has been utilized for the calculation of overall impacts on the value chain.*

Over 80 percent of these losses can be directly attributed at the stage of organized roller flourmills while the rest occur at the level of unorganized roller flourmills. Like other value chains studied, most post-production losses are directly attributable to higher operations costs due to adherence to quality parameters because of the adverse impacts of climate change on the quality of the yield. Over the next decade, climate change variations can have a significant impact on the quality as well as productivity increasing overheads at the processing stage.

7

Climate Change Impacts on Potato Cultivation, Potato Value Chain and Adaptations by Various Stakeholders

Potato is the fourth most important food crop after rice, wheat and maize and the most important vegetable crop grown in IGP. India is the second largest producer of potato after China. Major potato growing states in India are Himachal Pradesh, Punjab, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Karnataka, West Bengal, Bihar and Assam. The Indian potato belt stretches from Punjab (North West) to West Bengal in East India. Uttar Pradesh, West Bengal, Bihar and Punjab together account for about 86 percent of India's potato production. Uttar Pradesh is the largest producer of potatoes in India.

Potato is usually sown in October-November and becomes ready to harvest by February-March. To take advantage of the high price, enterprising farmers also grow it a little earlier to get the crop ready even a month earlier than the regular schedule. Potato is a cool season crop and tolerates frost moderately. The ideal temperature for its growth during the initial stage is around 25^{o}C. Deep, well-drained and friable soils having good organic matter are ideal for its cultivation. In India, more than 80 percent of the potato crop is grown in the winter season (rabi) under irrigation during the short duration from October to March. The rainy season (kharif) potato production takes place in Karnataka, Maharashtra, Himachal Pradesh, Jammu and Kashmir and Uttaranchal.

Potato is one of the most widely consumed vegetables both in Bihar and Uttar Pradesh and a large part of production is used for table purposes, followed by use for seed. As no processing takes place in these uses, the value chain is very small. Participants in this value chain are producer, aggregator/trader, cold storage owner, wholesale trader and retail trader.

The longer value chain for potato is for processed products such as potato chips, potato fries, etc., which accounts for less than 10 percent of the total potato produced in the study area. Potato is a perishable commodity and its harvesting time coincides with the rise in temperature in IGP.

7.1 Impact of Climate Change on Potato Crop

Potato is highly susceptible to climate change in comparison to other crops and adverse climatic situations can affect productivity, quality (size and appearance), cost of production and storage. The potato plant has mainly two different growth stages. The first stage includes sprout development and plant establishment while the second stage is the phase of tuber development and maturing. Plant growth in both

these phases is dependent upon environmental factors, such as temperature, soil, moisture availability and geographic location. Any climatic variation during these stages has the significant potential of creating a negative impact on the production or cost of production.

Potato is best adapted to cool climates with temperatures in the range of 15 to 25^{0}C. Temperature higher than this range retards tuberization. Additionally, heat stress also leads to a higher proportion of smaller tubers with paler skin colour of tubers. Temperature above 25-30ºC shortens the growing period of potatoes and reduces tuber yield.

During the winter, longer than usual periods of frost and dew cause the foliage to remain wet for prolonged periods during the day; this also affects the crop growth.

The crop is also sensitive to water and yield is reduced in drought as well as in waterlogged conditions. Drought events occurring early in the growing season reduce the number of tubers per plant and even a single, short-term drought during tuber bulking decreases potato quality (i.e., tuber size and appearance) along with the overall yield.

Unseasonal rains around harvest lead to high soil moisture conditions which result in the crop rotting, making produce extremely vulnerable to disease/pest infestation even after harvesting. Variations in irrigation and temperatures also cause the harvested produce to be of smaller size, substantially increasing the on- and off-farm grading and sorting costs.

7.2 Adaptation Measures by Small Farmers

Climate change adaptation involves taking action to adjust to, or respond to, the effects of changes in the climate. Potato grower's adaptation ranges from usage of newer seeds, more application of inputs, change in planting and harvest dates, and increased applications of fertilizers or pesticides.

The most common adaptation happening at the potato growers' level is experimentation with sowing and harvesting dates which helps them in minimizing the effect of temperature or residual moisture. Some small and marginal farmers prefer early harvesting at 60-70 days after planting with a compromise of 30 to 40 percent lower yield compared to a fully mature crop due to the higher price they get for this potato in the market. Both the size of the tuber as well the number of tubers is reduced in such a situation.

In order to adapt to frequent temperature variations, small and marginal farmers have reported use of shorter duration varieties that mature much earlier than the traditional varieties. These varieties can be harvested in 70-90 days which not only helps the farmer in avoiding the high stress periods by strategically sowing the crop but also gives higher income as early harvested potato fetches a higher price in the market. Table 26 shows the level of adaptation by small farmers.

7.3 Impact of Climate Change on Value Chain Participants for Potato

Potato is considered a staple crop and is used in three ways: 60 to 65 percent is utilized as a vegetable for domestic table consumption while another 18 to 20 percent is retained as seed. Roughly 8 to 10 percent of the produce is used for higher value-added potato products. Amongst the various value-added products, potato chips account for approximately 60 percent of the processed potato products. Other processed potato products are potato flakes, *alu bhujia,* etc.

Table 26: Impact of climate change and adaptations for potato

Perceived Impact of Climate Change	Key Adaptations by Small Holder/Marginal Farmers
• Late/early arrival of winter and lower crop duration affect productivity (reduce tuber yield) • Smaller duration of winter with lower decline of temperature affects the number and size of tubers • Short-term drought during tuber bulking decreases potato quality • High frost and dew conditions (wet foliage) damage the crop • Heat stress also leads to a higher proportion of smaller tubers with paler skin colour of the tubers • High temperature and humidity at the time/after harvesting leads to rotting of crops	• Change in sowing time by 10-15 days has become very common • Increased intercultural operations with frequent earthing up and mulching of ridges • More usage of nitrogen-based fertilizer and chemical pesticides • Adoption of light but frequent irrigations is increasing especially in stages of crop development, tuber initiation and tuber development • Small and marginal farmers prefer to sell immediately after harvesting due to high incidence of rotting

Potato processing is split into organized and unorganized sectors. The organized sector is under the control of large manufacturers with a presence across the country while the unorganized sector comprises small manufacturers with lesser-known or no brand names operating at the regional level. Potato chips are the most common product across both sectors. The processing industry in the IGP region is restricted to unorganized sectors with small players. The suitability of the variety grown in both Bihar and Uttar Pradesh is the key hindrance in the development of large potato processing units. Additionally, the accumulation of reducing sugar in high amounts during the cold storage process makes the potato unsuitable for processing. This affects both the taste and appearance of the final product. During the storage process, high usage of the sprout suppressant, CIPC, also limits the scope of its usage in processing. The varieties grown in these areas also have lower dry matter content.

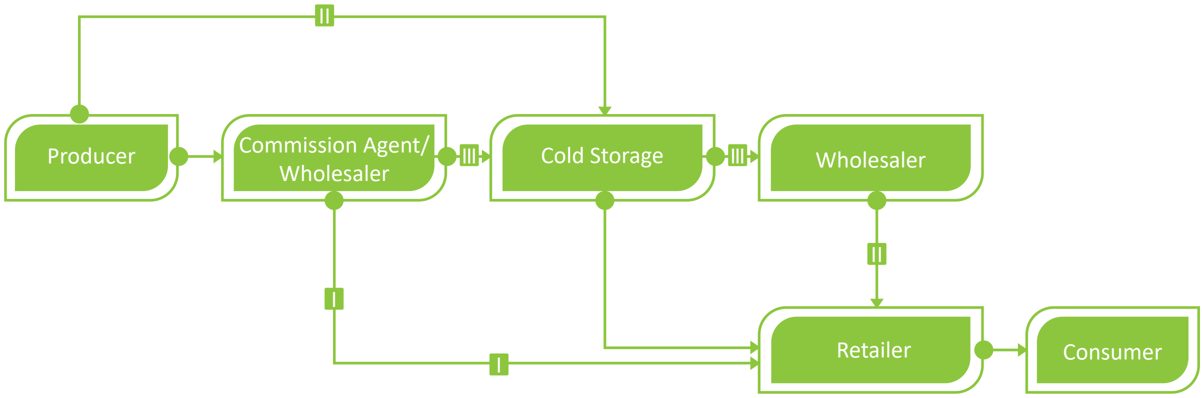
Channel I: Producer - commission agent/wholesaler - retailer - consumer

This is the most prevalent value chain adopted by potato growers, especially by small and marginal farmers. Volume wise, this value chain accounts for about 10 percent of the potato produced. Farmers, after keeping aside some part for self-consumption (for three to four months) sell the remaining potato immediately. Rotting of potato starts very soon due to hot temperature. As small farmers lack the volume to take care of transportation and storage cost associated with cold storage, they prefer to sell it immediately at the prevalent market prices. Even traders/wholesalers sell as early as possible in nearby urban mandis; the produce is purchased by end users through retailers. In this channel, 3 to 5 percent of losses happen due to rotting of potato. The losses are spread out across all value chain participants in the process with an aggregate loss of 3 to 5 percent in the process.

Channel II: Producer - cold storage - commission agent/ wholesaler - retailer - consumer

This value chain accounts for the maximum percentage of potato produced in the region. Farmers belonging to medium and large category participate in this value chain which accounts for about 25 to 30 percent of the total potato grown in the area. They generally deliver potato in 50 kg bags in March and April to cold storage warehouses; this is taken out from September onwards. The rate for storage is independent of the period of storage. Generally, farmers must pay between INR 200 to 300 per quintal for storage for six months. This value chain is impacted by climate change the most. Cold storage owners reported that their cost had risen due to increased power consumption (electricity and diesel charges), spray of chemical to delay sprouting, sorting and repackaging of potato, etc. Overall this increases the cost of operation and maintenance by approximately 10 to 15 percent. The remaining value chain losses are borne by farmers. At the time of taking potato out of the cold storage, 3 kg of potato is deducted as shrinkage/ weight loss which happens during the period of storage.

Figure 23: Potato value chains



Channel I : Producer- commission agent/wholesaler- retailer- consumer
Channel II : Producer- cold storage- commission agent/ wholesaler- retailer- consumer
Channel III : Producer- commission agent/wholesale-cold storage- wholesaler-retailer- consumer

Farmers also store potato which is used as seed in the next cropping season.

Channel III: Producer - commission agent/wholesale - cold storage - wholesaler - retailer - consumer

This value chain also accounts for a significant proportion of potato produced in this region. The share of this value chain is constantly increasing. The only difference with the previous value chain is that, in this value chain, traders store the potato after purchasing from farmers/ aggregators at the time of harvesting. This value chain accounts for about 15 to 20 percent of the potato grown in the area. Traders begin storage in 50 kg bags in March and April and start taking the potato out according to the price movement in the market. Rates are fixed between INR 200 to 300 per quintal and are independent of the storage duration. This value chain is also impacted significantly due to climate change in the form of higher storage charges for traders and higher operational cost for cold storage owners.

Channel IV: Producer - cold storage - wholesaler - retailer - consumer

This value chain is relatively new. In this model, cold storage owners procure potato on behalf of traders and store it in their cold storage. Traders in this model need not be from the local production centres. Traders from other states too ask cold storage owners to procure potato on their behalf and store in their cold storage. Quality checks are the responsibility of cold storage owners at the time of procurement. Based on prevailing market rates, cold storage owners procure potato after receiving order confirmation and part payment.

7.3.1 Effect of Climate Change on Cold Storage

Cold storage units are the most important link in the potato value chain. Potato is a highly perishable commodity and with its harvest time coinciding with rise in temperature in IGP, there is high risk of rotting and wastage of potato.

From April onwards, temperature in the plains increases rapidly, and produce has either to be consumed within a short period or shifted to cold stores. Due to the expensive and unevenly distributed nature of cold storages, there are cases of oversupply in the market causing economic losses in the value chain. Unlike cereals where storage is primarily driven by traders, in potato, a large proportion of cold storage users are farmers. Storage begins in March-April till September onwards; no activity takes place in cold storage from mid-November to middle of February. Most cold

Figure 24: Potato value chain

storages close in December and January for maintenance activities. The two critical environmental factors involved in properly storing potatoes are temperature and humidity. Adequate and unrestricted air movement is also necessary to maintain constant temperature and humidity throughout the storage pile, and to prevent excessive shrinkage from moisture loss and decay. The charge for potato storage is INR 2,000-3,000 per MT with a condition of 6 to 8 percentage weight loss.

The impact of climate change on cold storage occurs on two ways: electricity charges due to high rise in temperature; and humidity management. A longer summer season and delayed monsoons also affect the operations of cold storages by increasing the operational costs of running as they require larger amounts of electricity to maintain the optimal levels of temperature and humidity in the cold stores. As reported by cold storage owners, their electricity consumption units have increased by about 10-12 percent in the last few years. This amounts to INR 75 to 100 per MT.

Cold storages also face challenges related to capacity utilization, but this happens mainly due to fluctuation in production. The design of cold storage is such that it is only conducive for long-term storage of potato; they also store vegetables such as carrot for short durations.

Value Chain Losses: Potato Cold Storage

INR 6,000 million

High temperature related wastage of potato - increasing temperature - high electricity charges - increasing humidity - high electricity charges.

7.3.2 Effect of Climate Change on Potato Processors

In the area of study, we did not come across any of the organized potato processors. Whatsoever processed activity does take place is undertaken by unorganized processors who cater to the local/regional market. The selling price of potato chips produced by the unorganized sector is at least 50 percent less than that produced by the organized sector. The former mainly supplies to the local eateries/snack shops. Apart from potato chips, these processors also prepare potato *lachcha*, potato *bhujia*, etc. In terms of potato production, Uttar Pradesh and Bihar rank first and third, respectively, at the national level. However, there are not many processing industries in the region due to the non-suitability of the varieties of potatoes grown in this region for processing industries. Chips prepared from the varieties grown in the IGP region tend to have a high percentage of brown colour chips as well as a higher proportion of broken chips.

Most of the climate change impact faced by potato processors is in terms of the quality of potato. Increased temperature often leads to smaller size of potato which increases wastage during the peeling process due to the higher amount of peeling losses as more potatoes have a diameter less than 40 millimetre (mm).

Farmers in the IGP region prefer early maturing varieties while late maturing varieties contain high dry matter as required for processing industries. A high usage of fertilizers also reduces the dry matter presence in potatoes. Potatoes with lower dry matter increase the energy cost as well as the amount of cooking oil required to fry them for processing industries. Additionally, during cold storage of potato, the proportion of sugar increases which leads to a change in colour to brown/black.

As the impact of climate change on the processing industry is entirely related to the presence of a suitable quality of potato at a reasonable price, processors reported that, due to size and appearance related issues, the amount of wastage during the chips manufacturing process increases by about 10 percent. In addition to this labour charges and other processing expenses in drying and other processes also increase by 5 to 10 percent.

Value Chain Losses for Potato: Organized and Unorganized Processing

INR 1,840 million

Increasing temperature - effect on size of potato - increase in wastages - increasing use of fertilizer - reduction in dry matter - increased use of labour and dryers.

Table 27: Estimation of loss on potato value chain

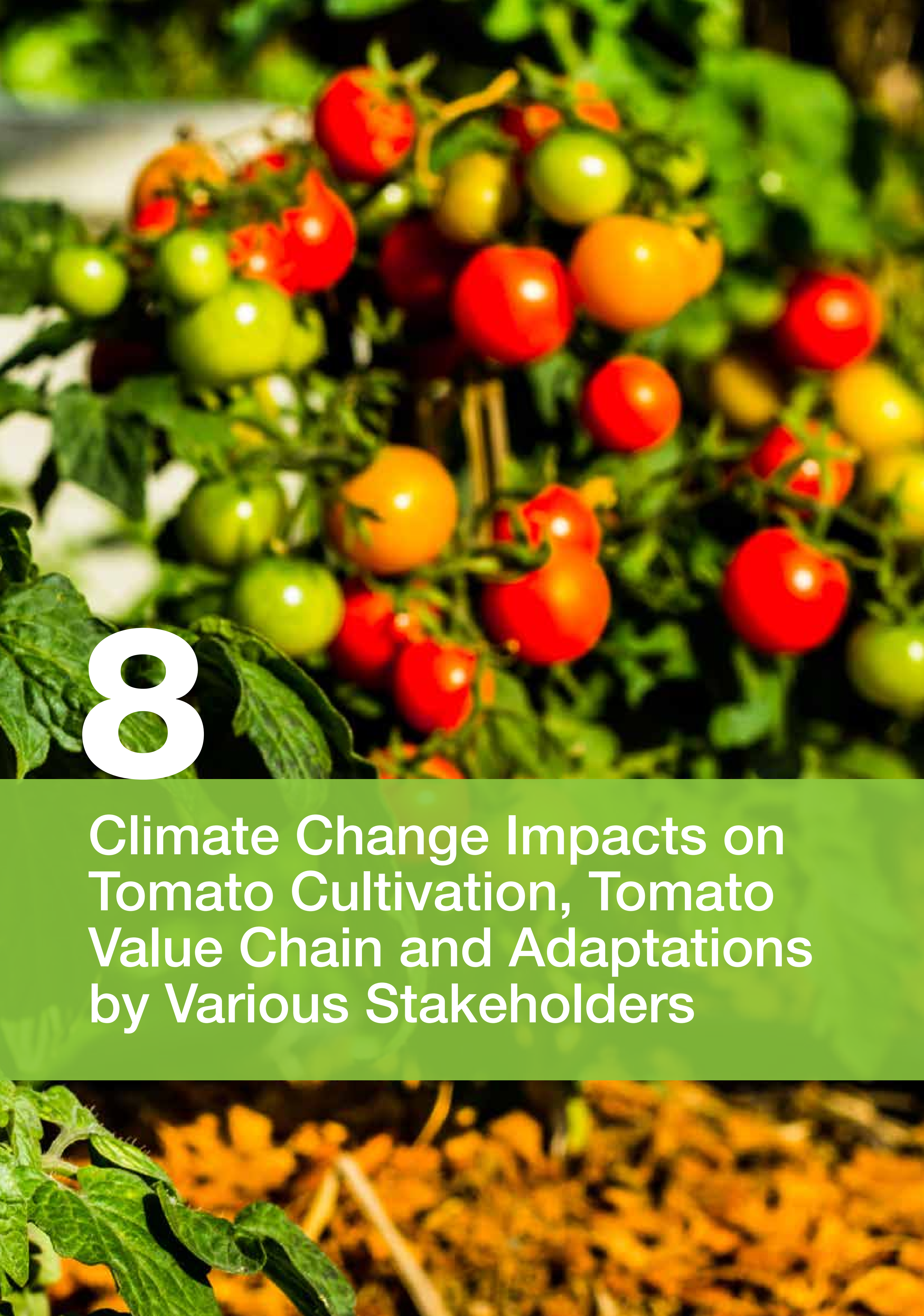
	Total Potato Production in MMT* (2017)	Total Value of Production in INR (00,000)*	Stage of Value Chain	Share of Total Production Involved in Stage
Total	41	310,769	Table purpose	90%
Bihar	38	291,832	Processing, organized	4%
Uttar Pradesh	2	18,936	Processing, unorganized	6%
			Cold storage	50%
**Prices calculated are based on inputs received from interviews with value chain actors: potato average wholesale price @ INR 7,600/MT*				

Table 28: Estimation of loss on potato value chain

Processing Stage	Reasons	Under Normal Situation		Under Climate Change-induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
		Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Potato	Storage loss	5%	3%	7%	4%	-2%	-1%	-2,797	-1,398
	Increased electricity/ operation costs	INR 100 /MT						-1,840	-1840
	Wastage	5.0%	3.0%	8.0%	5.0%	-3%	-2%	-4,195	-2,797
Potato processing-organized	Weight loss	1.0%	0.5%	2.0%	1.5%	-1%	-1%	-124	-124
	Increased labour/ operation costs	INR 30/MT						-49	-49
Potato processing unorganized		1.0%	0.5%	2.0%	1.5%	-1%	-1%	-11	-11
	Estimated value chain loss							6,220	9,017
The total value chain loss in potato due to climate change in the IGP region is in the range of INR 6,220 to 9,010 million									

Assumptions: *Losses attributable to climate change subsequent to harvest have only been considered for calculation purposes. For the present study, calculation has been done primarily using the feedback received from various actors and by comparing normal conditions prior to observable climate change impacts and by assessing potential impacts as perceived by the participants; the in between has been documented in the absence of a baseline figure. In order to maintain uniformity in calculation of prices of the various commodities, MSP as determined by the Government of India for the financial year 2018-19 has been utilized for the calculation of overall impacts on the value chain.*

The maximum losses occur at the level of cold storages where they have been documented to be in the tune of over INR 6,000 million. Even at this stage of the value, the maximum share of losses can be accounted for due to wastage at the cold storages which account for over 33 percent of the total documented negative impact on the value chain. Increased operations costs due to climate changes account for almost INR 1,840 million of total losses. Increased operations costs, labour charges and wastage losses at the organized and unorganized potato processing stages account for almost a total loss of around INR 1,840 million.



8

Climate Change Impacts on Tomato Cultivation, Tomato Value Chain and Adaptations by Various Stakeholders

Tomato is the second most grown vegetable in the districts of IGP after potato. It is grown as a winter as well as a summer crop. The harvesting period is between December and March for winter plantation and from August to October for summer plantation. To take advantage of high prices, farmers in Sonebhadra as well in Samastipur were also observed to be growing tomato a little earlier with production ready around July. In IGP, the adoption of tomato has been very high especially by small and marginal farmers and it is grown by all types of vegetable growers.

Flexibility of growing all through the year, higher cost-benefit ratio, benefits of taking multiple harvests leading to higher cash flow and liquidity with returns spreading out over time make tomato cultivation an attractive proposition. India is the world's second largest tomato producer but processes less than 1 percent of its production. This impacts farmers by way of high post-harvest losses and low returns during periods of market glut. Earlier this crop was being grown only as a rabi crop in IGP but now its adoption has increased in late summer as well as in early kharif especially in regions without water logging. Cultivation of tomato in later summer as well as in early kharif gives the price advantage to the growers. Due to changing dietary habits and reducing distance between rural and urban centres, one marketing-related challenge is that of easing out of the crop especially grown in late summer and early kharif.

In the last 15 years, there has been significant increase in area, production and productivity of tomato almost across India, including in IGP. For the year 2017-18, the crop was grown in Bihar on 45.01 thousand ha with a production of 941.56 thousand MT. The productivity in Bihar is around 20.92 MT per ha. Vaishali, Muzaffarpur, Patna, Nalanda, Begusarai, Samastipur and Purbi-Champaran, etc., are the main tomato producing districts in the state. In Uttar Pradesh, it was cultivated in 21.24 thousand ha with production of 841.61 thousand MT with productivity around 39.62 MT per ha. Mainpuri, Agra, Etah, Barabanki, Kannauj, Kanpur, Lucknow, Amethi, Sonbhadra and Mirzapur are some of the main tomato producing districts in Uttar Pradesh. Productivity, all India, is around 25 MT per ha with the area under crop of 789,000 ha and production of 19,759,000 MT[25].

Complete failure of crops, shortage of yields, reduction in quality and increasing pest and disease infestations are some of the key challenges faced by farmers due to climatic variations. As input costs for tomato are very high (hybrid seeds and high usage of pesticides), small and marginal farmers are much more affected. To merely maintain basic quality, farmers regularly need to spray chemical insecticides/pesticides.

8.1 Climate Change Impact on Tomato Cultivation

Tomato is one of the crops most vulnerable to climate change and adverse climatic conditions cause severe damage to it. It is highly susceptible to increased temperature and drought-like conditions. It affects production as well as quality. The crop needs a controlled supply of water throughout the growing period to maintain quality and productivity. As the crop is sensitive to water deficits, regular water supply needs to be ensured in phases such as post transplantation, flowering stage and during fruit development.

Long periods of heat stress also have very adverse impact on crop production as it affects the vegetative and reproductive processes of tomato leading to a reduction in yield and fruit quality.

Rains with high intensity can cause severe damage to plants both in the nursery as well as the initial days after transplantation.

During the ripening season, high rainfalls significantly damage both the quality and quantity of the tomato produced. Incidence of water logging causes serious damage to the tomato. Disease attacks have increased significantly with a high incidence of cases of complete burning of flowers and curling of leaves. Conditions such as erratic rainfall also lead to rapid wilting and death of tomato plants as the plant is highly sensitive to water logging. Long dry spells or high temperatures cause significant loss in productivity due to reduced fruit setting, smaller size and low-quality fruits. Climatic variations also affect post-harvest quality and further cause severe losses in the value chain. Variations in

25 Horticulture Statistics at a Glance 2018, Ministry of Agriculture & Farmers' Welfare, Government of India.

temperature, rainfall, humidity and dew affect the growth and spread of fungi and bacteria which affects the fruit's colour and appearance as well the shelf life after harvesting.

Farmers also reported that short duration varieties have much smaller harvesting period. The shelf life has also reduced from four to five days earlier to just one to two days now.

8.2 Adaptations by Small and Marginal Farmers

Based on their past cropping experience and suggestions from fellow farmers and input suppliers, farmers adapt one or other strategies to minimize the impact of adverse climate stresses. Some adaptations take place in terms of changing the processes while others tend to change quantity and types of inputs. Unlike paddy and

Table 29: Impact of climate change and adaptations for white

Perceived Impact of Climate Change	Key Adaptations by Small Holder/Marginal Farmers
• Heat stress adversely affects the crop production (vegetative and reproductive processes) • Crop is sensitive to water deficit as well extra water • Incidence of diseases/pest attacks have increased and burning of flowers, curling of leaves, etc., are often witnessed • Variations in temperature and humidity affect the growth and spread of fungi and bacteria which impact fruit colour and the appearance • High temperatures with variations lead to cracking in the fruit and decrease the stiffness of tomato skin and strength	• Very frequent change in seed variety • Adoption of practices such as raised nursery beds, staking and plant spacing • Prevalence of disease is increasing and many previously used pesticides are rarely effective in the following years • Immediate sale of tomatoes after harvest

wheat where farmers necessarily grow only these crops, tomato farmers also adopt strategies related to crop diversification or changes in the cropping calendar.

8.3 Climate Change Impact on Tomato Value Chain

In the last two decades, there has been a significant increase in the area under tomato crop, production and productivity. Unfortunately, the processing industry has not been able to match production. After China, India is the world's second largest tomato producer. However, when it comes to processing, hardly 1 percent of the tomatoes produced in the country are processed.

Availability of the suitable variety in adequate quantities and deterioration of quality in post-harvest phases are some of the key challenges in the value chain. When it comes to climate change, some factors that affect the value chain are the suitability of the quality of tomato grown for the processing industry, deterioration of quality during the harvest and post-harvest phase, limited shelf life and high usage of chemical fertilizers and pesticides. High temperatures with variations often lead to cracking in the fruit and decrease the tautness of tomato skin and strength. With increased splitting of tomato, the quality of produce becomes less preferable for processing and value addition. Deviations with respect to colour, fruit firmness, total soluble solids, soluble solids and sugar content make the tomato less viable for processors. Attacks of insects are also significant in high temperatures which also affects marketable fruit quality.

Traditional Value Chain

The traditional value chain dominates the tomato value chain in the districts of IGP. This chain accounts for most of the tomato produced. Under this channel, most farmers/aggregators bring tomato to the urban markets/mandis. This market works according to the seasonality of production with huge price fluctuations during the season. As this channel is used for the bulk of the production, competition is high and sale prices low as compared to other channels. Farmers bring their produce to the trading centres and, based on quality and supply for that day, prices are determined and procured by wholesalers who further sell the produce to retail vegetable vendors. Sometimes wholesalers also supply it to neighbouring districts. A small extension of this value chain involves commission agents who procure tomato from growers and supply it to wholesalers from where it reaches the consumer via retailer vendors. The loss in this value chain due to climate change is largely restricted to the tomato growers. As the supply pipeline used in this value chain is not efficient, it is difficult to assess how much loss can be attributed to climate change and how much to supply chain inefficiencies.

Evolving Value Chain

This value chain is evolving in the region and its share is gradually increasing. In this channel, village-based

aggregators directly develop contacts with institutional buyers and supply tomato directly to them. This channel is also used by local processors who supply processed products (ketchup/sauce, purée) to local eateries especially restaurants. Arrangements for supplies are informal and, in terms of deficit of supply, purchasers procure from markets. Similarly, if there is surplus production, commission agents supply it to local trading centres.

Processors Value Chain

In the study area, processors source tomatoes through different channels. Processed products manufactured by the sample processors include tomato paste/purée, sauce and ketchup. They plan most of their procurement during peak season and when there is glut in market resulting in cheaper prices. Generally, tomatoes supplied to processing industries are inferior to the ones sold in the market which are largely used for direct consumption. Processors also have vendors for procurement of tomato from major production areas. Vendors pool tomatoes from farmers in clusters of villages and supply based on demand from these processing industries.

8.3.1 Impact of Climate Change on Transportation and Storage

Due to high perishability and shorter shelf-life of the product, transportation is one of the most critical factors in the value chain of tomato. The quality of tomatoes is affected at every level during transportation, starting from the farms to the end consumers. Supply chain bottlenecks and quality of the yield which is highly vulnerable consequently results in poor price realization for producers. In between, there are very high losses in the value chain. The biggest challenge for transportation and storage is the lack of a cold chain in the tomato value chain.

In the districts of IGP, there is lack of storage facilities around the production centres. The number of cold storages in Uttar Pradesh is higher than that in Bihar. Cold storages which we came across were largely designed for storage of a single commodity and operate mostly on a seasonal basis. In fact, most storage facilities are customized for storage of potato and other crops which requires similar temperatures.

For long term storage, ripe tomatoes need to be stored at temperatures of about 10-15°C while the existing cold storages generally maintain a temperature of 2 to 4°C which is required to be maintained for potato. If tomato is stored at that temperature, it leads to chilling injuries as well as loss of flavour which depends on the total soluble solids and pH of the fruit which is linked to temperature, heat stress and water availability.

Value Chain Losses- Tomato Transportation-Traders and Unorganized Processing

INR 1,300 million

Climate extremes - low shelf life - lack of cold storage facilities - transportation losses.

8.3.2 Climate Change Impact on Tomato Traders

Both in Bihar and Uttar Pradesh produce is sold by farmers through the local aggregator or trader at the local *mandi*. In the kharif season, when the supply is low in comparison to demand, traders also visit villages to procure through the local aggregator or via a trader at the local or regional trading centres. Tomato traders have complained of the shortening of trading months for tomato.

In recent years, the trading season has been shortening and is now available for two months only. This has disturbed the trading cycle of traders. Like farmers, traders too have reported that they have observed a reduction in the shelf life of tomato and resultant distress sale to processing units, incurring 40-50 percent losses. Traders have reported the direct impact of climate change on the logistic decisions as well. Lately, unseasonable rains and humidity are some of the climate variables that have had an important bearing on their decisions. Traders are more cautious while placing orders now and observe the daily demand more closely.

8.3.3 Impact of Climate Change on Tomato Processing Units

Representatives of processing units of tomato, consulted during the study, stated that the price and quality of tomato are important criteria while purchasing the tomato. They also said that farmers as well as agents prefer to sell to urban/peri-urban markets rather than to them as there is a price difference of INR 1 to 2 per kg. Demand by the processing industry has been continuously increasing over the last few years. To minimize the risks, processing units source tomato from different regions since it is available throughout the year in states such as Maharashtra and Gujarat. This year, due to a drought-like situation in southern states, the supply of tomatoes in (May to July) was drastically affected thereby increasing the prices and transportation cost by 20-30 percent.

Processors also reported that most tomato varieties currently used by farmers for crop cultivation are more suitable for direct consumption. Most varieties produced in this area are those with the thin skin which are considered less suited for processing. Additionally, processors also face challenges related to cost in maintaining the stock of tomato. Tomatoes require cold storage systems for longer periods than a few days, and few processors prefer to maintain a stockpile of tomatoes for subsequent processing requirements.

The very nature of processing of tomato by processing units reduces the impact of climate related quality changes on tomato. Due to decreasing shelf life, in recent years, the supply of tomato is in fact increasing for the processors as traders consider these units as the last resort to minimize their losses. On the other hand, processors are matching the shortfall in supply due to adverse climatic conditions from distant regions and sometimes even importing.

Table 30: Estimation of climate change loss in tomato

	Total Tomato Production in MMT (2015-16)
Total	13
Bihar	7
Uttar Pradesh	6

Table 31: Estimation of climate change loss in tomato

Processing Stage		Reasons	Normal Situation		Climate Change Induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
			Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Tomato	Transportation loss		15%	10%	25%	20%	-10%	-10%	12,948	2,948

**Prices calculated are based on inputs received from interviews of value chain actors: tomato average wholesale price @ INR 10,000/MT*

The impact of climate change for tomato crop is around INR 1,300 million in the IGP region

Assumptions: *Losses attributable to climate change subsequent to harvest have only been considered for calculation purposes. For the present study, calculation has been done primarily using the feedback received from various actors and by comparing normal conditions prior to observable climate change impacts and by assessing potential impacts as perceived by the participants; the in between has been documented in the absence of a baseline figure. In order to maintain uniformity in calculation of prices of the various commodities, MSP as determined by the Government of India for the financial year 2018-19 has been utilized for the calculation of overall impacts on the value chain.*

These losses are primarily incurred during the transportation of tomatoes. In the absence of adequate storage facilities for a commodity like tomato, which has an extremely short shelf life, losses at the farmer level are maximum. Low value addition impacts farmers by way of high post-harvest losses and low returns during periods of market glut. Conversely, Indian tomato-based product manufacturers import significant quantities of tomato pulp and paste due to the non-suitability of locally grown varieties. This results in extremely low to negligible losses at the level of tomato processors.

9 Conclusion

During the study, all stakeholders (small land holders/marginal farmers, aggregators, grain/cold storage functionaries, processors) with whom we interacted, unanimously observed that incidences of extreme weather events have become more common with increasing climate variability.

All stakeholders were also unanimous in their views that the whole agricultural system needs to adapt and become more resilient to these changes. Some potential responses already exist through change in agriculture practices, such as farmers purchasing higher yielding and short duration varieties, more application of chemical fertilizers and more dosages of chemical pesticides to fight against pest attacks. However, it is also important to note that only farmers making adaptations is not going to suffice. Unless all stakeholders make adaptions in their own ecosystems, the total returns from the agriculture value chain will be below optimal and one or the other stakeholder will always be at risk of business viability.

The nature of business of the agri value chain involves incremental value addition by all value chain actors on the commodities which are produced by farmers. Hence for success and sustainability of the value chain, it is imperative that an uninterrupted flow of commodities from farmers to all value chain actors is maintained.

As reported by farmers, adaptations made by them at the farm level help only to minimize productivity losses while climate change impacts both quality and quantity. The adverse effect on quality leads often to poor quality of raw material (produce/commodity) supply into the agriculture value chain. This results in higher rejection rates at the processors' end or higher costs of activities such as storage and processing. Due to the nature of procurement system which is often localized, sourcing of material from alternative sources increases the cost of raw material. Similarly, increased temperature and humidity raises the cost of operations and maintenance of warehouses and cold chains. In value chains such as that of paddy, the proportion of inferior products such as broken rice is increasing. The entry of discoloured grains or presence of more foreign matters in the procured grains increases the per unit cost of raw materials. In addition, processors need to invest more in procurement of instruments such as commercial sieves. Maize processors must invest heavily in drying of maize which often has higher moisture content than the acceptable limit for preparation of feed. The impact of climate change in value chains such as potato is also felt since the produce is highly sensitive to climate indicators. The business of cold storage which is highly sensitive to electricity costs is facing increased operating costs to maintain the quality of potato due to higher levels of temperature variability and humidity.

Structural issues such as design of cold storage which is more suitable for single or similar commodities are also affecting mitigation plans for growers of other horticulture crops. The location of grain storage warehouse or of cold storages is also impacting farmers' mitigation plans. At an individual level, the cost of transactions involved in accessing the services of warehouse or cold storages makes it unviable for farmers. In the IGP region, the participation of collectives/community institutions in the downstream value chain activities is almost non-existent.

Table 32: Estimation of the value chain losses in IGP in select crops

Value Chain	Storage Loss (INR million)	Quality Loss (INR million)	Processing Loss (INR million)	Transportation Loss (INR million)	Total (INR million)
Rice	~ 990	~ 2,250	~ 250	NA	3,820
Maize	~ 100	~ 840	~ 470	NA	900-1,410
Wheat	~ 90	~ 120	~ 620	NA	830
Potato	~ 3,240	~ 2,800	~ 180	NA	6,220-9,011
Tomato	NA	NA	NA	~ 1,300	~ 1,300
Total estimated loss				**13,740-15,370**	

While assessing the estimated loss in some of the key commodities grown in the IGP regions, it was observed that more than INR 14,000 million is the estimated value chain loss in the agriculture value chain only in the districts of IGP. This loss could be even higher but, due to a lack of awareness, stakeholders are unable to realize or attribute it to climate change. There is limited realization of the disruptions in logistics that happen very frequently in the supply chain due to sudden climatic events/ adverse climatic conditions.

- In this context it is certain that the climate is changing, and it will continue to change with increasing uncertainty about its future in the short and medium terms. As the impact of climate change is not uniform across the value chain, with different stakeholders facing different sets of climate-related challenges, it is important to develop robust solutions that build resilience across the value chain while considering the entire suite of future climate scenarios. The adaptation approach must be holistic and transformational. At present, at best, adaptations are largely incremental wherein stakeholders are making incremental adjustments in their value addition process and systems to improve resilience. Long-term focus must providing a boost to the absorptive coping capacity or persistence of all stakeholders to buffer the impact of a shock. Along with technological solutions, solutions related to knowledge, awareness and behaviour also need to be included. All stakeholders must revisit decision making and resources allocation processes to cope with climate change. In this context, following areas need all stakeholders to make investments for improving adaptations. Improved coordination and deeper integration, across the existing supply chain, will be the key to mitigate climate change impact in the agriculture value chain.

Required areas of investments at the farmer level: At the farmer level, there are three areas in which urgent steps need to be undertaken to improve the adaptive capacity of producers.

- At the first level, it is necessary to develop locally relevant climate-smart agricultural practices using improved climate and weather information for decision making. Farmers can then decide the most effective adaptive strategy at a specific time period in their local context and constraints. The challenge with the existing system of weather forecasts is related with the dissemination of this information and its customization in the context of locally grown crop. Farmers don't know what lies next once they receive information from various sources. The inconsistency in the format and types of information aggravates the situation; farmers are often in a confusing situation and adapt solutions with short-term benefits that make agriculture unsustainable. High-cost adaptations also place financial stress on farming households. It should be noted that climate services will only be effective if farmers have the resources and knowledge to act on the information. Hence, climate services also need to supplement development of appropriate CSA advisories. Along with advisories services, such a system will also help farmers in developing a real-time contingency plan. Farmers will thus be supported in understanding which types of package of practices and inputs need to be purchased and applied or altering their yearly cropping calendar, if required, by using regular and seasonal forecasts. This will also assist in the proper selection of crop/seed varieties which, as of now, is biased towards short duration, high yielding/hybrid varieties. Shorter duration (daily/weekly) forecasts will optimize the decisions related to input usage during the cropping season; medium-term forecasts (seasonal) will provide advisories related to seed and variety selection. Longer-term use of this data can also be made by agriculture research institutions to develop them flood/drought/pest resistant/ tolerant varieties.

- The second level of intervention is required at the level of building farmer awareness. A lack of awareness or misconceptions about climate change effects at the farmer level often leads to no adaptation or maladaptation resulting in production, productivity, quality and sustainability losses. In the absence of awareness, adaptations at the farmer level are often reactive and ad hoc. The severity of the problem requires proactive measures that are sustainable and integrated into farming practices of farming households. Hence, it is necessary to acquire a proper understanding and awareness on climate change and variability so that farmers can adopt innovations and undertake timely and appropriate initiatives developed for coping with and adapting to climate change and variability. Even though more awareness and knowledge cannot guarantee adaptation, it will certainly help households to make informed decisions. To increase the adaptive capacity of farming households, the first step must be to increase their awareness and work on helping them develop the right perspectives on climate change impacts on their cropping systems. This needs to be followed up with boosting their access to effective and locally relevant adaptation approaches that have been customized according to technical and financial capabilities of the targeted households.

Table 33 shows the key areas for capacity building for farmers.

Table 33: Key areas of farmer capacity building

Information Gap Themes	Key Areas for Capacity Building
Production and productivity	Varietal knowledge which includes awareness on flood and drought resistant/tolerant varieties, staggered cropping planning, shift in sowing/transplantation and harvesting dates, community nurseries, weed and pest management, intercropping and crop rotation, etc.
Harvesting, post-harvest and value chain	Grain maturity and harvesting, drying, in-house storage, moisture management, commercial warehouse functioning, transportation, cold storage, seasonal fluctuation of prices, shelf-life management, etc.
Sustainability enhancement	Nutrient management, soil moisture management, water management, rainwater conservation, natural farming, system of crop intensification, agriculture residue disposal (stubble burning), etc.
Financial linkages, insurance and leveraging government support	Crop insurance, farm credit, warehouse financing, agriculture credit (Kisan Credit Card (KCC)), community institutions (self-help groups (SHGs)) and their federations, producer groups and companies, micro financial institutions, Primary Agricultural Credit Society (PACS), credit cooperatives, NABARD schemes, etc.
Technological/mechanization	Usage of commercial driers, moisture management, combine threshers, and other implements, custom hiring centre concepts, etc.
Weather and climate	Crop advisory, weather advisory and predictions, other sources of weather-related information (mass media, print media), etc.

This can only be achieved through a participatory planning process which involves all key stakeholders (farmers, women, collectives, extension services, research institutions, government, etc.) targeted specifically to reach the small and marginal farming households that are most vulnerable to climate change events. It will require work on enabling services to communities through partnerships with research institutions or resource organizations.

- The third area of interventions is in developing an institutional architecture for community institutions/collectives to play a larger role in both upstream and downstream value chain activities. In upstream activities, farmers' collectives can play an important role in ensuring availability of quality seeds and inputs through partnership activities with research institutions and private sectors to increase the availability. At the production level, collectives can work in the areas of development of community nurseries which will ensure availability of seedlings all during the transplantation window. This will be very effective in crops such as paddy and horticulture crops like tomato and other vegetables. Collectives and community institutions can also participate in downstream value activities. They can collectively take part in storage and transportation activities as well as collectively bargaining for space. In addition to this, the collective can invest in building small warehouses or processing units. Collectives can also participate in primary processing activities such as grading and sorting to ensure higher value realization for farmers.

Required areas of investment at the storage/ warehousing level: IGP primarily has a rice and wheat cropping pattern which accounts for 80 percent of the gross cropping area. Cereal crops remain stored for a minimum of three to four months before processing. These activities are mostly carried out by traders or small processors.

- Participation of farmers is still low in storage activities. More than 40 percent of the warehouse capacity of India is government owned. Apart from this, government agencies also give out warehousing space on hire to store food grains; during peak requirement periods, they hire additional capacity as well. In the agriculture value chain, storage increases time value and hence direct participation by farmers in warehousing will increase their value realization. The location of a warehouse is the most important factor. A small or marginal producer with meagre marketable surplus will not find it convenient to carry his produce all the way from his farm to the warehousing point. During the study, it was also realized that many of the warehouses are underutilized. On the one hand, cold storages/ private warehouses are not able to optimally utilize the available capacities, on the other hand, small and marginal farmers don't find them cost-effective because of transportation/fixed storage charges. It was also found that existing operators prefer large traders; this creates problems of access and discourages the use of these facilities by small and marginal farmers. The government can promote decentralization of these facilities for better utilization by encouraging investment in the creation of small-sized cold storage units. The government may need to support construction of small and decentralized warehouses through appropriate policy initiatives. Both private entrepreneurs and collectives need to be encouraged for investment in construction of warehouses or small storage infrastructures.

- Crops such as tomato and other horticulture crops are highly sensitive to temperature and water. An increase in productivity and adverse climatic conditions, especially due to heat stress and temperature, has necessitated the development of cold storage facilities around the growing as well as consuming centres to prolong their shelf life. The development of cold storage industries can be the first step in maximizing gains from the tomato value chain and minimizing the impact of climate change. The existing system of cold storage is suitable mostly for a single use commodity which is predominantly utilized for storage of potato in IGP. Tomatoes are highly perishable and transportation and storage account for losses to the extent of more than 20 percent. Tomatoes, after harvesting, require immediate cold storage to maintain them for longer periods. Though a large number of cold storages has been developed in the region, they are designed for storage of a single commodity which is mostly potato. Small cold storages which are suitable for storage of multiple crops need to be developed. Hence the area that requires investment is construction of cold storages which are chamber based and can be utilized for storage of all types of horticulture products. The requirement of cold storage design for tomato is different from that for potato as the temperature requirement if higher than that required for potato. In most IGP districts, there is a complete lack of such infrastructures which leads to high losses.

Required areas of investment for agri processors: Processors are one of the most critical stakeholders in the agri value chain as the success of the entire value chain depends upon the success of the final product, the form in which the commodity produced is provided to end consumers. As they are directly involved in changing the form of the raw commodity into the product which is consumed by the end consumer, they need to ensure the quality of the complete value chain. Some areas in which investment needs to be made are:

- Most units in the paddy value chain are micro and small-scale industries that undertake limited value addition activities and do not deal in premium rice varieties. Such industries may need support through specific schemes for additional investments in purchase of new machines/replacement of old machineries. Access to finance is an important area in which the government can facilitate linkages between financial institutions and processing units. Agri processing units of both the organized and unorganized value chains require access to sources of finance to start, grow, upgrade and diversify their businesses. The nature of finance required varies considerably depending on the size of the firm and its stage of development. Interest subsidy/capital subsidy and technical support to prepare financial proposals are some areas in which the government can work with the private processors. The government can also provide technical assistance such as business development services especially for micro, and mini and small processing units in the commodity value chain. These units can be guided on new climate-smart technology, financing and other cost-effective production techniques. Support for the purchase of driers for maize processing units, commercial sieves for paddy units or upgradation of paddy units to shift into single boil/parboil units are some of the areas in which units may need to be supported.

- The wheat value chain is highly localized as it makes adjustments of the final products to local culinary preferences. The market for flourmills, which has been traditionally unorganized, is going through transformation in urban locations. The share of organized players has started increasing. Many millers stated that they were unable to run their units at full capacity due to low local demand as well as limited marketing/branding capabilities. The government should encourage contract milling in the districts. Millers will benefit due to assured processing volumes, low investment in procurement of wheat and marketing of finished products while large companies will have low transportation costs and localized quality of flour which will increase their market share.

Required areas of investment in agriculture research institutes: Farmers realize that their knowledge is based on traditional farming practices and that they are not equipped to deal with climate change. Agricultural research institutions and agriculture extension services needs to actively work with the government and non-government institutions by developing experimental model fields. As the cost of hybrid seeds is very high, the government also needs to place more emphasis on the development of heat- and drought-resistant crops and supplying them to farmers at subsidized or low costs. Agriculture research institutes also need to work on developing traits such as multiple insect resistance and herbicide tolerance in the seeds being promoted so that the use of chemical pesticides may be reduced. Most seeds used are already of the hybrid variety in maize and the choice of seeds is influenced by seed shops/ marketing agents from seed companies. Agriculture research and agriculture extension should work to ensure the availability of such seeds to farmers:

- Agriculture research and seed companies need to be encouraged to develop locally adaptable varieties that meet the quality requirements of the processing industry in India. Varieties need to be developed that have resistance against disease and heat, and attractive size and colour which makes them suitable for processing.

- A series of initiatives should be undertaken to improve production technology by changing the varieties grown and providing an improved package of practices. Better coordination across the value chain actors is also required to improve supply access to processors and enhance price realization for farmers. One of the key strategies will be the development and availability of seeds of such varieties that are consistent with processing parameters.

10

Strategic Notes

Strategy Note 1
Bridge the Information Gap on Climate Change and Farmers

Context

IGP which covers five states (Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal) occupies nearly 15 percent of the total geographical area of India and houses approximately 38 percent of the population. The agricultural sector is the main source of livelihoods for a large proportion of households in IGP. It is one of the most intensely farmed areas and is popularly known as the food bowl of India. Major crops grown in this area are rice, wheat, maize, chickpea, lentil, mustard, potato, sugarcane and vegetables. The main cropping system is rice and wheat based which may be attributed to its climate suitability, better adaptability, availability of high yielding varieties and increased mechanization of both crops.

The concentration of small and marginal farmers with small land holdings is very high in these regions. The risk of climate change on agriculture is extremely high in this region not only due to its high dependency on rainfall but also as IGP is strongly connected to the tectonics and climate of the Himalaya. Thus, any change in these factors will have an adverse effect on the hydrology, soil fertility, food production and settlement pattern of IGP. This note is an outcome of the study titled "Understanding Climate Change Adaptation for Smallholders/Marginal Farmers and Quantifying its Impact on Agri-allied Value Chains in Indo-Gangetic Plains". At the farmer level, the study explored the impacts of climate change on small holder farmers and their adaptations to mitigate climate change impacts. It covered crops such as paddy, maize, wheat, potato and tomato which are prominent crops of the Upper and Middle IGP. In this note, we lay out strategies which can be helpful in bridging the information gap on climate change and farmers. This note also discusses measures that could be taken up through enhancing capacities of farmers which may lead to better and more sustainable adaptations at the farm level.

Consequences of Information Gap

Small holder farmers who are the major producers of food crops are increasingly finding it difficult to cope with the hazards of climate change and variability. Farmers reported that, in recent years, climatic conditions have become unpredictable and their traditional knowledge and wisdom was inadequate in coping with such sudden climatic changes. Unexplainable delay in rains, insufficient and untimely rains, excessive humidity and prolonged periods of high or low temperature are affecting their agricultural practices and farmers feel the effects at multiple levels. At the first level, climate change affects production and productivity; at the second level, the quality of produce; and at the third there is increased cost of production. In extreme situations (flood/severe drought) there is also the risk of complete loss of production. Climate change effects are also leading to increased incidences of pest attacks on all crops.

Farmers have also reported that recently peak temperature has been soaring high every year and due to the prolonged period of heat, the moisture level in the soil has also been decreasing. Crop immunity is reducing which makes the crop more susceptible to disease. An increase in pollen sterility, reduced seed set and number of grains, and reduced grain weight which causes yield reduction are some other impacts perceived to be interlinked with climate change. To mitigate the effects of climate change, farmers resort to adaptations which include changes in planting and harvesting dates, using improved seeds and chemical fertilizers, adoption of new crops, etc.

Most adaptations at the farmer level have been reactive and ad hoc while the severity of the problem requires proactive and sustainable measures that are integrated into the farming practices of farming households. The extent of adaptation of these measures is contingent upon the farmers' awareness and perception of climate change impact. However, adaptation to climate change needs also to be considered from the perspective of risk which includes awareness on risk factors, perception of climate change risk and the farmers' own resources (knowledge, finance, infrastructure) to mitigate the negative impacts.

A lack of awareness or misconceptions about climate change effects also leads to no adaptation or maladaptation resulting in production, productivity, quality and sustainability losses. Hence it is necessary to acquire a proper understanding and awareness on climate change and variability so that farmers can adopt innovations, undertake timely and appropriate initiatives for coping with and adapting to climate change and variability. Even though more awareness and knowledge cannot guarantee adaptation, it will certainly help households to make informed decisions. To reduce households' vulnerabilities, climate change-related information needs to be provided to farmers regularly, complemented by increased access to economic, institutional and technical resources which can be integrated with their existing capacities, assets and resources.

Key Information Gap Areas

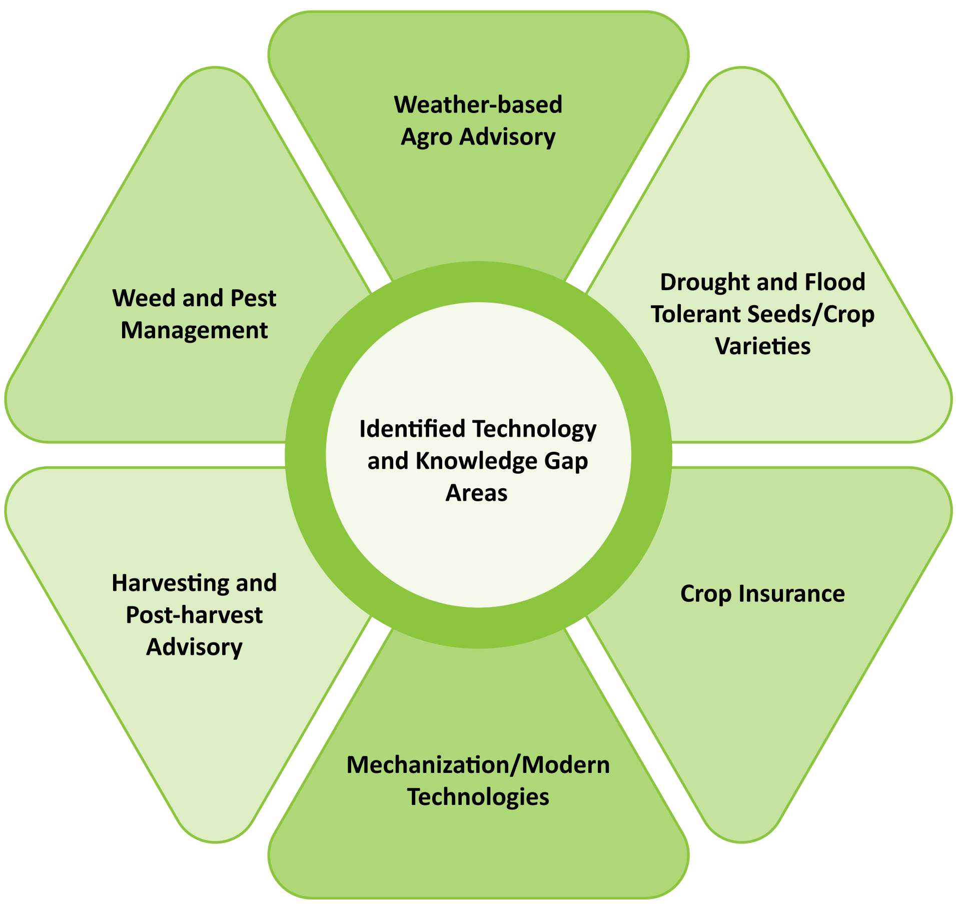
Even though climate change and variations are recurring events in the region, only a few households adopt proactive approaches (weather and crop advisory, insurance, safe storage, etc.). Most farming households use reactive measures to ease the immediate impact of climate change/ variability with limited emphasis on climate resilience. Farmers' adaptation levels are closely interlinked with their knowledge and awareness levels, their perception of climate change impacts on their cropping system, and their access to resources which help them to prepare their coping strategy. Low awareness levels may adversely affect their resilience as awareness is crucial to help farmers in devising their coping strategy against climate change and variability. Perceptions of farmers about climate change strongly affect how they deal with climate-induced risks and uncertainties and undertake measures to mitigate the adverse impact of climate change on agriculture. Hence it is important to understand:

- Farmers' awareness of climate change and key factors which affect their awareness;
- Farmers' perception of the impact of climate change on agricultural practices; and
- Farmers' coping strategies against climate change in the context of awareness and perceptions.

How to Bridge the Information Gap

To increase the adaptive capacity of farming households, the first step should be to increase their awareness and work on helping them develop the right perspective of climate change impacts on their cropping systems. This needs to be followed up with increasing their access to effective and locally relevant adaptation approaches which have been customized basis technical and financial capabilities of the targeted households.

Figure SN1: Technology and knowledge gaps identified



This can only be achieved through a participatory planning process which involves all key stakeholders (farmers, women, collectives, extension services, research institutions, government, etc.) and is targeted specifically to reach the small and marginal farming households that are most vulnerable to climate change events. It will require work on enabling services to communities through partnerships with research institutions or resource organizations.

It will also require strategic investments involving multiple interventions aimed at filling the adaptation gap, such as improvement of the climate resilience of production systems, building technical capacity for decision-making, designing of better agriculture insurance products and accessible and affordable credit with more awareness on such financial products, skills development, and provisioning of and support for on-farm productivity enhancement. Agencies such as the National Mission on Sustainable Agriculture (NMSA), NICRA and agriculture research institutions/universities that are identifying and researching innovative pilots and technology need to be more focused on sharing knowledge and research findings with farmers on a much wider scale. The adaptation measures suggested should also be based on existing financial resources of

Table SN1: Information gaps and how to address them

Information Gap Themes	Key Areas for Capacity Building
Production and productivity	Varietal knowledge which includes awareness on flood- and drought-resistant/tolerant varieties, staggered cropping planning, shift in sowing/transplantation and harvesting dates, community nurseries, weed and pest management, intercropping and crop rotation, etc.
Harvesting, post-harvest and value chain	Grain maturity and harvesting, drying, in-house storage, moisture management, orientation on commercial warehouse functioning, transportation, cold storage, seasonal fluctuation of prices, shelf-life management, etc.
Sustainability enhancement	Nutrient management, soil moisture management, water management, rainwater conservation, natural farming, system of crop intensification, agriculture residue disposal (stubble burning), etc.
Financial linkage, insurance and leveraging government support	Crop Insurance, farm credit, warehouse financing, KCC, community institutions (SHGs and federations, producer groups and companies), micro financial institutions, PACS, credit cooperatives, NABARD schemes, etc.
Technological/mechanization	Usage of commercial driers, moisture management, combine threshers, and other implements, custom hiring centre concepts, etc.
Weather and climate	Crop advisory, weather advisory, and predictions, other sources of weather-related information (mass media, print media), etc.

Figure SN2: Framework to bridge gaps on climate change

the households as both the degree of vulnerabilities and adaptation deficit are somehow linked to financial capabilities/poverty levels of households.

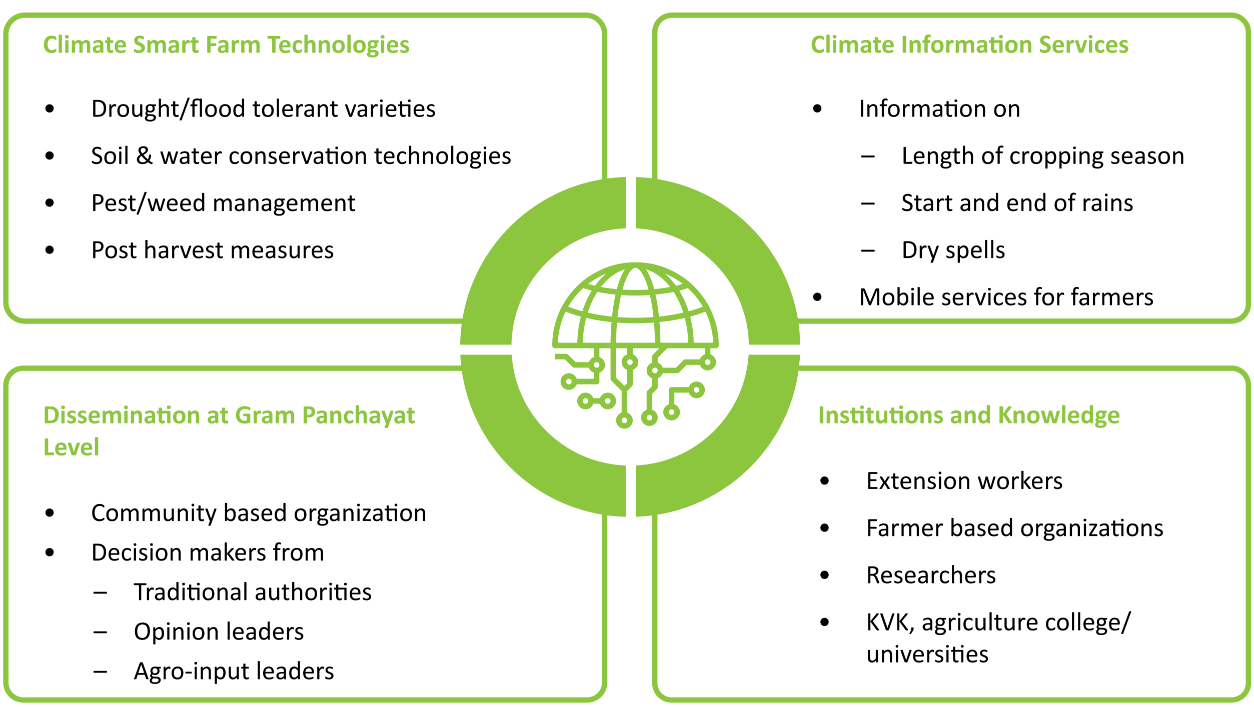
Comprehensive Framework for Bridging the Gap on Climate Change

Due to the high dependency of a large proportion of poor households on agriculture and the allied sector, it is essential to protect the poor and vulnerable sections of society through an inclusive climate change mitigation strategy. This may be done by deploying appropriate technologies for extensive adaptation at an accelerated pace through large-scale capacity-building measures. The interventions need to be specialized and local specific with a focus on increased adaptations through awareness building. Based on the existing assessment of adaptations and planning, technology-based solutions such as weather-based agri-advisories (through smartphones, mass media, print media) need to be upscaled. By involving workers from various departments, research and resource organizations, community/producer institutions, community resource persons, and other stakeholders, knowledge dissemination exercises need to be undertaken. These initiatives will enhance the capacity of farmers through strengthened awareness of adaptation and climate change processes as well as adaptive capacities to reduce vulnerabilities and risks to climate-induced losses.

At the first level, weather-based, agri-advisory services can help farmers make climate-smart decisions. The government and private sector agencies such as Skymet/meteorological departments, etc., can help in designing and customizing early warning systems (EWS) for one time/seasonal forecasts as well as non-disaster forecasts. At the local levels, participatory/communitized information-sharing mechanisms can be developed through the concept of farmer schools or other institutional mechanisms through convergence with the Gram Panchayats, Village Organizations (VOs), and other government departments. These village-level demonstration centres can be managed through institutional collaborations with research institutions/resource organizations (National Rural Livelihoods Mission (NRLM), KVKs, etc.) Extension services can also help farmers to receive information on soil, water and nutrient management.

These centres will also increase the knowledge of farmers on newer varieties, cropping calendar, weed and pest management, intercropping, crop rotation, etc. Insurance-related information can be shared at both macro and micro levels. Mass media, print media, web- and mobile-based media can be used to disseminate knowledge at the macro level while resource organizations/Gram Panchayats and block and district agriculture offices can disseminate knowledge at the

Figure SN3: Climate change management matrix



local level. Local input shops can play a very constructive role in increasing the awareness of farmers, as they are the first source with whom farmers consult for solutions when they face any challenges with their agricultural practices. Due to their outreach and spread they can be one of the most efficient and effective solutions for bridging information gaps.

Conclusion and Way Forward

Climate change impacts are here to stay with increased levels of climatic variations with more frequent occurrence of events such as droughts and flood. The only option is to mitigate the impacts through increased adaptation. The first step in this direction will be through creating awareness and increased understanding of climate change and its risks at all levels. This will enable farmers and rural communities to effectively identify and utilize their available adaptive capacity. Due to its huge impact, particularly on small and marginal farmers, coordinated events need to be undertaken by involving all stakeholders. The government, in consultation with private service providers, can take the first step by providing weather-based agro-advisory services which will help in better crop planning. Extension service providers, in convergence with Panchayati Raj Institutions and community institutions, can establish demonstration centres which will pass information related to production, productivity, pest management, harvest and post-harvest measures to farmer households. The other area in which there is a requirement to bridge the gap is through a partnership with insurance and other financial service providers. Private seed/fertilizer/medicine supplying companies also need to work for bridging the information gap as they have the most extensive outreach.

Strategy Note 2
Livelihood Diversification in IGP

Context

IGP, one of the most intensely farmed areas in the country, is popularly known as the food bowl of India. The area produces about 50 percent of India's total food grains. It rice- and wheat-based cropping systems may be attributed to its climate suitability, better adaptability, availability of high yielding varieties and increasing mechanization of both crops. Rice is mostly grown in the kharif season while wheat is mostly grown in the rabi season. In terms of net cultivated areas, rice and wheat occupy 72 percent of the total cultivated area.

The concentration of small and marginal farmers with small land holdings is very high in these regions. The risk of climate change on agriculture is extremely high for this region not only due to its high dependency on rainfall but also as IGP is strongly connected to the tectonics and climate of the Himalaya. Thus, any change in these factors will have an adverse effect on hydrology, soil fertility, food production and settlement patterns of IGP. This note is an outcome of the study titled "Understanding Climate Change Adaptation for Smallholders/Marginal Farmers and Quantifying its Impact on Agri-allied Value Chains in the Indo-Gangetic Plains". Through this note, we lay out strategies that can help to diversify livelihood opportunities especially for small and marginal landholder households. This note also discusses measures that could be undertaken to help farmers in diversifying their livelihood opportunities as a mitigation strategy against climate change risks.

Existing Livelihood Scenario

Most households in the region derive their livelihoods from a variety of on-farm, off-farm and non-farm sectors; their choice of livelihoods depends upon several factors which include land holding, livestock, availability of human resources, education and skills, migration status, access to common resources, etc. The majority of the households has agriculture as the key livelihood strategy with a focus on food crops, specifically rice and wheat. Other crops grown in this area are maize, chickpea, lentil, mustard, potato, sugarcane, and fruits and vegetables. The choice of crops depends mostly on food security of the households and then on access to assured irrigation facilities. The availability of irrigation facilities enhances on-farm diversification across different rainfall regimes. Assured irrigation facilities enable farmers to diversify cropping systems, minimize risk from erratic rainfall patterns, increase the number of crops grown and optimize the usage of inputs. Apart from agriculture, livestock (off-farm) is another source of livelihood for most households. Livestock includes milch animals, meat animals such as goat, poultry birds, pigs, etc. These off-farm based activities help households in generating cash-based income. Non-farm-based activities primarily consist of skill-based small economic activities. A large proportion of households has one or more of its members engaged in wage-earning either on others' farms and/or in other non-farm sectors, followed by employment in different sectors. A small proportion has specific skills; they are engaged in skill-based employment while mostly are non-skilled and engaged as wage labour.

Linked Livelihood Diversification Scenario in IGP

A livelihood diversification strategy is as activities undertaken by households to find new ways to raise incomes and reduce their risks and vulnerabilities. Households adopt diversification to construct a diverse range of livelihood portfolios either in expectation of increasing their income or in anticipation of some expected risks/unforeseen loss. It has also been observed that small and marginal households are the ones that are most impacted by climate change events due to the lack of assets required for mitigation.

In IGP, where farm-based livelihoods predominate, diversification strategies range from a change in farming practices to extreme cases where households completely leave their existing livelihood and shift to some new livelihood. Due to extreme climate change events such as drought and floods, many poor and vulnerable households from IGP (both Uttar Pradesh and Bihar) leave their farm-based livelihoods and shift to non-farm sectors. This often leads to large-scale migration from their native places to urban centres where they work as skilled/unskilled workers. This shift is also affecting the off-farm sector as this sector is closely linked with the farm sector. Many small households abandon off farm-based livelihoods and shift to non-farm-based livelihoods when the availability of field-based fodder reduces.

For farming households, a change in produce/commodities is the natural starting point as restructuring their crop mix is much easier in comparison to adopting a new sub-sector for livelihoods. The next stage of diversification is integration with new livelihood activities which is based upon their previous activities. The most common example is that of crop-livestock integration. Many households are not able to choose such diversifications due to resource constraints but they try to minimize their risks through process diversification as an adaptation to mitigate climate change impacts. Change from a traditional variety of seeds to short duration, high yielding/hybrid varieties is one of the most common process diversification strategies.

In IGP, farmers prefer to grow short-duration varieties. They also try to grow two varieties of the same crops with one for self-consumption and the other for sale of marketing surplus. This strategy was observed to be most common in paddy growers. Even in maize, some farmers prefer to grow white maize for self-consumption and yellow maize for commercial purposes. In addition to these varietal changes, farmers also change production technologies such as increased usage of fertilizers and chemical fertilizers, change in sowing and harvesting dates, etc., as a diversification strategy. Another diversification strategy adopted by farmers especially in Bihar is the increasing trend of a shift from paddy and wheat towards maize. This shift is both in kharif and rabi crops as farmers find maize to be more climate change-resistant than paddy and wheat. The easy marketability of maize provides an additional advantage to households.

In both Uttar Pradesh and Bihar, there is an increasing trend of households adopting off-farm activities. Many households have started activities such as dairy, goat rearing and poultry. The cash-based income from these activities helps them in minimizing their risk. Sometimes households also adopt activities from the non-farm sector which include starting a new enterprise/business or a skill-based activity. Extreme climatic change impacts/shocks force households to diversify their livelihood options for survival. Often, these adoptions are reversible and households shift back after the period of vulnerability is over; others may not if they find that the new activities are more remunerative than their existing livelihood options. This form of adaptation is often involuntary but necessary to adapt to survive or sustain. Table SN2 explains some of the key adaptations in diversification of various livelihood options.

Livelihood Diversification Strategies

Diversification is recognized as a key strategy to strengthen resilience and adapt to climate change and variability. There is no universal framework to design a common strategy for diversification. It depends upon external factors such as agro-climatic conditions, market context as well on the household asset base which comprises natural capital, physical capital, human capital, social capital and financial capital[26]. These assets form the basis for households' choices of livelihood strategies, including agricultural practices, which in turn influence their food security status and level of well-being. These assets are interlinked and influence critical factors which include existing livelihood choices, adaptive capabilities and choice of future diversification options. Livelihood assets are the means of production available for households that can be used for their livelihood activities and, in general, the greater and more varied the asset base the higher and more durable the level of sustainability and security of their livelihoods. The existing poverty level/economic status of the households determines the extent by which one or the other type of asset base affects their decision-making capabilities and extent of diversification that they are willing or ready to make.

Table SN2: Key adaptations in diversification of livelihoods

Types of Diversification	Diversification Strategies	Targeted Households/Communities
Process diversification	• Change in inputs • Intensification of activities • Scattered agriculture planning • Inter-cropping	Poor and vulnerable households with a low natural, financial and human asset base, sharecroppers, lack of access to irrigated lands
Crop diversification	• Crop rotation • Shift from paddy/wheat to maize • Shift/partial adoption of commercial crops from food crop-based ecosystems	Sharecroppers, households with low natural assets but more human assets, small and marginal farmers

26 Adapted from DFID Livelihood Framework.

Types of Diversification	Diversification Strategies	Targeted Households/Communities
Integration of related sectors	• Dairying with agriculture • Goat-rearing with subsistence agriculture • Poultry with subsistence agriculture • Poultry for agricultural labour households • Integration of off-farm-based livelihoods with non-farm livelihoods (micro-enterprise) • Shift to horticulture/plantation crops	Small and medium farmers, households with better access to physical and financial assets, households with surplus human assets
Adoption of non-integrated sectors	• Shift from agriculture labour to non-farm/ skill-based enterprise • Adoption of new livelihood activities such as beekeeping • Migration after skilling for agricultural labour	Households with high human capital and moderate financial capital

Suggested Implementation Process

Poor households are those that are most dependent on natural resources due to their high dependency on on-farm and off-farm livelihoods. This makes them highly vulnerable to climate change events. Climate-induced changes continuously affect the viability of livelihoods which forces them to undertake measures through adaptation. Diversification is a key adaptation strategy in the direction of mitigating climate change impacts. As diversifications are directly linked with people's livelihoods, there must be a continuous process that is adaptive and flexible to specific and changing circumstances. For the poor and vulnerable, the situation becomes very delicate as they are constrained by their limited assets and capabilities. Hence to plan and design diversification strategies for poor and vulnerable households, a comprehensive and holistic approach should be undertaken rather than activities in isolation. A list of some key steps for planning and designing which should be considered during the phase is presented below[27]:

(i) Understanding Vulnerability and Livelihood Interactions

- Identification of climate-induced vulnerabilities (temporary or long lasting);
- Understanding the impact of vulnerabilities on five types of asset bases with special emphasis on natural capital and human capital;
- Clustering households as per their asset base for each of the five types of the asset base;
- Assessing the existing adaptation measures that households have already undertaken and use to understand their resilience to withstand climate-induced vulnerabilities;
- Analysing the strengths, weaknesses, opportunities and threats of existing and potential livelihood adaptations and sharing the analysis with households/communities in a transparent and participative manner with special focus on risk associated with various adaptations;
- Identify factors and conditions which enable or hinder the acceptance of new measures/activities; and
- Understand the needs, priorities and capabilities of different stakeholder groups in relation to adaptation to climate-induced vulnerabilities through the process of diversification.

(ii) Understanding the Legal, Policy and Institutional Framework

- A thorough analysis of laws, policies and regulatory systems if some new livelihood activities are planned;
- Sharing of information on laws, policies and regulatory systems with households for better planning and resource management;
- Analysis of various linkages and institutions which can be of help during the adoption phase; and

27 Adapted from Livelihoods and Climate Change; a conceptual framework paper prepared by the Task Force on Climate Change, Vulnerable Communities and Adaptation https://www.iisd.org/pdf/2003/natres_livelihoods_cc.pdf.

- Defining the institutional processes through which adaptation measures will be implemented, at local and intermediary levels.

(iii) Developing a Sustainable Adaptation Strategy

- Identification of potential investment options to enhance resilience and reduce vulnerability during the process of diversification;
- Implementation of necessary institutional changes through the development of community institutions such as producer groups/companies; and
- Linkages with institutions to access financial and technical resources.

Conclusion and Way Forward

Livelihood assets which include natural, social, human, physical and financial capital have a key bearing on how people will respond to the impacts of climate change, and which type of adaptation strategy they follow. Livelihood diversification as an adaptation strategy requires attention from all stakeholders as traditional agriculture-based livelihoods are unable to fulfil the growing financial requirements of households. A comprehensive diversification strategy must include a mix of farm/off-farm and non-farm activities, and households should be encouraged and capacitated to adopt strategies such as production of other agricultural commodities, increased livestock-related activities, or self-employment/skilled labour to spread their risk. Agriculture extension agencies along with research agencies can help and train farmers to adopt better agricultural practices, intercropping and crop rotation to reduce their risks and vulnerabilities. The government department in convergence with resource organizations can help the farmers in increasing their asset base through alignment with financial and technical institutions. Agencies such as NRLM, with their community institutions, can play a very active role. Government departments, particularly those for animal husbandry and agriculture, need to work together as livelihood options in both these sectors are closely interlinked.

Strategy Note 3
Capacity Building Measures to Improve Adaptation Capabilities through Collective Institutions

The impact of climate change is increasingly visible around us. Though to some, these changes are limited to just excessive heat and thus increased dependence on air-conditioning systems, for some others these could be life defining. One of those most vulnerable are small/marginal farmers and lower-level agri-value chain players. They would be the most impacted unless they adopt coping mechanisms to deal with climate change well in time.

Through this note, we lay out strategies that can help value chain players mitigate impacts to some extent. One underlying assumption in this note is that climate change is irreversible. Nowhere have we claimed to nullify deep rooted impacts it is going to have on livelihood choices.

This note is the outcome of the study titled "Understanding Climate Change Adaptation for Smallholders/Marginal Farmers and Quantifying its Impact on Agri-allied Value Chains in the Indo-Gangetic Plains". The study has explored the impacts of climate change on value chains of identified agri-commodities. The study covered commodities such as paddy, maize, wheat, potato and tomato which are the prominent crops in Upper and Middle IGP. As the study made an effort to estimate losses on different value chains due to climate change risks, it becomes imperative that we should also explore potential strategies for small holder farmers and value chain actors to mitigate impacts. This note discusses measures that could be taken up by enhancing the capacities of collectives.

Collectives are defined as organized groups of individuals that pool in their resources to enhance their bargaining power and achieve economies of scale in a market. By this definition, collectives are involved in any such business activity that deals with value addition and thus exchange of goods/services. A few examples of collectives are cooperatives and Farmer Producer Companies (FPCs).

Given their organization and mandates, one of the most important role collectives can play in this entire climate change conundrum, is utilizing capabilities of different sets of individual players to help them specialize in specific activities. This note goes deep into delineating these activities and how to ensure that the collectives are built around those activities and stakeholders have appropriate capacities to perform their tasks efficiently.

Cropping pattern of IGP

One key defining feature of IGP's cropping system is paddy-wheat rotation wherein paddy is grown in the kharif season while wheat grows in the rabi season. These two are dominant crops and cover as much 57 percent of the net sown area during these two seasons. In case of Bihar, maize production has also picked up pace in a big way. This is primarily because of the deep inroads chicken-feed companies have made into the hinterlands. However, despite this, during the seasons, respective prevalence of paddy and wheat gives the impression of entire cropping system being a mono-cropping one.

In horticulture, potato (in Uttar Pradesh) and tomato (in Bihar) are the two most prevalent crops. For the purpose of this study we studied these five crops. However, lessons learnt can easily be stretched to cover other crops as well.

A typical value chain

Figure SN4 presents a typical value chain in its generic form. As is easily identified from this figure, the value chain is not that long and complex; it is rather a very short and simple one.

For specific crops, this value chain differs, but ever so slightly as there isn't much of value addition, especially in IGP.

Table SN3 summarizes the impacts climate change is having on various value chain agents in a generic value chain.

Figure SN4: A typical value chain

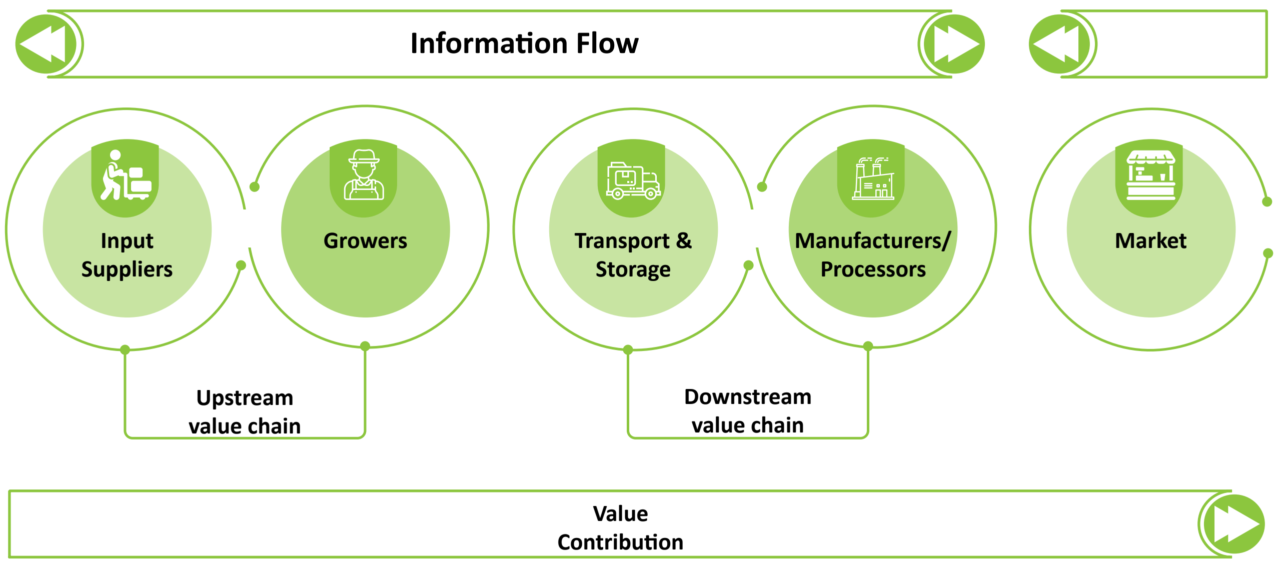
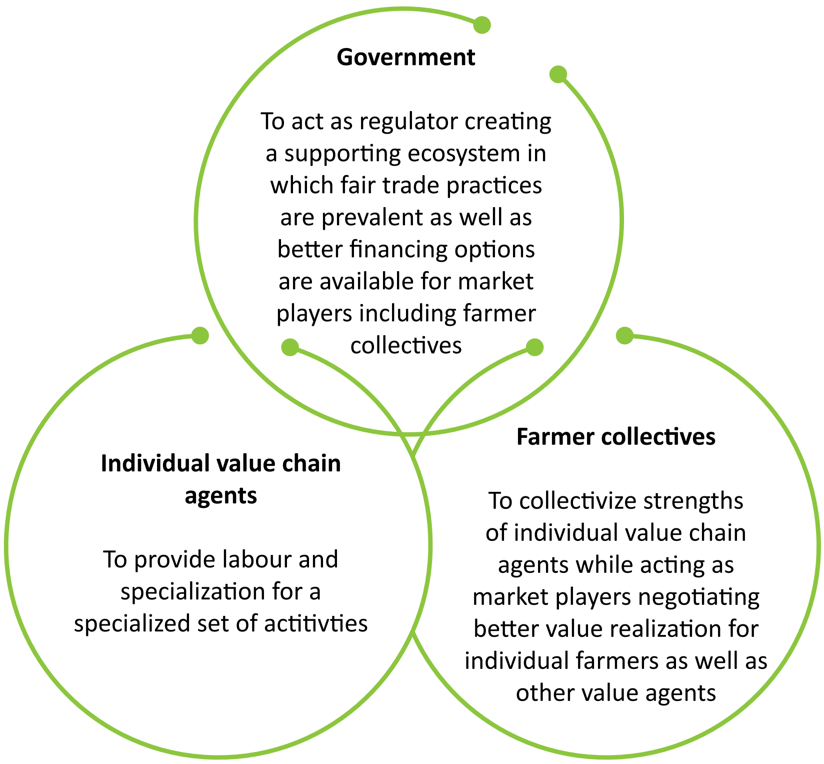


Table SN3: Impacts of climate change on generic value chains

Type of Value Chain Agent	Climate Change Impact	Crops Impacted	Mitigation Strategy	Responsibility
Small and marginal farmer	No rains at sowing time	Paddy	Better irrigation and shorter duration crops	Individual farmers through collectives
	Excessive rains during germination/transplantation phase	Paddy, maize	Phase wise nursery/ plantation	Individual farmers through collectives
	Excessive heat during flowering phase	Wheat	Heat resistant	Research institutes with government support
	Storm/hailstorm during harvest time	Wheat/paddy	Localized weather stations and enhanced weather insurance	Collectives, private players and government
Warehouse	Increased susceptibility to fungus and deterioration in quality	All	Aggressive fumigation/ decentralized warehousing	Collectives and government
Unorganized processing units such as *chakki*, chips and ketchup manufacturing	Increased percentage of stones, soil and leftover of other crops	All	Grade-based pricing	Collectives, private players and government
Vendors for fast moving commercial goods (FMCG) companies	Increased percentage of stones, soil, and leftover of other crops	All	Grade-based pricing	Collectives, private players and government
	Increasing humidity and moisture level	All	Increased use of dryers and additional hours of milling	Private players and government

Figure SN5: Activities performed by value chain participants



As is amply clear from Table SN3, each responsible party needs to play its role performing specific activities. To put it into context, we propose the matrix shown in Figure SN5 delineating these activities.

Having established this context, this note further puts forward capacity-building measures required to improve adaptation capabilities of individual value chain agents.

Framework to identify key capacity building measures

Figure SN6 puts forward a framework to identify and prioritize capacity building measures required to enhance the capacity of individual value chain agents.

If we put specific activities into the framework proposed in Figure SN6, we will get the scenario shown in Table SN4.

Figure SN6: Framework to prioritize capacity-building measures

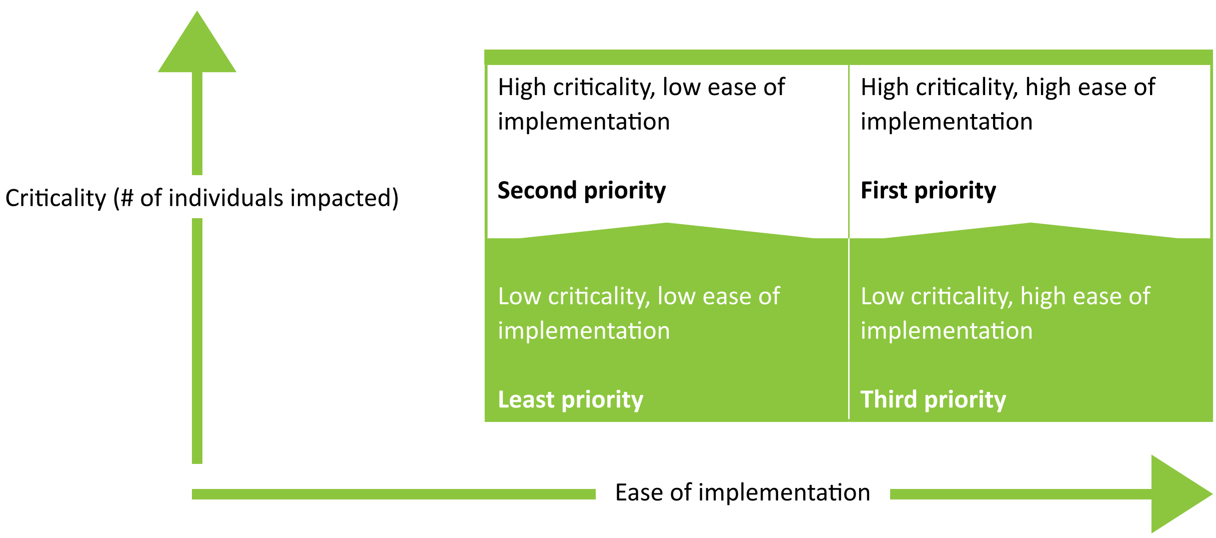


Table SN4: Activities place in the framework

Second priority	First priority
• Improved weather insurance mechanisms • Improved seed varieties • Better irrigation facilities	• Phase-wise nursery/plantation planning • Enhanced information dissemination mechanism
Fourth priority • Incentivized financing options for value addition machines	**Third priority** • Decentralized warehousing • Grading of output

Table SN5: Activity planning and skills matrix

Area	Priority	Activity	Requisite Skills of Primary Member/Value Agent
Phase-wise nursery/ plantation planning	First	• Member-wise crop planning • Placing order with seed companies • Bidding by members for planting nurseries • Pricing mechanism for nursery delivery	• Crop planning • Farm mechanisation usage • Bookkeeping
Enhanced information dissemination mechanism	First	• Dedicated cadre for weather and crop advisory related information dissemination • Skill development of information warriors • Recorded voice calls with actionable advisory	• Basic understanding of agriculture • Familiarity with smartphone • Interpersonal skills
Improved weather insurance covers	Second	• Localized weather stations • Enhanced use of technology in production loss assessment • Adherence to turnaround time in claim settlement • Import duty cut on localized weather stations • Viability gap funding for insurance companies using collectives in insurance ecosystem	• Not applicable
Enhanced irrigation facilities	Second	• Tax incentives for collectives running irrigation as service	• Not applicable
Weather resistant crops	Second	• Corporate incentives for research into weather resistant varieties • Strong intellectual property rights regime • Time-bound dispute resolution mechanism through arbitration • Incentives for government-funded research institutes for monetization of researches • Dissemination through collectives	• Dissemination through "crop warriors"

Area	Priority	Activity	Requisite Skills of Primary Member/Value Agent
Decentralized warehousing	Third	• Incentives for collectives to run small warehouses • Mechanism similar to the Insolvency and Bankruptcy Code for collectives to deal with business failures in timely manner	• A few of primary members to take up role of warehousing • Understanding technological aspects
Grading of output and lower level of value addition	Third	• Collectives to negotiate with FMCG companies to understand and deliver on grading using manual labour and low level machines • Collectives to get their members skilled on grading/value addition through PMKVY	• Understanding of grading techniques • Usage of protective gwears and props for grading

Conclusion

Climate change is an overwhelming phenomenon that cannot be reversed now. The only possibility is to cope with it while ensuring that the most vulnerable have a chance to survive it. In this endeavour, collectives are likely to play the most important role. The primary role of a collective will be to harness the comparative strength of its members while ensuring specialization across different sets of activities. Also collectives would ensure that individual members have enhanced bargaining power while negotiating with market forces. The government and regulatory bodies need to play a constructive role in strengthening collectives to fulfil this role in the best interest of their members. What it requires is the right incentives and a fair and transparent ecosystem. This is of utmost importance; the time to act on this is now. If all of it doesn't come together quickly, it will become next to impossible to mitigate the negative consequences of climate change that threaten to overrun our way of life.

Strategy Note 4
Capacity Building of Governing Boards and Staffs of Collectives

Climate change is a reality of life which we encounter on a daily basis. Unseasonal rains, excessive and prolonged heat spells and resulting desertification of erstwhile green areas is a definite outcome of this phenomenon. It will surely impact each of our lives; for some these impacts would be more devastating than others. The consensus is that small holder farmers and low-level agriculture commodity value chain players will be most impacted.

This note is the outcome of the study titled "Understanding Climate Change Adaptation for Smallholders/Marginal Farmers and Quantifying its Impact on Agri-allied Value Chains in the Indo-Gangetic Plains". The study has explored the impacts of climate change on value chains of identified agri-commodities. The study covered commodities such as paddy, maize, wheat, potato and tomato which are the prominent crops in Upper and Middle IGP. Through this note, we lay out strategies that can help governance boards of collectives mitigate impacts of climate change on their primary members. One underlying assumption for this note is that climate change is irreversible. Nowhere do we claim to nullify the deep-rooted impacts climate change is going to have on livelihood choices. As the study made an effort to estimate losses on different value chains due to climate change risks, it becomes imperative that we should also explore potential strategies for small holder farmers and value chain actors to mitigate impacts. This note discusses measures that could be taken up through enhancing capacities of the government and regulatory institutions.

Collectives are defined as organized group of individuals that pool in their resources to enhance their bargaining power and achieve economies of scale in a market. By this definition collectives are involved in any such business activity that deals with value addition and thus exchange of goods/services. A few examples of collectives are cooperatives and FPCs.

Governance boards and top management of collectives are engines of these collectives. They need to play their role in such a manner that they are both inward looking as well as outward looking. In the inward looking role, they need to ensure that their primary members are equipped to deal with the vagaries of climate change while putting their individual strengths together, while, in their outward looking role, the management needs to keep negotiating and managing external relationships. These could be with government research institutions to get access to the latest technologies or with private market players to maximize value realization for their members.

Context of IGP and cropping pattern

One key defining feature of the cropping system of IGP is paddy-wheat rotation wherein paddy is grown in the kharif season while wheat grows in the rabi season. These two are dominant crops and cover as much 57 percent of net sown area during these two seasons. In case of Bihar, maize production has also picked up pace in big way. This is primarily because of the deep inroads chicken-feed companies have made into the hinterlands. However, despite that, during seasons respective prevalence of paddy and wheat gives the impression of the entire cropping system being mono-cropping. In horticulture, potato (in Uttar Pradesh) and tomato (in Bihar) are two most prevalent crops. For the purpose of this study, we studied these five crops. However, the lessons learnt can easily be applied to other crops as well.

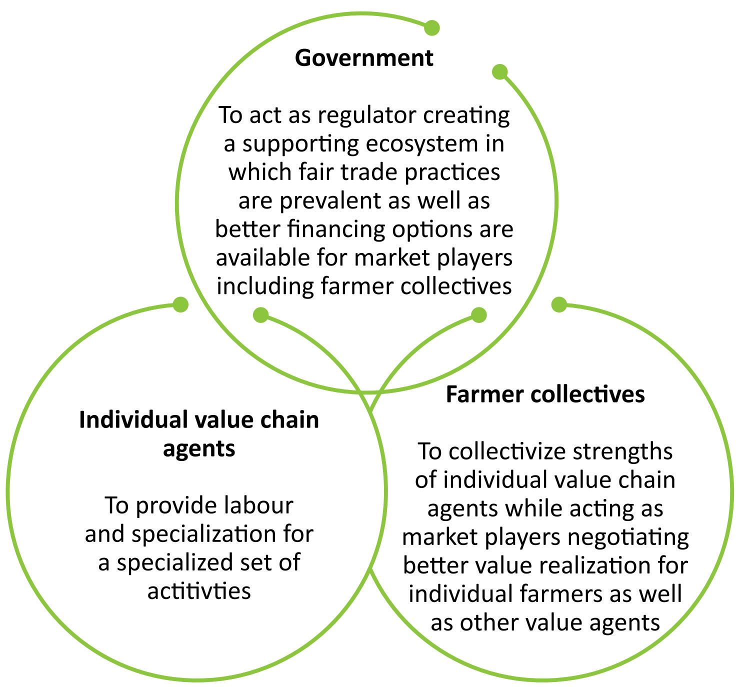
Value chain analysis: Clues for action points

We summarize the impacts climate change is having on various value chain agents in a generic value chain in Table SN6.

Table SN6: Impacts of climate change on generic value chains

Type of Value Chain Agent	Climate Change Impact	Crops Impacted	Mitigation Strategy	Responsibility
Small and marginal farmer	No rains at sowing time	Paddy	Better irrigation and shorter duration crops	Individual farmers through collectives
	Excessive rains during germination/transplantation phase	Paddy, maize	Phase wise nursery/ plantation	Individual farmers through collectives
	Excessive heat during flowering phase	Wheat	Heat resistant	Research institutes with government support
	Storm/hailstorm during harvest time	Wheat/paddy	Localized weather stations and enhanced weather insurance	Collectives, private players and government
Warehouse	Increased susceptibility to fungus and deterioration in quality	All	Aggressive fumigation/ decentralized warehousing	Collectives and government
Unorganized processing units such as *chakki*, chips and ketchup manufacturing	Increased percentage of stones, soil and leftover of other crops	All	Grade-based pricing	Collectives, private players and government
Vendors for FMCG companies	Increased percentage of stones, soil, and leftover of other crops	All	Grade-based pricing	Collectives, private players and government
	Increasing humidity and moisture level	All	Increased use of dryers and additional hours of milling	Private players and government

Figure SN6: Activities performed by value chain participants



As is amply clear from Table SN6, each responsible party needs to play its role performing specific activities. To put it into context, we propose the matrix shown in Figure SN7 delineating these activities.

Having established this context, this note further puts forward capacity-building measures required to improve adaptation capabilities of individual value chain agents.

Framework to identify key capacity building measures

Figure SN7 puts forward a framework to identify and prioritize capacity building measures required to enhance the capacity of individual value chain agents.

If we put specific activities into the framework proposed in Figure SN8, we will get the scenario shown in Table SN8.

Figure SN7: Framework to prioritize capacity-building measures

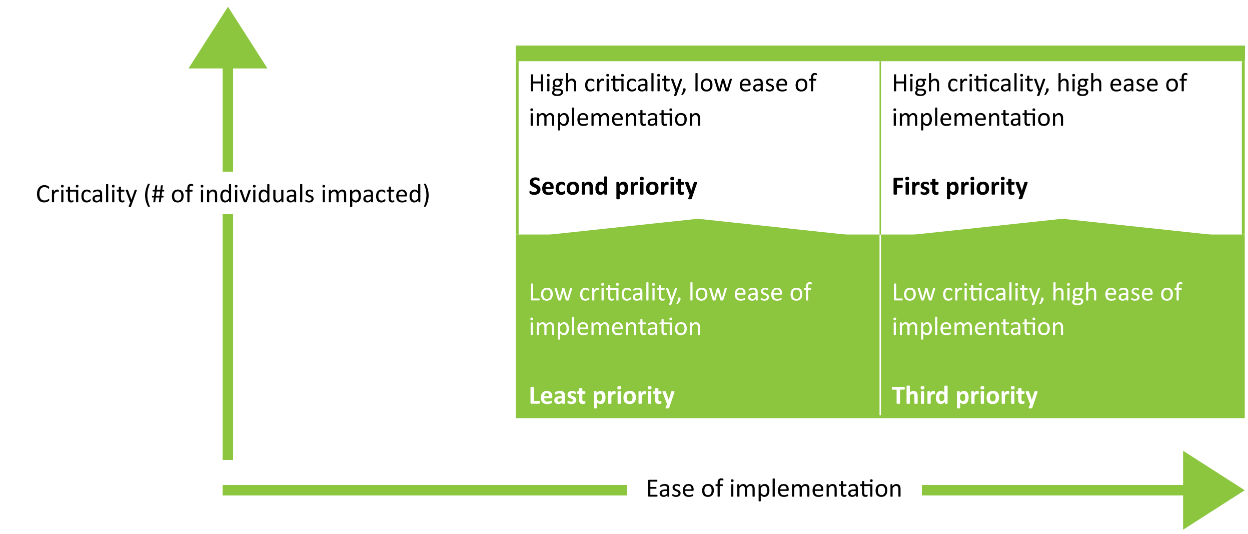


Table SN7: Activities place in the framework

Second priority • Improved weather insurance mechanisms • Improved seed varieties • Better irrigation facilities	**First priority** • Phase-wise nursery/plantation planning • Enhanced information dissemination mechanism
Fourth priority • Incentivized financing options for value addition machines	**Third priority** • Decentralized warehousing • Grading of output

Table SN8: Activity planning and skills matrix

Area	Priority	Activity	Requisite Skills of Primary Member/Value Agent
Phase-wise nursery/ plantation planning	First	• Member-wise crop planning • Placing order with seed companies • Bidding by members for planting nurseries • Pricing mechanism for nursery delivery	• Crop planning • Farm mechanisation usage • Bookkeeping

Area	Priority	Activity	Requisite Skills of Primary Member/Value Agent
Enhanced information dissemination mechanism	First	• Dedicated cadre for weather and crop advisory related information dissemination • Skill development of information warriors • Recorded voice calls with actionable advisory	• Basic understanding of agriculture • Familiarity with smartphone • Interpersonal skills
Improved weather insurance covers	Second	• Localized weather stations • Enhanced use of technology in production loss assessment • Adherence to turnaround time in claim settlement • Import duty cut on localized weather stations • Viability gap funding for insurance companies using collectives in insurance ecosystem	• Not applicable
Enhanced irrigation facilities	Second	• Tax incentives for collectives running irrigation as service	• Not applicable
Weather resistant crops	Second	• Corporate incentives for research into weather resistant varieties • Strong intellectual property rights regime • Time-bound dispute resolution mechanism through arbitration • Incentives for government-funded research institutes for monetization of researches • Dissemination through collectives	• Dissemination through "crop warriors"
Decentralized warehousing	Third	• Incentives for collectives to run small warehouses • Mechanism similar to the Insolvency and Bankruptcy Code for collectives to deal with business failures in timely manner	• A few of primary members to take up role of warehousing • Understanding technological aspects
Grading of output and lower level of value addition	Third	• Collectives to negotiate with FMCG companies to understand and deliver on grading using manual labour and low level machines • Collectives to get their members skilled on grading/value addition through PMKVY	• Understanding of grading techniques • Usage of protective gears and props for grading

Conclusion

Climate change is an overwhelming phenomenon that cannot be reversed now. The only possibility is to cope with it while ensuring that the most vulnerable have a chance to survive it. In this endeavour, collectives are likely to play the most important role. The primary role of a collective will be to harness the comparative strength of its members while ensuring specialization across different sets of activities. Also, collectives would ensure that individual members have enhanced bargaining power while negotiating with market forces.

The government and regulatory bodies need to play a constructive role in strengthening collectives to fulfil this role in the best interest of their members. What it requires is the right incentives and a fair and transparent ecosystem. This is of utmost importance; the time to act on this is now. If all of it doesn't come together quickly, it will become next to impossible to mitigate the negative consequences of climate change that threaten to overrun our way of life.

Strategy Note 5
Capacity Building of Government to Improve the Adaptation of Small holder Farmers to Climate Change

The impact of climate change is increasingly visible around us. Though to some, these changes are limited to just excessive heat and thus increased dependence on air-conditioning systems, for some others these could be life defining. One of those most vulnerable are small/marginal farmers and lower-level agri-value chain players. They would be the most impacted unless they adopt coping mechanisms to deal with climate change well in time.

Through this note, we lay out strategies that can help value chain players mitigate impacts to some extent. One underlying assumption in this note is that climate change is irreversible. Nowhere have we claimed to nullify deep rooted impacts it is going to have on livelihood choices.

This note is the outcome of the study titled "Understanding Climate Change Adaptation for Smallholders/Marginal Farmers and Quantifying its Impact on Agri-allied Value Chains in the Indo-Gangetic Plains". The study has explored the impacts of climate change on value chains of identified agri-commodities. The study covered commodities such as paddy, maize, wheat, potato and tomato which are the prominent crops in Upper and Middle IGP. As the study made an effort to estimate losses on different value chains due to climate change risks, it becomes imperative that we should also explore potential strategies for small holder farmers and value chain actors to mitigate impacts. This note discusses measures that could be taken up by enhancing the capacities of collectives.

Collectives are defined as organized groups of individuals that pool in their resources to enhance their bargaining power and achieve economies of scale in a market. By this definition, collectives are involved in any such business activity that deals with value addition and thus exchange of goods/services. A few examples of collectives are cooperatives and FPCs.

Given their organization and mandates, one of the most important role collectives can play in this entire climate change conundrum, is utilizing capabilities of different sets of individual players to help them specialize into specific activities. This note goes deep into delineating these activities and how to ensure that the collectives are built around those activities and stakeholders have appropriate capacities to perform their tasks efficiently.

Cropping pattern of IGP

One key defining feature of IGP's cropping system is paddy-wheat rotation wherein paddy is grown in the kharif season while wheat grows in the rabi season. These two are dominant crops and cover as much 57 percent of the net sown area during these two seasons. In case of Bihar, maize production has also picked up pace in a big way. This is primarily because of the deep inroads chicken-feed companies have made into the hinterlands. However, despite this, during the seasons, respective prevalence of paddy and wheat gives the impression of entire cropping system being a mono-cropping one.

In horticulture, potato (in Uttar Pradesh) and tomato (in Bihar) are the two most prevalent crops. For the purpose of this study we studied these five crops. However, lessons learnt can easily be stretched to cover other crops as well.

A typical value chain

Figure SN8 presents a typical value chain in its generic form. As is easily identified from this figure, the value chain is not that long and complex; it is rather a very short and simple one.

For specific crops, this value chain differs, but ever so slightly as there isn't much of value addition, especially in IGP.

Table SN9 summarizes the impacts climate change is having on various value chain agents in a generic value chain.

Figure SN8: A typical value chain

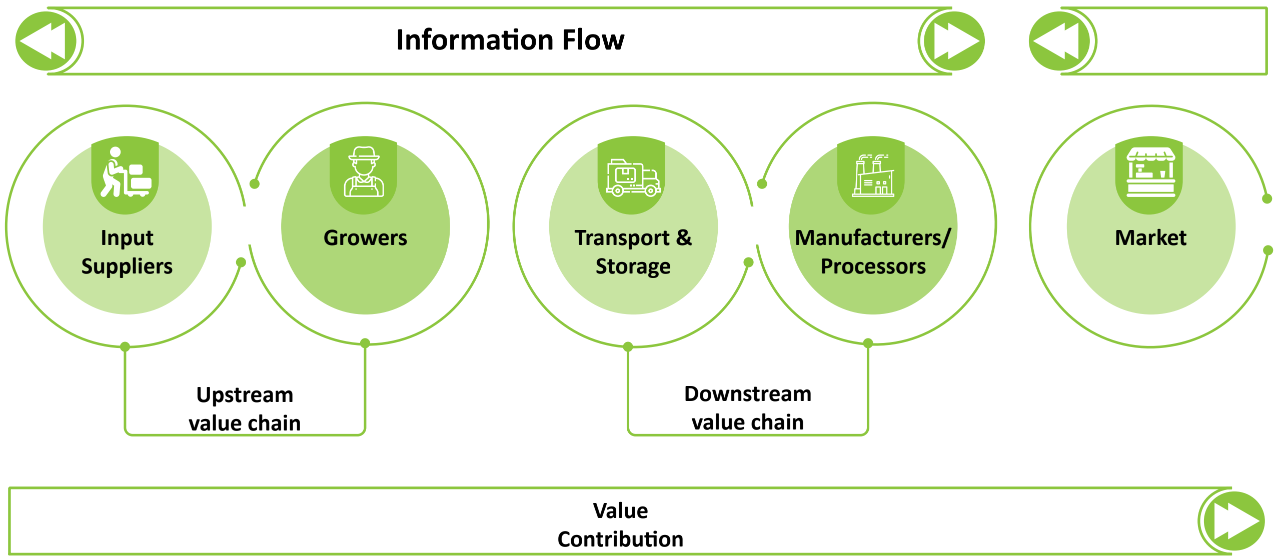
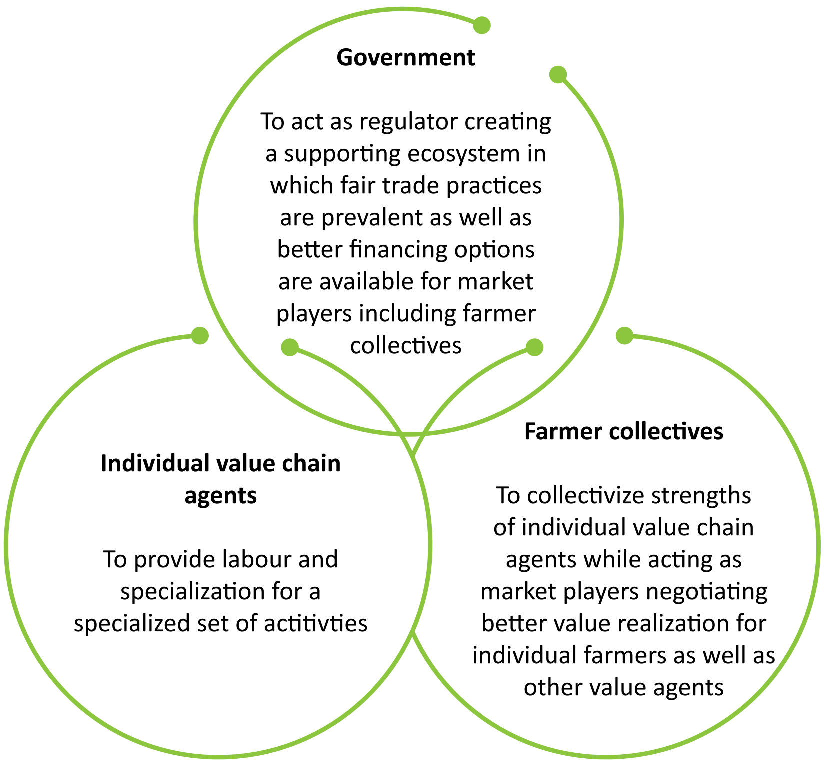


Table SN9: Impacts of climate change on generic value chains

Type of Value Chain Agent	Climate Change Impact	Crops Impacted	Mitigation Strategy	Responsibility
Small and marginal farmer	No rains at sowing time	Paddy	Better irrigation and shorter duration crops	Individual farmers through collectives
	Excessive rains during germination/transplantation phase	Paddy, maize	Phase wise nursery/ plantation	Individual farmers through collectives
	Excessive heat during flowering phase	Wheat	Heat resistant	Research institutes with government support
	Storm/hailstorm during harvest time	Wheat/paddy	Localized weather stations and enhanced weather insurance	Collectives, private players and government
Warehouse	Increased susceptibility to fungus and deterioration in quality.	All	Aggressive fumigation/ decentralized warehousing	Collectives and government
Unorganized processing units such as *chakki*, chips and ketchup manufacturing	Increased percentage of stones, soil and leftover of other crops.	All	Grade-based pricing	Collectives, private players and government
Vendors for fast moving commercial goods (FMCG) companies	Increased percentage of stones, soil, and leftover of other crops	All	Grade-based pricing	Collectives, private players and government
	Increasing humidity and moisture level	All	Increased use of dryers and additional hours of milling	Private players and government

Figure SN9: Activities performed by value chain participants



As is amply clear from Table SN9, each responsible party needs to play its role performing specific activities. To put it into context, we propose the matrix shown in Figure SN9 delineating these activities.

Having established this context, this note further puts forward capacity-building measures required to improve adaptation capabilities of individual value chain agents.

Framework to identify key capacity building measures

Figure SN10 puts forward a framework to identify and prioritize capacity building measures required to enhance the capacity of individual value chain agents.

If we put specific activities into the framework proposed in Figure SN10, we will get the scenario shown in Table SN11.

Figure SN10: Framework to prioritize capacity-building measures

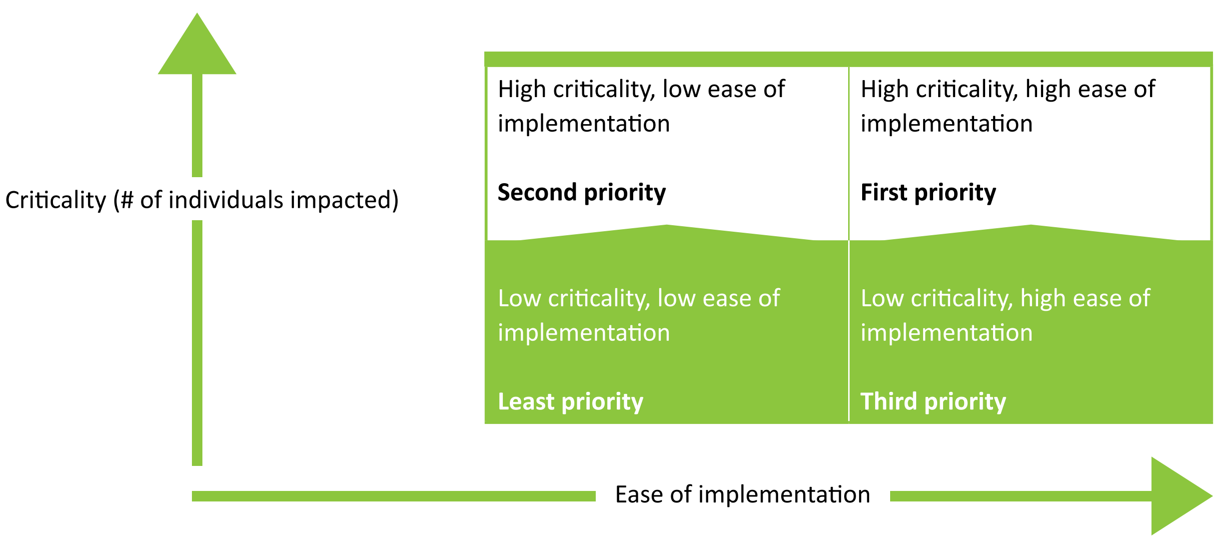


Table SN10: Activities place in the framework

Second priority	First priority
• Improved weather insurance mechanisms • Improved seed varieties • Better irrigation facilities	• Phase-wise nursery/plantation planning • Enhanced information dissemination mechanism
Fourth priority • Incentivized financing options for value addition machines	**Third priority** • Decentralized warehousing • Grading of output

Table SN11: Activity planning and skills matrix

Area	Priority	Activity	Requisite Skills of Primary Member/Value Agent
Phase-wise nursery/ plantation planning	First	• Member-wise crop planning • Placing order with seed companies • Bidding by members for planting nurseries • Pricing mechanism for nursery delivery	• Crop planning • Farm mechanisation usage • Bookkeeping
Enhanced information dissemination mechanism	First	• Dedicated cadre for weather and crop advisory related information dissemination • Skill development of information warriors • Recorded voice calls with actionable advisory	• Basic understanding of agriculture • Familiarity with smartphone • Interpersonal skills
Improved weather insurance covers	Second	• Localized weather stations • Enhanced use of technology in production loss assessment • Adherence to turnaround time in claim settlement • Import duty cut on localized weather stations • Viability gap funding for insurance companies using collectives in insurance ecosystem	• Not applicable
Enhanced irrigation facilities	Second	• Tax incentives for collectives running irrigation as service	• Not applicable
Weather resistant crops	Second	• Corporate incentives for research into weather resistant varieties • Strong intellectual property rights regime • Time-bound dispute resolution mechanism through arbitration • Incentives for government-funded research institutes for monetization of researches • Dissemination through collectives	• Dissemination through "crop warriors"

Area	Priority	Activity	Requisite Skills of Primary Member/Value Agent
Decentralized warehousing	Third	• Incentives for collectives to run small warehouses • Mechanism similar to the Insolvency and Bankruptcy Code for collectives to deal with business failures in timely manner	• A few of primary members to take up role of warehousing • Understanding technological aspects
Grading of output and lower level of value addition	Third	• Collectives to negotiate with FMCG companies to understand and deliver on grading using manual labour and low level machines • Collectives to get their members skilled on grading/value addition through PMKVY	• Understanding of grading techniques • Usage of protective gears and props for grading

Conclusion

Most literature would have us believe that climate change is a phenomenon that's here to stay and not going away anytime soon. Against this background, it becomes extremely important to mitigate risks that it entails. For those who are in the most disadvantageous position because of their background, it becomes imperative on society at large and government institutions in particular to provide them a fair chance.

The government needs to do this using a mix of instruments at its disposal. At one hand, it needs to push its funded research institutions to continue to innovating keeping this "new normal" in mind. On the other hand, it needs to provide a fair, transparent and consistent ecosystem for market players to interact more with the collectives formed by small holders to ensure fair prices to realize conversion for growers. A part of this ecosystem is to ensure that the cost of owning risk cover reduces and it becomes comprehensive. It should become economically remunerative to own a small warehouse rather than building large ones which are capital intensive. At the same time, the government needs to continue investing in disseminating information through all channels at its disposal. A judicious mix of all the above mentioned measures will give a fighting chance to the small holder farmers as well as low level value chain agents to face the daunting impacts of climate change on their livelihoods.

Strategic Note 6
Dovetail State Action Plan on Climate Change with Selected Agri Value Chains

This strategy note aims to leverage opportunities from the State Action Plan on Climate Change (SAPCC) for cultivators and value chain in the ecological fragile region of IGP. In addition to the identification of vulnerable districts by NICRA in IGP, UNDP, in its unique study, examined the impact of climate change on agro value chain agents and small/marginal holders for five selected produce: paddy, maize, wheat, potato and tomato. Value chain approaches are considered because climate change impact affects every participant beyond cultivators, processors, cooperatives and end consumers in various degree. The value chain approach supports integrated climate risk management through better connection of producers to markets and increased economic returns to small farmers. Thus, it is an approach not just for building climate resilience but for providing more effective support to agriculture generally. It acknowledges that when it comes to responding to the impacts of climate change, the whole value chain should be considered.

Within this approach, special focus has been placed on small holders and local value chain actors. Identified adaptative deficits are to be bridged by various measures through partnerships between and collaboration by state and non-state actors. SAPCC is one such attempt from the state government to integrate climate change concerns into sectoral policies, annual action plans and budget. Disaster risk will continue to increase, as more vulnerable people and assets are exposed to weather extremes. IGP districts have witnessed extreme events in the recent past. Flood and drought have not only impacted agriculture severely but also sub-sectors which are dependent on agriculture. Crop production is highly influenced by weather and change in climate has a major impact on crop yield and productivity. As climate change impacts become more dramatic, their effect on a range of climate extremes will become increasingly important and will play a significant role in disaster impacts. However, it is also expected that even minor variations in existing climate extremes can exacerbate the challenges that the state, its different sectors and its people face.

Guided by the structured initiatives enunciated in the National Action Plan for Climate Change, SAPCC has been drafted for interventions and activities in nine sectors. SAPCCs describe the vulnerability of states to climate change risks and how the state government plans to reduce that vulnerability and close the adaptation gap. In agriculture, priorities advocated in the action plan are on an increase in the yield, removal of constrains in procurement and market linkages, promotion of processing capabilities at the local level, augmentation of warehousing and storage facilities for food security, and establishment and strengthening of institutions for human resource development.

Time bound budget allocations were proposed for climate action strategies in agriculture development to enhance resilience and build institutional linkages with national agriculture research institutions for technical advice, capacity building and for sector-specific vulnerability analysis to arrive at strategic plans for agro climatic zones.

Strengthening weather advisories through telemetry and agro-met system

An Automated Weather Station (AWS). - enables data management on resource availability and adoption of public-private partnerships are among other conservation measures on soil and water losses that have been advocated. Budgets for these programmes were estimated with short- and long-term perspectives. Policy reviews, capacity building, knowledge management and forecasting EWS were proposed for risk management. Similarly, allocations for improved flood and drought tolerant varieties and micro irrigation augmentation were proposed. Translating strategic planning into action in the IGP districts will help to curtail loss and damage. Resources assigned for different components of agriculture activities under SPACC may be channelized for IGP's and other districts in the future. To transform the SAPCC into an actionable work plan in the IGP districts, the following steps are being proposed that align with the short- and long-term prospective and funding allocation proposed in state plans.

Capacity building for effective planning: Planning is the first and pivotal step to mitigate the effects of various climate-induced contingencies. Climate mitigation planning requires collaborative efforts from partner organizations and state departments.

Identified key stakeholders amongst the community, various line departments from agriculture, rural development and state cooperative are to be trained in assessing their vulnerabilities and preparing plans in the light of the various contingencies. In the planning process, stakeholders at various levels are to be mapped (primary, secondary and tertiary). Ecosystem enablers of agriculture need to bring in value chain actors in commodities along with cultivators, value chain agents and local processing units are exposed to climate risk. Secondary stakeholders are the service providers at the local level, which includes three-tier governance of the Gram Panchayat, Panchayat samitis, extension workers and knowledge partners (KVK/NGOs).

In addition to sensitization, line departments at the state and district levels need training on preparation, implementation, financing and mainstreaming of climate proofing practices in the existing programme and allocation of earmarked annual funds. In IGP's districts, efforts on capacity building of stakeholders could be explored through leveraging capacity building funds earmarked for extension workers and training of employees of line department officials. Capacity building modules that are readily available as open sources could be a starting point for procuring knowledge products.

Preparation/application of soft infrastructure measures: EWS and climate advisories are often discussed as climate proofing measures for informed decision making. Nature-based solutions such as water storage irrigation tanks, ridge and furrow cultivation practices, zero budgeting cultivation practices, among other measures, have been suggested for climate proofing. Early rainfall alerts (before, days) and forecast advisories are offered by the Indian Meteorological Department (IMD) at block levels. The small holders and processing units could use forecasting services offered on rainfall in IGP districts on an immediate basis. Agriculture advisories are provided by state agriculture extension departments and private partners in states. Indian Farmers Fertiliser Cooperative Limited and Crop-in are the two private agencies offering agro advisory services. In the medium and long term, AWSs and rain gauges are proposed to capture micro data and thereby improve forecasting precisions. Skymet, in association with Jeevika, has installed them in two districts and Bihar is contemplating their replication in more districts.

Flooding in IGP districts is governed by upstream events, high intensity rainfall and outflows from water reservoirs, further exacerbated by flash floods in local areas. To manage this situation, India and Nepal share information and conduct joint monitoring. The Centre Water Commission and institutional partners from Nepal and India exchange information and learnings. River basin flood water management and mitigation measures are being finalized to mitigate flooding. The state action plan provides a unique opportunity to collaborate at the regional level.

Adaptation activities: Previous studies on climate change indicated that famers were adapting to climate change; the cost of adaptation and gains vary with the type of climatic risk, agriculture and farm size. Strategies such as improved varieties, crop diversification, crop water and livestock management, value additions, etc., have led to farm resilience to climatic risks. Small and marginal farmers cannot support themselves with agriculture income alone, however, sustainable agriculture and value addition in crop processing need to be explored. The SRI method of rice cultivation is widely propagated in Bihar for paddy cultivation. The SRI method of transplanting eight to 12 day-old seedling at wider intervals was found to be superior to the traditional transplanted paddy system; also no requirement for standing water leads to savings in water use. SRI methods report increased yields by over 30 percent while using 40 percent less water than conventional methods. Besides, anaerobic decomposition of organic material in flooded rice fields produces methane which escapes into the atmosphere primarily by diffusive transport through the rice plants during the growing season is reduced in the case of SRI.

Varietal improvement: Development and identification of climate-resilient crop varieties, with enhanced tolerance to flooding, chilling and salinity stresses, are essential to sustain and improve crop yields to cope with the challenges of climate change. States have identified and promoted climate-resilient varieties to bridge the yield gaps, enhance productivity and profitability, minimize risk and improve the livelihoods of millions of people dependent on agriculture. Under NICRA, during 2012-17, about 450 climate-resilient varieties have been identified/released. Climate-resilient crop varieties, along with other suitable adaptation and mitigation strategies, will help to overcome the adverse impact of climate change by lowering yield losses under stress conditions.

Adaptation practices for climate action that are multi-sectoral and multi-dimension require more synergies to ground climate proof measure. Resource planning and funding from the budget and convergence with other development programmes are the first steps. This involves checking the SAPCC actions; funding in other development programmes and facilitating convergence that will improve efficient use of scarce resource Moreover, SAPCC actions will complement the activities funded in the development programme. In the light of the need inIGP for climate action, tasks that have possibilities of converging with other programmes are proposed as shown in Table SN12.

Table SN12: Activity planning and skills matrix

Intervention	Development Programme	Areas for Convergence	Budget Alocated under SPACC (INR)
Policy & planning	Rashtriya Krishi Vikas Yojana (RKVY): District Agriculture Plans (DAPs) and District Agriculture Plans (DAP/SAP)	DAPs could include climate resilience plan taking guidance from SPACC	Short-term budget allocation (1.5 million) Short-term allocation for planning (INR 10.6 million)
Capacity building	Agriculture Technology Management Agency (ATMA): The scheme promotes decentralized farmer-driven and farmer-accountable extension system through an institutional arrangement for technology dissemination	Farm School at the village level to promote, climate-resilient crop cultivation practices. Use of interactive and innovative methods of information dissemination such as low-cost films, handheld devices, mobile-based services, KCCs, etc., could be used as a vehicle for climate resilient awareness to farmers	Budget allocation 2.5 million
Capacity building	National Food Security Mission: Production support to rice and wheat. Seed distribution of certified seeds	Production support: Rice wheat and climate-resilient, short duration varieties	Short term budget allocation of 2.5 million
Improved varieties and practices	RKVY- Remunerative Approaches for Agriculture and Allied Sectors Rejuvenation (RAFTAAR): Seed testing labs, seed processing facilities, seed certification agencies and certification infrastructure, seed multiplication farms	Climate-resilient crop varieties promoted though the RAFTAAR initiative	75.0 million for research, development and promotion of climate-resilient varieties
Irrigation water management	NMSA promotes water use efficiency in farm management, micro irrigation technology and equipment.	Water user efficiency and climate resilient practices on retaining soil moisture would promote water conservation means by investing in climate resilient irrigation infrastructure like micro, drip irrigation	Study of irrigation improvement (2.5 million) Micro irrigation augmentation (50.0 million for 12th FYP 5 year)
Knowledge management/ innovation	RKVY: Support to incubates / individual youth/farmers/ Framer Producer Organizations (FPOs) with innovative ideas for setting up of agri- businesses that will benefit farmers empowerment of small and medium agri entrepreneurs, support for public/private institutions (state, national, international) KVKs involved in agri-businesses training and skill development	Learning, implementation and scaling up of innovative ways to minimize climate risk	Identification of potential research and development domains concerned with climate change issues in the sector; initiating studies

Intervention	Development Programme	Areas for Convergence	Budget Alocated under SPACC (INR)
Forecast early warning system	Weather stations and rain gauges are being promoted at villages and at grid level (10 km * 10 km) to improve data collection and enhance forecasting capacities at the local level NICRA support on weather based, agro-based advisory, risk management implemented through KVKs and other institutions	Risk of flood and drought could be mitigated by improved weather warning alert at the local level Weather-based, agro-based services will help in bridging the farm and lab yield gap that would further facilitate small and marginal holders to improve agriculture income	Improve risk management and EWS (20.0 million)

Planning and policy directive: District action plans are the stepping stone to develop climate resilience plans for IGP districts. RKVY-RAFTAAR advocates a district action plan that could be aligned to the state action plan on agriculture and an annual plan for subsequent years. With guidance from SPACC, district plans would facilitate implementation of the proposed climate proof interventions.

Capacity building on climate-resilient practices could converge with development programmes of RKVY, ATMA, NMSA, NRLM with training programmes for farmers and secondary stakeholders. Improved seed varieties and agronomical practices to reduce climate risk exposures demand closer learning and experiment at the farm level. Certain short duration varieties are promoted for flood prone districts. Acceptance and use of new varietal interventions would take some time to be assimilated by cultivators. Weather forecasting is promoted at villages and clusters within blocks to improve forecasting capacities at the local level. Weather-based agro advisories though information and communication technologies (ICT) such as SMS are being promoted across the cultivators' groups to augment their knowledge.

11 Thematic Notes

Thematic Note 1

Quantification of Losses Due to Climate Change in Select Agri Value Chains

A value chain is simply defined as the path or system which adds value to the product or service offered. In the case of agri value chains, this path has different actors and varying value contribution happens at different levels. Value contribution is a function of the relationships between these actors as well as information sharing and use and handling of processes efficiently. Growth and development of agricultural value chains is a powerful tool for economic empowerment, particularly for small and marginal farmers. The analytical framework for this assignment treats the value chain as a sequence of value addition activities, from the production of agriculture produce to making it fit for consumption in various forms through activities such as transportation, storage, and processing. Generally, value chain approaches focus on a range of activities from production to final consumption but, for this study, we have limited the scope till final processing only. Value chain actors such as wholesalers and retailers reported that, due to the nature of their business

Impact on Raw Material Supply

- Supply of farm produce not meeting quality specifications
- Inadequate supply from regular procurement area /fluctuating supply
- Working capital management issues due to disruptive procurement (credit/ payments/cash purchase, etc.)

Impact on Supply Chain

- High cost of storage in warehouses due to increased expense on fumigation, capacity under-utilization
- Quality deterioration risks of both raw material as well finished products

Impact on Logistics

- Increased cost of transportaion due to production loss in the natural procurement area
- Higher spending on transportation to maintain quality standards
- Increased risk in supplying finished products

Impact on Production/Processing

- Quality of final product
- Low shelf life of final product
- Additional investment in machinery

and the multiplicity of products in which they deal, it would be difficult to differentiate between supply chain inefficiency-related loss and climate change-related loss.

For most commodities grown in IGP, focus has been increasing on activities such as storage, processing and trading with a higher degree of coordination amongst farmers, warehouse/cold storage owners and processors in the value chain. Due to changes in consumption patterns, demand for value-added food products is increasing. Through this study, an attempt is being made to bring together various climate change-related issues that affect agriculture value chains in IGP, with specific focus on Uttar Pradesh and Bihar.

Climate change impacts value chains in many ways. It affects the quality and yield of agriculture commodities; to maintain the quality of final products, value chain agents need to adapt by making changes in their supply chain and production systems which require additional resources. Climate change sometimes adversely impacts production in their procurement areas and alternative arrangements are required leading to high procurement and transportation costs. Climate change can also have an impact on the quality of the final products as well their shelf life.

Changes in climatic conditions increase the cost of operations for warehouse/cold storage owners due to higher electricity charges and fumigation expenses along with lower capacity utilization. The impact of climate change are felt more by small businesses than big businesses as the former lack resources for adequate planning and preparedness. Vulnerability of small businesses also increases due to lack of financial resources to endure even a small rupture in the supply chain which may be caused, for instance, by an extreme weather event. As the flow of raw material starts from the farmers' end, adverse impacts affect all actors in the value chain.

Adoption of short duration HYV by farmers in the monsoon crops affects the business of traders, warehouse owners, transporters as well the final processors. Similarly, an increase in the moisture content of raw material affects the conversion ratio during processing, increases the cost of production and leads to higher investments in new equipment and machines. Climate change alters the capabilities of value chain participants, as the value created by them diminishes. These changes affect economic profitability, competitiveness, livelihoods and employment growth as well.

Value chain actors, other than farmers, try to mitigate the risks of climate change by adopting various strategies which include procurement of produce from alternative sources, improvement of the supply chain, making changes in the processes, investment in plants and machineries, etc. Though adoption of these measures helps value chain actors in minimizing operational risks, it increases their financial risks by raising the cost of production. They also face threats from competitors as barriers to entry are quite low in the agriculture value chain. The majority of studies that have made an attempt to estimate value chain losses has been limited to an assessment of losses at the production stage, i.e., at the famers' level, mostly analyzing climate change impacts on inputs costs borne by the farmer and, subsequently, impact on production or yield.

The current financial analysis has its inherent limitations due to the lack of information across various value chain actors after harvest. Value chain actors too find it difficult to segregate the total losses between inefficient handling and losses which can be specifically attributed to climate change impacts. Another limitation with attribution is the difference between long-term climate change trends and short duration climatic fluctuations, which have properties similar to climate change.

Given the limitations of the study, an attempt has been made to assess the monetary impacts on various participants across the value chains studied for the present study, primarily using feedback received from the actors involved and by assessing potential impacts as perceived by the participants in a best case and worst case situation in the absence of a baseline figure. Value chain-specific assessments are followed by a detailed calculation of the participant-specific calculations and a descriptive analysis of the overall impacts on the value chain. To maintain uniformity in calculation of prices of the various commodities, the MSPs as determined by the Government of India for the financial year 2018-19 have been utilized for the calculation of overall impacts on the value chain.

1. Monetary Impact on Paddy Value Chain

The effect of climate change on value chain participants is of two types. The first is related to the quality of paddy received at various levels of the value chain and the second to receiving adequate amount of paddy so that production facilities can run at the optimal level. These issues become important as the cost of mitigations by various value chain participants involves extra expense either in the form of capital investment or increased cost of operations.

A detailed analysis of the losses that occur at various stages of the value chain reveals that the total monetary losses can be quantified to a range of INR 3,492-3,823 million. Most losses happen in the rice milling value chain which roughly translate to around 69 percent of the overall monetary impact on the value chain. This is primarily because 90 percent of the paddy produced in the region goes through this section of the value chain. A detailed view of the rice milling stage of the value chain reveals that over 50 percent of the total negative monetary impact on the value chain can be directly attributed to the negative impacts on the quality of yield due to climatic vagaries. At the paddy processing stage, the losses total around INR 460-481 million. At the warehousing stage, the total losses that can be attributed to weight losses and higher operation costs are around INR 418 million. No significant monetary impacts were observed on the transportation stage or at the solvent unit stage of the value chain.

2. Estimation of Value Chain Losses in the Maize Value Chain

Adverse climatic conditions affect the quantity and quality of maize and have a cascading effect on the entire value chain albeit with varying degrees. Most of value chain agents use maize grain rather than some byproduct of it. This peculiarity of the maize value chain makes it susceptible to any adverse impact on the quantity and quality of maize production. Farmers reported that the impact of climate change during the production phase was observed to be lower than in other crops. At the time of harvesting, adverse climatic conditions affect colour and taste (contamination with toxins).

The total climate change impact on maize value chain in the IGP districts is in the range of INR 900 million to 1,410 million. The monetary impact is observed to be the maximum at the poultry feed level value chain which accounts for almost over 90 percent of the total negative monetary impact on the maize value chain. These losses occur primarily due to the adverse impact of climate change on the quality of the produce and its resultant effect. At the cattle feed stage of the value chain, the total negative impact ranges from INR 120 million to INR 170 million. These losses too primarily can be attributed to adherence to quality parameters which result in higher operations costs for the industry. An increase in fumigation expenses has also been documented during the study to the tune of almost INR 10 million.

3. Estimation of Value Chain Losses in the Wheat Value Chain

Wheat is a thermo-sensitive crop and both its growth and productivity depend on the temperature during the cropping phase. As wheat is grown as a winter-irrigated crop, the influence of rainfall is negligible on the yield but any rains at the time of harvesting can do serious damage to the crop. Around 30 to 35 percent of the wheat produced by the farmers is used for self-consumption, around 5 percent is retained for seed while the remaining produce is marketable surplus. Sudden rain, hailstorm, heavy wind sometimes destroy or damage the crop so much that such a crop is used for animal feed purposes only. Beside this, the by-product (wheat bran-*chokar*) from wheat milling is also used for cattle feed. Three types of value chains exist for wheat crops: 1. regulated value chain which mainly covers the food procured by FCI/nominated agencies and supplied back for distribution under PDS; 2. an organized value chain that caters to organized roller flourmills and organized flourmills; and 3. an unorganized value chain that caters mainly to direct customers and small traders. In terms of volume of wheat handled, the last is the largest value chain.

Any adverse impact of climate change on the quality and quantity of the yield can have a cascading effect on the entire value chain and its actors. Based on the study conducted, the total climate change impact on wheat value chain in the IGP districts is estimated to be around INR 830 million. Over 80 percent of these losses can be directly attributed at the stage of organized roller flourmills while the rest occur at the level of unorganized roller flourmills. Similar to other value chains studied, the majority of the post-harvest losses are directly attributable to higher operations costs due to adherence to quality parameters because of the adverse impacts of climate change on the quality of the yield.

4. Estimation of Losses on Potato Value Chain

Potato growers' adaptation to climate change ranges from the usage of newer seeds, more application of inputs, change in planting and harvest dates and increased applications of fertilizers or pesticides. Change in planting time, improved varieties of seeds and customized nutrient addition to the soil as per its quality and requirement are among different management strategies that help farmers to mitigate the vagaries of climate change. All these factors impact the value chain and its actors in a cascading manner. The total value chain loss in potato due to climate change is in the IGP region is in the range of INR 6,220 million to INR 9,010 million. The maximum losses occur at the level of cold storages where they have been documented to be in the tune of over INR 6,000 million. Even at this stage of the value, the maximum share of losses can be accounted for due to wastage at the cold storages which account for over 33 percent of the total documented negative impact on the value chain. Increased operations cost due to climate changes account for almost INR 1,840 million of total losses. Increased operations costs, labour charges and wastage losses at the organized and unorganized potato processing stages account for almost INR 1,840 million loss.

5. Estimation of Climate Change Loss in Tomato

In comparison to cereals crops, horticulture crops such as tomato are much more vulnerable to the consequence of climate change. Even minor climatic variations have the potential to destroy the crops. Any adverse impact of climate change on the quality and quantity of the yield can have a cascading effect on the entire value chain and its actors. The total monetary impact on the tomato value chain in the IGP region is around INR 1300 million. These losses are primarily those incurred during the transportation of tomatoes. In the absence of adequate storage facilities for a commodity such as tomato which has an extremely short shelf-life, the losses at the farmer level are the highest. Low value addition impacts farmers by way of high post-harvest losses and low returns during periods of market glut. On another hand, Indian tomato-based product manufacturers import significant quantities of tomato pulp and paste due to the non-suitability of locally grown varieties; this results in extremely low to negligible losses at the level of tomato processors.

6. Conclusion

Climate change impacts value chains in many ways. It can affect the quality and yield of the agriculture commodities; to maintain the quality of final products, value chain agents need to adapt by making changes in their supply chain and production systems which require additional resources. The change in climate sometimes adversely impacts production in one area, resulting in other value chains making alternative arrangements for procurement, leading to high procurement and transportation costs. In order to ascertain the gravity of the financial risks that climate change poses cumulatively across the value chain, an assessment of all the impacts on the studied value chains reveals a cumulative impact of over INR 12,740 million across all value chains.

Annexure 1: Quantification of value chain losses in the paddy value chain

Processing Stage		Key Reasons	Under Normal Situation		Under Climate Change Induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in Millions INR	
			Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Rice miller value chain (90% of paddy)	Paddy to rice conversion	Use of short duration hybrid variety by farmers	63%	65%	60%	63%	-3%	-2%	1,335	890
	Broken rice	Use of short duration hybrid variety by farmers	6%	8%	8%	9%	2%	1%	788	394
	Impurities	Weeds, farmers want to cut the crop as soon as possible as they fear adverse climatic conditions	3%	5%	6%	7%	-3%	-2%	899	599
	Increase in discoloration of grain	Untimely rains	1%	2%	3%	4%	-2%	-2%	599	599
	Dead paddy	Insufficient rains and lack of uniform maturity of grains	1%	2%	3%	4%	-2%	-2%	599	599
	Moisture loss	Loss of weight of produce from loss of moisture from the time of harvesting (moisture at time of milling is around 14-16%)	1%	2%	2%	3%	-1%	-1%	300	300
Paddy processing	Puffed rice-high moisture 5% with impurities at 60% extraction	Normal conversion of quality murhi is 90% of rice while with climate change the percentage of quality *murhi* goes down by 3-5%	90%	92%	86%	89%	-4%	-3%	260	195
		Cost of drying and blower @ INR 10/quintal							29	29

Processing Stage		Key Reasons	Under Normal Situation		Under Climate Change Induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in Millions INR	
	Flattened rice-broken rice 5%		62%	65%	60%	62%	-2%	-3%	171	257
Warehousing excluding FCI	Fumigation expenses *	Shelf life has gone down Excessive humidity	Fumigation rounds of 45 days		Fumigation rounds of 30 days		Additional cost of fumigation for 1.3333 rounds during the storage period		19	19
	Loss of weight	High temperature	1%	2%	3%	4%	-2%	-2%	399	399
	Total Impact on Paddy Value Chain								3,823	3,492
Transportation cost	No significant climate change impact observed on the value chain									
Solvent unit	No significant climate change impact observed on the value chain									
Total climate change impact on paddy value chain in the IGP districts is in the range of INR 3,492 million to INR 3,823 million										

Annexure 2: Quantification of value chain losses in the maize value chain

Processing Stage		Reasons	Under Normal Situation		Under Climate Change-induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
			Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Poultry feed		Presence of dust	0.5%	1.0%	1.0%	2.0%	-0.5%	-1.0%	84	168
		Presence of foreign matters/ impurities	1.0%	2.0%	2.0%	4.0%	-1.0%	-2.0%	168	335
		Rejections due to excessive moisture/ quality	0.0%	0.0%	1.0%	2.0%	-1.0%	-2.0%	168	335
		Drying cost/ increased labour charges			40 INR/quintal				395	395
Cattle feed		Drying cost	INR 30/quintal						80	80
		Rejections due to excessive moisture/ quality	0.0%	0.0%	1.0%	2.0%	-1.0%	-2.0%	45	91
Industrial processing	Starch	No such loss								
Food processing	Processed foods	No such loss								
	Fumigation		Fumigation rounds of 45 days		Fumigation rounds of 30 days		Additional cost of fumigation for 1 to 1.5 rounds during the storage period		9	9
									948	1,413
Total climate change impact on maize value chain in the IGP districts is in the range of INR 900 to INR 1,410 million										

Annexure 3: Quantification of value chain losses in the wheat value chain

Processing Stage	Reasons	Under Normal Situation		Under Climate Change-induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
		Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Organized flourmills	Increased impurities resulting in cleaning charges	Labour charges @INR 400/MT						86	86
	Increased impurities resulting in loss of grains	2.0%	1.0%	2.5%	1.5%	-0.5%	-0.5%	20	20
	Increased humidity and moisture in wheat resulting in drying charges	Incremental electricity costs and sun drying charges @INR 165/MT						35	35
	Increased humidity and moisture in wheat resulting in weight loss	2.0%	1.0%	2.5%	1.5%	-0.5%	-0.5%	20	20
Organized roller flourmills	Increased impurities resulting in cleaning charges	Labour charges @INR 400/MT						257	257
	Increased impurities resulting in loss of grains	2.5%	1.5%	3.5%	2.5%	-1.0%	-1.0%	119	119
	Increased humidity and moisture in wheat resulting in drying charges	Incremental electricity costs and sun drying charges @INR 350/MT						225	225
	Increased humidity and moisture in wheat resulting in weight loss	2.0%	1.0%	2.5%	1.5%	-0.5%	-0.5%	60	60
Warehouse	Fumigation charges	Fumigation rounds of 45 days		Fumigation rounds of 30 days		Additional cost of fumigation		10	10
	Total impact of climate change on wheat value chain							832	832
Total climate change impact on wheat value chain in the IGP districts is around INR 830 million									

Annexure 4: Quantification of value chain losses in the potato value chain

Processing Stage	Reasons	Under Normal Situation		Under Climate Change-induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
		Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Potato	Storage loss	5%	3%	7%	4%	-2%	-1%	2,797	1,398
	Increased electricity/ operation costs	INR 100 /MT						1,840	1840
	Wastage	5.0%	3.0%	8.0%	5.0%	-3%	-2%	4,195	2,797
Potato processing-organized	Weight loss	1.0%	0.5%	2.0%	1.5%	-1%	-1%	124	124
	Increased labour/ operation costs	INR 30/MT						49	49
Potato processing unorganized		1.0%	0.5%	2.0%	1.5%	-1%	-1%	11	11
	Estimated value chain loss							**6,220**	**9,017**
The total value chain loss in potato due to climate change is in IGP region is in the range of INR 6,220 to 9,010 million									

Annexure 5: Quantification of value chain losses in the tomato value chain

Processing Stage		Reasons	Normal Situation		Climate Change Induced Situations		Effect on Value Chain		Monetary Effect on Value Chain in INR	
			Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case	Worst Case	Best Case
Tomato	Transportation loss		15%	10%	25%	20%	-10%	-10%	12,948	2,948
*Prices calculated are based on inputs received from interviews of value chain actors: tomato average wholesale price @ INR 10,000/MT										
The impact of climate change for tomato crop is around INR 1,300 million in the IGP region										

Thematic Note 2

Estimation of Investment required by the Government and Private Sector to Support Farmers' Adaption to Climate Change in Select Value Chains

1. Introduction

Financial products and services that support adaptation to the vagaries of climate change at any point in the value chain help in addressing the changing requirements of various actors in the context of climate change. A structured way of financing agriculture that links stakeholders operating within the value chains reduces the risks that are commonly associated with climate change. An essential element of value chain finance is how it mitigates risks. There are many different types of risks: information risk, market knowledge risk or chain knowledge risk. Farmers' experience has shown that there are several ways to reduce risk.

Reduction of risk can help small holder farmers to participate in value chain operations that enhance their production, productivity and, most importantly, price realization. Adaptation to climate change helps both producers and value chain participants in reducing vulnerability. Farmers generally adapt by adopting different agricultural practices such as changes in inputs, seeds, amount of pesticides or cropping calendar. Other participants reduce their vulnerabilities by adopting new technologies. It is in this context that investments by governments and the private sector in the value chain become extremely critical for leveraging opportunities in the value chains to minimize adverse climate change impacts on the entire value chain.

Value chain finance helps in looking beyond the direct beneficiary of finance to understand the entire subsector and its risks and opportunities before designing appropriate products that fit the businesses in the value chain. Value chain financing is of two types, direct and indirect. Direct value chain finance is when financial services from banks and other financial institutions are provided directly to the producer, one of the most important players in the value chain.

Indirect value chain finance is when financial institutions finance any of the players in the value chain, either for addressing a gap/bottleneck in the value chain or for enhancing the efficiency of the player(s) in the chain, whereby the financing will indirectly benefit small and marginal producers. International trade in agricultural commodities has been growing very rapidly. Small holder farmers are unable to contribute to and avail of the benefits of export markets as their capacity to invest in production practices that result in high quality produce to meet the standards of international markets is low. Value chain finance enables the small holders to move up the value chain and increase productivity and quality of their produce. Adequate and strategic investments by governments as well as the private sector also help small holders to meet these requirements and increase their competitiveness.

Investments Required by Government and Private Sectors across Value Chains

The report on "Selected Value-chain Analysis for Adaptation to Climate Change and Recommendations regarding Change in Farm Management Practices to Minimize adverse effects of Climate Change in those Value Chains," submitted as a part of the current study, has documented the various climatic risks associated with the value chains and mitigation/adaptation strategies undertaken up by actors in the value chain. In the context of the value chains studies as a part of the aforementioned study, Table TN1 makes an attempt to summarize value chain-specific areas that require additional government or private sector investments so as to ensure that the value chain actors are supported in adaptation to climate change by reducing their vulnerability and making the overall value chain more efficient.

Table TN1: Value chain-specific areas that require additional investment

Value Chain	Areas Requiring Investment	Details of Investment Required
	• Crop-specific weather advisory systems	• The government should invest in setting up scientific weather advisory systems that provide timely location and crop-specific advisory services for farmers so as to increase their utility for farmers
Paddy	• Easy access to disease and weather resistant crop varieties • Impact on yield and quality • High input use and very strong dependence on water availability • Decentralized warehousing • Climate risk mitigation financial products • Easy access to value addition facilities/ infrastructure	• Support in research of crops resistant to pests/insects and easy availability of resistant and climate-resistant varieties • As the cost of hybrid seeds is very high, the government also needs to place more emphasis on development of heat- and drought-resistant crops and supplying it to farmers at subsidized or low costs • Paddy being a water dependent crop, one of the possible areas of intervention can be better water management systems. This requires interventions in creation of infrastructure as well training of farmers on water efficient agriculture such as SRI • During the study it was also realized that many warehouses are underutilized. The government may need to support construction of small and decentralized warehouses through appropriate policy initiatives • Another area of support required is in terms of better crop insurance products and assessment of losses due to flood and drought impacts • Timely and easy access to processing utilities can significantly reduce stress selling by farmers and can help in higher price realization if the government implements pay-per-use infrastructure facilities/ infrastructure/machinery or tie ups with private entities providing such services
Maize	• Decentralized warehousing • Setting up of dryer units • Easy access to disease and weather resistant crop varieties • Easy access to information and training on package of practices	• One of the biggest challenges faced by maize farmers is local availability of storage spaces ensuring the retention of quality of produce. The location of warehouses is also a challenge as farmers don't find it remunerative to carry their produce to far-off warehouses. Promoting micro warehouses/silos for storage may also help in reducing intermediaries in the supply chain and increase the overall efficiency of supply chain • Manual handling and poor storage infrastructure lead to an increase in moisture content of maize up to 20%, which should ideally be up to 13%. Maize with moisture levels of more than 15% is not considered suitable for the feed industry. This affects the farmers' share in the maize value chain. One of the areas of intervention can be to increase the establishment of dryer units near production locations. State governments may also plan to subsidize portable maize dryers • Agriculture research institutes also need to work on developing traits such as multiple insect resistance and herbicide tolerance in seeds being promoted so that use of chemical pesticides may be reduced. Most seeds used are already of a hybrid variety in maize and the choice of seeds is influenced by the seed shops/marketing agents from seed companies. Agriculture research and agriculture extension should work to ensure availability of such seeds to farmers • The government should invest in making its extension services accessible easily and on time for all farmers. Moreover, the extension delivery infrastructure should be well equipped to deliver such services.

Value Chain	Areas Requiring Investment	Details of Investment Required
Wheat	• Setting up of micro-warehouses • Contract milling	• The location of warehouses is an important factor affecting crop storage. The small or marginal producer with meagre marketable surplus will not find it convenient to carry his produce all the way from his farm to the warehousing point. During the study, it was also realized that many warehouses are underutilized. The government may need to support construction of small and decentralized warehouses • Many millers reported that they were unable to run their units at full capacity due to low local demand. The government should encourage contract milling in the districts. Millers will benefit due to assured processing volumes, low investment in procurement of wheat and marketing of finished products while large companies will pay low transportation cost and localized quality of flour which will increase their market share
Potato	• Decentralized cold storages • Promotion of contract farming • Easy access to disease and weather resistant crop varieties	• Small and marginal farmers don't find it cost-effective to use cold storage facilities due to transportation /fixed storage charges. These facilities are more concentrated in urban areasand operate at very high scale. These factors create problems of access and discourage small and marginal farmers. The government can encourage decentralization of these facilities for their better utilization by encouraging investment in creation of small cold storage units • Improved coordination and deeper integration, across the existing supply chain will be the key to processors mitigating climate change impact. Key steps would likely include implementing successful models of contract farming between processers (as well as traders) and farmers, integrating inputs and technical services to improve farming practices and marketing. • As hybrid seeds are expensive, the government also needs to place more emphasis on the development of heat- and drought-resistant crops and supply them to farmers at subsidized or low rates
Tomato	• Easy access to disease and weather resistant crop varieties • Decentralized cold storages	• Agriculture research companies and seed companies need to be encouraged to develop locally adaptable varieties that meet the quality requirements of the processing industry in India. Varieties need to be developed that have resistance against disease, tolerance against heat, and attractive size and colour which makes them suitable for processing • Small and marginal farmers don't find it cost-effective to pay transportation/fixed storage charges for cold storage. Moreover, the existing cold storages primarily cater to the storage of potato and are not well-suited for tomatoes or other vegetables which require a very specific controlled environment for enhancing shelf life without compromising on the quality parameters. Governments should invest heavily in setting up of decentralized storage facilities locally or ecourage the private sector in doing so by providing incentives/tax cuts

12 Project Proposal

Implement Adaptation of Farm and Allied Management Practices for Adaptation to Climate Change **Bihar**

1. Context

1.1 Project Context

Climate change is increasingly seen as one of the major threats to food security and sustainability of agriculture. Its impact on agriculture could result in threatening the livelihoods of a large number of households that are dependent on agriculture and allied activities. Agricultural productivity is affected by climate change in two ways: first, directly, due to changes in temperature, precipitation and/or CO^2 levels and second, indirectly, through changes in soil, distribution and frequency of infestation by pests, insects, diseases or weeds.

Climate change symptoms such as water deficit conditions combined with thermal stress could adversely affect the productivity of important food crops like wheat and rice. Climate change can affect crop yields and, in extreme cases, the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation as well as the prevalence of pests.

IARI examined the vulnerability of agricultural production to climate change, with the objective of determining differences in climate change impacts on agriculture by region and by crops. The study found that increases in temperature (by about 2^0C) reduced potential grain yields in most places. Climate change is also predicted to lead to boundary changes in areas suitable for growing certain crops. Reductions in yields as a result of climate change are predicted to be more pronounced for rain-fed crops (as opposed to irrigated crops) and under limited water supply situations because there are no coping mechanisms for rainfall variability. In sub-tropical environments, the decrease in potential wheat yields ranged from 1.5 to 5.8 percent while, in tropical areas, the decrease was relatively higher, suggesting that warmer regions can expect greater crop losses. Overall, temperature increases are predicted to reduce rice yields. An increase of 2-4^0C is predicted to result in a reduction in yields. Eastern regions are predicted to be most impacted by increased temperatures and decreased radiation, resulting in relatively fewer grains and shorter grain-filling durations[46].

In a reply to the Committee of Estimates headed by Mr. Murli Manohar Joshi on the impact of climate change on the agriculture sector, the Ministry of Agriculture's note had said that small farmers, who own less than 4 ha of farm land, may not be able to support their families with agriculture income alone due to the impact of climate change[47]. The Ministry note also mentioned that crops such as wheat, paddy, maize, potato, cotton, sorghum, mustard and coconut were likely to be badly affected by climate change. It informed the parliamentary committee that production of wheat would decline by 6 to 23 percent by 2050 if proper steps were not taken in a timely manner. The production of wheat could reduce by 6,000 kg for every 1°C rise in temperature[48]. In its note, the Ministry has suggested that adjusting to various measures, including time of sowing, suitable variety, fertilizers and irrigation, is likely to help in tackling the problem to a certain extent.

Climate change has about 4-9 percent impact on agriculture each year. As agriculture contributes 15 percent to India's GDP, climate change presumably causes noticeable loss in GDP. Crops such as rice, wheat, maize and sorghum are the worst hit by this phenomenon. By 2030, rice and wheat are likely to see about 6-10 per cent decrease in yields. Kharif crops will be affected more by rainfall variability and rabi crops by minimum temperature. Wheat is likely to be negatively impacted in the rabi season due to terminal heat stress with a 1°C rise in temperature resulting in loss of 4 MT of wheat[49].

46 Key sheet 6 Climate Change Impacts on Agriculture in India, The Indian Agricultural Research Institute http://www.indiaenvironmentportal.org.in/files/Defra-india-cc-agri.pdf
47 https://www.dailypioneer.com/2018/page1/climate-change-threatens-kisan.html``
48 https://krishijagran.com/news/climate-change-affecting-agriculture-wheat-production-in-india-could-drop-by-23-agri-ministry/
49 https://www.downtoearth.org.in/news/agriculture/climate-change-causes-about-1-5-per-cent-loss-in-india-s-gdp-57883

Several studies have been done over the years to observe the changing scenarios in agricultural productivity and impact on crop yield. The findings of a few such studies as Zhang et al. (2016), Ahlawat & Kaur (2015), Nube et al. (2015), Ahmad et al. (2014), Koshal (2014), Mishra & Sahu (2014), Gupta et al. (2012), Siddiqui et al. (2012) and Sanghi & Mendelsohn (2008) discussed various dimensions of the impact of climate change on agriculture productivity. Their findings, in general are similar, as almost all of them concluded that climate change variables (temperature and rainfall) have an adverse impact on agriculture crop yield[50].

In India, studies have illustrated the inverse relationship between climate change and agricultural productivity (Saseendran, Singh et al. 2000; Aggarwal and Mall 2002). An increase in temperature, depending upon the current ambient temperature, can reduce crop duration (Challinor and Wheeler 2007; Zhang et al., 2007), increase crop respiration rates, alter photosynthate partitioning to economic products (Albrizio and Steduto 2003; Wahid et al., 2007). All of these can have a tremendous impact on agricultural production and hence food security of any region. Recent studies on the impacts of possible future climate over this region indicate spatio-temporal variations in impacts on rice and wheat crops in India (Naresh Kumar et al., 2011, 2013, 2014). The increased incidence of weather extremes such as onset of rainfall and duration and frequencies of drought and floods will also have major effects, and preliminary reports indicate that the recent declines in yields of rice and wheat in the region could have been partly due to changes in weather extremes (Aggarwal et al., 2004).

The poor and vulnerable households are more at risk of climate change as climate change affects all three aspects of food security: availability, access and absorption. Vulnerability to climate change is closely related to poverty, as the poor have fewer financial and technical resources.

Climate change can also have significant impact across the food processing industry due to its huge dependency on agriculture produce as a raw material. With weather becoming unpredictable, it becomes difficult to foresee industry needs. As climate change and agriculture produce are directly related to the cost of production, any risk involved in acquiring agriculture produce will have serious implications on profitability and sustainability of food-based enterprises. Apart from the growers, actors involved in aggregation and collection, transportation and storage and food processors are considered the value chain actors who add value through different sets of activities.

Change in climate in the medium to long term will affect the soil moisture, groundwater recharge, and frequency of flood or drought, and finally groundwater level in different areas. The effect of climate change will impact the water cycle. Higher temperatures and changing precipitation patterns will severely affect the production patterns of different crops. Agricultural productivity will also be affected due to increased carbon dioxide in the atmosphere. All these changes will increase the vulnerability of the landless and the poor[51].

Climate change impacts will occur at all levels of the value chain and individual adaptive responses at each level will either enhance or reduce overall performance in terms of efficiency, continuity and product attributes. Climate change is, thereby, set to cause huge economic, social and environmental damage across the region, compromising growth potential and poverty-reduction efforts. Climate change affects agricultural activities and value chains in two ways. First, in order to sustain their value addition activities, value chain actors must adapt to changing conditions by means of incremental changes to their value addition systems by using additional resources. Secondly, climate change may alter production capabilities more deeply by making contemporary economic structures obsolete in a new environment. These changes will affect economic opportunities, profitability and competitiveness, livelihoods, sources of growth and employment and socio-economic outcomes.

The state government of Bihar acknowledges that climate change is one of the major challenges of agriculture in the state, and its overall strategy is to transform agriculture and its allied sectors into climate-resilient and vibrant production systems while developing their full potential and ensuring sustained food and nutritional security.

1.2 Location Context

IGP is very crucial from the point of production of major food grain crops. Owing to presence of fertile soil, the region carries the burden of a large population and is also popular for production of specially rice and wheat along with other crops. Characterized by favourable climate, fertile soils and abundant water supply, IGP is seen as the "bread basket" of South Asia, providing food and livelihood security for hundreds of millions of its inhabitants[52]. It is also known as

50 Kumar, Anuj, 2018. Economic Analysis of the Impact, Adaptation and Mitigation of Climate Change in the Dominant Cropping System of Indo-Gangetic Plains of India.

51 Kumar and Gautam, 2014. Climate Change and its impact on Agricultural Productivity, *India J Climatol Weather Forecasting,* 2:1.

52 Erenstein, Olaf, 2010. A comparative analysis of rice–wheat systems in Indian Haryana and Pakistan Punjab, *Land Use Policy* Vol.27 Issue 3 pages 869-879.

India's "bowl of food grains" because it contributes 48.4 percent of rice and 74.7 percent of wheat of India's total production of these two major food grain crops.

Most areas of these plains have two crops in a year. In some areas, three crops are produced in a year. Wheat, potato and mustard are the major crops of spring (rabi) season and paddy is grown in autumn (kharif) season[53]. The climatic trends of IGP show that the temperature of this region is increasing year by year. As per the weather trend variability analysis done for the IGP region, the average temperature of this region has increased by 0.2°C per decade from the year 1960. The range of possible temperature increase for IGP is 0.6–2.7°C, 0.5–3.1°C and 1.0–5.4°C above the 1070-1999 mean for the 2030s, 2050s and 2090s, respectively. In general, temperatures in the monsoon period increase less than in the dry seasons[54]. Research indicates that though the average precipitation of the plains is static, the timing of precipitation is changing[55].

A study was conducted by the Centre for Environment Science and Climate Resilient Agriculture on an assessment of impacts on rice and wheat in IGP[56] using climatic data as per the PRECIS regional climate model developed by the Hadley Centre, United Kingdom, in nine representative locations of IGP. The study suggested occurrence of extreme temperature events which could cause yield reduction particularly if these events coincide with sensitive stages of crop growth. Apart from differential growth and yield responses of crop species to high thermal stress, the study also suggested differential responses to high temperature stress during various growth phases[57]. The results indicated that an increase in temperatures adversely influences crop performance and these negative impacts of temperature are not compensated enough by elevated CO_2 concentrations as is evident from a reduction in the overall projected yields. Results also project occurrence of low yielding years more frequently due to climate change.

IGP is an environmentally sensitive, socially significant and economically strategic domain of India where landscape, hydrology and fertility are threatened by climate warming and anthropogenic pressure. A decline in food production will be a major problem. In order to make assessments of the environmental changes, concerted efforts should be initiated to understand the geological past and model the future[58]. A rise in temperature by a mere 2^0C can lead to a fall in farm production between 4 and 34 percent (IPCC, 2007)[59]. Soil salinity, already prevalent in the plains of Haryana, Punjab and western Uttar Pradesh, is bound to extend over the marginally saline areas, reducing the availability of agricultural land. This will bear additional stress on the already declining water table. Groundwater exploitation is likely to be intensified and, consequently, water stressed areas will become water scarce. According to another study on the current scenario of the rice-wheat system in IGP, a good correlation is indicated between rainfall and rice yield as per statistical and remote sensing data analysis. The study findings mention that the current scenario of climate changes, i.e., global warming, rising of temperature, irregular pattern of rainfall, excess use of fertilizers and irregular pattern of irrigation, significantly contribute to the decline in fertility of lands[60]. The risk of climate change on agriculture is very significant in IGP due to its high dependency on rainfall and its connections to the tectonics and climate of the Himalaya. Thus, any change in these factors will have an adverse effect on the hydrology, soil fertility, food production and settlement pattern of IGP. Incidences of pest and disease would be most severe in tropical regions due to favourable climate/weather conditions, multiple cropping and availability of alternate pests throughout the year. Climate change is likely to cause the spread of tropical and subtropical weed species into temperate areas and to increase the numbers of many temperate weed species currently limited by low temperature at high latitudes.

1.3 State and Sectoral Context

Demography: Bihar, with a population of approximately 104 million, is one of the most densely populated states of India. More than 80 percent of the population lives in rural areas and is predominantly dependent on agriculture and allied sectors. The state is 12th largest in terms

53 Koshal , A. K.,2014. Changing Current Scenario of Rice-Wheat System in Indo-Gangetic Plains Region of India. *International Journal of Scientific and Research Publications,* (4) (3)

54 New, M., Rahiz, M., and Karmacharya, J., 2012. Climate Change in Indo-Gangetic Agriculture: Recent Trends, Current Projections, Crop-Climate Suitability and Prospects for Improved Climate Model Information. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

55 Kumar, Anuj, 2018. Economic Analysis of the Impact, Adaptation and Mitigation of Climate Change in the Dominant Cropping System of Indo-Gangetic Plains of India.

56 Zacharias, Manju, Kumar, S. Naresh, Singh, S.D., Swaroopa Rani, D.N. and Aggarwal, P.K., June 2014. Assessment of impacts of climate change on rice and wheat in the Indo-Gangetic plains, *Journal of Agrometeorology* 16 (1) : 9-17,

57 Cheng, W., Sakai, H., Yagi, K., and Hasegawa, T.,2009. Interactions of elevated [CO2] and night temperature on rice growth and yield. *Agril. For. Meteorol.,* 149(1): 51-58.

58 Saini, H.S., 2008. Climate Change and its Future Impact on the Indo Gangetic Plain (IGP), e-Journal *Earth Science India,* Vol. I (III), 2008, pp. 138-147.

59 Inter-Governmental Panel on Climate Change (IPCC), 2007. Fourth assessment Report.

60 Koshal , A. K., 2014. Changing Current Scenario of Rice-Wheat System in Indo-Gangetic Plains Region of India, *International Journal of Scientific and Research Publications,* (4) (3).

of geographical area and third in terms of population in India. It has 38 districts, 534 blocks and 39,073 villages (census 2011). The sex ratio is 935 females per 1,000 males with a population density of 1,106 and total literacy rate of 63.82 percent (73.39 percent for males and 53.33 percent for females).

Economy: The economy of Bihar is presently on a continuous growth path and, according to the new series of data, on the state's GDP, the growth rate of its economy in 2017-18 was 11.3 percent. In 2017-18, the agriculture, manufacturing and services sectors contributed 23 percent, 15 percent and 62 percent, respectively, to the state gross value added tax. The per capita GDP of Bihar in 2017-18 (at current prices) was INR 42,242. This is 12.7 percent higher than the figure for 2016-17 (INR 37,478).

Agro Climatic Profile: The climate of Bihar is sub-tropical with peak summer temperatures averaging around 40^0C during March-May and around 8^0C in winter months during December-January. The river Ganges divides Bihar into two parts. Northern Bihar receives water from the Himalayan rivers and is largely flood prone while the south of Bihar benefits from the rivers of central India but it is prone to drought.

Figure PP1: Year-wise total rainfall of Bihar (in mm)

The northern districts receive more rainfall, on an average, from the south-west monsoons during June-September. As a result, the southern districts of Bihar experience poorer groundwater levels making them drought prone, while the northern districts suffer from extreme flood and waterlogging. Along with the huge geographical variability in the rainfall, the state also faces extreme variability in terms of total rainfall received in the state. It received an annual rainfall of around 1,000 mm during 2001-2017. Of this, 84.9 percent of rainfall was largely due to the south-west monsoons, occurring during the period of June to September. Winter rain, hot weather rain and north-west monsoons together accounted for the remaining 15.1 percent of the total rainfall in the state. During 2018, the annual rainfall received due to the south-west monsoons was 689.6 mm, which was about 20 percent less than the long run average rainfall of 848.2 mm. For the year 2019, Bihar received 3 percent more rains from the south-west monsoons than the long-term average.

The total geographical area of the state is 9.36 million ha, which falls under three distinct agro-climatic zones, namely North-West, North-East and South. The North-West zone comprises 13 districts. This zone receives an annual rainfall of 1,040-1,450 mm, and the soil here is mostly loam or sandy loam. The North-East zone has eight districts and it receives rainfall ranging from 1,200-1,700 mm. The soil here is loam or clay loam and the South zone, having 17 districts, receives an average annual rainfall of 990-1,300 mm and the soil is sandy loam, loam, clay and clay loam.

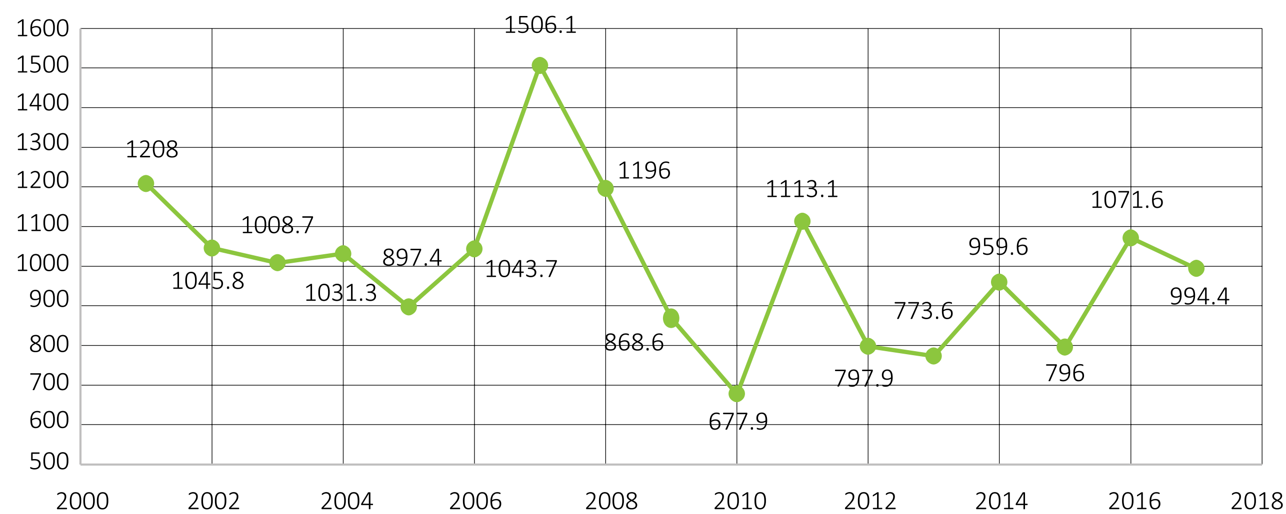


Table PP1: Agro-climatic profile of the state

Zones	Soil Type	Mean Rainfall (mm)	Temperature Range ^{o}C	Districts
North West Alluvial Plain	Medium acidic, heavy textured, sandy loam to clay loam, flood prone	1,235	Max: 36.6 Min: 7.7	West Champaran, East Champaran, Siwan, Saran, Sitamarhi, Sheohar, Muzaffarpur, Vaishali, Madhubani, Darbhanga, Samastipur, Gopalganj, Begusarai
North East Alluvial Plain	Light to medium textured, slightly acidic, sandy to silty loam	1,382	Max: 33.8 Min: 8.8	Purnea, Katihar, Saharsa, Supaul, Madhepura, Khagaria, Araria, Kishanganj
South Bihar Alluvial Plain	Alluvial to sandy loam	1,102	Max: 37.1 Min: 7.8	Sheikhpura, Munger, Jamui, Lakhisarai, Bhagalpur, Banka, Rohtas, Bhojpur, Buxar, Bhabhua, Arwal, Patna, Nalanda, Nawada, Jehanabad, Aurangabad, Gaya

Bihar is one of the most climate-sensitive states in India due to its geographical setting, hydro-meteorological uncertainties, dense rural population and high level of poverty.

Agriculture: Growth and sustainability of the agricultural sector is crucial for Bihar due to the contribution of agriculture in employment generation, poverty reduction and overall economy, which stems from substantial economic linkages which agriculture and allied sectors generate in the process of forward and backward linkages. Around 74 percent of the workforce depends on agricultural and allied activities for its livelihood (Census of India, 2011). Despite Bihar's economic growth which is quickly transitioning from agriculture towards the services sector, the agricultural sector contributes about 20 percent to the state's GDP. Significant progress has been achieved in the agriculture sector of the state. It received the Krishi Karman award from the Government of India for significant achievement in production of rice for the year 2012, in 2013 for wheat and for maize in 2016. Bihar has achieved record productivity for the crops of paddy and potato. Along with notable development in the agriculture and horticulture sectors, other allied sectors have also witnessed significant growth. The state has achieved a production of 8.7 million MT of milk, 1.11 billion egg, 0.326 million MT of meat and 0.506 million MT of fish production[61].

The state is also blessed with the rich natural resources of IGP which offer substantial opportunities for high agricultural productivity and crop diversification. Bihar's agricultural productivity has increased substantially in the last few years. The abundance of water and rich soil in the state has enabled this growth, along with diversification of agricultural produce in a variety of food and non-food crops. Increasing cereal crop productivity with use of improved technologies has been an important phenomenon in Bihar's agriculture in the recent years. Along with ensuring timely availability of seeds, nutrients, farm implements, credit, etc., are contributing to increasing the productivity of the crops grown while initiatives such as SRI, adoption of zero-tillage methods and continuous focus of the state government on irrigation facilities are contributing to increasing agricultural sustainability. The agriculture in Bihar is predominantly driven by small and marginal farmers who cultivate on small land holdings.

61 Bihar Agriculture Road Map III, 2017-2022.

Table PP2: Land holding details of Bihar

Category of Farmers	No. of Holdings	Percentage of Holdings	Operational Holding (In ha)	Area of Operational Holdings
Marginal (0-1 ha)	1,47,44,098	91.06	36,68,727.64	57.43
Small (1-2 ha)	9,48,016	5.85	11,85,695.24	18.56
Semi medium (2-4 ha)	4,14,664	2.56	10,72,969.00	16.80
Medium (4-10 ha)	81,484	0.50	4,14,941.12	6.50
Large (10-above ha)	3129	0.03	45,227.71	0.71
Total	1,61,91,391	100	63,87,560.71	100

Source: Agricultural Census (2010-11).

Bihar is primarily a cereal economy, with more than 85 percent of its gross cropped area under cereals. Food grains (cereals and pulses) together accounted for 93.7 percent of the gross cropped area in the state which has already achieved self-sufficiency in food grain production. Specific schemes for cultivation of pulses and oilseeds in rice fallow areas have been undertaken in the state. Pulses account for 6 to 7 percent of the cropping area while vegetables are being grown in around 10 to 12 percent of the cropping area. The total acreage under fruits was 0.309 million ha, producing a total output of 4.229 million tonnes during 2017-18[62].

The agricultural economy of Bihar is highly diversified with crops such as cereals which include paddy, wheat and maize, most varieties of pulses (urad, kulthi, arhar, gram, lentil, pea, moong, etc.), oilseeds (mustard, rapeseed, linseed, sunflower), sugarcane, potato, onion and a variety of fruits and other vegetables as its important crops. The prominence of horticulture crops which includes fruits and vegetables is increasing day-by-day and is becoming a major driver of agricultural growth especially due to their resilience against adverse weather conditions. Various plans and programmes have been outlined by the state government (Agriculture Roadmap III) (2017-22) towards achieving higher agricultural productivity and boosting rural incomes. However, the agricultural sector in Bihar is not bereft of risks and challenges, arising from both climatic and non-climatic factors. Factors such as low crop yield, fragmented land holdings, rainfall irregularities, heterogeneity in landscapes and information asymmetry continue to plague the growth of the agriculture sector.

Extension Services: Extension services in agriculture have a wide scope to focus on technology transfer and adoption, by enhancing the capacity of farmers through training, demonstrations, advisory services, etc. The state has already proactively established ATMAs and KVKs in different districts to ensure proper extension services. The government has also appointed subject matter specialists and ***Kisan Salahkars*** at the sub-block/block levels to provide proper support to farming households by facilitating activities such as exposure visits, farmer training and crop-specific demonstrations. Permanent posts of 4,391 agriculture coordinators have been created and a 24-hour toll-free number (1800-180-1551) is operational for first and second level advisory services to solve farmers' problems.

Agri-processing Value Chain: The state has undertaken various initiatives to increase the competitiveness of agriculture and allied sectors by encouraging development of agriculture infrastructure/facilities to increase farmer gains by encouraging the process of industrialization through an entrepreneur-friendly regime and an attractive package of incentives for entrepreneurs. The food processing sector has been provided the status of a "priority sector" under the Bihar State Industrial Policy, 2016 and many financial/non-financial incentives have been designed. In the last 10-12 years, significant progress has been achieved in the agri-processing and agri value chains. The state has developed a system of paddy procurement through PACS. During this period, more than 50 rural agri business centres have been established. Apart from more than 175 rice mills and 40 flour mills, maize processing units have been established. Along with that five dry warehouse-based rural agribusiness centres, 16 fruits and vegetables processing plants, nine milk processing plants, four ***makhana*** (fox-nut) processing plants, three honey processing plants, 12 biscuit production units, 10 edible oil mills, seven ice cream manufacturing

62 Bihar Economic Survey, 2018-19.

plants and 28 other food processing units were established in the state.

The state has huge raw material/production base for cereals (paddy, wheat and maize), vegetables (potato, brinjal and other green vegetables), fruits (mango, litchi, banana, guava, etc.) and livestock (cattle, poultry and fish). As of now the fruits and vegetables processing segment is marked by the absence of a cold chain, resulting in quality deterioration of raw materials. The products are stored in either minimum refrigeration or no refrigeration. Many processing units operate on work-order basis for the longer chain with limited scope for technology upgradation or expansion. Most rice mills are hullers and barely 5 percent of these mills may be considered as modern. There is a tremendous potential in maize processing, which needs to be exploited on a commercial basis. The potential of maize-based products are corn oil, poultry and animal feed, and high value products such as ethanol and extra neutral alcohols, given the high protein content of Bihar maize. The sugar industry is an important agro-based industry in Bihar. In Kishanganj, some small tea processing units are functional.

To provide marketing support to producers of commodities in the state, there are more than 100 agriculture markets which are located at district and sub-district/ block levels. The state has more than 400 food processing units (2015-16) of which about 278 were operational. Over two-thirds of the agro-based industries are engaged in processing of cereals. The state also has about 355 cold storage units with a capacity of 2.32 MMT[63]. The Central Warehousing Corporation, State Warehousing Corporation and individual entrepreneurs have contributed to the development of warehousing facilities which is more than 71.9 MMT.

Many small clusters have already been developed in the state which are being managed by micro and small processing units. For rice and rice-based products such as ***poha/murhi,*** small clusters have developed in the districts of Rohtas, Bhojpur, Kaimur, Patna, Purnea and Bhagalpur. Roller flourmill units are developing in Darbhanga, Patna, etc. In Hajipur and Muzaffarpur, biscuit manufacturing units of a large food company have been started. In the districts of Bhojpur and Rohtas, units of edible oil have been set up some time back. For spices and condiments, similar clusters have developed in the districts of Samastipur, Purnea and Patna. There is a very vibrant cluster of ***makhana*** which has developed in the districts of Darbhanga, Madhubani and Purnea. Honey-based clusters have developed in Gaya, Muzaffarpur and Vaishali. Nalanda, Samastipur, West/East Champaran districts have vibrant clusters of fresh fruits and vegetables.

In Purnea, Araria and Katihar, a very vibrant cluster of maize has developed. Jute-based industries are also developing in these districts. The number of functional co-operative societies has increased from 14.8 thousand in 2016-17 to 15.2 thousand in 2017-18. Marketing of dairy products by the Bihar State Milk Co-operative Federation Ltd. has improved immensely in the last few years. The number of retail outlets increased from 15.9 thousand in 2016-17 to 17.7 thousand in 2017-18[64]. The government is also supporting the setting up of Mega Food Parks in districts such as Nalanda, Vaishali, etc.

Climate change events will have a significant impact on the functioning of these industries/actors. As all these industries are dependent on agriculture for raw material supply, any impact on production/productivity/quality will have significant impacts on further value addition being done by these actors. They need to make changes in their production capabilities/process, etc., to mitigate the adverse impact of climate change. They may also need to continuously work on improving their linkages. At the macro level, climate change events/variabilities will affect the economic opportunities, sales/profitability, competitiveness, livelihoods, sources of growth and employment and socioeconomic outcomes of the state.

2. Project Description

2.1 Project Overview

The state recognizes that it has several existing vulnerabilities (ecological, economic, social and cultural), and that climate change is likely to exacerbate these further if they are not addressed adequately and holistically. It has articulated its climate concerns in an Approach Paper for the 12th Five Year Plan and, as such, is committed to fostering an integrated approach to inclusive, sustainable and climate resilient growth and development. The climate response strategy of Bihar has key elements such as accelerating inclusive economic growth, promoting sustainable development, securing and diversifying livelihoods, and safeguarding ecosystems. The overall motto of Bihar Action Plan of Climate Change is ‘Building Resilience through Development’.

The government’s vision will be achieved through pursuing: (a) a broad streaming of climate concerns into all aspects of development policy and implementation; (b) integrating low carbon and climate resilient

63 Investment Environment & Opportunities in Food Processing: Bihar, Ministry of Food Processing Industries, Government of India , November 2017, Confederation of Indian Industries (CII) and KPMG.
64 Economic Survey Bihar, 2018-19.

development models into its growth strategy; and (c) ensuring complementarity with and contributing to the national agenda on climate change. The Government of Bihar has also defined its priorities in the State Agriculture Roadmap, which aims to trigger processes of development in agriculture and allied sector. Bihar's Chief Minister, during the preparation of Agriculture on Road Map (III), has emphasized how the agriculture sector is becoming affected by the adverse impact of climate change and recurring erratic monsoons and floods.

The government has decided to focus on farmers rather than farms and, hence, the road map, with defined goals and time frames, provides a humanitarian dimension to agriculture. The focus will be holistic, and the interventions made under agriculture will cover all aspects of agriculture, from inputs to marketing of final products. Interventions suggested under the Agriculture Road Map have been categorized into four major groups: access, supply and quality of inputs; transfer of technology and extension; income generation schemes; and marketing of the produce. The interventions also cover seeds, horticulture planting materials, soil health management, crop protection (including for example, integrated pest management), farm mechanization, integrated farming models, soil and water conservation in rain fed areas, networks of mini weather stations, micro-irrigation, strategies for risk management, and many other programmes and activities.

This road map also included extension activities by taking cognizance of global challenges such as climate change, sustainable farming and quality production. The road map has also emphasized increasing knowledge about the agro-climatic zones and need-based techniques/ recommended practices.

It has emphasized specific adaptation and mitigation measures to reduce the risks of climate change. It has been emphasized that, to deal with the climate change, capacity building of the farmers, use of climate resilient agriculture, promotion of sustainability-based protected cultivation, identification and development of community-based smart villages, development of an EWS for short- and medium-range weather forecast, management of storage of agricultural production in light of climate risks as well as promotion of price augmentation for small holders and of other suitable technologies need to be adopted.
In the light of the changing weather pattern, adaptive and mitigation measures needs to be planned well in advance for the benefit of the farming community and to secure their livelihood. The road map has also emphasized a data-driven approach through collection, analysis and sharing of information regarding agriculture by the application of satellite-based remote sensing technology. Remote sensing and GIS techniques will be used extensively under the Krishi Road Map. The road map has continued its focus on value addition. It has placed emphasis on providing funding support (both loan/ subsidy) for the construction of grain warehouses in PACS by drawing support from NABARD/RKVY/State Plan, etc.

To reduce vulnerabilities, the road map also emphasizes the implementation of a crop insurance scheme. Emphasis has also been placed on support to construction of mills, vegetable processing unit and creation of basic infrastructure for the marketing of processed vegetables as part of the value-addition strategy.

It is under this backdrop that UNDP has conceptualized this Project on increasing the adaptive capacity of agriculture value chains with special focus on inclusion of small and marginal farmers from the seven districts from Koshi and Purnea divisions.

In support of the state government's focus on placing climate resilience at the core of agriculture growth and rural development in the state, the project's two-tier approach will ensure that initiatives promoted under the project reduce stakeholders' climate vulnerability (specifically their capacity to mitigate the impact of adverse climate events and/or to recover from climate disturbances) and contribute to increasing climate resilience in agriculture value chains as well as ensure that that smallholder farming remains a sustainable and viable livelihood option.

2.2 Project Development Objective

The project development objective will be "*to enhance climate-resilience and adaptability of agriculture value chains and smallholder farming systems in selected districts of bihar by increasing the adaptive capacity of all the stakeholders"*.

The project will be created around a comprehensive, multi-sector approach that will focus on building climate resilience in agriculture/value chain through capacity building and technical support to all stakeholders.
The project will try to address the twin objectives of enhancing climate resilience of the value chain as well increasing the productivity and income of small and marginal land holder farmers. It would focus on bringing transformational adaptations in the agriculture value chain through climate-smart technologies and practices at the farmer level.

Additionally, the project will also focus on increasing the adaptive capacity of other value chain actors by providing them technical support. It would focus on small holders (farmers up to 2.0 ha of farmland) as well as vulnerable populations whose livelihood is impacted by changing climate conditions and climatic uncertainties. Its key objectives will be:

i. To enhance the adaptive capacity of farmers through capacity building on improved and sustainable cropping patterns and agronomic practices;

ii. To enhance the adaptive capacity of farmers by ensuring effective and efficient backward and forward linkages;

iii. To improve the adaptive capacity of the smallholders by providing weather information and agro-advisory;

iv. To increase the adaptive capacity of value chain actors from the agriculture value chain to developing climate resilient value chains; and

v. To provide technical support to farmer organizations/collectives for their inclusion and active participation in the climate-resilient value chains.

2.3 Project Strategy

UNDP has commissioned a study to understand the impact of climate change on small holder farmers and value chain actors in the select value chains. The strategies for this project have been developed on the basis of key learnings that emanated from that study. The following key strategies will be adopted under the project:

1. The project will work with collectives, producer groups/producer companies/VOs/cluster federations which have been formed under different programmes. All existing FPOs/FPCs/SHGs/VOs/ Cluster Level Federations in the project area would be encouraged to participate to take forward the project. The project will ensure participation of community institutions in the planning, implementation and monitoring of the project activities;

2. The project will work in a partnership mode and will make best efforts to integrate all stakeholders. For implementation support, it will work closely with the State Rural Livelihoods Mission (SRLM)/JEEViKA and use the institutional platform developed under NRLM/ Bihar Transformative Development Project / Bihar Rural Livelihoods Promotion Society;

3. The project will work on development and promotion of climate-resilient cropping systems and practices with the objective of increasing the adaptability of small holder/marginal farmers. With this, the project will also make conscious efforts on farming households belonging to vulnerable groups such as Scheduled Caste (SC)/Scheduled Tribe (ST) households;

4. Development of farm-level advisories to improve adaptability. The advisory services will be customized as per local area weather forecast, cropping pattern, crop condition and status of natural resources such as land /water, etc.;

5. To increase adaptability of smallholder/marginal farmers through diversification of farming systems, livelihoods and incomes. The project will focus on diversifying the livelihood systems for the targeted households;

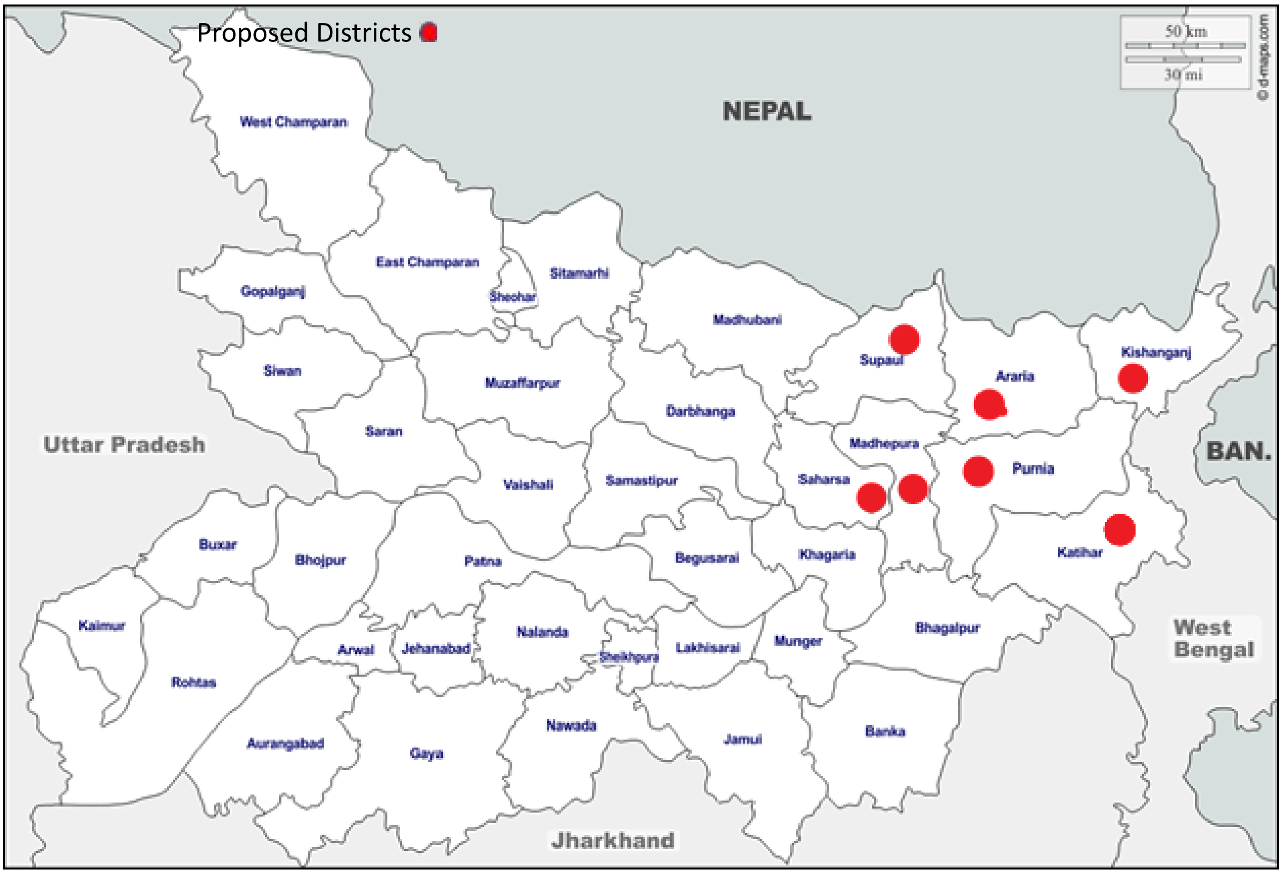
6. To work with agriculture research and agriculture extension agencies for development and promotion of drought/disease-tolerant seed varieties, climate-controlled farming structures and improved mechanization for farming households; and

7. The project will work with various value chain actors (traders/warehouses/processors, etc.) from select agri and allied value chains to make the entire ecosystem climate resilient. The objective will be to build climate resilience beyond the farm gate and provide end-to-end solutions. This will be achieved by planning comprehensive climate-sensitive interventions and investments to promote value addition and prevent losses in a select number of commodity chains by using farmers' collectives and by providing technical solutions for adopting climate-smart technologies and processes to strengthen the emerging value chains of field crops and horticultural crops.

2.4 Project Area

The project will cover minimum of 100,000 farming households. The districts proposed for intervention are from the two divisions of Purnea and Koshi and include Saharsa, Supaul, Madhepura, Purnea, Araria, Katihar and Kishanganj, the seven districts on the most vulnerable districts list realeased by NICRA. Purnea, Araria and Katihar are also part of the aspirational districts identified by NITI Aayog.

Figure PP2: A map of the districts where interventions are proposed



The districts selected are predominantly rural in nature with 93 percent of the households belonging to the rural category. In all districts more than 90 percent of the households are rural. About 15 percent of the population from these districts belong to the SC/ST category. The sex ratio for these districts in total is 921:1,000 (women:men) with a minimum of 906 is Saharsa and a maximum of 949 in Kishanganj district. The average literacy level is 43 percent with district-wise literacy percentage varying from 41 to 46 percent.

Table PP3: Demographic profile of the proposed districts

District	Number of Households	Percentage of Rural Households	Total Population	Percentage Rural Population	Total Population SC	Total Population ST	Percentage of SC/ST Population
Araria	568,142	94%	2,811,569	94%	382,654	38,848	15%
Katihar	619,076	91%	3,071,029	91%	263,100	179,971	14%
Kishanganj	338,445	91%	1,690,400	90%	113,118	64,224	10%
Madhepura	401,289	96%	2,001,762	96%	346,275	12,532	18%
Purnea	647,777	90%	3,264,619	89%	390,991	139,490	16%
Saharsa	368,979	92%	1,900,661	92%	317,249	6,009	17%
Supaul	443,073	95%	2,229,076	95%	354,249	10,168	16%
Total	3,386,781	93%	16,969,116	92%	2,167,636	451,242	15%

Source: Census 2011.

The proposed seven selected districts have a total of 80 blocks with the highest number of 16 blocks in Katihar and 14 blocks in Purnea while Kishanganj has only seven blocks. The total number of villages in these districts is 5,218.

Table PP4: Name and number of blocks in each district

District	Number of Blocks	Name of Blocks	Number of Villages
Araria	9	Araria, Bhargama, Forbesganj, Jokihat, Kursakanta, Narpatganj, Palasi, Raniganj and Sikti	716
Katihar	16	Amdabad, Azamnagar, Balrampur, Barari, Barsoi, Dandkhora, Falka, Hasanganj, Kadwa, Katihar, Korha, Kursela, Manihari, Mansahi, Pranpur and Sameli	1306
Kishanganj	7	Bahadurganj, Dighalbank, Kishanganj, Kochadhaman, Pothia, Terhagachh and Thakurganj,	732
Madhepura	13	Alamnagar, Bihariganj, Chausa, Ghailadh, Gamharia, Gualpara, Kumarkhand, Madhepura, Murliganj, Puraini, Shankarpur, Sigheshwarsthan and Uda Kishanganj	380
Purnea	14	Amour, Baisa, Baisi, Banmankhi, Barhara Kothi, Bhawanipur, Dagarua, Dhamdaha, Jalalgarh, Krityanandnagar, Kasba, Purnea, Rupouli and Srinagar	1113
Saharsa	10	Kahra, Sattar Katiya, Saur Bazar, Patarghat, Mahishi, Sonbarsa, Nauhatta, Salkhua, Banma Itahri, and Simri Bakhtiyarpur	445
Supaul	11	Nirmali, Marauna, Supaul, Kishanpur, Saraigarh, Pipra, Basantpur, Raghopur, Pratapganj, Trivenganj and Chhatapur	526
	80		**5218**

The project area consists of the alluvial plains of Kosi, Mahananda and its tributes and Ganga and is slightly undulating to rolling landscape mixed with long stretches of nearly flat landscape. Rainfall varies between 1,200 to 1,700 mm with an average of around 1,450 mm, with Kishanganj district having the maximum rainfall. The area is full of streams with abandoned dead channels of Kosi river, which has become notorious for its frequent and sudden change of courses, forming small lakes and shallow marshes.

The pH level of the soil is between 6.5 to 7.8 with a nitrogen availability of 150 to 300 kg per ha. Availability of phosphorus is 10-35 kg per ha while that of potash is 150 to 250 kg per ha. In the south, in between the natural levees of Ganga, on the one hand and Kosi and Mahananda, on the other, there are vast areas which remain waterlogged for a considerable part of the year. As both Kosi and Mahananda carry a tremendous load of sediments, the soil is mostly light textured except in the backwaters of rivers Ganga and Kosi. In three of the seven districts, there are functional agriculture college with Bihar Agriculture Universities. Apart from this, KVKs and ATMAs also undertake a wide range of extension activities.

2.5 Project Phasing

To tackle the challenges of climate change in a sector such as agriculture, especially in the context of small and marginal farming households, requires intensive application of human, knowledge and technological resources. To make the interventions sustainable it is also important to have an extensive focus on capacity building to increase the adaptability of small holder farmers and other participants in the value chain. As the challenge is also to include the small and marginal farming households into the ecosystem, it is prudent to implement the programme in a phased manner than spreading out everywhere in one go. The project, in the first year, will focus only on 10 blocks with about 25,000 households. This will also help in developing protypes which can be replicated at a much higher scale.

The selection of blocks will be done on vulnerability-related indicators. The blocks with maximum vulnerabilities will be prioritized first for intervention. Indicators shown in Table PP5 will be used to calculate the vulnerability score of the districts. Based on these indicators, all blocks for each of the districts will be ranked and the blocks with the maximum vulnerability score will be then taken up on priority; four to six blocks will be selected from each districts. The intervention will target 2,500 households per block form a total of 40 blocks from seven districts.

Table PP5: Indicators for prioritizing the blocks for intervention

Demographic Vulnerability	Climatic Vulnerability	Agricultural Vulnerability	Occupational Vulnerability
1. Density of population (persons per sq. km) 2. Literacy rate (percent)	1. Variance in annual rainfall 2. Variance in mean temperature 3. Maximum and minimum temperature	1. Productivity of major crops 2. Cropping intensity 3. Irrigation intensity 4. Livestock population, etc.	1. Total workers 2. Agricultural labourers 3. Cultivators

Table PP6: Project phasing

Year	Year 1	Year 2	Year 3	Year 4	Year 5
Cumulative number of blocks at end of the year	10	25	40	40	40
Number of households	25,000	62,500	1,00,000	1,00,000	1,00,000

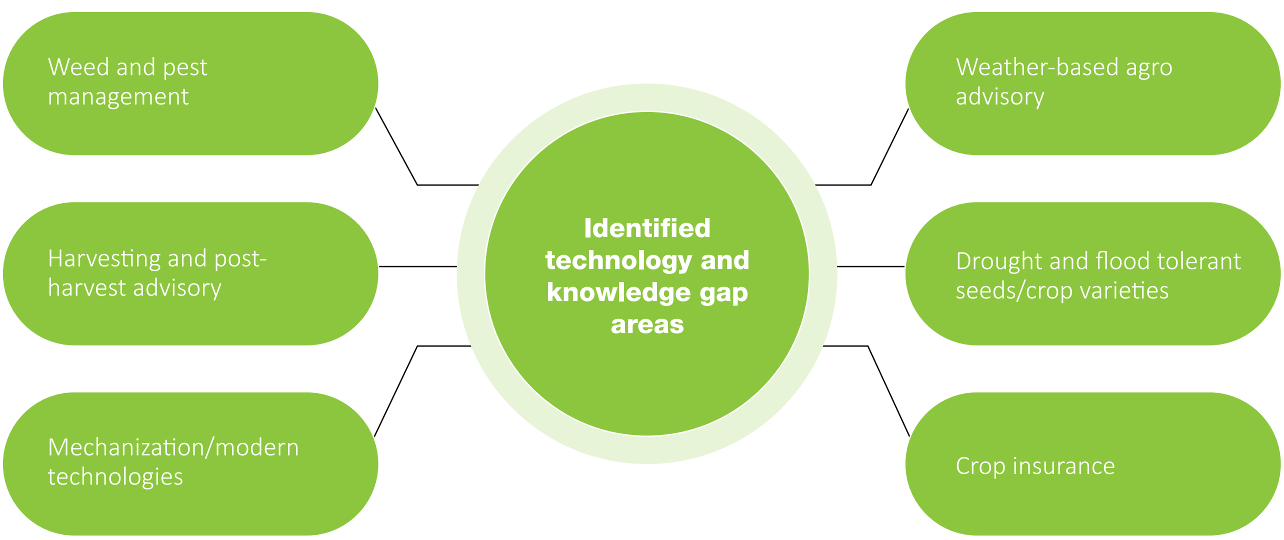
3. Project Components and Activities

Climate changes/variabilities are a recurring phenomenon faced by farmers in the IGP regions; farmers have not been successful in undertaking proactive measures in a sustainable manner due to access- and awareness-related constrains for interventions such as weather and crop advisory, insurance, safe storage and post-harvest management. Farming households adopt reactive measures to ease the immediate impact of climate change/ variability with low emphasis on climate resilience.

Farmers' adaptation levels are closely interlinked with the knowledge and awareness levels of the farmers, perception of climate change impacts on their cropping system, and their access to resources which help them to prepare their coping strategy.

Perceptions of farmers about climate change strongly affect how effectively they deal with climate-induced risks and uncertainties and undertake measures to mitigate the adverse impact of climate change on agriculture. To increase the adaptive capacity of

Figure PP3: Technology and knowledge gap areas identified



the farming households, the first step is to increase awareness levels of farmers through capacity building so that they can develop the right perspectives about climate change. This needs to be followed up by increasing their access to effective and locally-relevant adaptation approaches which have been customized as per the technical and financial capabilities of the targeted households. The commissioned study by UNDP has identified some of the gaps area which requires interventions to mitigate the impact of climate change.

Table PP7: Gaps and key areas of interventions

Themes	Key Areas of Interventions
Production and productivity	Varietal knowledge which includes awareness on flood and drought resistant/tolerant varieties, staggered cropping planning, the shift in sowing/transplantation and harvesting dates, community nurseries, weed and pest management, intercropping and crop rotation, etc.
Harvesting, post-harvest and value chain	Grain maturity and harvesting, drying, in-house storage, moisture management, orientation on commercial warehouse functioning, transportation, cold storage, seasonal fluctuation of prices, shelf-life management, etc.
Sustainability enhancing	Nutrient management, soil moisture management, water management, rainwater conservation, natural farming, system of crop intensification, agriculture residue disposal (stubble burning), etc.
Financial linkage, insurance and leveraging government support	Crop insurance, farm credit, warehouse financing, agriculture credit (KCC), community institutions (SHGs and Federations, FPOs, FPCs, micro financial institutions, PACS, credit cooperatives, NABARD schemes, etc.
Technological/mechanization	Usage of commercial driers, moisture management, combine threshers and other implements, custom hiring centre concepts, etc.
Weather and climate	Crop advisory, weather advisory, and predictions, other sources of weather-related information (mass media, print media), etc.

Based on the assessment of gaps and challenges with respect to climate changes, three critical areas have been identified for interventions. The project will have primarily three components:

- **Component 1:** Promotion of a climate resilient agriculture system;
- **Component 2:** Development of a climate smart value chain/post-harvest system; and
- **Component 3:** Knowledge, technology and institutional development.

3.1 Component 1: Promotion of a Climate Resilient Agriculture System

The objective of this component is to strengthen the adaptive capacity of small holder farmers to adjust and modify their production systems to moderate potential future impacts from climate events. The component will focus on building climate-resilience in agricultural production systems through a series of activities at the farm level. This component will focus on increasing varietal knowledge which will include awareness on flood and drought resistant/tolerant varieties, staggered cropping planning, shift in sowing/transplantation and harvesting dates, community nurseries, weed and pest management, intercropping and crop rotation, etc.

Awareness on sustainable agricultural practices such as nutrient management, soil moisture management, water management, rainwater conservation, natural farming, system of crop intensification, agriculture residue disposal (stubble burning), etc., will be the themes around which the component would try to focus its interventions.

- This component will focus on supporting the transfer and adoption of CSA technologies by small holder farmers, integrated pest and field management related practices aimed at enhancing farm productivity in the high climate variability context;
- The component will work on development and promotion of drought/flood-tolerant crop varieties for different crops and on crop substitution and livelihood diversification. The project will focus on field crops as well on horticulture crops. To bring sustainability to the interventions, this component will also focus on management of natural resources

such as water and soil through adoption of better packages of practices;

- This component will support the transfer and adoption of CSA practices by smallholder farmers through capacity building initiatives such as on-farm demonstrations which may be undertaken through a farmer field school approach. Key themes for capacity building are varietal knowledge, etc. This component will promote protected cultivation to address micro-climate variability by: (a) introducing shade-net houses; (b) poly-houses; and (c) poly tunnels in select crops along with micro-irrigation system. SRLM has already developed such architecture as well as a pool of trainers who can be mobilized for such purposes (Village Resource Person, Master Resource Person and Livelihood Specialists). These training centres/farm schools will provide the vital link between the farmers and the knowledge resources. KVKs and State Agriculture Universities will also be requested for support. Knowledge of farmers will also be upgraded through training at district/state levels and exposure visits, etc. While selecting the trainee farmers, preference will be given to small and marginal farmers and households from vulnerable communities. Knowledge and skills of trainers would be upgraded on a continuous basis through training. To streamline these activities a strategic Partner Management Committee will be developed at both state and district levels;

- The livelihood diversification strategy is a set of activities undertaken by households to find new ways to raise incomes and reduce their risks and vulnerabilities. Households adopt diversification to construct a diverse range of livelihood portfolios, either in expectation of increasing their income or in anticipation of some expected risks/unforeseen loss. This component will make diversification of livelihood a key intervention theme and will start with change in produce/commodities which will be the natural starting point. The next stage will be diversification in the context of integration with new livelihood activities which is based on their previous activities;

- Capacity building areas will focus on factors such as agro-climatic conditions, market context as well on household asset base which comprises of natural capital, physical capital, human capital, social capital, and financial capital[65]. These assets form the basis for households' choices of livelihood strategies, including agricultural practices, which in turn influence their food security status and level of well-being. These assets are interlinked and influence critical factors which include existing livelihood choices, adaptive capabilities and the choice of future diversification options; and

- The project will increase awareness of farmers on crop/weather insurance and will work towards improving the access of households to such products with the objective of risk mitigation. This will reduce the vulnerabilities of small and marginal farming households and help them to protect their existing livelihoods as well enable them to pursue riskier but potentially more profitable farming strategies.

3.2 Component 2: Development of a Climate Smart Value Chain/Post-harvest System

This component will build on promoting practices and technologies in post-harvest management and value-addition that support climate adaptation and/or mitigation for all value chain actors. Apart from farmers, other value chain partners such as traders, aggregators, processors, warehouse owners, cold storage and cold chain owners, etc., will also an integral part of the interventions made under this component. In addition to this existing pool of FPCs, FPOs will also be a major driver in increasing the adaptability of value chain actors in the select value chains. The component will develop the absorptive capacity of stakeholders in selected commodity value chains to prepare for and help recover from negative impacts of climate events. The component supports activities that enhance climate resilience beyond the farm gate and provides end-to-end solutions in value chains for agricultural commodities selected for their contribution to climate-resilient agri value chains.

This component will provide technical support to value chain actors to develop/upgrade/procure new systems and processes to mitigate the impact of value chains. It is important as gains for small and marginal farmers are interlinked with the sustainability of the value chain which revolves around the critical issue of financial viability of the value chain actors and sharing of gains with farmers. The following key features of the intervention are proposed under this component:

- For climate smart post-harvest management, it is important to start action immediately after the harvesting of the crops. The Project will focus on developing the capacity of collectives such as SHGs/VOs/FPOs on establishing infrastructure for drying and aggregation centres. These centres would also need to have facilities of elementary packaging. In addition to collectives, the project will also focus on capacity building of private players to participate

65 Adapted from DFID Livelihood Framework.

in such activities. The aggregation centres shall provide facilities to the farmers for sorting, grading, weighing and proper packaging of their farm produce. FPCs and other community collectives shall be encouraged to establish aggregation centres with sorting, grading, weighing and packaging facilities. Existing FPOs shall be strengthened and encouraged to actively participate in the value chain. Under this component, both FPOs and individual entrepreneurs will be supported in activities such as preparation of bankable proposals, establishing linkages with business development service providers, etc.;

- Storage management is an important link in the agriculture value chain as any adverse impact of quality of grains affects the functioning of all value chain actors including the end consumer. The location of existing warehouses/cold storages is such that small farmers do not find it cost-effective to store their crop due to high transactional costs involved in transportation and other activities. In case of cold storages, most are only suitable for storage of potato. The project will support existing grain warehouses in capacity optimization/ upgradation as well as construction of new warehouses/cold storages in the project area where such structures are not available for storage of agri produce with appropriate treatment. Along with private entrepreneurs, the project will also support FPCs and other community institutions in the establishment of godowns/warehouses. The focus will be on the development of micro warehouses and cold storages which need to be constructed at the block level. The long-term objective of this intervention is that farmers should have a proper storage/cold storage facility in less than 10 kilometres from their location;

- This component will also work for the establishment/ upgradation of primary processing units such as rice mills, roller/*chakki* flourmills, oil expellers/vegetable- and fruit-based primary processing units, etc., with private entrepreneurs as well with FPOs. The project will support existing processors to upgrade their plants and machineries to mitigate the impact of climate change. They will be supported through technical know-how as well in establishing linkages with service providers. The project will also facilitate the establishment of new units in the project area for value addition of the farm produce which shall help farmers in fetching better prices, longer shelf life and better marketability of their farm output. FPCs and interested community collectives shall be encouraged to establish primary processing units. Under this component, both FPOs and individual entrepreneurs will be supported in activities such as preparation of bankable proposals, establishing linkages with business development service providers, etc.;

- Capacity building of farmers and farmer collectives will be an important activity under this component. Individual farmers as well members/board and functionaries of collectives will be provided regular training on grain maturity and harvesting, drying, in-house storage, moisture management, orientation on commercial warehouse functioning, transportation, cold storage, seasonal fluctuation of prices, shelf-life management, etc. For strengthening linkages with the market, farmers will also be trained on assessing the volume and type of agri-commodities to be available for sale in different months, identifying potential buyers (wholesaler / processor/ industrial or corporate buyers hotels, etc.), appraising potential buyers on the availability status of agri commodities in the project areas and completing the contract/agreement process; and

- Apart from forward linkages, this component will also focus on developing backward linkages for the farmers especially with respect to availability of climate-resilient quality seeds and other inputs to the farmers/farmer groups on time. Climate-resilient varieties of major crops are one of the most important interventions intended to build resilience to changing climate and climate variabilities. Without improving the seed supply chain, the adaptation to climate variability and drought will be challenging. The project will support the creation of seed hubs linking FPOs, agriculture research and extension agencies and private and public sector players.

3.3 Component 3: Knowledge, Technology and Institutional Development

The objective of this component is to ensure adoption of the approach proposed for building climate resilience through a longer-term adaptive management of agriculture and other related natural resources such as soil and water. This component will make an effort to enhance the transformative capacity of institutions and all the stakeholders through knowledge, technology and policy-related interventions. This component will also focus on supporting farmers through the development of cutting-edge technological platform for weather/ climate information and related agro advisory. It will focus on the development of knowledge, tools, models and policies that are workable on the ground and scalable for resilience. This component will also focus on empowering stakeholders, enabling learning and creating ownership of various interventions under this project.

Figure PP4: Interventions planned under component 3

Climate Smart Farm Technologies

- Drought/flood tolerant varieties
- Soil & water conservation technologies
- Pest/weed management
- Post harvest measures

Climate Information Services

- Information on
  - Length of cropping season
  - Start and end of rains
  - Dry spells
- Mobile services for farmers

Dissemination at GP Level

- Community based organization
- Decision makers from
  - Traditional authorities
  - Opinion leaders
  - Agro-input leaders

Institutions and Knowledge

- Extension workers
- Farmer based organizations
- Researchers
- KVK, agriculture college/universities

- The project will adopt a climate risk management approach for smart systems development. It will use climate, local conditions data, soil and farming data, etc., to develop this system. This information, communication and technology system would plan to cover a broad range of potential actions, including early response systems and crop advisory, strategic diversification and capacity building of all stakeholders. The proposed approach is of immediate relevance to small and marginal farmers, because it plans to focus on coordinated resource with active engagement of all key stakeholders including farmers, agricultural support agencies, agriculture and rural services providers, rural and agricultural institutions.

  All subsystems under the proposed platform will be designed and deployed to allow multichannel access (web, mobile, interactive voice response, etc). The designed system will utilize SMAC (Social, Mobile, Analytic and Cloud) technologies coupled with Internet of Things for real-time collection, analysis and dissemination of data and information to all stakeholders (suppliers as well as users) of the project;

- Weather and localized crop advisory will be the most important activity under this component. It will focus on collecting, processing and managing agro-meteorological data and issuing agro advisories using the IT system and farmer feedback. This component will also make efforts to enhance the local capacity for community-level pest and disease surveillance. To that effect, the project will work closely with private service providers/state agriculture universities and IMD;

- The development of systems aimed at real time contingency measures by analyzing weather and climate data/trends will be an important activity under this component. Crops with narrow sowing windows or where transplantation of seedlings is required are affected if there is a delay in monsoon. Breaks in the monsoon cause prolonged dry spells and are responsible for early, mid, and terminal droughts. These aberrant situations often lead to poor crop performance and/or total crop failures. While early season droughts have to be combated with operations such gap filling and re-sowing, mid and late season droughts have to be managed with appropriate contingency measures related to crop, soil nutrient management and moisture conservation. Contingency measures which may be implemented based on real time weather patterns will be promoted as real time contingency measures;

- Activities under this component will also include building the capacity of FPOs which include FPCs, producer groups, VOs and cluster federations with a focus on nurturing producer organizations as a climate-resilient, growth-oriented agri-business enter-prises; and

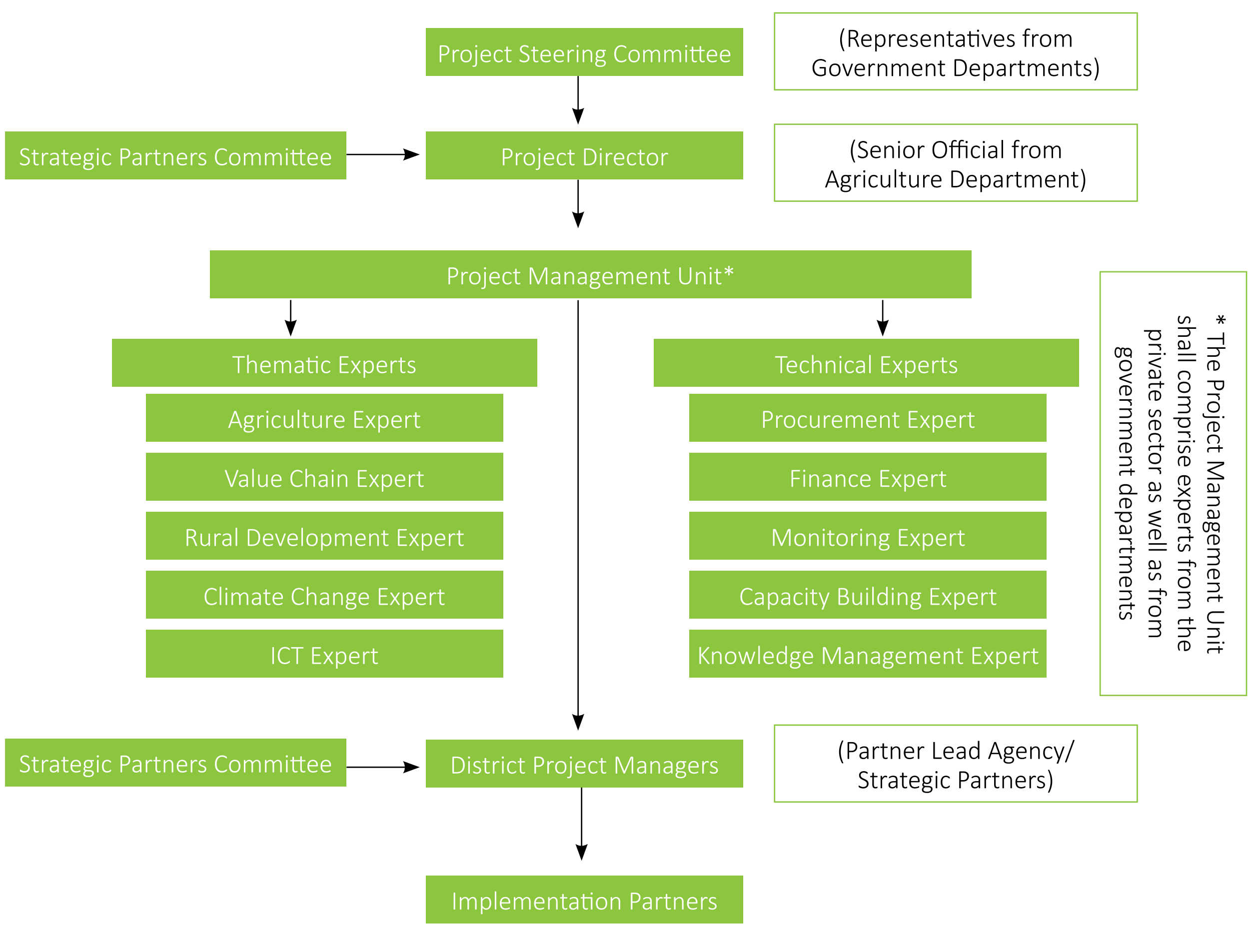
- The project shall arrange to avail of technical support from public sector institutions such as Central Research Institutes, State Seed Development Corporation, SRLM, state agriculture college/ universities, NICRA, Central Soil Salinity Research Institute, Central Institute of Agri Engineering, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IMD, etc. The project will have strategic partnership with institutions to develop several knowledge products, such as:
    - Long-term climate change model for the project area and its implications
    - Various thematic studies on climate resilience
    - Tools to carry out resource and opportunity analysis
    - Knowledge products for farmers, collectives/ FPOs, staff and board members of these FPOs and government staff working with the rural development and agriculture department.

These knowledge products will be developed on the basis of a series of action research projects taken up by strategic partners during the entire length of the project period. Lessons learnt from these action researches would be carefully documented and widely publicized to enrich the existing knowledge base.

3.4 Project Management and Implementation

The project management framework has been designed on the basis of convergence with government departments. The Agriculture Department will be the nodal department for the project and the responsibility for the overall oversight of the project will be that of the Project Steering Committee (PSC) which will be headed by a senior official from the Agriculture Department. The head of PSC will work in the capacity of a project director. will also have representations from the Department of Rural Development, Department of Climate Change & Environment, SRLM, and Department of Industries/Food Processing. The main responsibility of the PSC will be to provide strategic guidance for the implementation of the project and to act as the interface between the project and the state government.

Figure PP5: Organization structure of Project Steering Committee



The PSC will approve the annual work programme and budget for the project, endorse the partnership arrangements and renewal of Memoranda of Understanding with strategic partners and technical support agencies. PSC will meet quarterly and will do an overall review of the project progress. The project will pay attention to institutional coordination across departments, agencies and strategic partners involved in the implementation of project activities. The key departments with which the project will work in convergence are the Department of Agriculture, Department of Rural Development, Department of Climate Change and Environment, SRLM, Department of Industries/Food Processing, Department of Irrigation, etc. The project will also leverage support from agriculture universities/colleges, agriculture extension agencies, financial institutions (NABARD, banks, Small industrial Development Bank of India, etc.). Officials from these agencies will be part of PSC functional at both state and district levels. For each district, the project will hire one district project manager who will be responsible for the implementation of the project at the district level. The district project manager will work closely with strategic partner agencies and local partners.

For each of the districts, one local partner will be hired/ selected to carry out the work of awareness creation, mobilization and capacity building of farmers, collectives/ FPOs. The local partner agency will be responsible for implementation of all activities at the ground level in selected blocks. The local partner will work closely with strategic partners (agriculture research and extension agencies, srlms and other government departments):

- A Project Management Unit (PMU) led by the project director will be developed in the Department of Agriculture which will ensure that all project-related activities are carried out in line with the approved project implementation plan. PMU will also be responsible for the day-to-day operations of the project as well for liaison with different government departments, UNDP and strategic partners. It will also be responsible for institutional coordination among the various agencies which include agriculture research and extension agencies, technological and technical partners. PMU will also supervise and monitor the implementation at the district and block level. It will also be responsible for designing and developing the strategy for all three components including the overall project monitoring and reporting activities;

- The project will focus on both top-down and bottom-up departmental convergence. The high level PSC provides a strong convergence mandate for this project in the sense that the project is not implemented in isolation but as an additional catalytic investment for increasing the adaptive capacity of all stakeholders in the agriculture value chain with specific focus on small and marginal land holding farming households. The state has already prepared the climate action plan and agriculture road map by following this very approach. The specific crop/varietal advisories are available through the agriculture college/university and agriculture extension machinery. The bottom-up planning process from the block onwards will be ensuring participation of Block Agriculture Officer, District Agriculture Officer, Project Director ATMA, District Project Director SRLM, etc.;

- PMU will have both thematic experts and technical experts. Thematic experts will have a team of sectoral experts from the sectors of agriculture, climate change & environment, value chain, institutional finance & investment and ICT. Thematic experts from agriculture, climate change & environment will be from the respective departments, the state government while thematic experts for themes such as value chain, institutional finance & investment and ICT will be hired from market. Additionally, at PMU, there will be a team of technical consultants who will specialize in activities such as finance & accounts, procurement, monitoring and evaluation and knowledge management. The monitoring and evaluation consultant will be responsible for the quarterly consolidation and reporting;

- For implementation of technical work which will include comprehensive ICT activities such as weather and crop advisory, systems for real time contingency plan and development of IT-based knowledge products, technical agencies will be hired. The agencies recruited will work closely with the Project Director. PMU will also implement activities related to communication, public awareness and outreach, including setting up and maintaining a comprehensive project website that also accommodates an open space for lodging stakeholders' complaints as part of the project's grievance redress mechanism;

- The work at district level will be supervised by the district project managers who will be responsible for work in each of the respective districts. They will act as facilitators, collaborators, supervisors and bringconvergence. For overall supervision and guidance, a steering committee will be formed which will have members such as District Agriculture Officer, Project Director ATMA, District Project Manager SRLM, District Industries Centre, etc.; and

- Implementation work will be undertaken by the local partner agency that will be brought onboard through partnerships after proper screening. Block Agriculture Officers of such blocks will also be members of the district level steering committee. The District Project Manager will also be the administrative head at the district level and responsible for smooth implementation of the project in the district. He/she will also be responsible for implementation of the annual work plan, regular monitoring of project activities, and coordination with line departments at block/district level.

3.5 Project Cost

The project has three components along with project management. Table PP7 presents the key activities of each components and project management.

Table PP8: Components and key activities

Components	Key Activities	Financial Costs in INR
Component 1: Promotion of a climate resilient agriculture system	• Capacity building of farmers on varietal knowledge which includes awareness on flood and drought resistant/tolerant varieties • Partnership with agriculture college/universities/ agriculture extension for supply of flood and drought resistant varieties • Development of seed hubs linking FPOs, agriculture research and extension agencies, private and public sector players • Development of demonstration plots • Capacity building of farmers/collectives on staggered cropping planning, community nurseries, natural weed and pest management, intercropping/ crop rotation/crop substitution • Piloting and exposure to farmers on protected cultivation to address micro-climate variability (shade-net houses, poly-houses, poly tunnels) • Convergence with KVKs/State Agriculture Universities/ATMA/ SRLM • Capacity building and development of prototypes on nutrient management, soil moisture management, water management, rainwater conservation, system of crop intensification, agriculture residue disposal (stubble burning), etc.w	54,500,000.00
Component 2: Development of a climate smart value chain/post harvest system	• Capacity building of farmers on grain maturity and harvesting, drying, in-house storage, moisture management, commercial warehouse, transportation, cold storage & cold chain, price fluctuation, shelf-life management, etc. • Capacity building of farmers and collectives on primary value addition activities such as cleaning, grading, sorting • Capacity building of collectives/FPOs, etc., on micro grain warehouses, micro cold storages and cold chain • Capacity building of FPOs and private entrepreneurs on business development services which include support in preparation of bankable proposals, linkages with suppliers and buyers • Capacity building of collectives/FPOs on establishment and management of custom hiring centres • Support to FPOs/collectives in backward value chain integration	34,350,000.00
Component 3: Knowledge, technology and institutional development	• Development of training calendar and training content • Development of ICT enabled system for weather forecasts with localized crop advisory • Development of systems for real time contingency measures • Collaboration with strategic partnership agencies	53,400,000.00
Total Cost		142,250,000.00

Implement Adaptation of Farm and Allied Management Practices for Adaptation to Climate Change **Uttar Pradesh**

1. Context and Background

1.1 Project Context

Climate change is increasingly seen as one of the major threats to food security and sustainability of agriculture. Its impact on agriculture could result in threatening the livelihoods of a large number of households that are dependent on agriculture and allied activities. Agricultural productivity is affected by climate change in two ways: first, directly, due to changes in temperature, precipitation and/or CO_2 levels and second, indirectly, through changes in soil, distribution and frequency of infestation by pests, insects, diseases or weeds.

Climate change symptoms such as water deficit conditions combined with thermal stress could adversely affect the productivity of important food crops like wheat and rice. Climate change can affect crop yields and, in extreme cases, the types of crops that can be grown in certain areas, by impacting agricultural inputs such as water for irrigation, amounts of solar radiation as well as the prevalence of pests.

IARI examined the vulnerability of agricultural production to climate change, with the objective of determining differences in climate change impacts on agriculture by region and by crops. The study found that increases in temperature (by about 2^0C) reduced potential grain yields in most places. Climate change is also predicted to lead to boundary changes in areas suitable for growing certain crops. Reductions in yields as a result of climate change are predicted to be more pronounced for rain-fed crops (as opposed to irrigated crops) and under limited water supply situations because there are no coping mechanisms for rainfall variability. In sub-tropical environments, the decrease in potential wheat yields ranged from 1.5 to 5.8 percent while, in tropical areas, the decrease was relatively higher, suggesting that warmer regions can expect greater crop losses. Overall, temperature increases are predicted to reduce rice yields. An increase of 2-4^0C is predicted to result in a reduction in yields. Eastern regions are predicted to be most impacted by increased temperatures and decreased radiation, resulting in relatively fewer grains and shorter grain-filling durations[66].

In a reply to the Committee of Estimates headed by Mr. Murli Manohar Joshi on the impact of climate change on the agriculture sector, the Ministry of Agriculture's note had said that small farmers, who own less than 4 ha of farm land, may not be able to support their families with agriculture income alone due to the impact of climate change[67]. The Ministry note also mentioned that crops such as wheat, paddy, maize, potato, cotton, sorghum, mustard and coconut were likely to be badly affected by climate change. It informed the parliamentary committee that production of wheat would decline by 6 to 23 percent by 2050 if proper steps were not taken in a timely manner. The production of wheat could reduce by 6,000 kg for every 1°C rise in temperature[68]. In its note, the Ministry has suggested that adjusting to various measures, including time of sowing, suitable variety, fertilizers and irrigation, is likely to help in tackling the problem to a certain extent.

Climate change has about 4-9 percent impact on agriculture each year. As agriculture contributes 15 percent to India's GDP, climate change presumably causes noticeable loss in GDP. Crops such as rice, wheat, maize and sorghum are the worst hit by this phenomenon. By 2030, rice and wheat are likely to see about 6-10 per cent decrease in yields. Kharif crops will be affected more by rainfall variability and rabi crops by minimum

66 Key sheet 6 Climate Change Impacts on Agriculture in India, The Indian Agricultural Research Institute http://www.indiaenvironmentportal.org.in/files/Defra-india-cc-agri.pdf
67 https://www.dailypioneer.com/2018/page1/climate-change-threatens-kisan.html``
68 https://krishijagran.com/news/climate-change-affecting-agriculture-wheat-production-in-india-could-drop-by-23-agri-ministry/

temperature. Wheat is likely to be negatively impacted in the rabi season due to terminal heat stress with a 1°C rise in temperature resulting in loss of 4 MT of wheat[69].

Several studies have been done over the years to observe the changing scenarios in agricultural productivity and impact on crop yield. The findings of a few such studies as Zhang et al. (2016), Ahlawat & Kaur (2015), Nube et al. (2015), Ahmad et al. (2014), Koshal (2014), Mishra & Sahu (2014), Gupta et al. (2012), Siddiqui et al. (2012) and Sanghi & Mendelsohn (2008) discussed various dimensions of the impact of climate change on agriculture productivity. Their findings, in general are similar, as almost all of them concluded that climate change variables (temperature and rainfall) have an adverse impact on agriculture crop yield[70].

In India, studies have illustrated the inverse relationship between climate change and agricultural productivity (Saseendran, Singh et al. 2000; Aggarwal and Mall 2002). An increase in temperature, depending upon the current ambient temperature, can reduce crop duration (Challinor and Wheeler 2007; Zhang et al., 2007), increase crop respiration rates, alter photosynthate partitioning to economic products (Albrizio and Steduto 2003; Wahid et al., 2007). All of these can have a tremendous impact on agricultural production and hence food security of any region. Recent studies on the impacts of possible future climate over this region indicate spatio-temporal variations in impacts on rice and wheat crops in India (Naresh Kumar et al., 2011, 2013, 2014). The increased incidence of weather extremes such as onset of rainfall and duration and frequencies of drought and floods will also have major effects, and preliminary reports indicate that the recent declines in yields of rice and wheat in the region could have been partly due to changes in weather extremes (Aggarwal et al., 2004).

The poor and vulnerable households are more at risk of climate change as climate change affects all three aspects of food security: availability, access and absorption. Vulnerability to climate change is closely related to poverty, as the poor have fewer financial and technical resources.

Climate change can also have significant impact across the food processing industry due to its huge dependency on agriculture produce as a raw material. With weather becoming unpredictable, it becomes difficult to foresee industry needs. As climate change and agriculture produce are directly related to the cost of production, any risk involved in acquiring agriculture produce will have serious implications on profitability and sustainability of food-based enterprises. Apart from the growers, actors involved in aggregation and collection, transportation and storage and food processors are considered the value chain actors who add value through different sets of activities.

Change in climate in the medium to long term will affect the soil moisture, groundwater recharge, and frequency of flood or drought, and finally groundwater level in different areas. The effect of climate change will impact the water cycle. Higher temperatures and changing precipitation patterns will severely affect the production patterns of different crops. Agricultural productivity will also be affected due to increased carbon dioxide in the atmosphere. All these changes will increase the vulnerability of the landless and the poor[71].

Climate change impacts will occur at all levels of the value chain and individual adaptive responses at each level will either enhance or reduce overall performance in terms of efficiency, continuity and product attributes. Climate change is, thereby, set to cause huge economic, social and environmental damage across the region, compromising growth potential and poverty-reduction efforts. Climate change affects agricultural activities and value chains in two ways. First, in order to sustain their value addition activities, value chain actors must adapt to changing conditions by means of incremental changes to their value addition systems by using additional resources. Secondly, climate change may alter production capabilities more deeply by making contemporary economic structures obsolete in a new environment. These changes will affect economic opportunities, profitability and competitiveness, livelihoods, sources of growth and employment and socio-economic outcomes.

The state government of Bihar acknowledges that climate change is one of the major challenges of agriculture in the state, and its overall strategy is to transform agriculture and its allied sectors into climate-resilient and vibrant production systems while developing their full potential and ensuring sustained food and nutritional security.

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69 https://www.downtoearth.org.in/news/agriculture/climate-change-causes-about-1-5-per-cent-loss-in-india-s-gdp-57883

70 Kumar, Anuj, 2018. Economic Analysis of the Impact, Adaptation and Mitigation of Climate Change in the Dominant Cropping System of Indo-Gangetic Plains of India.

71 Kumar and Gautam, 2014. Climate Change and its impact on Agricultural Productivity, *India J Climatol Weather Forecasting,* 2:1.

1.2 Location Context

IGP is very crucial from the point of production of major food grain crops. Owing to presence of fertile soil, the region carries the burden of a large population and is also popular for production of specially rice and wheat along with other crops. Characterized by favourable climate, fertile soils and abundant water supply, IGP is seen as the "bread basket" of South Asia, providing food and livelihood security for hundreds of millions of its inhabitants[72]. It is also known as India's "bowl of food grains" because it contributes 48.4 percent of rice and 74.7 percent of wheat of India's total production of these two major food grain crops.

Most areas of these plains have two crops in a year. In some areas, three crops are produced in a year. Wheat, potato and mustard are the major crops of spring (rabi) season and paddy is grown in autumn (kharif) season[73]. The climatic trends of IGP show that the temperature of this region is increasing year by year. As per the weather trend variability analysis done for the IGP region, the average temperature of this region has increased by 0.2°C per decade from the year 1960. The range of possible temperature increase for IGP is 0.6–2.7°C, 0.5–3.1°C and 1.0–5.4°C above the 1070-1999 mean for the 2030s, 2050s and 2090s, respectively. In general, temperatures in the monsoon period increase less than in the dry seasons[74]. Research indicates that though the average precipitation of the plains is static, t the timing of precipitation is changing[75].

A study was conducted by the Centre for Environment Science and Climate Resilient Agriculture on an assessment of impacts on rice and wheat in IGP[76] using climatic data as per the PRECIS regional climate model developed by the Hadley Centre, United Kingdom, in nine representative locations of IGP. The study suggested occurrence of extreme temperature events which could cause yield reduction particularly if these events coincide with sensitive stages of crop growth. Apart from differential growth and yield responses of crop species to high thermal stress, the study also suggested differential responses to high temperature stress during various growth phases[77]. The results indicated that an increase in temperatures adversely influences crop performance and these negative impacts of temperature are not compensated enough by elevated CO_2 concentrations as is evident from a reduction in the overall projected yields. Results also project occurrence of low yielding years more frequently due to climate change.

IGP is an environmentally sensitive, socially significant and economically strategic domain of India where landscape, hydrology and fertility are threatened by climate warming and anthropogenic pressure. A decline in food production will be a major problem. In order to make assessments of the environmental changes, concerted efforts should be initiated to understand the geological past and model the future[78]. A rise in temperature by a mere 2^0C can lead to a fall in farm production between 4 and 34 percent (IPCC, 2007)[79]. Soil salinity, already prevalent in the plains of Haryana, Punjab and western Uttar Pradesh, is bound to extend over the marginally saline areas, reducing the availability of agricultural land. This will bear additional stress on the already declining water table. Groundwater exploitation is likely to be intensified and, consequently, water stressed areas will become water scarce. According to another study on the current scenario of the rice-wheat system in IGP, a good correlation is indicated between rainfall and rice yield as per statistical and remote sensing data analysis. The study findings mention that the current scenario of climate changes, i.e., global warming, rising of temperature, irregular pattern of rainfall, excess use of fertilizers and irregular pattern of irrigation, significantly contribute to the decline in fertility of lands[80]. The risk of climate change on agriculture is very significant in IGP due to its high dependency on rainfall and its connections to the tectonics and climate of the Himalaya. Thus, any change in these factors will have an adverse effect on the hydrology, soil fertility, food production and settlement pattern of IGP. Incidences of pest and disease would be most severe in tropical regions due to favourable climate/weather conditions, multiple cropping and availability of alternate pests throughout the year. Climate change is likely to cause the spread of tropical and subtropical

72 Erenstein, Olaf, 2010. A comparative analysis of rice–wheat systems in Indian Haryana and Pakistan Punjab, *Land Use Policy* Vol.27 Issue 3 pages 869-879.

73 Koshal , A. K.,2014. Changing Current Scenario of Rice-Wheat System in Indo-Gangetic Plains Region of India. *International Journal of Scientific and Research Publications,* (4) (3)

74 New, M., Rahiz, M., and Karmacharya, J., 2012. Climate Change in Indo-Gangetic Agriculture: Recent Trends, Current Projections, Crop-Climate Suitability and Prospects for Improved Climate Model Information. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

75 Kumar, Anuj, 2018. Economic Analysis of the Impact, Adaptation and Mitigation of Climate Change in the Dominant Cropping System of Indo-Gangetic Plains of India.

76 Zacharias, Manju, Kumar, S. Naresh, Singh, S.D., Swaroopa Rani, D.N. and Aggarwal, P.K., June 2014. Assessment of impacts of climate change on rice and wheat in the Indo-Gangetic plains, *Journal of Agrometeorology* 16 (1) : 9-17,

77 Cheng, W., Sakai, H., Yagi, K., and Hasegawa, T.,2009. Interactions of elevated [CO2] and night temperature on rice growth and yield. *Agril. For. Meteorol.,* 149(1): 51-58.

78 Saini, H.S., 2008. Climate Change and its Future Impact on the Indo Gangetic Plain (IGP), e-Journal *Earth Science India,* Vol. I (III), 2008, pp. 138-147.

79 Inter-Governmental Panel on Climate Change (IPCC), 2007. Fourth assessment Report.

80 Koshal , A. K., 2014. Changing Current Scenario of Rice-Wheat System in Indo-Gangetic Plains Region of India, *International Journal of Scientific and Research Publications,* (4) (3).

weed species into temperate areas and to increase the numbers of many temperate weed species currently limited by low temperature at high latitudes.

1.3 State and Sectoral Context

Demography: Uttar Pradesh, located in the northern part of India, is the fifth largest state of India in terms of geographical area covering roughly 240,928 square kilometres. This is nearly 7.33 percent of the total area of the country. In terms of population, Uttar Pradesh is the largest state of India with a population of about 199.8 million people (Census 2011) accounting for nearly 16.5 percent of the total population of India. The state has a female to male sex ratio of 912: 1,000 and literacy rate of 73 percent (census 2011). Uttar Pradesh is a large state divided into 18 divisions, 75 districts, 312 tehsils and 822 developmental blocks. The state has 648 statutory towns, 267 census towns and 0.106 million villages as per the Census of 2011. It is also among the most densely populated states of India with 829 persons inhabiting every square kilometre. Nearly 77.7 percent of the people in the state live in rural areas making Uttar Pradesh primarily a rural economy.

Economy: The economy of Uttar Pradesh is presently on a continuous growth path and, according to the new series of data on the state's GDP, it is estimated to be INR 15,798 billion (at current prices), which is 7 percent higher than the revised estimate for 2018-19. In 2016-17, agriculture, manufacturing and services contributed to 27 percent, 26 percent and 47 percent, respectively, of the state gross value added tax by sectors. The per capita GDP of Uttar Pradesh in 2016-17 (at current prices) was INR 57,480.

Agro Climatic Profile: Uttar Pradesh is situated between 23° 52'N to 31° 28' N latitude and 77° 51' E and 84° 38' E longitude with a geographical area of 243,290 square kilometre. The state has three geographical regions. The larger Gangetic Plain in the north which includes the Yamuna-Ganga Doab, Ghagra and Avadh Plains, the Terrai region, the Vindhya range and the plateau in Rohilkhand region. Generally, the people consider Uttar Pradesh to be divided into four zones which are Western, Central, Eastern and Bundelkhand regions. As per NARP undertaken by NITI Aayog, nine agro-climatic zones have been recognized in the state: Tarai; Western Plain; Mid-Western Plain; South-Western Semi-Dry Plain; Mid Plain; Bundelkhand; North-Eastern Plain; Eastern Plain; and Vindhyan.

The mean annual rainfall ranges from 650 mm in south west corner of the state to more than 1,000 mm in the eastern and south eastern parts of the state. As per IMD, long-term average rainfall is 946.07 mm with range of 501.2 mm to 1,444.25 mm. Of this, the main south-west monsoon contributes 84.4 percent of the annual rainfall while pre-monsoon rainfall and post monsoon rainfall accounts for 7.1 percent and 4.9 percent, respectively.

The climate of Uttar Pradesh has wide variations with temperatures ranging from 0 or below 0 in winter to about 45-47°C in summer. Summer season is between March and June with hot and dry weather with relative humidity around 20 percent. Winter months are between November and February and monsoon between July to September with 85 percent of the annual rainfall falling during that period. The state has a strong agriculture base with the most fertile land masses and a well-connected river network which enable it to play a significant role in the country's food and nutrition security programme.

Agriculture: Growth and sustainability of the agricultural sector is crucial for the state of Uttar Pradesh due to the contribution of agriculture in employment generation, poverty reduction and overall economy which stems from substantial economic linkages which agriculture and allied sectors in the process of forward and backward linkages. Around 68 percent of the workforce in Uttar Pradesh depends on agricultural and allied activities for its livelihood. The gross cropping area is around 26.1 million ha of which 12.1 million ha is for kharif crop, 13.6 million ha for rabi and remaining for zyad crops. The state has a cropping intensity of 157.53 percent. The gross irrigated area in the state is 21 million ha with a net irrigated area of 14.4 million ha. Net irrigated area percentage of the state is about 87 percent. About 80 percent (18.53 million) of the farmers in the state are marginal farmers and cultivate on 41 percent (7.17 million ha) of the land. Thirteen percent (3.06 million) of farmers are small farmers and they cultivate on 24 percent (4.243 million ha) of the land area. The remaining 7 percent (1.76 million) of the farming households cultivate on 35 percent (6.205 million ha) of the land area[81].

Though Uttar Pradesh's economy is transitioning from agriculture towards the service sector, the agricultural sector contributes more than 25 percent to the state's GDP. Significant progress has been achieved in the agriculture sector in the last few years. The state is a major producer of wheat, rice, pulses, sugarcane, potato, vegetables and milk.

81 http://upagripardarshi.gov.in/

The agricultural economy of Uttar Pradesh is highly diversified with crops such as cereals which include paddy, wheat, bajra, jowar and maize and most varieties of pulses (urad, arhar, gram, pea, etc.), oilseeds, sugarcane, potato, onion and a variety of fruits and vegetables as its important crops. The state is the highest producing state for food grains and produces more than 20 percent of that in the country (60,4 MMT/281.4 MMT) which is enough for the requirements of 16.9 percent of the population (2 billion of 12.1 billion approximately). In fact, there was a record production of food grains in 2018-19 with more than 60 MMT of production of which wheat production was 38.1 MMT, paddy 15.9 MMT, pulses 2.4 MMT and coarse cereals contributed to the production of 4.1 MMT. The state has also made a record 1.56 MMT of oil seeds and has also received the *Krishi Karman Purshakar* from the Government of India for productivity increases in oilseeds.

The productivity of rice and wheat has increased significantly in the last few years with rice production reaching 2.703 MT per ha while that of wheat stands at 3.860 MT per ha. The government had fixed the target of 2.810 MT per ha for paddy and 4 MT per ha for wheat for the year 2020-21. The average productivity of coarse grain was 2.06 MT per ha while that of pulse was 1.044 MT per ha in 2018-19. For oil seed, the productivity was 1.079 MT per ha in 2018-19. The state had an ambitious target of 62.8 MMT of food grain production in 2019-20 and that of 65.4 MMT in 2020-21.

The key reasons for improvement in productivity have been the availability of quality seeds and other agriculture inputs such as fertilizers and pesticides. In addition, innovative steps such as *Kisan Mela/Kisan Gosthi* and training for farmers have been undertaken. These activities have also been supplemented by making modern farming equipment available. In the financial year 2018-19, a total of 81,820,000 MT of seeds has been distributed for crops such as wheat, paddy and pulses. The fertilizer consumption in the state was about 7.42 MMT for the year 2018-19 and is growing at the rate of 5 percent per annum.

Mechanization is also in a developed stage. The use of tractors, seed drills, rotavators, threshers, cultivators, etc., is common in agriculture and allied activities. Under the Sub-Mission on Agriculture Mechanization, the government is promoting *Farm Machinery Banks* and *Custom Hiring Centres*. By 2018-19, a total of 2,300 Custom Hiring Centres and 140 Farm Machinery Banks had been opened.

In horticulture, mango, banana and citrus are the important fruit crops while potato, tomato, onion, brinjal, cabbage, cauliflower, chilli and ladyfinger are the prominent vegetable crops. As per the data available for financial year 2017-18, the total area under fruit crops is 6,506,000 ha with production of 97,358,000 MT. For vegetable crops, the total area was 10,259,000 ha with a production of 184,394,000 MT. There was a rise in fruit production of about 4.77 percent and in vegetable production of around 3.5 percent in comparison to year 2016-17.

The state government, under schemes such as National Food Security Mission and National Mission on Agriculture and Technology, has undertaken many innovative steps to increase mechanization, technology transfer and capacity building of farmers. These measures have also been supported by ensuring availability of implements and inputs. The state has made significant progress with schemes such as *RKVY* and NMSA. Under NMSA, the focus is on promotion of sustainable agriculture while RKVY focuses on development of allied sectors.

The state is also facilitating inclusion of more and more farmers under crop insurance schemes particularly *Pradhan Mantri Fasal Bima Yojana*. For the year 2018-19, 3.146 million farmers were covered under kharif crops while 2.969 million farmers were covered under rabi crops. The government is also promoting the spread of solar pumps for irrigation, rainwater harvesting and micro irrigation techniques such as sprinkler technology.

Uttar Pradesh was also one of the first states to start Direct Benefit Transfer in the agriculture sector and more than 2.7 million farmers have benefitted to the tune of approximately INR 67 million. More than 11 million farmers have also received benefits under the Prime Minister Kisan Samman Yojana. The International Rice Research Institute is starting its regional research centre in Varanasi. In 2019, Krishi *kumbh* was also organized in the state. Uttar Pradesh State Agro industries Corporation has been assigned the responsibility of ensuring delivery of agriculture implements and other inputs in the state.

The state is blessed with the rich natural resources of IGP which offer substantial opportunities for high agricultural productivity and crop diversification. The abundance of water and rich soil has enabled this growth, along with diversification of agricultural produce among a variety of food and non-food crops. However, the agricultural scenario is not bereft of risks and challenges, arising from both climatic and non-climatic factors. Factors such as near stagnation of crop yield, fragmented land holdings, rainfall irregularities, heterogeneity in landscapes and information asymmetry continue to plague the growth of both agriculture and horticulture sectors.

Extension Services: Extension services in agriculture are working with the objective of enhancing the capacity of farmers through technology transfer and adoption, through means such as on-field/off-field training, demonstrations, exposures advisory services, etc. The state has four State Agriculture Universities and one deemed Agriculture University at Allahabad. These universities have 33 research stations.

In addition, there are 25 state agriculture colleges, 28 KVKs and 24 Krishi Gyan Kendras. ICAR has several centres, Project Directorates, National Research Centres and Regional Research Stations. Since 2014-15, ATMA has been merged with the national Mission on Agriculture Extension and Technology. Under the new scheme, four sub-missions on agriculture extension, agriculture mechanization, seed and planting material, and strengthening and modernization of the pest management approach are being implemented in the state.

Agri-processing/Value Chain: Uttar Pradesh is well-known for its agricultural production potential wherein different food grains, pulses and various high-value crops such as sugarcane, fruits, vegetables, etc., are grown around the year in all cropping seasons in different regions of the state. The state ranks on the top in terms of production of wheat, sugarcane, maize, vegetables and potato and livestock products, including milk, among major states in the country. The distribution of agri-processing industries is not uniform across the state. Districts from Vindhya Zone (Mirzapur and Sone Bhadra) and Bundelkhand Zone (Jhansi, Jalaun, Banda, Hamirpur, Lalitpur, etc.) have low concentrations of agricultural industries with very few units existing there. Most agro-processing/agri industries are in the districts of Saharanpur, Bijnaur, Pilibhit, Muzaffarnagar, Meerut, Ghaziabad, Gautam-Budh Nagar, Bareilly, Moradabad, Rampur, Shjanpur, Agra, Kanpur, Lucknow, Sitapur, Khiri Lakhimpur, Chandauli, Barabanki, Hardoi and Etawa districts.

The state has a total of 157 established sugar mills of which at present 119 sugar mills are operational. The total area under sugarcane production is 2.79 million ha with sugarcane productivity of 80.50 tonne per ha. In crushing season 2018-19, sugar recovery was around 11.46 percent.

The growth of agriculture value chain has been mostly along the cluster model with the concentration of specific type of agri value chains in specific pockets. Value chain units related to meat, fish, fruits and vegetables, oils and fats are largely concentrated around districts of Agra, Kanpur Nagar/Dehat while the concentration of dairy units has been largely around districts of Bulandshahar, Agra and Kanpur. Grain milling products, starches and animal feed units are located in districts such as Rampur, Shahjanpur, Pilibhit, Bahraich, Balrampur, etc. Grain milling units consist of the maximum number of units which include rice mills, roller flour mills and flour mills, pulse mills, starch units, cattle feed units, etc. Most agriculture units of the state belong to this food category. The bulk of agri-processing industries fall into the category of largely unorganized small units or organized but small and medium units which operate at the lower end of technological inputs. Even the scope of value addition is minimal.

Processing units for horticultural crops have not been developed to meet the production requirement of the state. Therefore, a huge quantity of vegetables, fruits, flowers, etc., goes waste every day. The state has a huge number of cold storages but most of these units have been established to fulfill the requirements of a single crop which is potato.

The state has undertaken various initiatives to increase the competitiveness of agriculture and allied sectors by encouraging the development of agriculture infrastructure/facilities to increase farmer gains it is encouraging the process of industrialization by assuring an entrepreneur-friendly regime and an attractive package of incentives for entrepreneurs. In this context, the Department of Horticulture and Food Processing, Uttar Pradesh, is making efforts to continuously develop the sub sector by implementing various schemes for fruits, vegetables, flowers, spices, medicinal and aromatic plant. Moreover, to promote assured development of food processing within the state, the Uttar Pradesh Food Processing Industry Policy 2012 has also been promulgated by the state government with inbuilt components of interest subsidies, quality and certification market development, research and development and exports. Furthermore, through promulgation of the Uttar Pradesh Potato Development Policy 2014, various subsidies and concessions incentivize planned development of the main potato crop in the state.

Climate change events will have a significant impact on the functioning of these industries/actors. As all these industries are dependent on agriculture for raw material supply, any impact on production/productivity/quality will have significant impacts on further value addition being made by these actors. They need to make changes in their production capabilities/process, etc., to mitigate the adverse impact of climate change. They may also need to continuously work on improving their linkages. At the macro level, climate change events/variabilities will affect economic opportunities, sales/profitability, competitiveness, livelihoods, sources of growth and employment and socio-economic outcomes for the state.

2. Project Description

2.1 Project Overview

The climate sensitivity of agriculture is very high in the state and high-level poverty, rapid and unplanned urbanization coupled with floods, heat waves and cold waves makes it one of the most vulnerable states of India. Many districts from the Bundelkhand and Vindhya regions and some districts from the central and north eastern plains are highly vulnerable.

The state faces several types of vulnerabilities; climate change is likely to exacerbate these further if not addressed adequately and holistically. Around 80 percent of the population of the state is engaged in agriculture-related activities and most farming households belong to the category of small farmers who are solely dependent on agriculture for their livelihood. The state faces a challenge from both floods and droughts due to the structure of the state.

In eastern Uttar Pradesh, which is chronically flood prone, the very nature of flooding has also changed, with a greater intensity of flash floods which are sudden and accidental. Water logging has also increased in the flood-prone areas due to which the frequency of crop damage is high. These incidences are also affecting the cropping pattern. In the Bundelkhand area, farmers are affected by increasing temperatures and water shortages. Due to the high dependency on agriculture, any adverse impact of climate change on the sector will have huge implications on the economy and livelihoods of the people.

The state is facing a change in frequency, timing and quantity of rainfall with a decreasing number of rainy days in the monsoons. Erratic rainfall is also affecting moisture and carrying capacity of the soil. Rabi crops are being affected due to a rise in temperature in the winter while untimely increases in temperature destroy the growing flower of crops which may lead to a decrease in agriculture production. Untimely flow of wind from the west reduces the size and number of food grain may also lead to a decrease in production. Though the impact of production has been minimal, it is affecting the quality of wheat as well as increasing the cost of cultivation. The contribution of Uttar Pradesh to the national food grain basket is well recognized but challenges such as near stagnation in productivity are becoming a cause of concern. The impact of climate change is much higher on small and marginal households as they are more dependent on natural resource for their livelihood and climate change impact these resources more. Therefore, considering population growth and limited availability of natural resources, agricultural productivity needs to continuously increase to meet the growing demand of food despite adverse impacts of changing climate. It is, therefore, imperative to plan and implement measures judiciously to cope with the changing climate.

To sustain agriculture, it is required to undertake specific adaptation and mitigation measures to reduce the risks of climate change and to deal with the adverse effect of climate change. Under the State Action Plan on Climate Change, the state has formulated an action plan for a sustainable agriculture mission which has the following components:

1. Establishment of climate change and agriculture cell/ coordination and monitoring;
2. Identification of vulnerable areas and assessment of vulnerability;
3. Establishment of climate field schools (one in each block);
4. Promotion of carbon sequestration agricultural practices;
5. Use of organic manures (one village per block per year);
6. Soil management practices (farm machineries in adopted villages);
7. Farming system approaches for diversifying incomes and livelihoods (10 farmers from each identified village);
8. Diversification of cropping systems and promotion of a biotic stress tolerant crop varieties in identified villages;
9. Popularization of aerobic rice cultivation methods in identified rice villages;
10. Popularization of agro-forestry in identified villages; and
11. Climate responsive research programmes.

The state government has shifted its focus from production of agriculture produce to integrating backward and forward linkages. The focus has become holistic, and interventions now cover every aspect of agriculture, from inputs to marketing of final products. The state Department of Agriculture, in coordination with institutions such as the Uttar Pradesh State Agro Industrial Corporation Limited, Uttar Pradesh Mandi Parishad, Bhumi Sudhar Nigam, Uttar Pradesh Seed Development Institution and Uttar Pradesh Seed Certification Institute and Department of Horticulture and

Food Processing are working in close coordination.

Due to changes in weather parameters, the selection of crops and their varieties, timing of planting and sowing and other agronomic practices are being influenced substantially. Therefore, area-specific crop planning and identification of appropriate crops and their varieties is needed to protect the farmers from adverse weather aberrations. Farmers need to be provided accurate and precise weather forecasting and agro-advisories on a regular basis through various dissemination methods and techniques. In addition, management of storage of agricultural production in light of climate risks, promotion of price augmentation for small holders and suitable technologies needs to be undertaken. In light of the changing weather pattern, adaptive and mitigation measures needs to be planned well in advance for the benefit of the farming community to secure their livelihood.

It is against this backdrop that UNDP has conceptualized a Project on increasing the adaptive capacity of agriculture value chains with special focus on inclusion of small and marginal holder farmers from Bahraich, Balrampur, Siddharth Nagar, Sant Kabir Nagar and Shrarhasti districts. Most of these districts are already part of the list of vulnerable districts released by NICRA; some are also listed as aspirational districts by NITI Aayog.

The state government places climate resilience at the core of agriculture growth and rural development in the state. The project's two-tier approach will ensure that initiatives promoted under the project to reduce stakeholders' climate vulnerability (specifically their capacity to mitigate the impact of adverse climate events and/or to recover from climate disturbances) contribute to increasing climate resilience in the agriculture value chain as well as to ensure that the smallholder farming remains a sustainable and viable livelihood option.

2.2 Project Development Objective

The project development objective will be "*to enhance climate-resilience and adaptability of agriculture value chains and smallholder farming systems in selected districts of Bihar by increasing the adaptive capacity of all the stakeholders"*.

The project will be created around a comprehensive, multi-sector approach that will focus on building climate resilience in agriculture/value chain through capacity building and technical support to all stakeholders. The project will try to address the twin objectives of enhancing climate resilience of the value chain as well increasing the productivity and income of small and marginal land holder farmers. It would focus on bringing transformational adaptations in the agriculture value chain through climate-smart technologies and practices at the farmer level.

Additionally, the project will also focus on increasing the adaptive capacity of other value chain actors by providing them technical support. It would focus on small holders (farmers up to 2.0 ha of farmland) as well as vulnerable populations whose livelihood is impacted by changing climate conditions and climatic uncertainties. Its key objectives will be:

i. To enhance the adaptive capacity of farmers through capacity building on improved and sustainable cropping patterns and agronomic practices;

ii. To enhance the adaptive capacity of farmers by ensuring effective and efficient backward and forward linkages;

iii. To improve the adaptive capacity of the smallholders by providing weather information and agro-advisory;

iv. To increase the adaptive capacity of value chain actors from the agriculture value chain to developing climate resilient value chains; and

v. To provide technical support to farmer organizations/ collectives for their inclusion and active participation in the climate-resilient value chains.

2.3 Project Strategy

UNDP has commissioned a study to understand the impact of climate change on small holder farmers and value chain actors in the select value chains. The strategies for this project have been developed on the basis of key learnings that emanated from that study. The following key strategies will be adopted under the project:

i. The project will work with collectives, producer groups/producer companies/VOs/cluster federations which have been formed under different programmes. All existing FPOs/ FPCs/ SHGs/VOs/ CLFs in the project area would be encouraged to participate to take forward the project. The project will ensure participation of community institutions in the planning, implementation and monitoring of the project activities.

ii. The project will work in a partnership mode and will make best efforts to integrate all stakeholders. For implementation support the project will work closely with SRLM/PRERNA and will use the institutional platform developed under NRLM.

iii. The project will work on development and promotion of climate-resilient cropping systems and practices with the objective of increasing the adaptability of small holder/marginal farmers. Within this, the project will also make conscious efforts with farming households belonging to vulnerable groups such as SC/ST households.

iv. The project will work on development and promotion of climate-resilient cropping systems and practices with the objective of increasing the adaptability of small holder/marginal farmers. Within this, the project will also make aconscious efforts on farming households belonging to vulnerable groups such as Scheduled Caste (SC)/Scheduled Tribe (ST) households;

v. Development of farm-level advisories to improve adaptability. The advisory services will be customized as per local area weather forecast, cropping pattern, crop condition and status of natural resources such as land /water, etc.;

vi. To increase adaptability of smallholder/marginal farmers through diversification of farming systems, livelihoods and incomes. The project will focus on diversifying the livelihood systems for the targeted households;

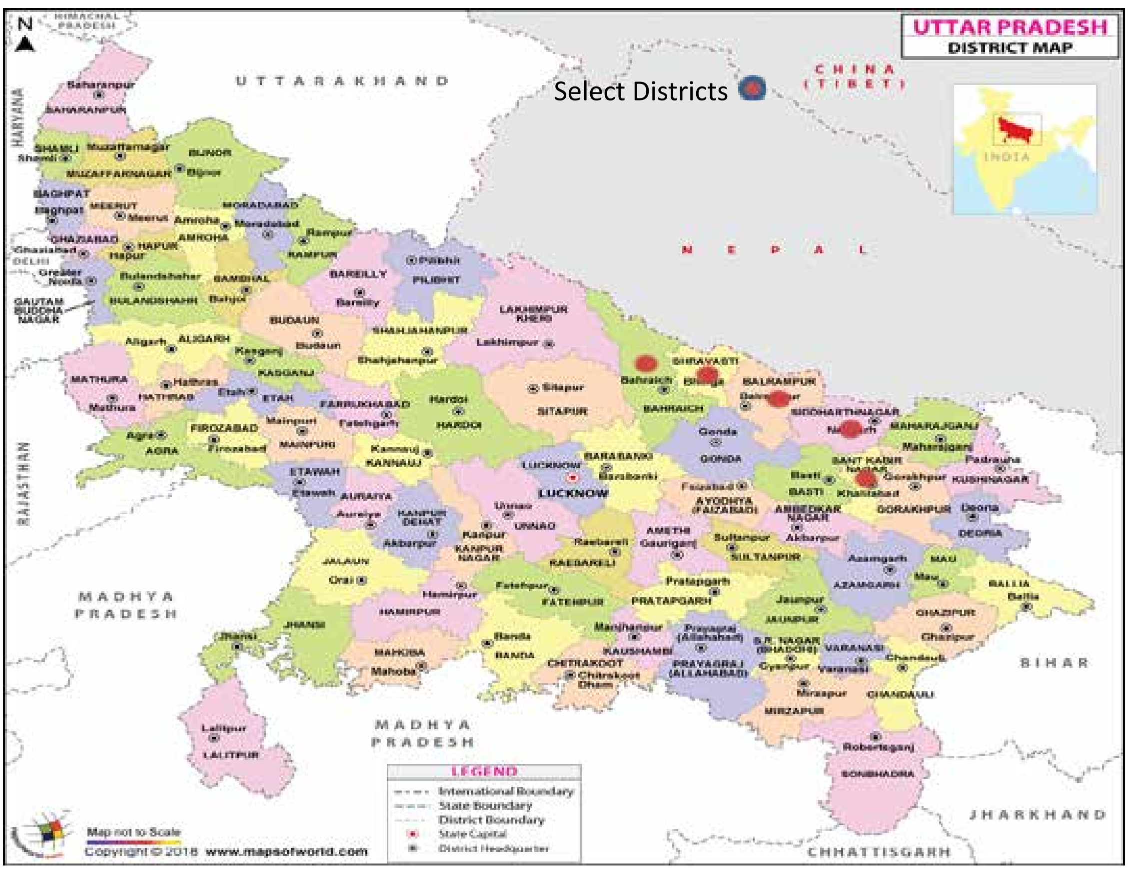
vii. To work with agriculture research and agriculture extension agencies for development and promotion of drought/disease-tolerant seed varieties, climate-controlled farming structures and improved mechanization for farming households; and

The project will work with various value chain actors (traders/warehouses/processors, etc.) from select agri and allied value chains to make the entire ecosystem climate resilient. The objective will be to build climate resilience beyond the farm gate and provide end-to-end solutions. This will be achieved by planning comprehensive climate-sensitive interventions and investments to promote value addition and prevent losses in a select number of commodity chains by using farmers' collectives and by providing technical solutions for adopting climate-smart technologies and processes to strengthen the emerging value chains of field crops and horticultural crops.

2.4 Project Area

The project will cover minimum of 100,000 farming households. The districts proposed for the intervention are Bahraich, Balrampur, Siddharth Nagar, Sant Kabir Nagar and Shrarhasti. Four of the districts are from the North-East agro-climatic zone and one from Tarai and Bhabhar zone.

Figure PP6: Project intervention area



The districts selected are predominantly rural in nature with most households belonging to the ruralural category. In these districts, the project will focus on a select 40 blocks only while targetting 2,500 households from each of the block.

2.5 Project Phasing

To tackle the challenges of climate change in a sector such as agriculture, especially in the context of small and marginal farming households, requires intensive application of human, knowledge and technological resources. To make the interventions sustainable it is also important to have an extensive focus on capacity building to increase the adaptability of small holder farmers and other participants in the value chain. As the challenge is also to include the small and marginal farming households into the ecosystem, it is prudent to implement the programme in a phased manner than spreading out everywhere in one go. The project, in the first year, will focus only on 10 blocks with about 25,000 households. This will also help in developing protypes which can be replicated at a much higher scale.

The selection of blocks will be done on vulnerability-related indicators. The blocks with maximum vulnerabilities will be prioritized first for intervention. Indicators shown in Table PP5 will be used to calculate the vulnerability score of the districts. Based on these indicators, all blocks for each of the districts will be ranked and the blocks with the maximum vulnerability score will be then taken up on priority; four to six blocks will be selected from each districts. The intervention will target 2,500 households per block form a total of 40 blocks from seven districts.

Table PP9: Indicators for prioritizing the blocks for intervention

Demographic Vulnerability	Climatic Vulnerability	Agricultural Vulnerability	Occupational Vulnerability
1. Density of population (persons per sq. km) 2. Literacy rate (percent)	1. Variance in 2. annual rainfall 3. Variance in mean temperature 4. Maximum and minimum temperature	1. Productivity of major crops 2. Cropping intensity 3. Irrigation intensity 4. Livestock population, etc.	1. Total workers 2. Agricultural labourers 3. Cultivators

Table PP10: Project phasing

Year	Year 1	Year 2	Year 3	Year 4	Year 5
Cumulative number of blocks at end of the year	10	25	40	40	40
Number of households	25,000	62,500	1,00,000	1,00,000	1,00,000

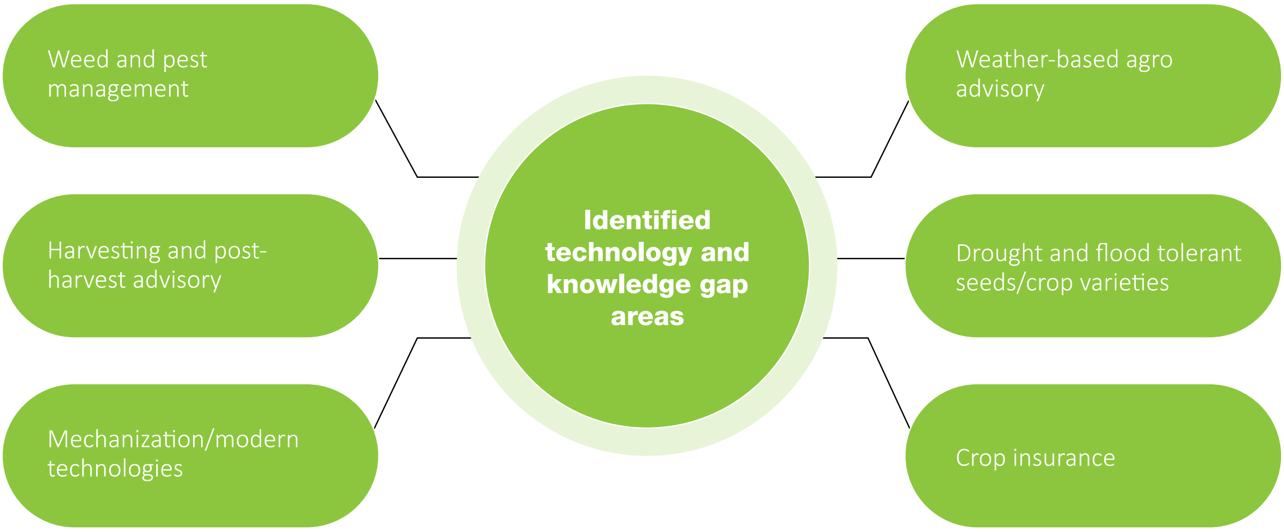
3. Project Components and Activities

Climate changes/variabilities are a recurring phenomenon faced by farmers in the IGP regions; farmers have not been successful in undertaking proactive measures in a sustainable manner due to access- and awareness-related constrains for interventions such as weather and crop advisory, insurance, safe storage and post-harvest management. Farming households adopt reactive measures to ease the immediate impact of climate change/ variability with low emphasis on climate resilience.

Farmers' adaptation levels are closely interlinked with the knowledge and awareness levels of the farmers, perception of climate change impacts on their cropping system, and their access to resources which help them to prepare their coping strategy.

Perceptions of farmers about climate change strongly affect how effectively they deal with climate-induced risks and uncertainties and undertake measures to mitigate the adverse impact of climate change on agriculture. To increase the adaptive capacity of the farming households, the first step is to increase awareness levels of farmers

Figure PP7: Technology and knowledge gap areas identified



through capacity building so that they can develop the right perspectives about climate change. This needs to be followed up by increasing their access to effective and locally-relevant adaptation approaches which have been customized as per the technical and financial capabilities of the targeted households. The commissioned study by UNDP has identified some of the gaps area which requires interventions to mitigate the impact of climate change.

Based on the assessment of gaps and challenges with respect to climate changes, three critical areas have been identified for interventions. The project will have primarily three components:

- **Component 1:** Promotion of a climate resilient agriculture system;
- **Component 2:** Development of a climate smart value chain/post-harvest system; and
- **Component 3:** Knowledge, technology and institutional development.

Table PP11: Gaps and key areas of interventions

Themes	Key Areas of Interventions
Production and productivity	Varietal knowledge which includes awareness on flood and drought resistant/tolerant varieties, staggered cropping planning, the shift in sowing/transplantation and harvesting dates, community nurseries, weed and pest management, intercropping and crop rotation, etc.
Harvesting, post-harvest and value chain	Grain maturity and harvesting, drying, in-house storage, moisture management, orientation on commercial warehouse functioning, transportation, cold storage, seasonal fluctuation of prices, shelf-life management, etc.
Sustainability enhancing	Nutrient management, soil moisture management, water management, rainwater conservation, natural farming, system of crop intensification, agriculture residue disposal (stubble burning), etc.
Financial linkage, insurance and leveraging government support	Crop insurance, farm credit, warehouse financing, agriculture credit (KCC), community institutions (SHGs and Federations, FPOs, FPCs, micro financial institutions, PACS, credit cooperatives, NABARD schemes, etc.
Technological/mechanization	Usage of commercial driers, moisture management, combine threshers and other implements, custom hiring centre concepts, etc.
Weather and climate	Crop advisory, weather advisory, and predictions, other sources of weather-related information (mass media, print media), etc.

82 Adapted from DFID Livelihood Framework.

3.1 Component 1: Promotion of a Climate Resilient Agriculture System

The objective of this component is to strengthen the adaptive capacity of smallholder farmers to adjust and modify their production systems to moderate potential future impacts from climate events. The component will focus on building climate-resilience in agricultural production systems through a series of activities at the farm level. This component will focus on increasing varietal knowledge which will include awareness on flood and drought resistant/tolerant varieties, staggered cropping planning, shift in sowing/transplantation and harvesting dates, community nurseries, weed and pest management, intercropping and crop rotation, etc.

Awareness on sustainable agricultural practices such as nutrient management, soil moisture management, water management, rainwater conservation, natural farming, system of crop intensification, agriculture residue disposal (stubble burning), etc., will be the themes around which the component would try to focus its interventions.

- This component will focus on supporting the transfer and adoption of CSA technologies by smallholder farmers, integrated pest and field management related practices aimed at enhancing farm productivity in the high climate variability context;

- The component will work on development and promotion of drought/flood-tolerant crop varieties for different crops and on crop substitution and livelihood diversification. The project will focus on field crops as well on horticulture crops. To bring sustainability to the interventions, this component will also focus on management of natural resources such as water and soil through adoption of better packages of practices;

- This component will support the transfer and adoption of CSA practices by smallholder farmers through capacity building initiatives such as on-farm demonstrations which may be undertaken through a farmer field school approach. Key themes for capacity building are varietal knowledge, etc. This component will promote protected cultivation to address micro-climate variability by: (a) introducing shade-net houses; (b) poly-houses; and (c) poly tunnels in select crops along with micro-irrigation system. SRLM has already developed such architecture as well as a pool of trainers who can be mobilized for such purposes (Village Resource Person, Master Resource Person and Livelihood Specialists). These training centres/farm schools will provide the vital link between the farmers and the knowledge resources. KVKs and State Agriculture Universities will also be requested for support. Knowledge of farmers will also be upgraded through training at district/ state levels and exposure visits, etc. While selecting the trainee farmers, preference will be given to small and marginal farmers and households from vulnerable communities. Knowledge and skills of trainers would be upgraded on a continuous basis through training. To streamline these activities a strategic Partner Management Committee will be developed at both state and district levels;

- The livelihood diversification strategy is a set of activities undertaken by households to find new ways to raise incomes and reduce their risks and vulnerabilities. Households adopt diversification to construct a diverse range of livelihood portfolios, either in expectation of increasing their income or in anticipation of some expected risks/unforeseen loss. This component will make diversification of livelihood a key intervention theme and will start with change in produce/commodities which will be the natural starting point. The next stage will be diversification in the context of integration with new livelihood activities which is based on their previous activities;

- Capacity building areas will focus on factors such as agro-climatic conditions, market context as well on household asset base which comprises of natural capital, physical capital, human capital, social capital, and financial capital[82]. These assets form the basis for households' choices of livelihood strategies, including agricultural practices, which in turn influence their food security status and level of well-being. These assets are interlinked and influence critical factors which include existing livelihood choices, adaptive capabilities and the choice of future diversification options; and

- The project will increase awareness of farmers on crop/weather insurance and will work towards improving the access of households to such products with the objective of risk mitigation. This will reduce the vulnerabilities of small and marginal farming households and help them to protect their existing livelihoods as well enable them to pursue riskier but potentially more profitable farming strategies.

3.2 Component 2: Development of a Climate Smart Value Chain/Post-harvest System

This component will build on promoting practices and technologies in post-harvest management and value-addition that support climate adaptation and/or mitigation for all value chain actors. Apart from farmers, other value chain partners such as traders, aggregators, processors, warehouse owners, cold storage and cold chain owners, etc., will also an integral part of the interventions made under this component. In addition to this existing pool of FPCs, FPOs will also be a major driver in increasing the adaptability of value chain actors in the select value chains. The component will develop the absorptive capacity of stakeholders in selected commodity value chains to prepare for and help recover from negative impacts of climate events. The component supports activities that enhance climate resilience beyond the farm gate and provides end-to-end solutions in value chains for agricultural commodities selected for their contribution to climate-resilient agri value chains. This component will provide technical support to value chain actors to develop/upgrade/procure new systems and processes to mitigate the impact of value chains. It is important as gains for small and marginal farmers are interlinked with the sustainability of the value chain which revolves around the critical issue of financial viability of the value chain actors and sharing of gains with farmers. The following key features of the intervention are proposed under this component:

- For climate smart post-harvest management, it is important to start action immediately after the harvesting of the crops. Project will focus on developing the capacity of collectives such as SHGs/VOs /FPOs on establishing infrastructure for drying and aggregation centres. These centres would also need to have facilities of elementary packaging. In addition to collectives, the project will also focus on capacity building of private players to participate in such activities. The aggregation centres shall provide facilities to the farmers for sorting, grading, weighing and proper packaging of their farm produce. FPCs and other community collectives shall be encouraged to establish aggregation centres with sorting, grading, weighing and packaging facilities. Existing FPOs shall be strengthened and encouraged to actively participate in the value chain. Under this component, both FPOs and individual entrepreneurs will be supported in activities such as preparation of bankable proposals, establishing linkages with business development service providers, etc.;

- Storage management is an important link in the agriculture value chain as any adverse impact of quality of grains affects the functioning of all value chain actors including the end consumer. The location of existing warehouses/cold storages is such that small farmers do not find it cost-effective to store their crop due to high transactional costs involved in transportation and other activities. In case of cold storages, most are only suitable for storage of potato. The project will support existing grain warehouses in capacity optimization/upgradation as well as construction of new warehouses/cold storages in the project area where such structures are not available for storage of agri produce with appropriate treatment. Along with private entrepreneurs, the project will also support FPCs and other community institutions in the establishment of godowns/warehouses. The focus will be on the development of micro warehouses and cold storages which need to be constructed at the block level. The long-term objective of this intervention is that farmers should have a proper storage/cold storage facility in less than 10 kilometres from their location;

- This component will also work for the establishment/upgradation of primary processing units sch as rice mills, roller/chakki flourmills, oil expellers/vegetable- and fruit-based primary processing units, etc., with private entrepreneurs as well with FPOs. The project will support existing processors to upgrade their plants and machineries to mitigate the impact of climate change. They will be supported through technical know-how as well in establishing linkages with service providers. The project will also facilitate the establishment of new units in the project area for value addition of the farm produce which shall help farmers in fetching better prices, longer shelf life and better marketability of their farm output. FPCs and interested community collectives shall be encouraged to establish primary processing units. Under this component, both FPOs and individual entrepreneurs will be supported in activities such as preparation of bankable proposals, establishing linkages with business development service providers, etc.;

- Capacity building of farmers and farmer collectives will be an important activity under this component. Individual farmers as well members/board and functionaries of collectives will be provided regular training on grain maturity and harvesting, drying, in-house storage, moisture management, orientation on commercial warehouse functioning, transportation, cold storage, seasonal fluctuation of prices, shelf-life management, etc. For strengthening linkages with the market, farmers will also be trained on assessing the volume and type of agri- commodities to be available for sale in different months, identifying potential buyers (wholesaler /processor/ industrial or corporate buyers hotels, etc.), appraising potential buyers on the availability status of agri commodities in the project areas and completing the contract/agreement process; and

- Apart from forward linkages, this component will also focus on developing backward linkages for the farmers especially with respect to availability of climate-resilient quality seeds and other inputs to the farmers/farmer groups on time. Climate-resilient varieties of major crops are one of the most important interventions intended to build resilience to changing climate and climate variabilities. Without improving the seed supply chain, the adaptation to climate variability and drought will be challenging. The project will support the creation of seed hubs linking FPOs, agriculture research and extension agencies and private and public sector players.

3.3 Component 3: Knowledge, Technology and Institutional Development

The objective of this component is to ensure adoption of the approach proposed for building climate resilience through a longer-term adaptive management of agriculture and other related natural resources such as soil and water. This component will make an effort to enhance the transformative capacity of institutions and all the stakeholders through knowledge, technology and policy-related interventions. This component will also focus on supporting farmers through the development of cutting-edge technological platform for weather/climate information and related agro advisory. It will focus on the development of knowledge, tools, models and policies that are workable on the ground and scalable for resilience. This component will also focus on empowering stakeholders, enabling learning and creating ownership of various interventions under this project.

- The project will adopt a climate risk management approach for smart systems development. It will use climate, local conditions data, soil and farming data, etc., to develop this system. This information, communication and technology system would plan to cover a broad range of potential actions, including early response systems and crop advisory, strategic diversification and capacity building of all stakeholders. The proposed approach is of immediate relevance to small and marginal farmers, because it plans to focus on coordinated resource with active engagement of all key stakeholders including farmers, agricultural support agencies, agriculture and rural services providers, rural and agricultural institutions.

All subsystems under the proposed platform will be designed and deployed to allow multichannel access (web, mobile, interactive voice response, etc). The designed system will utilize SMAC (Social, Mobile, Analytic and Cloud) technologies coupled with Internet of Things for real-time collection, analysis and dissemination of data and informa-

Figure PP8: Interventions planned under component 3

Climate Smart Farm Technologies

- Drought/flood tolerant varieties
- Soil & water conservation technologies
- Pest/weed management
- Post harvest measures

Climate Information Services

- Information on
  - Length of cropping season
  - Start and end of rains
  - Dry spells
- Mobile services for farmers

Dissemination at GP Level

- Community based organization
- Decision makers from
  - Traditional authorities
  - Opinion leaders
  - Agro-input leaders

Institutions and Knowledge

- Extension workers
- Farmer based organizations
- Researchers
- KVK, agriculture college/universities

tion to all stakeholders (suppliers as well as users) of the project;

- Weather and localized crop advisory will be the most important activity under this component. It will focus on collecting, processing and managing agro-meteorological data and issuing agro advisories using the IT system and farmer feedback. This component will also make efforts to enhance the local capacity for community-level pest and disease surveillance. To that effect, the project will work closely with private service providers/state agriculture universities and IMD;

- The development of systems aimed at real time contingency measures by analyzing weather and climate data/trends will be an important activity under this component. Crops with narrow sowing windows or where transplantation of seedlings is required are affected if there is a delay in monsoon. Breaks in the monsoon cause prolonged dry spells and are responsible for early, mid, and terminal droughts. These aberrant situations often lead to poor crop performance and/or total crop failures. While early season droughts have to be combated with operations such gap filling and re-sowing, mid and late season droughts have to be managed with appropriate contingency measures related to crop, soil nutrient management and moisture conservation. Contingency measures which may be implemented based on real time weather patterns will be promoted as real time contingency measures;

- Activities under this component will also include building the capacity of FPOs which include FPCs, producer groups, VOs and cluster federations with a focus on nurturing producer organizations as a climate-resilient, growth-oriented agri-business enterprises; and

- The project shall arrange to avail of technical support from public sector institutions such as Central Research Institutes, State Seed Development Corporation, SRLM, state agriculture college/universities, NICRA, Central Soil Salinity Research Institute, Central Institute of Agri Engineering, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IMD, etc. The project will have strategic partnership with institutions to develop several knowledge products, such as:

    - Long-term climate change model for the project area and its implications

    - Various thematic studies on climate resilience

    - Tools to carry out resource and opportunity analysis

    - Knowledge products for farmers, collectives/ FPOs, staff and board members of these FPOs and government staff working with the rural development and agriculture department.

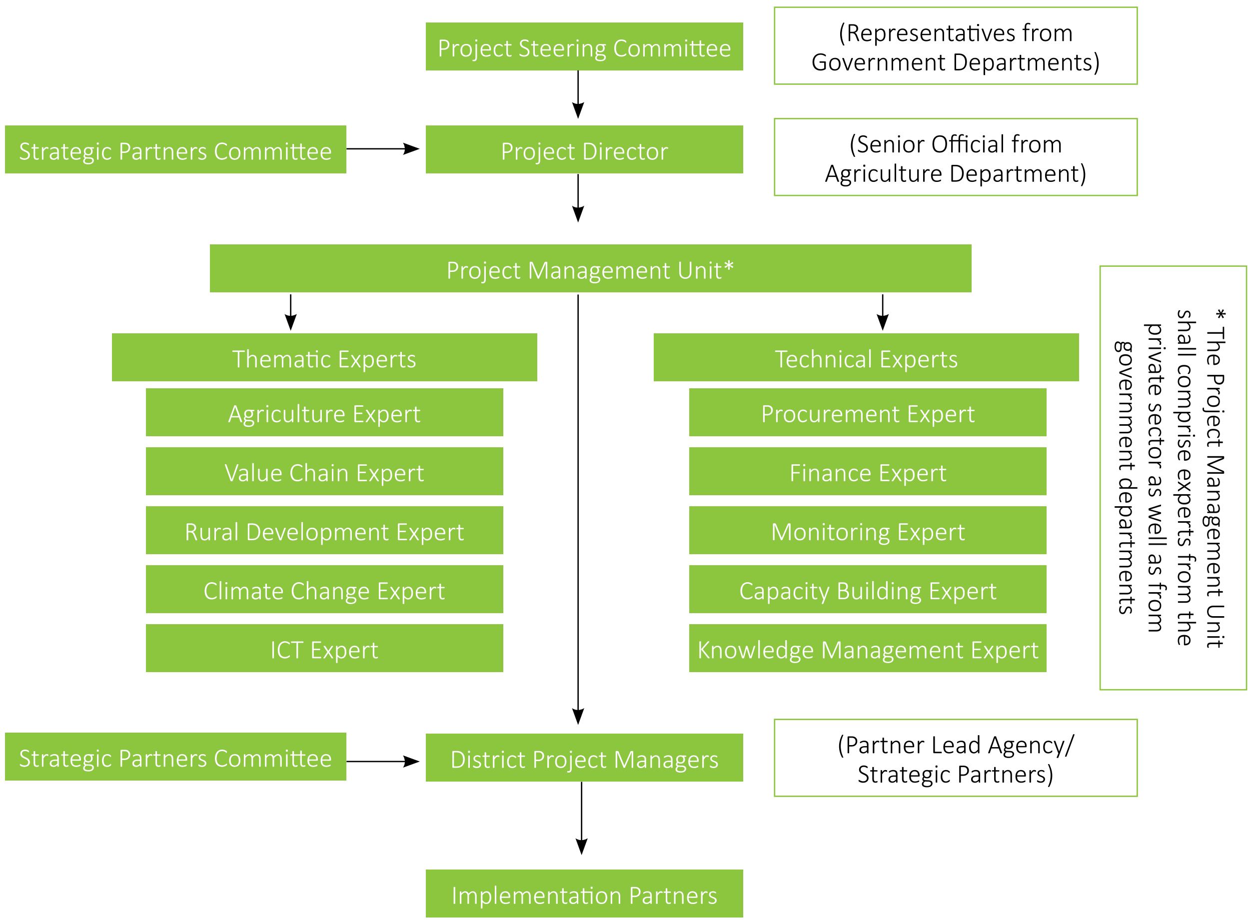
These knowledge products will be developed on the basis of a series of action research projects taken up by strategic partners during the entire length of the project period. Lessons learnt from these action researches would be carefully documented and widely publicized to enrich the existing knowledge base.

3.4 Project Management and Implementation

The project management framework has been designed on the basis of convergence with government departments. The Agriculture Department will be the nodal department for the project and the responsibility for the overall oversight of the project will be that of the Project Steering Committee (PSC) which will be headed by a senior official from the Agriculture Department. The head of PSC will work in the capacity of a project director. will also have representations from the Department of Rural Development, Department of Climate Change & Environment, SRLM, and Department of Industries/Food Processing. The main responsibility of the PSC will be to provide strategic guidance for the implementation of the project and to act as the interface between the project and the state government.

The PSC will approve the annual work programme and budget for the project, endorse the partnership arrangements and renewal of Memoranda of Understanding with strategic partners and technical support agencies. PSC will meet quarterly and will do an overall review of the project progress. The project will pay attention to institutional coordination across departments, agencies and strategic partners involved in the implementation of project activities. The key departments with which the project will work in convergence are the Department of Agriculture, Department of Rural Development, Department of Climate Change and Environment, SRLM, Department of Industries/Food Processing, Department of Irrigation, etc. The project will also leverage support from agriculture universities/colleges, agriculture extension agencies, financial institutions (NABARD, banks, Small industrial Development Bank of India, etc.). Officials from these

Figure PP9: Organization structure of Project Steering Committee



agencies will be part of PSC functional at both state and district levels. For each district, the project will hire one district project manager who will be responsible for the implementation of the project at the district level. The district project manager will work closely with strategic partner agencies and local partners.

For each of the districts, one local partner will be hired/ selected to carry out the work of awareness creation, mobilization and capacity building of farmers, collectives/ FPOs. The local partner agency will be responsible for implementation of all activities at the ground level in selected blocks. The local partner will work closely with strategic partners (agriculture research and extension agencies, SRLMs, and other government departments):

- A Project Management Unit (PMU) led by the project director will be developed in the Department of Agriculture which will ensure that all project-related activities are carried out in line with the approved project implementation plan. PMU will also be responsible for the day-to-day operations of the project as well for liaison with different government departments, UNDP and strategic partners. It will also be responsible for institutional coordination among the various agencies which include agriculture research and extension agencies, technological and technical partners. PMU will also supervise and monitor the implementation at the district and block level. It will also be responsible for designing and developing the strategy for all three components including the overall project monitoring and reporting activities;

- The project will focus on both top-down and bottom-up departmental convergence. The high level PSC provides a strong convergence mandate for this project in the sense that the project is not implemented in isolation but as an additional catalytic investment for increasing the adaptive capacity of all stakeholders in the agriculture value chain with specific focus on small and marginal land holding farming households. The state has already prepared the climate action plan and agriculture road map by following this very approach. The specific crop/varietal advisories are available through the agriculture college/university and agriculture extension machinery. The bottom-up planning process from the block onwards will be ensuring participation of Block Agriculture Officer, District Agriculture Officer, Project Director ATMA, District Project Director SRLM, etc.;

- PMU will have both thematic experts and technical experts. Thematic experts will have a team of sectoral experts from the sectors of agriculture, climate change & environment, value chain, institutional finance & investment and ICT. Thematic experts from agriculture, climate change & environment will be from the respective departments, the state government while thematic experts for themes such as value chain, institutional finance & investment and ICT will be hired from market. Additionally, at PMU, there will be team of technical consultants who will specialize in activities such as finance & accounts, procurement, monitoring and evaluation and knowledge management. The monitoring and evaluation consultant will be a responsible for the quarterly consolidation and reporting;

- For implementation of technical work which will include comprehensive ICT activities such as weather and crop advisory, systems for real time contingency plan and development of IT-based knowledge products, technical agencies will be hired. The agencies recruited will work closely the Project Director. PMU will also implement activities related to communication, public awareness and outreach, including setting up and maintaining a comprehensive project website that also accommodates an open space for lodging stakeholders' complaints as part of the project's grievance redress mechanism;

- The work at district level will be supervised by the district project managers who will be responsible for work in each of the respective districts. They will act as facilitators, collaborators, supervisors and bring-convergence. For overall supervision and guidance, a steering committee will be formed which will have members such as District Agriculture Officer, Project Director ATMA, District Project Manager SRLM, District Industries Centre, etc.; and

- Implementation work will be undertaken by the local partner agency that will be brought onboard through partnerships after proper screening. Block Agriculture Officers of such blocks will also be members of the district level steering committee. The District Project Manager will also be the administrative head at the district level and responsible for smooth implementation of the project in the district. He/she will also be responsible for implementation of the annual work plan, regular monitoring of project activities, and coordination with line departments at block/district level.

3.5 Project Cost

The project has three components along with project management. Table PP12 presents the key activities of each components and project management.

Table PP12: Components and key activities

Components	Key Activities	Financial Costs in INR
Component 1: Promotion of the climate resilient agriculture system	• Capacity building of farmers on varietal knowledge which includes awareness on flood and drought resistant/tolerant varieties • Partnership with agriculture college/universities/ agriculture extension for supply of flood and drought resistant varieties • Development of seed hubs linking FPOs, agriculture research and extension agencies, private and public sector players • Development of demonstration plots • Capacity building of farmers/collectives on staggered cropping planning, community nurseries, natural weed and pest management, intercropping/crop rotation/crop substitution • Piloting and exposure to farmers on protected cultivation to address micro-climate variability (shade-net houses, poly-houses, poly tunnels) • Convergence with KVKs/State Agriculture Universities/ATMA/ SRLM • Capacity building and development of prototypes on nutrient management, soil moisture management, water management, rainwater conservation, system of crop intensification, agriculture residue disposal (stubble burning), etc.	54,500,000.00
Component 2: Development of the climate smart value chain/post harvest system	• Capacity building of farmers on grain maturity and harvesting, drying, in-house storage, moisture management, commercial warehouse, transportation, cold storage & cold chain, price fluctuation, shelf-life management, etc. • Capacity building of farmers and collectives on primary value addition activities such as cleaning, grading, sorting • Capacity building of collectives/FPOs, etc., on micro grain warehouses, micro cold storages and cold chain • Capacity building of FPOs and private entrepreneurs on business development services which include support in preparation of bankable proposals, linkages with suppliers and buyers • Capacity building of collectives/FPOs on establishment and management of custom hiring centres • Support to FPOs/collectives in backward value chain integration	34,350,000.00
Component 3: Knowledge, technology and institutional development	• Development of training calendar and training content • Development of ICT enabled system for weather forecasts with localized crop advisory • Development of systems for real time contingency measures • Collaboration with strategic partnership agencies	53,400,000.00
Total Cost		142,250,000.00

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