An Economic Analysis of Climate Change Effects on Agricultural Productivity: A Case Study on Climate Vulnerability of Farmers in Bundelkhand Region of Uttar Pradesh

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CERTIFICATE

This is to certify that the thesis titled "**An Economic Analysis of Climate Change Effects on Agricultural Productivity: A Case Study on Climate Vulnerability of Farmers in Bundelkhand Region of Uttar Pradesh**" submitted by Mr.Surendra Singh is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other university.

The thesis submitted to BabasahebBhimraoAmbedkar University, Lucknow satisfies all the requirements as stipulated in the *Doctor of Philosophy (Ph.D.) regulations- 1999 as amended in 2008/2010/2013* and it is fit for submission and evaluation for the award of the degree of Doctor of Philosophy of the University.

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DECLARATION

I hereby declare that the thesis entitled "**An Economic Analysis of Climate Change Effects on Agricultural Productivity: A Case Study on Climate Vulnerability of Farmers in Bundelkhand Region of Uttar Pradesh**" submitted to the Babasaheb Bhimrao Ambedakar University for the award of Doctor of Philosophy in Economics is my original work and that is not previously formed the basis for the award of any degree, diploma, fellowship or similar other title.

This study is carried out under the guidance of my research guide Professor Sanatan Nayak, Professor of the Department, Department of Economics, Babasaheb Bhimrao Ambedkar University, Lucknow.

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PREFACE

Climate change in the present century is one of the most serious and has biggest threat to the mankind. Over utilisation of natural resources caused biodiversity loss in the form of deforestation, depletion, pollution and acidification and food security becomes one of the most serious threat for the world's growing population. Variability in the environmental factors, viz., rainfall and temperature reduces the farm productivity in the low latitudes countries, where agriculture is only source of livelihood security for majority of the population. Further, elevated levels of greenhouse gases added an additional layer in the vulnerability.

The present study is an attempt to estimate the impact of climate change on the Indian agriculture. The present study covers 15 major and minor food crops in 291 districts of 15 states during 1966-2011. The present study found that major food crops, viz., rice and wheat are highly sensitive and adversely affected by the rise in temperature and fall in rainfall, whereas, maize, finger millet, pearl millet, pigeon pea, lime seeds, chickpea and rabi pulses are less sensitive. Furthermore, the present study has also made an attempts to examine livelihood and climate vulnerability in one of the most backward region of Uttar Pradesh, viz., Bundelkhand region. The study found that least amount of basic amenities, least amount of crop & income diversification, lack of non-farm employment opportunities and lower educational qualification are major contributors for the livelihood vulnerability among the surveyed households. Subsequently, higher exposure from the environmental factors, viz., rainfall and temperature, female headed households and higher dependency on conventional natural capital for the cooking purposes are major contributors for the climate vulnerability among the surveyed households. Although, surveyed households are applied differential adaptation strategies to cope with climate change, viz., change in cropping pattern, less water consuming crops, higher use of chemical fertilisers & pesticides, early maturing varieties and improved irrigation, but due to the high exposure to the rainfall and temperature, the current adaptation practices are insufficient to deal with current environmental crisis in the Bundelkhand region of Uttar Pradesh.

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ABBEREVIATIONS

Access to Resource Model	:	ARM
Adaptation Fund Board	:	AFB
Adaptive Capacity Index	:	ACI
Agro-Ecological Zone	:	AEZ
Analytic Hierarchy Process	:	AHP
Away from District Headquarter	:	ADH
Benefit Cost Ratio	:	BCR
Compound Annual Growth Rate	:	CAGR
Carbon Dioxide	:	CO_2
Climate Vulnerability Index	:	CVI
Cobb- Douglas Production Function	:	CDFP
Conference of Parties	:	CoP
Convention on Biological Diversity	:	UNCBD
Cost Benefit Analysis	:	CBA
Cost Effectiveness Analysis	:	CEA
Dynamic International Vulnerability Assessment	:	DIVA
Economic Commission for Europe	:	ECE
Ehrlich Commoner	:	EC
Erosion Productivity Impact Calculator	:	EPIC
Economic Reform Period	:	ERP
Feasible Generalised Least Square	:	FGLS
Future Agricultural Resources Model	:	FARM
General Circulation Models	:	GCM
Geographic Information System	:	GIS
Gross Irrigated Area	:	GIA
Global Computable General Equilibrium	:	CGE
Global Environmental Facility	:	GEF
Greenhouse Gas	:	GHG

Gross Domestic Product	:	GDP
Gross National Product	:	GNP
Gross Sown Area	:	GSA
International Crop Research Institute for the Semi- Arid and Tropics		ICRISAT
Indian Meteorological Department	:	IMD
Indo Gangetic Plains	:	IGP
Integrated Assessment Models	:	IAM
Intergovernmental Panel on Climate Change	:	IPCC
International Whaling Commission	:	IWC
International Whaling of Whale	:	ICRW
Kyoto Protocol	:	KP
Livelihood Vulnerability Index	:	LVI
Long Range Transboundary Air Pollution	:	LRTAP
Mid Indo Gangetic Plain	:	MIGP
Montreal Protocol	:	MP
Multi-Criteria Analysis	:	MCA
Multi Criteria Decision Analysis	:	MCDA
Net Irrigated Area	:	NIA
Non- Government Organisations	:	NGOs
Net Sown Area	:	NSA
Ordinary Least Square	:	OLS
Post Green Revolution	:	PGR
Pressure and Release Model	:	PARM
Risk Hazard	:	RH
Safe Minimum Standard	:	SMS
Southern Plateau	:	SP
Steady State Economy	:	SSE
Third Assessment Report	:	TRA
United Nations Conference on Environment and Development		UNCED
United Nations Framework Convention on Climate Change	:	UNFCCC

United Nations	:	UN
United Nations conference on Human Environment	:	UNCHE
United Nations Environment Programme	:	UNEP
Vulnerability- Resilience Indicator Prototype	:	VRIP

Chapter- 1

Climate Change: Issues and Challenges

1.0 The Context

The Earth has unique features viz., distance from the sun, period of rotation, more than 70 percent surface area covered by oceans and rest of surface area covered by forest, mountains, grasslands, rivers and deserts in the solar system. Therefore, Earth is only known planet in the human knowledge, where life is available in the survival form (IPCC, 2013, p. 2). However, due to heterogeneity in climatic conditions, Earth's climate is a complex interactive aggregate of physio-chemical and biological systems (Panda A., 2013, p. 1). The climate in a narrow sense is usually defined as "average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years" (IPCC, 2014a, pp. 119-120). The classical period of averaging these variables is 30 years, as defined by the World Meteorological Organisation. The relevant quantities are most often surface variables such as temperature, rainfall and wind speed. Further, climate in a wider sense includes a statistical description of the climate system (IPCC, 2014a, p. 120). On the other hand, climate change refers to a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties and persists for an extended period, typically decades or longer (IPCC, 2014a, p. 120). The difference in temperature is due to a suite of gases called greenhouse gases, which affect the overall energy balance of the Earth's system by absorbing infrared radiation. In its existing state, the Earth-atmosphere system balances absorption of solar radiation by the emission of infrared radiation to space. Due to greenhouse gases, the atmosphere absorbs more infrared energy that it re-radiates to space, resulting in a net warming of the Earth-atmosphere system and of surface temperature. This is the "Natural Greenhouse Effect". Thus, natural greenhouse effect makes life possible on the Earth by maintaining the required temperature[1] (IPCC, 2014a, p. 124). However, it is observed that global concentration of greenhouse gases (carbon dioxide, methane, nitrous oxide and

[1] Climate varies naturally on all time-scales from hundreds of millions of years down to the year-to-year. Prominent in the Earth's history have been the 100,000 years glacial-interglacial cycles when climate was mostly cooler than at present. Global surface temperature have typically varied by 5^0C to 7^0C through these cycles, with large changes in ice volume and sea level, and temperature changes as great as 10^0C to 15^0 in some middle and high latitude regions of the Northern Hemisphere.

fluorinated gases) has rapidly increased in the atmosphere since pre-industrial era as a result of mainly anthropogenic activities (IPCC, 2014a, p. 120).

The recent Intergovernmental Panel on Climate Change (IPCC) in its fifth assessment report observed that the Earth's climate system has demonstrably changed on both global and regional levels compared to the pre- industrial era (IPCC, 2014a, p. 1). The report states that "warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and oceans have warmed, the amount of snow and ice have diminished, and sea level has risen" (IPCC, 2014c, p. 2). Further, each of the last three decades has been successively warmer at the Earth's surface than any preceding decades since 1850. The period from 1983 to 2012 was likely the warmest 30 year period of the last 1400 years in the Northern Hemisphere. The globally averaged combined land and ocean surface temperature data show a warming of 0.85^0C over the period 1880 to 2012. The frequency of extreme weather events has increased observed since 1950 (IPCC, 2014c, p. 2). Decrease in cold temperature extremes, an increase in warm temperature extremes, and increase in extreme sea levels and an increase in the number of heavy precipitation events in a number of regions have observed since 1950 (IPCC, 2014a, p. 2). By using large-scale datasets report projected that surface temperature rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise.

Further, synthesis report under fifth assessment of IPCC confirms that human influence on the climate system is clear and growing, with impacts observed across all continents and oceans. The IPCC is now 95 percent certain that humans are the main cause of current global climate change, the greater risks of severe, pervasive, and irreversible impacts for people and ecosystems, and long- lasting changes in all components of the climate system. Furthermore, the anthropogenic greenhouse gas emission has increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This had led to atmospheric concentrations of carbon dioxide, methane, and nitrous oxide that are unprecedented in at least the last 260 years[2] (IPCC, 2014a, p. 124). Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid- 20th century.

Humans are in the center of the undesirable changes in the Earth system. Their past and current unsustainable economic actions are mainly responsible. The undesirable changes are more profound and increase the degree of sensitivity with less adaptive capability. Anthropogenic greenhouse gases released into the atmosphere remains more than 100 years if we stop adding greenhouse gases to the atmosphere today. Ecological economists argue that sustainable use of natural resources keep in mind availability for the future generation and carrying capacity of the earth will help in human footprint reduction. Rockstrom et al. (2009, p. 3) proposed the concept of "Planetary Boundaries approach[3]". This is the synonyms of "Safe Minimum Standard".[4] Both planetary boundaries and safe minimum standard concepts argued that the use of natural resource should be below from the threshold level. Rockstrom et al. (2009, p. 4) identified important Earth- system processes and their associated thresholds, if crossed, could generate unacceptable environmental change. They found nine such processes to define planetary boundaries viz., climate change, the rate of biodiversity loss (terrestrial, land and marine), interference with nitrogen and phosphorus cycles, stratospheric ozone depletion, ocean acidification, global freshwater use, change in land use, chemical pollution and atmospheric aerosol loading. The planetary boundaries approach rests on three branches of scientific enquiry. The first addresses the scale of human action in relation to the capacity of the Earth to sustain it, a significant feature of the ecological economics research agenda, drawing on work on the essential role of the expansion of the economic subsystem (Boulding, 1966, pp. 125-130). The second is the work on understanding essential Earth- system processes, including human actions brought together in the evolution of global change research towards Earth-

[2] 1750 BC is taken the pre- industrial period.

[3] The idea that there is an identifiable set of boundaries, beyond which anthropogenic change will put the Earth system outside a safe operating space for humanity, is attracting interest in the scientific community and gaining support in the environmental policy world.

[4] The Safe Minimum Standard (SMS) approach is a collective choice process that prescribes protecting a minimum level of a renewable natural resource unless the social costs of doing so are somehow excessive or intolerably high.

system science and in the development of sustainability science. The lastly, framework of resilience and its links to complex dynamics and self-regulation of living systems, emphasizing multiple basins of attraction and threshold effects.

Furthermore, by used large-scale data, a group of scientist found that four of nine planetary boundaries have now been crossed as a result of anthropogenic activity. The four are: climate change, loss of biosphere integrity, land-system change and altered biogeochemical cycles (phosphorus and nitrogen) (Steffen et al., 2015, pp. 1-15). They proposed that concentration of carbon dioxide in the atmosphere should not exceed 350 parts per million above from pre- industrial era, which they were observed 387 parts per million. Similarly, the rate of biodiversity loss in terms of species extinction rate (number of species per million species per year) is currently more than 100 in comparison to the proposed boundary of 10 numbers of species per million per year. Interference with the nitrogen cycle, the study argued that the amount of reactive nitrogen has already pushed into land, ocean, and atmospheric systems from the carrying capacity of the earth. Local level to regional- scale of anthropogenic interference with the nitrogen cycle and phosphorus flows have induced an abrupt shift in lakes and marine ecosystems (Rockstrom et al., 2009, p. 2). It is argued by the authors that transgressing these boundaries will increase the risk of irreversible climate change, viz., loss of ice sheets, sea level rise, shifts in forest, and importantly agricultural system.

Agriculture in the developing countries like India provides employment for the more than half of the unskilled population. Macro agricultural statistics such as net sown area and average land size is either skewed or decline. On the other hand, consumption of fertiliser, area under irrigation, use of hybrid seeds and use of pesticides have increased over the decades. In other words, Indian agriculture after implementation of green revolution becomes resource intensive, less profitable for small and marginal farmers, which are nearly 85 percent of total land holders in recent years. Further, small and marginal farmers in the absence of sufficient non- farm employment are highly vulnerable, less productive and remain unemployed in the off cropping season. The total food grains production statistics show a surplus in quantities and sufficient to feed domestic demand. On the other hand, minor cereals, pulses and some non- food grain crop productivity has still very much lower and imported from rest of the world to feed domestic demand. It increases the domestic prices and leads to higher food inflation.

Apart from the important agricultural determinants, viz., irrigated area, consumption of chemical fertilisers, pesticides, seeds, and technology used in agriculture, the role of environmental factors, viz., rainfall, temperature, solar radiation, wind speed, and concentration of carbon dioxide in the atmosphere etc. are vital and crucial for agricultural productivity. It is observed that variability in climatic factors such as rainfall and temperature has been increased over the last five decades. In India, where the majority of farm practices depend on Monsoon rainfall, it becomes highly variable and unpredictable due to rise in mean surface temperature and concentration of greenhouse gases especially carbon dioxide in the atmosphere. These environmental factors adversely affect the current farm- practices.

Therefore, the issue is that the current farm practices with lower socio-economic and biophysical conditions are not able to cope with current abrupt climate change, which is not only a major global environmental problem but also an issue of great concern to the developing countries like India. More specifically, current research work addressed four key issues in the Indian agriculture, i.e., resource intensive, adversely affect the climate change, highly vulnerable farmers, and lower adaptive capabilities. IPCC (2014c, p. 124) in the fifth assessment report (working group I, II, III) observed that farm practices in the developing countries are highly unsustainable. Farmers are using artificial sub-additives in the unsustainable manners. It declines farm productivity and increased the cost per hectare. Farmers are still living bottom of the line in the complex social system with nominal basic amenities. Given the lack of resources and access to technology and finance, the developing countries such as India have limited capacity to develop adaptive capacities to reduce their degree of vulnerability to change in climate.

1.1 Climate Change and Its Impact on Agriculture: Global View

Climate change is affecting the farm productivity across the agro-climatic zones at large extent (IPCC, 2014a, p. 1). The impact of climate change (positive or negative) on farm productivity depends on the geographic location of the farm. In 1990, the IPCC first assessment report predicted that there is a possibility that the potential productivity of high and mid-latitudes may increase because of a prolonged growing season. On the other hand, report also predicted that farm productivity in the low latitude areas (Africa and Asian continents) potentially decline. Therefore, broadly the studies on climate change impact of farm productivity divided into two groups of studies viz., high & mid-latitude location countries and low latitude countries.

The First group of studies are examined the impact of climate change on farm productivity in the high & mid- latitude countries like European countries. Several studies related to climate change impact predicted/projected that temperature is likely to be increased 1.5^0C to 5.8^0C and precipitation pattern to shift by 2100 (IPCC, 2014a, p. 124 and Mendelsohn, 2006, p. 159). Before the published Mendelsohn study in environmental and development studies in 2006, the majority of researchers believed that damages were a linear or quadratic function of the change in temperature. As a result, initial studies predicted that every country would suffer damages from the warming and that they would be roughly proportional to income. The literature at this time, assumed that almost every region would be damaged by warming (Pearce et al., 1966, pp. 362-384). However, the new research work indicates that several climate-sensitive sectors have a hill-shaped relationship with absolute temperature (Mendelsohn and Neuman, 1999, pp. 234-240 and McCarthy et. al., 2001, pp. 125-130). For each sector, they argued that there is an optimum temperature that maximizes welfare in that sector. Farming in the high latitudes that are cooler that the optimum temperature, warming would cause net revenues to go up. On the other hand, farming in low latitudes that are warmers that the optimum temperature, warming would cause net revenues to fall. These results imply that countries that happen to be in relatively cool regions of the world will likely benefit from the warming and that countries that happen to be in relatively warm regions of the world will likely be harmed by warming.

Further, the intensity of the adverse impact of climate change on farm productivity will be depends on the socio-economic conditions of the farmers, depending on the farm income and availability of non-farm employment also. A country with high economic growth are relying on the high latitudes called developed or rich countries. On the other hand, a country with low economic growth are rely on low latitudes called developed or poor[5]. Therefore, climate change likely to more adversely affect poor compare with rich country. Further, they argued that the poor nations of the world bear the brunt of climate change damages primarily because they are located in the low latitudes and are already too hot. The rich nations may well benefit from climate change because they are located in the mid-latitudes and are currently cool. They also argued that the proportion of GDP in agriculture, technology, wealth and adaptation has a major role to moderate adverse impacts of climate change. Furthermore, Gianpiero M. et al. (2005, pp. 117-135) predicted that most of the parts of Europe show an increase in surface air temperature during the 20th century which, average across the continent, amounts to about 0.8^0C in annual temperature. This warming has been largest over the north-western Russia and Iberian Peninsula. The last decade in Europe (1990-1999) has been the warmest in instrumental record, both annually and for winter. Increase in growing season length has also been observed in Europe. However, variations in the precipitation between northern Europe (wetting) and southern Europe (drying), reflecting a wider hemispheric pattern of contrasting zonal-mean precipitation trends between high and low latitudes. Precipitation over northern Europe has increased by between 10 and 40 percent in the 20th century, whereas some parts of southern Europe have dried by up to 20 percent. They predicted that the effect of climate change on Europe is likely to increase the productivity of agricultural and forestry systems, because increasing CO_2 concentration will directly increase resource use efficiency of plants, and because warming will give more favorable conditions for plant production in northern Europe (Gianpiero M. et al., 2005, pp. 117-135). Similarly Ewert F. et al. (2005, pp. 101-116) by using the Food and Agriculture Organisation datasets during 1961-2002 of 15 EU-member countries plus Norway estimated the future wheat yield. They found that wheat yield would be increased by 6 tonnes per hectare from the baseline (baseline year is 2000) and increase 8 to 15 percent per hectare for B2 and A1FI scenario in 2080 respectively. They applied

[5] Mendelsohn and Neuman, (2006, p. 164) argued that forcing climate change impact on the poor (developing) and rich (developed) countries, the poor still bear the brunt of the world's damages. However, forcing the initial climate to be the same for all counties changes the distributional results. If all countries had the same initial climate, the absolute magnitude of climate damages would rise with income, because richer nations have larger climate-sensitive sectors. As a fraction of gross domestic product (GDP), poorer nations would still suffer higher climate damages that richer nations.

two separate models for the prediction of wheat yield, viz., regional environmental scenario and global economic scenario. They found that the wheat yield increases small in the regional environmental scenario and the largest in the global economic scenario. Technological development was identified as the most important driver, but relationship that determine technology development remain unclear and deserve further attention. Moreover, Peltonen S. et al. (2009b, pp. 71-97) emphasised the role of adaptation measures. They argued that in the in northern European crop production might benefit from climate change in the long-run, but not without comprehensive and extremely costly adaptation measures. The successful adaptation, northern European agriculture may even increase in productive capacities.

The second group of studies assessed the impact of climate change on farm productivity in the low latitude areas like Asian and African countries. IPCC (2013, p. 124) projected that temperature in the majority Asian and African countries reached up to a threshold level. Therefore, marginal increase in temperature will be adverse impact on the crop productivity. It will affect twin mode, viz., biophysically and economically. Biophysical impact- Increasing temperature accelerate the process of photosynthesis and reduce plant growth period. Economic impact- shorter germination period reduced seed size and the weight of the fruit also. It means the net crop production decline in the respective cropping season. Mendelsohn (2005, pp. 121-135) examined the impact of climate change on the Southern Asian agriculture for 2100 by using three different climate simulation models from AOGCM's: the PCM model, the CCSR model and the CCC model. According to the results, the CCSR and the CCC scenario would cause net revenues to fall by about $60 billion per year, 11 percent loss and $219 billion, 39 percent loss to South Asian agriculture. Similarly, Seo et al. (2005, pp. 581-597) examined the climate change impacts on Sri Lankan agriculture by using the Ricardian method and Five AOGCM experimental models. The Model analysised that the net revenue per hectare of the four most important crops, viz., rice, coconut, rubber and tea. The study found that increase in temperature to be harmful to the nation and the loss ranges from -18 percent to -50 percent of the current agricultural productivity.

In addition, Basak (2009, pp. 110-115) has analysed climate change impact on rice production in Bangladesh by using a simulation model. The model is specially focused on the Boro rice production, which accounts for 58 percent of the total rice production during 2008. The simulation model results show that rice production decreases drastically from 2.6 percent to 13.5 percent and from 0.11 percent to 28.7 percent when the maximum temperature increased by 2^0C and 4^0C. Further, Mendelsohn (2008, pp. 309-313) examined the impact of climate change on agriculture in the developing countries by using cross sectional panel data[6]. Study confirmed the hypothesis that tropical and subtropical agriculture in the developing countries are more climate sensitive than temperate agriculture. Even marginal warming causes damages in Africa and Latin America to crops. Crops are also sensitive to changes in precipitation. In semi-arid locations, increased rainfall is beneficial. However, in very wet places, increased rainfall can be harmful. He found that if climate scenarios turn out to be relatively hot and dry, they will cause a lot of damage to farm in low latitude countries. Furthermore, Namrata K. et al. (2012, pp. 663-687) develops a new method to measure the impact of climate change on agriculture called the Agro-Ecological Zone (AEZ) model and tested in the Africa. A multinomial logit model is estimated to predict the probability of each AEZ in each district. The average percentage of cropland and average crop net revenue are calculated for each AEZ. Then an estimate of the amount of cropland in Africa and where it is located is provided. Using current conditions, the model calculates baseline values of cropland and crop net revenue, and estimates the future impact of climate change using two scenarios, viz., harsh and mild. They found that the total cropland does not change much across the two climate scenarios. However, the predicted change in African crop revenue changes from a loss of 14 percent in the mild climate scenario to 30 percent in the harsher climate scenario. The analysis reveals that the greatest harm from climate change is that it will shift farms from high to low productivity AEZs. The approach not only identifies the aggregate impacts, but also indicates where the impacts occur across Africa. The central region of Africa is hurting the most, especially in the harsher climate scenario they observed.

[66] Study conducted in the 11 African countries, viz., Burkina Fiasco, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, Zambia and Zimbabwe. A survey instrument was designed and tested for Africa. Teams from each country collected data using this instrument across a wide range of African climate zones. Over 10,000 farmers were interviewed about their livestock and crop incomes, costs and faming choices.

1.2 Climate Change Impacts on Indian Agriculture

With heterogeneous agro-climatic conditions, lower fertility, decline mean land size, higher reliance on farming, decline in investment, increase in greenhouse gases concentration, increase in temperatures and increase in rainfall variability, Indian agriculture is potentially affected in the recent years. Further, least adoption of modern technology in the marginal and small farmers has increased the degree of vulnerability. Therefore, in the Indian agriculture context, studies are broadly classified in three groups, viz., potential impact, vulnerability assessment, and adaptation assessment.

The first group of studies are assessed the potential impact of climatic factors, viz., rainfall, temperatures and greenhouse gases on farm productivity. Goswami et al. (2006, pp. 245-250) observed that intensity of climate-related events during 1950-2000 has increased. In India, agriculture still depends on monsoon rainfall pattern which is now less predictable and more intense. Rainy days are declined on one hand and on the other hand, the intensity of heavy and heavier rainfall events has increased. Monsoon pattern is changing towards early Rabi cropping season (post monsoon period). This change adversely affects both two major cropping seasons, viz., kharif and rabi. They argued that the agricultural situation is more critical in two ways. First, more than 60 percent of cropped area are under rainfed conditions, which means monsoon rainfall is not sufficiently available to maintain the current cropping pattern. Second, in the absence of water for irrigation, unregulated bore wells are responsible for desertification. Farmers are over- utilising water for irrigation, which leads to water shortage in the lean season.

Similarly, Ramanathan et al. (2005, pp. 5326- 5333) argued that when the monsoon rainfall deficiency exceeds 10 percent and affects more than 20 percent of the country area, it is categorised as an all-India drought year. However, farming in India is much more sensitive and it adversely affects, even rainfall deficiency exceeds 2-3 percent. Temperature statistics also confirm acceleration. In India, last 100 years mean temperature has increased by 0.57^0C (NATCOM, 2004, p. 13 and 2012, p. 19). This warming is mainly contributed by the winter and post- monsoons temperatures, which has been increased by 0.7^0C and 0.52^0C in the last 100 years, respectively. Sinha and Swaminathan (1991, p. 234) estimated that an increase 2^0C in mean temperature could decrease rice yield by about 0.75

ton/hectare in high yield areas and 0.6ton/hectare in the low yield coastal regions. Further, 0.5^0C increase in winter temperature would reduce wheat crop duration of seven days and reduce yield by 0.45 ton/hectare, and 10 percent reduction in wheat production in the high yield states of Northern India. Hundal and Kaur (1996, p. 21) estimated climate change impact in high yield regions. A temperature rise of 1^0C, 2^0C and 3^0C from present-day level would reduce rice yield by 5.4 percent, 7.4 percent and 25.1 percent respectively.

Concentration of carbon dioxide gas in the atmosphere is also affected for crop duration. Lal et al. (1998, p. 54) estimated that a doubling of carbon dioxide: rice and wheat yield increased significantly by 15 and 28 percent, respectively, but rise in 3^0C temperature for wheat and 2^0C temperature for rice cancelled out the positive effects of carbon dioxide. Further, Kumar and Parikh (2001, p. 32) estimated that the increase in 2^0C and 7 percent precipitation has a negative impact and about 8.4 percent of the total farm-level net revenue in India is lost. Mall and Aggarwal (2002, pp. 315-330) estimated that without an increase in carbon dioxide level and rise in temperature of 1-2^0C rice production decline by 3-17 percent with regional heterogeneity.

The second group of studies assessed vulnerability in the India agriculture. Aggarwal et al. (2004, pp. 487-498) argued that Southern and Western India, compared to northern and eastern regions, are likely to show a greater sensitivity and vulnerability to climate change. Districts concentrated in Rajasthan, Madhya Pradesh, Gujarat, as well as southern Bihar and western Maharashtra are highly vulnerable to globalisation and climate change is likely to pose simultaneous challenges to the agricultural sector. Low vulnerability areas lie in the Indo-Gangatic Plains. Further, their regional analysis, Brenkert and Malone (2005, p. 21) assessed the climate- induced vulnerability in I Indian states using the Vulnerability-Resilience Indicator Prototype (VRIP). Results show nine Indian states to be moderately resilient to climate change, principally because of low sulphur emission and a relatively large percentage of unmanaged land. Further, six states are more vulnerable than India as a whole, attributable largely to sensitivity to sea storm surges. They found that most vulnerable states are six coastal states in India are most vulnerable with high population density[7]. The small mountainous northern inland states show the highest resilience among the India States. Orissa and Tamil Nadu show high sensitivity to sea- storm surges. Further, Chaliha et al. (2012, p. 54) estimated composite vulnerability index by using indicator approach in the Assam state. The index values of biophysical, agricultural, socio-economic and demographic show that the biophysical factors have the greatest impact on the overall vulnerability.

The third group of studies assessed adaptation strategies at a farm level. Copping with climate change, farmers started different autonomous adaptation strategies. Crop rotation, less water consuming crops, short- duration crops, improved irrigation facilities, use of hybrid seed, and insurance are key adaptation strategies applied at a farm level**.** Pandey R. and Shashidhar K. Jha (2008, pp. 487- 506) observed that farmers are using indigenous varieties of seeds, shifting cropping pattern and delay sowing period. But the exposure of the adverse impact of climate change has increased in the unpredictable manners. On the other hand, the cropped area sown by using indigenous varieties of seeds is much lower. In majority, large as well as small and marginal farmers are using hybrid varieties of seeds without testing soil requirements and, it leads to lower farm productivity. In India, more than 60 percent of cropped area is rainfed and still, they are growing high water consuming crops, viz., rice and wheat to feed family's annual food demand. Further, with the promotional government irrigation policy, over exploitation of ground water is general and it leads to water scarcity. The accessibility of agriculture credit from the institutional sources still lower. Due to complicated documentation process, illiterate small and marginal farmers are not familiar and unable to take the loan from the institutional sources. They usually take loans from the non- institutional sources with higher interest rate. More important, the coverage of national agricultural insurance policy is lower. It is about only 20 percent. This policy provides extra protection if crop failure occurs. However, the level of awareness in the small and marginal farmers is very low. All these least adaptation capabilities in the agriculture have increased the degree of vulnerability.

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[7] Sensitivity indicator results show that sixe coastal states, viz., Goa, West Bengal, Tamil Nadu, Kerala, Orissa and Gujarat.

1.3 Review of Literature

The extensive research work has been done in the field of climate change and its potential impact on farm productivity, the socio-economic impact of farmer's life.

1.3.1 Agriculture Situation and Variability in the Major Agricultural Determinants

In India, traditionally farmers were growing indigenous varieties of seeds in a sustainable environmental friendly manner before implementation of an ambitious agriculture development plan, i.e., Green Revolution. In the 1950s the core issue in the front of policy makers was food security followed by high death birth rate and, it increased the population. Increasing population mismatched demand and supply relation between food production and population growth. To match demand and supply, policy maker had proposed a new strategic plan to deal with food adequacy and make a balance between demand and supply. After adoption to Green Revolution, which was brought genetically modified seeds, chemical fertilisers and pesticides with improved irrigation facilities had boosted farm productivity in many folds. However, time series statistics show that Green Revolution had become resource intensive to Indian agriculture. The positive impact limited only for four crops, viz., rice, wheat, sugarcane and cotton in the majority. Due to unbalance, unplanned and unsustainable farm practices, the productivity of minor cereals, pulses and oilseed declined subsequently. Broadly the impact on the green revolution in Indian agriculture divided into five groups of studies, viz., Loss of Farm Sustainability and Impact of Green Revolution; Cropping Pattern Change, Land Use Pattern Change and Crop Productivity; Changes in Operational Land Size; Imbalance use of Chemical Fertilisers and Changes in Technological Tools in Agriculture.

The first group of studies investigated about the farm productivity and operational land holding size. Since the early green revolution years, mainstream group of researchers argued that there is an inverse relationship between farm size and farm productivity (Sen A, 1962, p. 43). Chadha (1978, p. 65) argued that Indian agriculture has heterogeneous in soil quality, agro-climatic zones and land sizes. Therefore, the validity of this hypothetical relation in the Indian context not valid. Ghose (1979, p. 43) argued that the essential precondition for the existence of the inverse relationship phenomenon is technical backwardness implying that with the advances in technology the inverse relationship will vanish. Further, Deolalikar (1981, p. 12) argued that the inverse relationship cannot be rejected at low levels of agricultural technology in India, but can be rejected at higher levels. Chand et al. (2011, p. 25) rejected hypothetical relationship by using agriculture input survey data. They argued that smallholder does not lag behind other farm size categories in an adoption of improved technologies and use of fertiliser and irrigation. More recently, Gaurav S. and Srijit M. (2014, pp. 165-193) reopened on this classical debate that the relative productivity advantages of the smallholder by utilized National Sample Survey Organisation 59th round unit level data. The empirical results show that at aggregate all- India level reject null hypothesis on the absence of a relationship between farm size and productivity measured in terms of returns, and indicate the existence of an inverse relationship. The results are valid with a controlled household type (occupation), social group, agro-climatic zone and agricultural season. It is also important to discuss here that the data they utilized was collected during the drought year. With low adaptive capabilities of the small and marginal farmers, the productivity in 2002-03 was reported lower. Therefore, it is needs to utilize more than one round agricultural statistics for the validation of the classical debate.

The second group of studies discussed the cropping pattern change and land use pattern change. Gulati A. and Sharma P. K. (1990, p. 13) argued that green revolution increased imbalance in cropping pattern. Due to government support policy and market demand, the majority of cropping pattern has been shifted in favour of rice, wheat, sugarcane and cotton at the cost of minor cereals, pulses and some non- food crops. Sharma J.L. (1990, p. 43) argued that the size of land holdings is the basic factor affecting the structure of agriculture and there exist vast disparities across the states in India. The share of marginal and small farmers have increased over the period of time at the cost of the share of large farmers. The net sown area marginally increased after the adoption of the green revolution. However, the area under barren land, an area under the uncultivated land has declined. The area under barren land and under uncultivated land either used for horticultural farming or infrastructure development like housing etc. It is argued that urbanisation has the main reason behind the slow growth of net sown area (Vijay, P. Sharma, 2015, p. 2).

The third group of studies discussed the role of technology in the Indian agriculture after adoption green revolution. IFPRI (2002, pp. 1-4) argued that Owners of large farms were the main adopters of the new technology. By used of technological tools especially tractors, the farm productivity has increased many fold in one hand and on the other hand, it reduced input cost and created non- farm employment (GoI, 2014, p. 3). Sale statistics confirmed that sale of tractors in all districts after adoption has increased sharply. Farmers not only using tractors for agricultural purposes, but also using non- farm employment activities. It has already been argued in the earlier that gross sown area only increased about 15 percent after green revolution. Further, the share of total cropped area under food crops has declined. This means agriculture is not able to provide employment in all calendar's months. Therefore, non-farm employment opportunities are the only source of income in the rural India. The dark side of technology adoption in Indian agriculture is, it reduced unskilled employment demand and creates employment insecurity to the agricultural labourers.

The fourth group of studies investigated the role of chemical fertilisers and its imbalance use. After adoption of the Green Revolution, the use of Nitro based chemical fertilisers like Urea has increased in many folds. Many agricultural researchers raised the voice on the balanced use chemical fertilisers. Prasad R. (2009, pp. 1-17) argued that the probable reason for the higher emphasis on nitrogen-based fertilisers were the higher response of crops, especially of irrigated wheat, to applied nitrogen as compared to phosphorus and potassium. Nitrogen, Phosphate and Potassium statistics confirmed that farmers in all operational land holding have used Nitro based chemical fertilisers at a larger scale. In the early 1950s, agricultural scientists were given balance ratio of these main agro-fertilisers, viz., 4:2:1. Statistics also confirmed that all classes of land holding farmers are violated suggested balanced use of chemical fertilisers' ratio. However, Chand R. and Pavitra S. (2015, p. 54) criticised that agricultural survey was conducted in the early fifties. Now environmental, soil conditions and cropping pattern has been changed. Therefore, it needs to re-calculate NPK ratio.

The fifth group of studies discussed the loss of farm- sustainability in India Agriculture. Ranade C.G. (1980, p. 12) argued that after implementation of the green revolution, the input cost in agriculture has increased sharply. Genetically modified seeds, fertilisers and pesticides are costly compared with traditional bio-fertilisers. Further, the accessibility of these additional modified inputs for small and marginal farmers also an emerging issue. Chadha G.K. and Sharma R.K. (1982, p. 10) argued that irrigation is an important input after injection of chemical fertilisers. In the absence of improved irrigation facilities, the impact of chemical fertiliser is limited or adverse. On the other hand, in the irrigated areas they observed a positive relationship between irrigation, chemical fertilisers and farm productivity. Dev Mahendra S. (1986, p. 96) argued that agricultural development strategy in India was more about raising the yield of a particular crop per unit of land rather than increasing the total output per unit of land from all crops growth in a year. Moreover, early green revolution studies, such as Mruthyunjya and Praduman K. (1989, p. 32) argued that share of indigenous varieties declined. Critics of the Green Revolution argued that owners of large farms were the main adopters of the new technologies because of their better access to irrigation water, fertilisers, seeds and credit. Small and marginal farmers were either unaffected or harmed because the Green Revolution resulted in lower product prices, higher input prices, and efforts by landlords to increase rent or force tenants off the land (IFPRI, 2002, pp. 1-4). The study also confirmed in the field survey reports that Green Revolution was that it spread only in irrigated and high- potential rainfed area, and many villages without access to sufficient water were left out. The major adverse impact of green revolution was on the environment. Excessive and inappropriate use of fertilisers and pesticides has polluted waterways, poisoned agricultural workers, and killed beneficial insects and other wildlife. Further, poverty in Asia as well as in India still the major barrier in the path of sustainable and equitable development. It is estimated that in Asian, each one percent increase in crop productivity, reduces the number of poor people by 0.48 percent. Whereas, in India, it is estimated that a one percent increase in agricultural value added per hectare leads to a 0.4 percent reduction in poverty in the short- run and 1.9 percent reduction in the long-run. Moreover, the cost of the green revolution to the society as a part of this development was the serious influence on cropping pattern, increased regional disparities, increased instability and resulted from unplanned imports of commodities.

Moreover, Sanatan N. (2005, pp. 167-168) highlighted the performance of individual and all crops, viz., food and non-food crops in Andhra Pradesh during 1970-2000. He found that the performance of agriculture sector in the state has come down in the nineties after reaching its highest in the eighties for some crops, while declined continuously after the seventies for other crops. Further, it also found that area under food grains declined from the seventies to nineties, whereas non-food grain crops had made acceleration to the overall increase in the cropping pattern, due to technological development in the state. Study also attributed that the performance of both food and non-food crops has declined in the nineties compared to earlier periods. Besides, the agricultural performance of the state has moved from high growth with low instability for non-food grains in the eighties and high growth with low instability in the seventies for food grains, to low growth with low to medium/ high instability in the nineties. Reason behind this deceleration in the nineties, Sanatan N. (2005, pp. 167-168) argued that irrigation was disproportionately spread over the region, as 55 percent of the net sown area is irrigated in the Coastal region, whereas only 22 percent and 37 percent of the net sown area is irrigated in the Rayalaseema and Telengna regions, respectively. Apart from the irrigation, study also highlighted the role of environmental factors in the deceleration in crops performance. The proportion of the wasteland to total geographical area has increased from the eighties to nineties in the state. Besides, irrigation induced waterlogging and salinity area increased up to 50 percent of the total canal irrigated area and 19.1 percent of the net cropped area study found. The use of fertilisers is felt excessive and unbalanced, which caused for polluting the soil large irrigated as well as unirrigated areas.

1.3.2 The Potential Impact of Climate Change on Indian Agriculture Productivity

Farm practices are directly associated with climate. Rainfall, temperature and concentration of greenhouse gases and are key factors responsible for better farm productivity (IPCC, 2007a, p. 3). Studies on climate change revealed that rainfall, temperature and higher concentration of atmospheric greenhouse gases (especially carbon dioxide) adversely affected to farm productivity in India (IPCC, 2007a, p. 1; Goswami et.

al., 2006, pp. 212-234; Kavikumar, 2009, p. 11 and INCCA, 2010, p. 23). An anthropogenic action in the form of chain as follow.

Higher concentration of greenhouse gases → Higher Temperature → Variability in Rainfall

The higher concentration of greenhouse gasses beyond carrying capacity of the earth leads to increase mean surface as well as air temperature. These two factors, viz., greenhouse gasses and temperature changes the hydrological cycle of the earth and leads to changes in rainfall pattern (IPCC, 2007a, p. 23). Therefore, climate change impact studies on farm productivity divided into three categories viz., rainfall, temperature, and concentration of greenhouse gasses mainly carbon dioxide.

The first set of studies discussed about the adverse impact of temperature on farm productivity in India. In the early 1990s, Sinha and Swaminathan (1991, p. 10) estimated that increase in temperature has a potential adverse impact on farm productivity. They estimated that 2^{0}C in mean temperature could decrease rice yield by about 0.75 ton/hectare in high yield areas and 0.6ton/hectare in the low yield of coastal regions. Further, 0.5^{0}C increase in winter temperature would reduce wheat crop duration of seven days and reduce yield by 0.45 ton/hectare, and 10 percent reduction in wheat production in the high yield states of Northern India. Furthermore, Kumar and Parikh (1998, p. 32) estimated that the loss in net revenue at the farm level is estimated in a range between 9 to 25 percent for a temperature rise of 2^{0}C to 3.5^{0}C. Chandna et al. (2004, p. 54) predicted effects on wheat production include reduced grain yield over most of India, with the greatest impacts in the lower potential areas by rise in 1^{0}C maximum temperature.

The more scientific observation came out from the fourth IPCC assessment report. The report predicted that higher minimum as well as maximum air temperatures affect agriculture in central Asia including India. This would raise the water- demand of rainfed and irrigated crops in general. The risk of heat stress during flowering time of winter and spring crops (wheat and barley) grown also increases in the coming years. Subsequently, Aggarwal, (2009a, p. 23) in his cross-crops season study estimated that a one degree increase in temperature may reduce yield of wheat, soybean, mustard, potato and groundnut by 3.7 percent in India. Moreover, in the 2010 government of India under the Ministry of Environment, Forest and Climate Change launched Indian Network for Climate Change Assessment. The outcome of the initiative was that the climate change scenarios for the 2030s indicate an overall warming for all the four regions with a net increase in annual temperatures in 2030s, with respect 1970s, ranging between 1.7^0C to 2.2^0C, with extreme temperatures increasing by $1\text{-}4^0$C, and with the maximum increase in coastal regions. All regions are projected to experience an increase in precipitation in the 2030s, with respect to the 1970s and the increase is highest in the Himalayan region and lowest in the North-Eastern region. Maize and sorghum are projected to reduce yields in all the regions. Coconut productivity is projected to rise in the western coast and reduce in the eastern coastal region. The recently published two studies, viz., Chattaraj S. (2014, p. 32) and Abebe H. et al. (2016, p. 18) confirmed that an increase in the temperature by 3.6^0C resulted in 11 days shorter growing period. Further, elevated temperature by 1.5^0C to 3^0C decreased food grain yield by 4.9 percent.

The second set of studies discussed the adverse impact of rainfall on farm productivity. Kumar R. et al. (1992, pp. 257-268) observed that seasonal variation in monsoon rainfall has increased up to 10 percent along the west coast, north Andhra Pradesh, and northwest India also. Further, increase in a number of drought events has been observed in eastern-Madhya Pradesh and the adjoining areas, northeast India and parts of Kerala and Gujarat. Further, by using 1*1 daily grid data of all meteorological stations within Indian geography during 1950-2000, Goswami et al. (2006, pp. 212-234) found that the intensity of rainfall increased and rainy days declined at the national level. They also observed that the frequency of heavy rainfall events in central India was increased by nearly 50 percent in the monsoon period and more than 100 percent in the post-monsoon period respectively. While the frequency of moderate events decreased by about 10 percent. Goswami et al. (2006, pp. 212-234) also found that monsoon has changed in two significant ways. First, it had weakened (less total rainfall during June-September). Second, the distribution of rainfall within the monsoon season has become more extreme. Furthermore, Dash et al. (2009, pp. 123-125) observed that for the country as a whole, the frequency of long rainy spells decreased and the frequency of the short rainy spells, dry spells and prolonged dry spell all increased. Moreover, Auffhamer M. et al. (2011, p. 87) estimated monsoon rainfall impact on rice crop. They found that monsoon rainfall become less frequent but more intense in India during the latter half of the 20^{th} century. Thus, increasing the risk of drought and flood damage to the country's kharif crop, i.e., rice. More recently, NATCOM- II (2012, p. 23) observed that the annual rainfall pattern does not show any clear acceleration or deceleration trends. However, out of 526 meteorological districts, 215 districts (41 percent) received excess/normal rainfall and remaining 311 districts (59 percent) received deficient/scanty rainfall during the season, which reflect adverse on the overall production of kharif crops, viz., rice and coarse cereals.

The third set of studies discussed the combined effect of carbon dioxide, temperature, and rainfall. Lal et al. (1998, p. 18) estimated that a doubling of carbon dioxide, rice and wheat yield increased significantly from 15 to 28 percent but rise in 3^0C temperature for wheat and 2^0C temperature for rice cancelled out the positive effect of carbon dioxide. Aggarwal and Mall (2002, p. 2) estimated that increase in carbon dioxide level and rise in temperature of 1-20C rice production decline by 3-17 percent with regional heterogeneity. Further, Johkan et al. (2011, pp. 139-152) argued that elevated temperature as a result of elevated carbon dioxide will have a major influence on food grain production.

1.3.3 Climate Change induced Vulnerability in Indian Agriculture

The Third Assessment Report (TRA) of the Intergovernmental Panel on Climate change (IPCC) defines vulnerability as a "function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity" (McCarthy et. al., 2001, p. 995). Furthermore, it is defined as "the degree to which a system is susceptible or unable to cope with adverse effects of climate change, including climate variability and extremes, and vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Brenkert and Malone, 2005, pp. 57-102). Mathematically, it is expressed as follows.

Vulnerability = *f*(Exposure, Sensitivity, Adaptive Capacity)[8]

Indian agriculture with heterogeneous features has highly vulnerable. It has small and marginal farmers in the majority, variability in environmental factors, the decline in average land size, increase in population size, lack of non-farm employment opportunities and the decline in farm productivity increasing the degree of vulnerability. Broadly studies on the climate-induced agricultural vulnerability in the Indian agriculture divided into the two groups, viz., by using secondary data at national or state level and by using field survey data a household or community level.

The first group of studies are focused on the vulnerability to climate change at different spatial scales in India using secondary data. O' Brien et al. (2004b, p. 28) developed vulnerability profiles to climate change and globalisation by assessing each region's exposure, sensitivity, and adaptive capacity indicators. They found that Indian agriculture is vulnerable in two ways, i.e., climate change, and economic change. An unpredictable monsoon pattern and elevated levels of temperature and carbon dioxide levels increase degree of climate vulnerability. Further, the deceleration in the net- farm revenue among the small and marginal farmers increases the degree of economic vulnerability. The identification of the hotspot of climate change and economic vulnerability, they develop three indices representing biophysical, social and technological factors based on the average value of a set of the normalised variable in order to assist in the identification of high and low vulnerable regions. The districts associated with Rajasthan, Gujarat, and Madhya Pradesh as well as in Southern Bihar and Western Maharashtra are highly vulnerable to globalisation and climate change is likely to pose a simultaneous challenge to the agriculture sector. Brenkert and Malone (2005, pp. 234-240) used Vulnerability Resilience Indicator Prototype (VRIP) and a set of indicators (exposure, sensitivity, and adaptive capacity) in India at the state level. State level vulnerability assessment results indicate a wide range vulnerability among the states. For example, Kerala and Sikkim are

[8] Here, "Exposure" refers to the nature and degree to which a system is exposed to significant climate variations, "Sensitivity" to the degree to which system is affected either adversely or beneficially, by climate-related stimuli, and "adaptive capacity" as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences (IPCC, 2001a, p. 1).

more sensitive than Punjab. However, Punjab has highest ecosystem sensitivity because of the pollution caused by the use of chemical fertilisers. They identified that most vulnerable states are six coastal states in India[9] with high population density. Orissa and Tamil Nadu also show high sensitivity to sea-storm surges. Further, Sharma and Pattwardhan (2008, p. 32) assessed climate vulnerability by using the Vulnerability Index and Cluster Analysis at a district level. In their all India analysis they found that the top six most vulnerable districts on the basis of vulnerability index are Krishna (Andhra Pradesh, Jagatsinghpur (Orissa), Nellore (Karnataka), South 24 Parganas (West Bengal), Kendrapara (Orissa) and North 24 Paragnas (West Bengal). Kelkar U et al. (2008, pp. 564-574) used a participatory approach to investigate vulnerability and adaptive capacity to climate variability and water stress in the Lakhwar watershed in Uttarakhand. The study identified that current coping capacity of people in the region to climate variability and water stress is quite low. Households are considerably dependent on low-value rainfed agriculture. Institutional capacity is also poor, particularly in terms of connectivity and availability of formal credit, which constrains their ability to use their agricultural skills and assets more effectively. Farmers also have limited human resources in terms of formal education or vocational skills, which limits their options in seeking off- farm employment opportunities. The types of responses to poor rainfall reported by households are only temporary coping measures, some of which, like selling assets or taking loans from traditional money lenders, may actually increase their vulnerability over time by worsening impoverishment or indebtedness.

Shakeel A. Khan et al. (2009, p. 8) have given emphasis on economic change due to climate change. They argued that the impacts of climate change could hinder development and progress in eradicating poverty and potentially aggravating social and environmental conditions. Methew S. et al. (2012, p. 32) studied in the coastal regions of India. By using Bayesian model approach, they argued that investment for adaptation action not be hindered by future uncertainty. Local adaptation measures must be in the centre. Risk evaluation and reduction need to be locally contextualised based on resources available, immediate community requirements, planning periods and local expert

[9] Goa, West Bengal, Tamil Nadu, Kerala, Orissa and Gujarat.

knowledge. Recently, Rama Rao et al. (2016, pp. 1939- 1950) used climate vulnerability indicator approach, assessed district level vulnerability of Indian agriculture to climate change. They observed that the most important factors responsible for vulnerability were identified in each component (exposure, sensitivity and adaptive capacity) in the case of more vulnerable districts, those with 'very high and high'. The degree of vulnerability increases in drought incidence, increase in minimum temperature and decrease in rainfall during June and July. Low rainfall, high drought incidence, high flood proneness and larger area under agriculture are the most sensitivity- related factors contributing to the climate-induced vulnerability. Further, the changing rainfall pattern, spatial and temporal, need to be appropriate and adequately factored into planning for expansion of irrigation facilities. It is also needed to give more emphasis on supplemental and critical irrigation using rainwater harvesting.

The second group of studies assessed climate and social factors induced vulnerability at household and community level. It is well-known that India has heterogeneous in nature of social characteristics. Less adaptive capability in small and marginal farmers increases the degree of vulnerability of the climate change. Haldar et al. (2012, p. 32) by using village-level participatory qualitative approach, assessed the perception of local communities about climate change in Madhya Pradesh, Orissa, and Chhattisgarh. They observed that local communities had already perceived impacts of climate change in the forms of increasing temperature, decrease rainfall, increasing the intensity of cyclones and storms in the coastal area, depletion of water table, drying up of rivers, spreading of diseases among the people and livestock, and reducing wildlife and forest resources. The current climate crisis is not only bringing new survival challenges, but also amplifying the existing livelihood challenges of the poor and marginalised communities in India. Further, in the participatory approach method, they found that local communities held a climate change as responsible for the present crisis of livelihood and diminishing natural resources. The local communities perceived deforestation as the common cause affecting their livelihoods. According to their perceptions, deforestation had not only reduced the access and availability of forest products, it has also affected the rainfall that in turn affected the agricultural activities in those villages. Further, the study has been revealed two important aspects. One aspect shows that much of the current vulnerabilities of those local communities have links with the historic socio-economic changes that took place in their settlements due to various developmental projects. The other aspect shows that since those communities were already worse off due to those historic changes, the current climate conditions are escalating their already vulnerable conditions rapidly.

Furthermore, accessibility of resources also has a major contributing factor in the climate-induced vulnerability. Pandey et al. (2012, p. 7) by using climate vulnerability index found that communities lived away from district headquarter have highly vulnerable than those lived nearer to the district headquarter. Natural disaster due to extreme events was higher in the away from district headquarter (ADH) households, as these households were more prone to mountain specificity in terms of fragility, marginality, and accessibility besides poor infrastructure. In their village level study Kattumuria R. et al. (2015, pp. 1-14) found that the current climate variability and climate risks resulted in farmers in both villages suffering from loss of agricultural productivity (leaving land fallow, a sale of livestock and assets).This stress is likely to increase based on projected climate change impacts which could lead to ecosystem degradation and loss of goods and services from natural resources on which they are highly reliant. More recently, Tashina E. et al. (2016, p. 5) by using multi-scale assessment method has assessed district level vulnerability. They have collected 1220 observations and found that low level of education and skills are the dominant factors contributing to vulnerability. At the village and household level, the lack of income diversification and livelihood support institutions are a key driver of vulnerability.

1.3.4 Adaptation to Climate Change in Indian Agriculture

Farmers have a long history of responding to climate change by developing a wide range of adaptation strategies, viz., pre-monsoon dry seeds, stubble mulching, crop- rotation, indigenous varieties of seeds, rainwater harvesting and inter-cropping etc. Pandey R. and Shashidhar K. Jha (2008, pp. 487-506) observed that farmers are changing cropping pattern from high irrigated crop to less irrigated crops. Further, sustainable soil and crop management, adoption of biodiversity based organic farming, use of indigenous seeds and crop varieties, and delayed in sowing were observed. The role of agriculture credit after implementation of green revolution has increased many folds. Nhemechena and Hassan

(2009, p. 32) argued that those having access to agricultural credit are less vulnerable and it increases the adaptive capability to cope with climate change. Further, Shakeel A. Khan et al. (2009, p. 23) emphasised on awareness and knowledge about climate change. The rural knowledge centres should provide computer aided and internet connected information services, so that farm family has timely and relevant meteorological, management and marketing information. The restructuring to State Land Use Boards in a manner that they are in a position to offer proactive advice to farm families on land use and cropping systems, based on likely monsoon behaviour, ecological efficiency and trends in prices and markets. Multiple livelihood opportunities are essential both as an insurance mechanism and for a reasonable total "take-home" income.

Zero-tillage also has an important adaptation strategy. Pathak H. et al. (2012, p. 12) observed that Zero-tillage is gaining popularity amongst the farmers in the Indo-Gangetic Plains for establishing wheat and to some extent in rice and other crops. By using this technology, the rice-wheat farmers can undertake direct drilling of wheat soon after harvesting of rice without any preparatory tillage, so that wheat crop heads and fills grains before the onset of pre-monsoon hot weather. This cost cutting technique required less seed and fertilisers. Pandey R. and Shashidhar K. Jha (2012, p. 21) focused on income diversification in the rural areas. They suggested that the creation of more diverse income-generation strategies with conservation and sustainable use of primary forest resources would be help in reducing climate-induced vulnerability. For the mitigation efforts, the rural poor should be compensated through payment/reward for environmental services for their activities that lead to mitigation. More recently, Tashina E. et al. (2016, p. 23) conducted an intensive study in the Karnataka state. They observed that farmers at village level applied indigenous strategies to cope with climate change. Delaying the time of sowing, changing cropping pattern according to rainfall intensity, using trap crops against pests, leaving croplands fallow, distress sale of assets, pursuing other sources of employment, including daily wage and migration to towns and cities, as they do not have enough water resources for irrigation to help buffer the impacts of climate variability. The study suggested that once the most vulnerable districts and villages have been identified, the most vulnerable households in each of those villages should be the top priority of any adaptation programme.

1.4 Research Gap

An extensive literature review has been done for assessing agricultural situation, i.e., impact of climate change on crop productivity, farmer's life and current adaptation strategies to deal with climate change in India. It is identified that in India, majority of studies (Kumar et al. 2015a, pp. 12-16 and Gupta S et al. 2012, pp. 1-10) estimated climate change impact on crops productivity by using state level data. Only Birthal et al. (2014, pp. 145-155) used district level panel data compiled by ICRISAT. However, Birthal et al. (2014, pp. 145-155) have used data during 1970 to 2001 for 200 district and nine crops of kharif and rabi season. The present study has added more district 291 of 16 states and 15 crops. Further, it is identified that in Bundelkhand region part of Uttar Pradesh, no such type study has earlier conducted to examine agro, social, economic and demographic impact of climate change. Furthermore, present study assesse climate and livelihood vulnerability, adaptation strategies of farmers to reduce the degree of climate vulnerability in a detailed way, where earlier researchers have studies in a staggered manner.

1.5 Objectives of the Study

The objectives of the present study are as follow.

1. To examine growth, extent and dimensions of various crops during post Green revolution period of Indian agriculture
2. To estimate the climate change impact on Indian Agriculture.
3. To examine climate and livelihood vulnerability among the farmers in Bundelkhand region of Uttar Pradesh.
4. To examine adaptation methods for preventing the impact of climate change on agriculture productivity in Bundelkhand region of Uttar Pradesh.

1.6 Hypothesis of the Study

1. Green Revolution brought disparities in the cropping pattern change and resource use among land holders and regions.
2. Climate change adversely affected to the crop productivity in India.
3. Climate Change increases the degree of vulnerability among the surveyed farmers.

4. Current copping strategies in agriculture are not able to cope with adversity of climate change sufficiently.

1.7 Methodology

(a) Data & Study Area

Both secondary and primary data have been used to assess the objectives of the study. Secondary data on agricultural statistics, viz., net sown area, gross sown area, net irrigated area, and total fertiliser consumption, number of tractors, land holding size and environmental parameters, viz., annual rainfall, minimum & maximum temperature are collected during 1966 to 2011 from the ICRISAT database, IMD database and Ministry of Agriculture and Farmers Welfare, Government of India. The present study estimated climate change impact on crop productivity by using district level agricultural and environmental statistics during 1966 to 2011 in India. For the crop productivity estimation, sixteen major food grains producing states are selected, viz., Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Further, 291 districts of these states are included in the climate change impact estimation.

The field level study is also conducted in one of the backward regions in India viz., Bundelkhand region. Bundelkhand region comprises in the two states and thirteen districts. Seven districts belong to the Uttar Pradesh and six districts are with the Madhya Pradesh. In the Bundelkhand region of Uttar Pradesh, the bulk of economic activities takes place in the primary sector. Besides, economic underdevelopment, the region is also prone to the frequent disaster like drought. Further, Bundelkhand has a hot and semi-humid climate. The average annual temperature is over 25^0C. However, the mean monthly temperature vary considerably from the annual means and consequently. The range of temperature is high. In summer, mean temperature ranges around 30^0C and can rise beyond 43^0C in May and June. The monsoon from June to September bring down temperature to around 22^0C-25^0C with relative humidity varying between 70 to 80 percent. The mean annual precipitation varies from 75 centimeter in the north to 125 centimeter in the south-east. The average for the region can be considered around 100 cm and falls mainly in the monsoon months of June to September.

(b) Sampling Method and Size

Based on the agro, socio-economic profile of the seven districts, two districts are identified for the field survey, viz., Jhansi and Jalaun. Jhansi district is most developed among the seven districts of Bundelkhand region part of Uttar Pradesh. The coverage of the canal network is higher. The soil quality and education level of rural population, connectivity to headquarter through a road network are also higher. On the other hand, the characteristics, viz., agro, social, economic and demographic of Jalaun district are similar to other districts and lower compare to Jhansi. Therefore, Jalaun district is selected as an under developed district. Total 200 samples (100 from each district) are collected. Within districts, all Tehshils are covered (each district has five Tehshils). Further, from each Tehshil, one block is selected and within the block, one village is selected for the household identification. Furthermore, within selected village, 20 samples are collected by considering social-economic characteristics. Therefore, 200 samples from the ten villages are collected. Primary data comprises socio-economic conditions, farm productivity, access to agricultural credit, basic amenities, income and expenditure, cropping pattern, adaptation and coping strategies to drought and climate change and barriers to adaptation of the sample households.

(c) Statistical Techniques and Model

The current study used five tier estimation methods, viz., descriptive statistics, semi- log model, multiple regression analysis, indicator approach and binary logistic regression.

1. Descriptive Statistics

Descriptive statistics are used to describe the basic feature of both secondary & primary data. Together with simple graphics analysis, mean, standard deviation, correlation, etc. are used to analyse the data at the preliminary stage.

2. Semi-log Model

The compound annual growth rate (CAGR) of the cropped area and production during 1966-90 and 1991-2011 is estimate by using semi-log model, which is as follows.

$$\ln Y_t = \beta_1 + \beta_2 T + U_t \ldots\ldots\ldots\ldots\ldots(1)$$

Where, $\ln Y_t$ is log of dependent variable, i.e., area & production of the crop, β_1 is constant, β_2 is time and U_t error term.

3. Fixed Effect Feasible Generalized Least Square Model

An estimation of climate change impact on crop productivity, fixed effect feasible generalized least square model is used. The regression model assumes that aggregate production for each time period depends upon irrigated area, sown area, rainfall, minimum & maximum temperature in sowing, germination & harvesting period, rural literates, fertiliser consumption, number of tractors and number of pump sets. Further, by using regression coefficient values, marginal effect and future impact of rainfall and temperatures on crop productivity in four time periods, 2040, 2060, 2080 and 2100 are estimated.

4. Indicator Approach

The examination of degree of vulnerability to climate change at community level is done by indicator based method, viz., Climate Vulnerability Index (CVI) and Livelihood Vulnerability Index (LVI). Based on which the extent of climate change vulnerability of the 10 villages has been indexed. CVI is used, where the vulnerability was based on components of exposure, sensitivity and adaptive capacity at the community level. Each component in the framework is composed of several sub-components. Selection of sub-components are based on the insights gained from the review of literature, indicator that are specific to drought prone regions and adaptation actions among the community farmers. The Iyegar and Sudarshan (1982, p. 12) method has been adopted to calculate and rank the block in terms of vulnerability score.

5. Binary logistic Regression Analysis

Factors affecting the current adaptation strategies to cope with climate induced vulnerability and potential impacts, binary logistic regression model is used to analyse the factors influence the adaptation strategies in the region.

1.8 Organisation of the Thesis

The thesis consists of seven chapters, which are as follows.

Chapter 1 entitled "Climate Change: Issues and Challenges" consists nine sections. First three sections deal with context, impact of climate change on farm productivity at global level and impact of climate change on the Indian farm productivity. Section four consists four sub-sections. It provides intensive & critical review on the changes in the agricultural situation after adoption to green revolution in 1.3.1, impact of climate change on farm productivity in 1.3.2, climate induced vulnerability in 1.3.3 and the current coping strategies to deal with climate change. Section five discuss the research gap and need of the study. Section six and seven discuss the objective and hypotheses of the study. While section seven explains detailed methodology of the present study.

Chapter 2 entitled "Climate Change and Economic Development: Perspectives and Approaches" provides the background on the theoretical scope of the study. It raised two issues. First, the debate on economic development and environmental degradation. The debate started the classical literature that economists view on growth in the absence of efficient management of natural resources. Over utilization of natural resources leads to environmental negative externalities. The ecological economists view on the sustainability environment only possible solution to deal with adverse climate change. Second, the development of methods for capturing the impact climate change on farm productivity.

Chapter 3 entitled "Agriculture Development in India: State Level Analysis" consists six sections. First section discusses the current position in the India economy. Second section discusses the estimation methods for examination of crop growth during 1966-2011. Section three and four discusses in the change in cropping pattern and land use pattern. Section four discusses the performance of the Indian agriculture. Further, section five discusses the change in the major agricultural production determinants. It includes various determinants, viz., economic, technological, institutional and environmental. Section six provides major findings and conclusion.

Chapter 4 entitled "Impact of Climate Change on Agricultural Productivity in India" consists nine sections. First two sections deal with introduction and approaches for estimation of climate change impact. Section three, four and five deal with estimation method, formulation of final method and hypothesis testing. Section six discusses the regression results. Section seven and eight show marginal impact on the crops productivity during 1966-2011 and future impact of climate change on the studied crop by the 2100.

Chapter 5 entitled "Assessment of Climate Vulnerability at Community Level" explores the factors, which are responsible for higher vulnerability. It consists six sections. First three sections deal with introduction about vulnerability, approaches and measurement of the climate induced vulnerability at community level. Section four provides socio-economic and agronomic conditions of the surveyed households. Section five and six shows the degree of climate & livelihood vulnerability indexes at community level. Lastly, section six provides conclusion.

Chapter 6 entitled "Assessment of Adaptation Strategies at Household Level" consists thirteen sections. First five sections deal with introduction, adaptive capacity and adaptation, autonomous and planned adaptations and adaptation in the agriculture. Section six shows the current adaptation option followed by the studies households. Section seven, eight, and nine examined the relation between operational land holding size, nature of household & education level and adaptation options. Further, section ten, eleven and twelve deal & examined the probability of adoption of the various adaptation strategies. Lastly, section thirteen provides conclusion.

Chapter 7 entitled "Summary and Conclusion" finally makes some concluding remarks and policy implication which may be useful to reduce present climate change impact on both crop productivity and farmers life.

Chapter- 2

Climate Change and Economic Development: Perspectives and Approaches

2.0 Introduction

There has been a subject of controversy for more than two centuries that, we expected unlimited economic growth in a world endowed with finite resources, if biophysical limits are important factors in determining future trends of economic growth. With scare natural resources and exponential growth in population, can we achieve economic growth indefinitely?. Does technology should be perceived as the “ultimate” escape from the problem of resource scarcity or technology contribute further environmental deterioration?. Does human- made capital equally substitute from the natural capital?. These are some key questions raised by the (i) Malthusian, (ii) Neoclassical, and (iii) Ecological economists in the context of biophysical limits to growth. First, Malthusian economists argued that economic activity cannot be expected to grow indefinitely unless the rates of population growth and/or the rate of resource utilization are effectively controlled. Limits to economic growth could come through either the depletion of key resources and/ or large-scale degradation of the natural environment (Meadows et al., 1974, pp. 10-125). Even though, Malthusian economists have been provided a simple relationship between population, growth and resource scarcity, but it ignores the institutional factors that affect population growth, an underestimate the role of technology in the growth process and fails to explain the effect of economic growth on the natural ecosystem and its inhabitants as a whole. In totality, the simple Malthusian theory of population and resources is viewed as incomplete from economic, technological, and ecological perspectives. Second, neoclassical economists argued that natural resource scarcity can be continually augmented by technological means. Human-made capital such as machines, building, roads, etc., and natural capital such as forests, coal deposits, wetland preserves, wilderness, etc. are substitutable indefinitely. They believed that technology- by finding substitutes, through discovery of new resources, and by increasing the efficiency of resource utilisation has almost no bounds in ameliorating natural resource scarcity. Although, neoclassical economists have provided a better understanding about the relationship between technology, resource scarcity and economic growth, yet ecological economist criticized that human- made capital and natural capital are not substitutable indefinitely. They are complementary in nature. They argued by the use of the second law of thermodynamics. The law place limits on the substitution of human-made capital for natural capital (law of entropy matter and energy) and, therefore, the ability of technological change to compensate for the depletion or degradation of natural capital. In fact, in the long run, natural and human-made capital are complements because the later requires material and energy for its production and maintenance. This is indeed a rejection of one of the important core principle of the neoclassical growth paradigm, i.e., the notion of infinite substitution between human-made and natural capital. Third, ecological economists suggested that economic growth is a subsystem of natural ecosystems. They suggested that balance between human economy and natural ecosystem should be maintained through sustainability approach. In the economic growth estimation, loss of natural resources should be accounted[10].

2.1 Biophysical Limits to Economic Growth

(a) Malthusian Perspective

Malthus started debate on biophysical limits to economic growth by using of his first official known work on the relationship between resource use, population, and unlimited economic growth. Malthus argued that the development of mankind was severely limited by the pressure of population growth exerted on the availability of resources. Malthus had given three assumptions in his population and resource use theory, i.e., (i) natural resources are fixed in absolute term, (ii) the world's population tends to increase at a faster rate than the resource regenerate, and (iii) population grows at a geometric rate, the production capacity of resources only grows arithmetically. By using these three assumptions, Malthus predicted that in a short period of time, limits to economic growth would be in reliability. To avoid limits to economic growth, Malthus was suggested two possible solutions, viz., preventive and positive checks. The preventive check consists of voluntary limitations of population growth.[11] On the other hand, the positive check to population is a direct consequence of the lack of a preventive check. When society, does not limit population

[10]Stern (2006, p. 21) suggested that without accounting of natural resources depletion, we cannot estimate real growth rate. The defensive expenditure in terms of health expenditure also to be accounted. Further, the rate of renewable and non-renewable resources depletion should be account in the gross national product, which is best acceptable indicator for economic growth.

[11]The positive check suggested that individuals, before getting married and building a family, make rational decisions based on the income they expect to earn and the quality of life anticipate for maintaining in the future for themselves and their families.

growth voluntarily, diseases, famines, and wars reduce population size and establish the necessary balance with resources.[12] Therefore, preventive and positive checks, by controlling population growth, eventually close the mismatch between the size of population and availability of resources. The preventive and positive checks are temporary measures and in the long-run, cost of creating misery and wickedness, such as climate change and loss of biodiversity cannot be avoided and are beyond the control of mankind.

Malthus also discussed about the role of technology in the economic growth paradigm. He argued that technological improvement that contribute to the increase in agricultural yields would not only produce a temporary increase in living standards, but also offset in the long-run by a corresponding increase in population size[13]. Malthus has opposed to resources substitution such as monetary transfer from rich to poor individuals.[14] He argued that increasing welfare of the poor by giving them more money would eventually worsen their living conditions, as they would mistakenly be lead to think that they can support a bigger family, which would in turn depress the preventive check and generate higher population growth. At the end of this process, the same amount of resources has to be divided into a larger population, triggering the work of the positive populations check. More specifically, an immediately after such a transfer, people can afford buying more food, bidding its price up and decreasing real wages which hurt poor individuals whose main income comes from their labour.

After nearly two centuries of Malthus argument on limits to economic growth, Ehrlich-Commoner (EC) (1968, p. 7) has developed a model by using the population, affluence, and technology. In this model, population was in the center, as Malthus was taken, however Ehrlich & Commoner have taken an unwavering position that human population growth is the primary culprit in a period of continued resource depletion and environmental degradation. By using the law of diminishing marginal returns, he argued that the total

[12] Malthus argued that, the positive checks acts more intensively in lower classes, where infant mortality rates are higher and unhealthy conditions are more common.
[13] Malthus was criticized on the role of technology in the production process by the neoclassical economists. Malthus' argument on biophysical limits to economic growth was mainly for agrarian economies, where use of technology in the production process and transfer of resources were temporary solution for the biophysical limits to economic growth.
[14] Later on neoclassical adopted this assumption that natural resources and human-made resources are equally substitutable and we can achieve indefinitely economic growth.

impact on the environment is equaled total population multiplied by the average impact that each person has on the environment. The argument is that most of developed nations' economies are already operating at a high level of production capacity. These nations are, therefore, on the diminishing returns of their production activities. Under these circumstances, if other factors are held constant, successive additions of population would require the increased use of natural resources. Thus, as population continues to grow, per capita impact, in terms of resource depletion and environmental deterioration will increase successively. Further, the decision to change the composition of economic inputs and outputs is made purely for profit motives. Therefore, input and output decisions are made on the basis of technical efficiency (increased per capita production, which increases profit), rather than the impacts these decisions may on the environment.

The EC have criticized to Malthus on the role of population. He argued that population is not solely responsible for the natural resource depletion. His argument was that the population growth plays a minor role in explaining the environmental and resource conditions of the modern era, especially in economically advanced regions of the world. Instead, EC believes that a major part of environmental results from the inappropriate application of modern technology in the economy. This is because technological choices are often made purely on the basis of profitability rather than environmental sustainability.[15]

(b) Neoclassical Perspective

Neoclassical economists in majority believed that there is no such kind of resources depletion as pointed by the Malthusian and neo-Malthusian economists. Instead, the real issue of significance is to understand the circumstances under which technological progress would continue to ameliorate resource scarcity as pointed by the Malthusian economists. In other words, the fundamental issue addressed in this context was not much in existence for biophysical limits, but rather important, through technological progress and appropriate

[15]Ehrlich-Commoner (1968, p. 7) belongs to neo-Malthusian club of economists. He believed that use of technology can be harmful in the resource full closed agro-based economy. Later on ecological economists partially agreed with commoner that technology can be increased the rate of natural resources depletion especially of non-renewable resources. In many parts of the world, the rate of mining for coal and fossil fuels has increased many fold observed in the recent decades.

institutional arrangements. The neoclassical economic prospective of natural resource scarcity, allocation and measurement is based on the following assumptions: (i) nothing rivals the market as a medium for resource allocation, (ii) resources valuation depends only on individual preferences and initial endowments as determinants of prices, (iii) for privately owned resources, market prices are "true" measures of resource scarcity, (iv) price distortions arising from externalities can be effectively remedied through appropriate institutional adjustments (v) resource scarcity can be continually augmented by technological means, and (vi) human-made capital (such as machines, buildings, roads etc.) and natural capital (such as forests, coal deposits, wetlands preserves, wilderness, etc.) are perfectly substitutes.

On the basis of these assumptions, neoclassical economists rejected Malthusian theory of population and resource scarcity. They criticized about the role of technology in the economic growth process. They believed that, under the right circumstances, technology will continue not only spare resources, but also to expand our role (Ausubel, 1996, pp. 166-177 and Hussain A., 2000, p. 109). Kuznets's (1955, pp. 1-28) by used of inverse relationship between pollution and economic growth, and Grossman and Krueger (1996, pp. 119-122) argued that continued improvement in pollution abatement technology will not allow the cost of environmental cleanup to grow without bound. That is, in a healthy and growing economy, growth in pollution abatement expenditures will be continually moderated by technological advancement. Further, even if this is not the case, increase in pollution cleanup expenditure need not be a major concern unless it is a large proportion of the Gross National Product (GNP). In general, expenditures on pollution abatement are a very small portion of GNP.

Neoclassical economists also rejected Malthusian assumption that natural resources are fixed in absolute term. They argued that biophysical limits to economic growth can be overcome by substituting natural resources by the human-made resources. By using of the advance and efficient technological development, resources can be substituted from more plentiful to less plentiful, such as wood replaced by coal, coal replaced by natural gas, and natural gas replaced by solar energy.

Lastly, neoclassical economists criticized the Malthusian economists on the issue of population. They believed that economic growth is not only good for the environment, but also a cure for a nation's population problem. This contention is supported by what is commonly known as the theory of demographic transition. This theory is based on the empirical generalization and it claims that as nations develop, they eventually reach a point where birth rate falls. In other words, in the long-run, the process of industrialization is accompanied by a sustained reduction in population growth. This is because the increase in income of the average family in the course of industrialization, reduces the desire for more children (Beaker, 1960, p. 12). However, they ignored the heterogeneity in the growth placed by the regional disparities. They failed to explain individual preference (s) and change in consumption pattern in the developed countries with reducing population size maintain the level of resource use. Further, current pattern of resource use, technological advancement, population size, and economic growth in the so called developed countries, rejected the core principle of neoclassical (Kuznets's, 1955, pp. 1-28) that technology would be ultimate solution of all environmental evils.

(c) Ecological Perspective

The resource use, growth in population size, improvement in technology, the role of institutional sector, depletion of natural resources and human wisdom presented complex relationship between natural and human-made economy as discussed by Malthus, Malthusian and neoclassical economists. In contrast to neoclassical economists, ecological economist believed that human economy is a subsystem of the ecosystems. Limits to economic growth could no longer be argued solely on the basis of the possibility of running out of conventional resources as Malthusian believed nor could technology be viewed as the ultimate means of circumventing ecological limits as neoclassical economists advocated. Ecological economists argued that technology can be abused or misused and it could be blessed. For example, a technological advance that decreases the need for throughput, while maintaining a material standard of living at some desired level, is indeed to be sought after. On the other hand, if technological advance is directed towards producing more goods and services with no limit in sight, such a strategy is highly questionable from the viewpoint of long-term sustainability. Further, the use of technology in the production process purely based on cost-benefit analysis. For example, a producer or entrepreneur only used technology when the cost of technology adoption is cheaper than the substitutes, i.e., labour and natural resources. On the other hand, if cost of technology is higher than the labour and natural resources, the entrepreneur preference would be labour and natural resources rather than technology. Ecological economists argued by using the steady- state economy model, any technological change that results in the maintenance of a given stock (labour, capital and natural resources) with a lessened throughput is clearly to be encouraged.

Ecological economists criticized the Neo- classical economists on resource substitution through the use of the law of thermodynamics. It placed limits on the substitution of technological change to compensate for the depletion or degradation of natural capital (Ayres, 1978, p. 32). It is valid in the short-run, because regeneration rate of natural resources quite slow as compared with its use in the economic growth process we observed over the last century. In fact, in the long-run, natural and human-made capital are complements because the later requires material and energy for its production and maintenance. Furthermore, neither capital not labour physically creates natural resources, depletion of natural resources cannot be resolved through endless substitutions of labour and capital for natural resources. This is indeed a rejection of one of the core principle of the neoclassical growth paradigm, i.e., the notion of infinite substitution between human-made and natural capital.

Ecological economists such as Daly (1993, p. 123) argued that neoclassical economic growth paradigm is untenable, because it is not based on sustainable biophysical and moral consideration. He explained this argument by using a simple scheme of a mean and end spectrum. He argued that standard economic growth model ignore the ultimate means by which the growth of material standards of living are attainable.[16] The fact is that the ultimate means are scarce in absolute or that these basic resources constrained by natural laws is considered irrelevant by mainstream economists.[17] Instead, because of their blind faith in technology, neoclassical economists exclusively focused on the availability

[16] Ultimate means refers to the low-entropy matter-energy of the ecosphere.
[17] Malthus discussed that land has absolute scarce natural resource in the closed economy.

of intermediate means such as labour, capital, and conventional natural resources (such as raw material). In the process, the fact is that the availability of intermediate means ultimately depend on the availability of ultimate means seems to have escaped standard economic thinking. For this reason, focusing on intermediate means, ecological economists discussed relative scarcity and process, on the basis of which resources are allocated to alternative societal uses.

By criticising the two core assumptions, ecological economists suggested that the loss of ecosystem resilience has key limiting factors in humanity's pursuit for a material pleasure (Boulding K., 1966, p. 121; Roegen G., 1966, p. 20; Daly H., 1973, p. 15 and Hussain A., 2000, p. 127). The loss of ecosystem resilience is potentially important for at least three reasons. First, the discontinuous change in ecosystem flips from one equilibrium to another could be associated with a sudden loss of biological productivity and so to a reduced capacity to support human life. Second, it may imply an irreversible change in the set of option open to both present and future generations such as loss of biodiversity, soil erosion, and desertification. Lastly, discontinuous, and irreversible changes from familiar to unfamiliar states increase the uncertainties associated with the environmental effects of economic activities (Arrow K. et al., 1995, p. 1). If economic growth is to be sustainable, we need to ensure that the ecological systems on which our economy depend are resilient.

Given this biophysical reality, it is no wonder that neoclassical economists are so captivated with continual growth in intermediate ends such as market- valued goods and services. But, how the total quality of goods and services produced in a given period of time is distributed among the people of the current generation (intra-generational), and how current economic growth may affect the well-being of the future generation (intergenerational), are simply not considered by the neoclassical economists. Here, argument is not that neoclassical and ecological economists are in denial of the existence of misdistribution of income among the current generation, or that they are insensitive to the possible adverse effects of current production (such as climate change) on the well-being of the future generation. Rather, the main position of ecological economists has been for sustaining a moderate to high economic growth rate is the single most effective solution for the current and future economic and ecological problems.

Now question arises that if above growth paradigm is to be rejected on the basis of its incomplete material and ethical consideration, what alternative model could be proposed. On this point, ecological economists suggested a new growth model called steady-state economy (SSE). Model consists of biophysical, economic, and ethical dimensions. SSE in the purely biophysical state Daly (1996, p. 23) suggested that the total inventory of all intermediate means and ends, including human population, is frozen at some "desirable" constant. In other words, in quantitative terms, the material requirements to run an economy are held constant at all times. Thus the primary focus is on stock maintenance: maintaining a constant inventory of intermediate means and ends.[18]

How it is possible because the economic world is defined not only by material flow or transformation of matter-energy, but by "an immaterial flux: the enjoyment of life". How does the SSE address this important dimension of the economic world?. Daly (1996, p. 121) suggested that this objective can be achieved through what he called service efficiency, which is identified as the ratio of service to the constant stock. Maximization of this ratio amounts to finding ways of making the numerator larger while keeping the denominator constant. Now again question arise, how to constant stock?. For this Daly (1996, p. 123) provided two specific solutions, viz., allocative and distributive efficiencies[19].

Fulfilment of allocative efficiency requires two specific conditions. First, the production of goods and services should use the least amount of intermediate means (labour, capital and natural resources). Second, the good and services that are produced should be the once that provide the most satisfaction to people. On the other hand, distributive efficiencies require that the distribution of the constant stock should be done in such a way that the "unimportant" wants of some people do not take precedence over

[18]Here the term stock will be used in reference to this constant inventory of intermediate means and ends.

[19]Allocation refers to the relative division of the resource flow among alternative products uses. A good allocation is one that is efficient, i.e. that allocates resources among product end-uses in conformity with individual preferences as weights by the ability of the individual to pay. On the other hand, distribution refers to the relative division of the resource flow, as embodied in final goods and services, among alternative people. A good distribution is one that is just or fair, or at least one in which the degree of inequality is limited within some acceptable range (Daly H.E., 1991, p. 186).

the basic needs of others.[20] It is important to ensure that current generations are not enriching themselves at the expense of future generations.[21] There are, conceptually, three general principles which govern the operation of the SSE. First, the SSE requires the use of throughput (low-entropy matter-energy) to be minimized at times. This suggests that in the SSE, as much as feasible, all possible technological avenues must be pursued to produce goods and services that are long-lasting and easily recyclable. Second, in the SSE, service (utility) is to be maximized. This should be done through a combination of both production efficiency and distributive efficiency. Finally, the SSE requires that stock should be held constant because in a world endowed with finite resources, equity considerations in both time and space make the requirement of constant stock as an essential prerequisite of the SSE.

First two preconditions of SSE cannot achieve without violating third condition. If the natural resources are finite in absolute term, then how stock remains constant, whereas natural resources are key determinants of economic growth. Daly (1996, p. 220) replied on this question that (i) while physical stocks are held constant, the stress should be on measuring economic improvements in terms of non-physical goods, i.e., services and leisure, (ii) emphasis should be placed on technological progress that increases leisure activities (such as a growing appreciation of environmental amenities, friendships and meditation), which are far less material-intensive that the production of physical outputs. With these adjustments, economic growth, measured in terms of increasing level of satisfaction from a given level of resource stocks, it is quite possible.

Ecological economists emphasized more on sustainable use of natural resources by use of efficient technological improvements. SSE model somehow successful (at least theoretically) that indefinite economic growth can be achieved if all suggested precautionary measures would be taken. But they are more or less silent about irreversible changes in the extremely uncertain circumstances, such as global warming and climate change. Since first intergovernmental panel on climate change (IPCC, 1990a, p. 1) report

[20] It is important to note that this requirement is not motivated by ethical considerations alone. If the postulate of diminishing marginal utility is accepted, than distributive efficiency would lead to increased total social welfare.
[21]This is foundation definition of sustainable development given by Brundtland report in 1987.

came in public domain that it has a hard task to predict that which types of changes occur in the near future. The predictions about global warming and climate change are yet not valid predicted in the first IPCC report.

Uncertainty is a vital consideration among the researchers associated with sustainability, because it is expected that changes will occur in technology, income, and people's preference over time. Technology may change enormously in response to change in relative scarcities and knowledge. Income will not be constant and preference will differ across generations. The problem is not that changes will occur, but rather that we do not know for sure how and when these changes will occur and we do not know what the implications of these changes will be on future resource availability. Therefore, a special branch of economics called the economics of sustainability has given attention to the uncertain effects of the current level and pattern of human enterprise on the integrity of the natural ecosystem (Krutill, 1967, pp. 787-796; Perrings, 1991, p. 12 and Hussain, A., 2000, p. 15). It deals with the issue of irreversibility. That is, beyond a certain threshold level, continued human exploitation of nature or economic growth may cause irreversible damage to certain vital components of a natural ecosystem such as forestland. Therefore, sustainable development cannot be achieved without addressing following four key issues. (i) physical limits of natural system, (ii) intergenerational equity and economic efficiency, (iii) technological options and social values, and (iv) inter-temporal management of natural resources under in conditions of uncertainty and irreversibility. These four broad issues are examined by assuming that the overriding social goal, which are in progress toward sustainable economic development[22].

The term "sustainability" was coined in the Brundtland commission report (1987, p. 1) "our common future". It was already discussed by the Malthusian and neoclassical economists called week sustainability. Malthusian economists were against monetary

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[22]The official definition of sustainable development was used in the Brundtland commission report (1987, p. 1) "our common future" in 1987. Report defined sustainable development as "development which meets the needs of the present without sacrificing the ability of the future to meets its needs" there are several key features of the above definition that are worth pointing out. First, the definition clearly established sustainable development as an equity issue. Second, definition offers a rather specific ethical criterion, i.e., the needs of the present are not to be satisfied at the expense of future needs. It therefore, deals with equity across generations: intergenerational equity. Third, by emphasizing equity, raises a question concerning the validity of standard economic analysis based exclusively on efficiency.

transfer from rich to poor (weak sustainability). They believed that due to this, the rate of resource use would be increased. On the other hand, neoclassical were in favor of and they believed that natural resources are equally substitutes towards the human-made resources[23]. Hartwick (1974, pp. 972-974) and Solow (1986, pp. 141-149) defined "weak sustainability" in terms of maintaining a constant real consumption of goods and services over an indefinite period of time while recognizing the constraints imposed by a given set of resource endowments. They suggested that maintaining a constant real consumption of goods and services, or real income (in the Hicksian sense), is possible even in the presence of exhaustible resources, and provided that the rent (income) derived from an inter-temporally efficient use of these resources is re-invested in renewable capital assets. Thus, the focus of concern is on the prudent use of the returns on, or a savings of exhaustible resources, rather than the depletion of these resources. Basically, to maintain sustainability (weak) needs of a situation in which a nation could maintain a non-declining of consumption income over several generations, provided the productive capacity (capital stock) of the nation in held intact. This can be achieved provided that allowances for capital consumption as kept proportionate to the level of investment necessary for the country to maintain its productive capacity.

In contrast, the concept of "strong sustainability" implies a physical principle which is founded upon the laws of thermodynamics and processes of biological growth. As a basic principle of resource management, it has a long tradition in forestry, and has logically been extended to other domains of natural resource management. For instance, minimum criteria of "strong" sustainability" is generally in physical terms, saying that certain properties of the physical environment must be sustained. It is argued that ecological sustainability needs to be beyond human interest. At least in principle, the ecological economists approach to sustainability involves concerns extending beyond the human species, i.e., the well-being of ecological systems in their entirety. For this reason, the ecological approach to sustainability is broadly defined and has both economic and ecological dimensions. Thus, the level at which the non-declining natural capital stock is set is expected to be consistent

[23]Criticized by monetary transfer from richer to poorer and by use of technology the natural and human-made resources are indefinitely substitutable without conserving natural resources as ecological economist, both Malthusian and Neoclassical economists have in favoured of weak sustainability.

not only with economic sustainability, but also with the ability of the ecosystem to withstand shocks, i.e., ecological resilience. The ultimate effect of all this will be to provide greater allowance for natural resource preservation for the purpose of safe-guarding future generations against large-scale, irreversible ecological damage such as biodiversity loss and climate change. To maintain strong sustainability, following goal should be achievable: (i) the rate of exploitation of renewable resources should not exceed that regeneration rate, (ii) waste emission (pollution) should be kept at or below the waste-absorptive capacity of the environment. For flow or degradable wastes the rate of discharge should be less than the rate at which the ecosystem can absorb those wastes, and (iii) the extraction of non-renewable resources such as oil should be consistent with the development of renewable substitutes.

Sustainability approaches of neoclassical and ecological economists partially cleared the importance of natural resources in the production process, but still, there is a possibility that natural resources stock is not available in the future or remain constant. Therefore, (Ciriacy- Wantrup, 1952, p. 12; Hardin, G., 1968, p. 15; Krutilla, 1967, p. 54 and Bishop 1978, pp. 10-18) emphasized the collective actions of the society for the preservation of natural resources. They argued that the collective actions of all class population groups deal with irreversible environmental changes such as climate change. They have suggested a new approach called safe minimum standard (SMS). SMS has provided a more realistic solution for the environmental negative externalities. It started as a practical guide to natural resource management under the conditions of extreme uncertainty, for example, the preservation of individual species such as Asiatic lions. For problem of this nature, it is argued that irreversibility becomes a key issue to consider. That is beyond a certain threshold or critical zone, the exploitation of natural resources may lead to irreversible damage. For example, the Asiatic lions would be declared extinct if managing natural resources of this certain minimum; and this maximum is greater than zero. Therefore, in managing natural resources of this nature, it is highly important to pay serious attention to not extending resource use beyond a certain safe minimum standard (SMS). Otherwise, the social opportunity cost of reversing direction might become "unacceptably large". However, it is important to note that considerable uncertainty exists regarding both the cost and the irreversibility of particular human impacts on the natural environment. Therefore, in this sense, uncertainty is central to the concept of safe minimum standard.

The SMS approach to sustainability does not totally invalidate the standard economists approach to resource assessment and management (neoclassical "weak" and ecological "strong"). It simply narrows the scope and the applicability of the standard economics conception of sustainability by restricting its relevance to human impact on the natural environment, where the potential consequences are regarded as being small and reversible. In some degree, the SMS and the ecological approaches to sustainability share common features. Both approaches adhere to the notion of limits in the substitution possibilities between human and natural capital. However, these two approaches provide different explanations for limits in factor substitution. The SMS uses irreversibility, while the ecological economics approach relies on all encompassing physical laws (of which ecological irreversibility in only a part). The SMS approach to sustainability can be perceived as a hybrid between the weak and strong approaches to sustainability (Hussain A., 2000, p. 153).

The idea of sustainability has very much fascinating. But in practical, it is requires lots of efforts to imply in the current economic growth estimation. It requires a modification of the conventional national accounting concepts of income, in particular the gross national product (GNP). The key issue has been that a nation's income as measures traditionally by the GNP does not account for all the resources, costs that are attributable to the production of goods and services and cannot reflect a level of income that is sustainable indefinitely (Daly, 1996, p. 123 and Hussain A., 2000, p. 154). Therefore, to the measurement of real economic growth, Daly (1996, p. 123) and Pearce (1993, p. 16) suggested that the cost of natural resources depletion should be deducted from the national income accounting. Thus, the relevant income measurement is the net national income (NNP) not gross national income (GNP) (Serafy, 1997, p. 12). Therefore, modified national income accounting terms as follows.

$$NNP = GNP-DHC \ldots\ldots\ldots\ldots\ldots\ldots(1.1)$$

Where NNP is net national product (income), GNP is gross national product and DHC is the depreciation allowance of human capital.[24] Apart from the cost of natural resources depletion, Daly (1996, p.13) and Pearce (1993, p. 14) suggested the cost of defensive expenditure due to depletion of natural resource quantity as well as quality to be included.[25]

$$NNP = DNC-EDE \ldots\ldots\ldots\ldots\ldots\ldots(1.2)$$

Where NNP is net national product (income), DNC is the depreciation of natural capital and EDE represents the environmentally defensive expenditures. Although, Daly (1996, p. 123); Pearce (1993, p. 12) and Hussain A. (2000, p. 156) presented a modified version of national income accounting, but they did not included the cost incurs due to uncertainty and irreversibility. It is important where the intensity of natural calamities is increasing with highly uncertain consequences. Therefore, net national product (NNP) could be sustainable national income (SNI) if following condition is accepted.

$$SNI = NNP- DNC- EDE- UC- EIC \ldots\ldots(1.3)$$

Where, SNI is sustainable national income, NNP, net national income, DNC depreciation of natural cost, EDE, environmental defensive expenditures, EC uncertainty cost and EIC represents environment irreversibility cost. It is important to recognize that conceptually, assuming no change in technology, SNI represents the maximum amount of income that can be expended for current consumption without impairing the future productive capacity of a nation keeping natural capital stock intact.

[24]Here question is how to capture the cost of natural resources depletion. For this Daly (1996, p. 13) suggested that cost can be measured by the accounting the monetary costs of net degradation and depletion of natural assets (forest, air and water qualities) directly attributable to current production and consumption activities.

[25] Defensive expenditure are real costs incurred by society to prevent or avoid damage to the environment caused by the side effects of normal production and consumption activities. For example, due to air pollution, water pollution, the rate of defensive expenditure such as health expenditure also increased to cope with adverse environmental consequences.

2.2 Development in Methodology to Capture Climate Change Impact

The uncertainty related to future climate change impacts on the global commons has prominent issue in the growing literature. An uncertainty about the future rise in temperatures, concentration of greenhouse gases, loss of biodiversity and change in precipitation has barrier in the prediction about the degree of climate change impact on the specific sector, such as agriculture. Therefore, the idea of environment conservation was officially started in 1946 in the form of International Whaling of Whale (ICRW) and its International Whaling Commission (IWC) for conservation of Whaling industry and preservation of great Whales. Further, the United Nations (UN) conference on Human Environment (UNCHE) in 1972 at Stockholm created United Nations Environment Programme (UNEP) and established environmental department by various governments. The first treaty on emission of pollution was adopted in 1979 at a meeting conveyed in Geneva by UN Economic Commission for Europe (ECE). In this treaty, there was little support for the adoption of mandatory reduction of emission of SO_2 and other acid forming pollutants. This convention is otherwise known as Long Range Transboundary Air Pollution (LRTAP). The LRTAP had vague understanding that states would insures the activities taking place within other countries (Soroos M. S., 2004, pp. 12-14). The reduction of substances caused for depletion of ozone layer also got similar significance at international level negotiations. The first international convention on ozone layer was held at Vienna in 1985, which decided to control/limit or prevent activities to diminish the ozone layer depletion. Furthermore, the landmark Montreal Protocol (MP) on substances of ozone layer depletion was held in 1987, which decided to reduce the production and use of CFC by 20 percent up to 1993 and 50 percent up to 1998 with 1986 as the base year. The MP of 1987 and the amendments made in 1990 and 1992 had drastically reduce the production and use of CFC, halons, carbon tetrachloride and methyl chloroform.

In the series of environment conservation and sustainable development, the Brandtland commission in 1987 was formulated, and the environmental issues had been pushed to the periphery of the international agenda out of the global economic downturn in the previous decades (Nayak, S., 2014, p. 501). The UN conference on Environment and Development (UNCED) or Earth summit held at Rio in 1992, which was the largest international conference held so far. It finalised several significant documents and agreements such as agenda 21 and UN Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (UNCBD), and establishment of UN Conference on Sustainable Development. Many countries joined at UNFCCC to cooperate one another in 1992 in order to limit the average increase in global temperature. In the Conference of Parties (CoP- 1) of UNFCCC at Berlin in 1995 agreed that the original treaty was not achieved much and further commitment was negotiated for binding reductions. They launched negotiations to strengthen the global response to climate change after two years and consequently, the Kyoto Protocol (KP) was adopted. The KP legally binds developed countries for emission reduction targets. The Protocol's first commitment period (CP) started in 2008 and ended in 2012. The second commitment period (CP2) began on 1st January 2013 and will end in 2020 (UNFCCC, 1997). The KP committed for the developed countries to make an average of 5.2 percent cut in their GHGs from the 1990 baseline. Under the KP many steps were taken to increase the carbon sinks, such as expanding forest cover including developed countries, joint implementation, clean development fund, whose emission were below their KP targets. Further, Bali Action Plan (CoP- 13) in 2007, launched a new, comprehensive process to enable the full, effective and sustained implementation of the convention through long-term cooperative action, even beyond 2012. The aim at reaching an agreed at Cop-15 in Copenhagen. The output is that all government divided into the five categories, viz., shared vision, mitigation, adaptation, technology and financing, some other important agreement included a decision on deforestation and forest management, a decision on technology for developing countries, the establishment of the Adaptation Fund Board (AFB), the review of the financial mechanisms, going beyond the existing Global Environmental Facility (GEF). The Cop-15 contained several key elements on which there was strong convergence of the views of governments. These included the long-term goal of limiting the maximum global average temperature increase to not more than 2^0C over pre- industrial levels. Furthermore, Cop-18 at Doha in Qatar 2012 has extended the life of KP from the end of 2012 to 2020 to cut 15 percent CO_2 emission. Second, the conference incorporated for the first time the concept of "loss and damage", an agreement in principle that richer nations could be financially responsible to other nations for their failure to reduce carbon emissions. Third, some important aspects, such as adaptation, mitigation and technology are discussed to adapt to climate change but not limit to change in agriculture and urban planning.

These institutional development in the form of negotiations and treaties have played two tier role in the conservation of global commons. First, enhanced the awareness at the global and regional level. Second, motivated to the researchers that develop to new approaches to capture the impact of climate change on the global commons, such as agriculture. The progressive literature since early- 90s provides three major approaches to capture climate change impact by incorporating several farm- level adjustments (at least theoretically) viz., (i) structural modelling approach, (ii) spatial analogue approach, and (iii) panel data approach. Structural approach combines crop agronomic response with economic/farmer management decisions and practices (Adams et al., 1998a, p. 12). Spatial analogue approach is measured the spatial differences in agricultural production. Panel data approach bridge the gap between structural modelling approach and spatial analogue approach by incorporating full range, farm-level current and future adaptation measures and able to predict more reliable results. Each approach was developed systematically after another due to the limitations of former. Structural approaches (agronomic-economic models) start by using crop simulation models such as the crop estimation through resource and environment synthesis (CERES) family of models, viz., CROPWAT, or Erosion Productivity Impact Calculator (EPIC). These models are based on detailed experiments to determine the response of a specific crop and crop varieties to different climatic conditions. The challenge is normally faced when implementing the structural approaches that adaptations included in agronomic models fail to account for economic considerations and limitations in human capital and other resources that affect actual farm-level decisions (Mendelsohn, 2000, pp. 383-600). In addition, if the economist fails to correctly anticipate the potential farmer adjustments and adaptations, the estimates might be biased (either overestimating the damages or underestimating the potential benefits of climate change) (Adams R. et al., 1999, pp. 219-224). On the other hand, spatial analogue approach uses cross-sectional information to undertake statistical (econometric) estimations of how changes in climate would affect agricultural production across different climate zones. Statistical and programming analyses across different geographic areas make it possible to make a comparative assessment of factors affecting production across different regions.

Spatial approach gives evidence of changes in farmer management practices and decisions in response to changing climatic conditions. The major advantage of this approach is that other factors affect crop production, such as soil type and quality, are taken into account in statistical estimation. This cannot be done by using the structural approach, since it depends on the quality of the data and how representative it is, as well as on the ability of the statistical analysis to separate to confounding effects (Adams et al., 1998a, p. 1 and Schimmelpfenning et al., 1996, p. 12). Further, under the spatial analogue approach, two main methods have been developed to account for adaptation in response to changes in climate, i.e., (i) Future Agricultural Resources Model (FARM) by Darwin, R. et al. (1994, p. 1), and (ii) Ricardian approach by Mendelsohn et al. (1994, p. 23). The basic underlying assumption for both the FARM and Ricardian methods is that similar climatic means similar to production practices. This allows the two approaches implicitly to capture changes in crop or livestock outputs, production inputs or management practices that farmers are likely to take in response to change in climatic and other conditions (Darwin R., 1999, p. 12).

Though, spatial analogue approach (FARM and Ricardian models) provides several advantage compare with structural approach, but has suffers from the some serious limitations, i.e., (i) estimation to be biased if the dependent variable is the farm's net revenue measured in an unrepresentative year, (ii) how to capture future technological changes, (iii) how to consider changing prices, (iv) the choice of the best variables to represent climate change, and (v) the validity of hypothetical relationship between profits and climate change. This gap has been bridged by the Deschenes and Greenstone (2007, p. 12) by introducing a panel data approach. They suggested that the use of panel data can be resolved the distortions caused by the correlation between climatic variable and farmers' strategies treated explicitly. Panel data approach differs from the Ricardian in a few key ways. First, under an additive separability assumption, its estimated parameters are purged of the influence of all unobserved time invariant factors. Second, it is not feasible to use land values as the dependent variable once country fixed effects are included. This is because land values reflect long-run averages of weather, not annual deviations from these averages, and there is no time variation in such variables. Panel data approach has more dynamic in nature with incorporating all possible current and future adaptation measures.

2.3 Development of Approaches for Measuring the Potential Impact of Climate Change on Agriculture

(a) Structural Modelling Approach

The impact assessment of agriculture due to the changing nature of climatic factors is one of the significant area in positive economic analysis **(**Nayak, S. and Surendra, S., 2016, p. 140**)**. Under the structural change framework, the impact assessment of climatic factors, especially on agriculture was traditionally estimated by using the production function model (Adam, R. et al., 1989, p. 12, & 1998, p. 2 and Ritchie et al., 1989, p. 12). There are three main components of this approach, i.e., (i) physiological studies, through computable general equilibrium (CGE) model (Darwin et al., 1994, p. 12), (ii) crop models (partial equilibrium models that include mathematical programming (Kumar and Parikh, 2001, pp. 1-14) (iii) spatial equilibrium models of the agriculture sector, (Adams et al., 1998b, p. 12), and (iv) economic model is known as linked system approach (Rosenzweig and Parry, 1994, pp. 23-25). Each component can stand on its own and represents an important body of research, but the components can also be linked together to present a more complete picture. First, physiological model address the changing nature of weather (e.g., temperature, precipitation and concentration of greenhouse gases) and other factors which affects crops. Second, crop models simulate the change in yields under different conditions, by using historical data or future projections. Finally, economic model estimates the changes in yields by considering market interactions are its impacts on prices, production, consumption, and trade.

Structural approach provides a flexible, scenario based framework which can offer a more complete understanding of the complex and diverse impacts of climate change on agriculture and food security. In other words, this type of models allow for detailed understanding of the biophysical responses, as well as adjustments that farmers can make in response to changing climatic and other conditions (Adams et al., 1998a, p. 12). Economic models can estimate changes in clearing prices that can be translated into aggregate changes in well-being for consumers and producers. This enables identification of the gainers and losers from change in climate conditions, as well as the distribution of the impacts. Such information might be important for focused policy and adaptation of planning in identifying the group of people for providing support.

Though, structural model is more sophisticate and have many advantages, but there are many studies, which are criticized structural approach on following ground. (i) structural approach models have historically ignored the adoption of new technologies and most of them impose climate change scenarios on current agricultural systems (Mendelsohn, 2000, p. 12), the problem with this is that the impact of climate change does not materialize for decades and by the time climate actually change, the farming systems could have changed from their current form. (ii) The problem of using such approaches is that in aggregate studies, inferences need to be made on results from very few laboratories and experimental sites and crops analyses, to large areas and drivers agricultural production systems (Schimmelpfennig et al., 1996, p. 23). It fails to account for the diversity of factors that affect production in the field. (iii) this approach estimates the effect of weather on the yields of specific crops that are purged of bias due to the determinants of agricultural output that are beyond farmers' control, e.g., soil quality (Deschenes and Greenstone, 2007, p. 14). Finally, this approach does not account for the full range of compensatory responses to changes in weather made by profit maximizing farmers. For example, in response to a change in climate, farmers may alter their use of fertilizers, change their mix of crops, or even decide to use their farmland for another activity, e.g., housing complex (Nayak, S. and Surendra, S., 2016, p. 142).

(b) Spatial Analogue Approach

The spatial analogue approach uses cross-sectional evidence to undertake statistical estimation on changes in climate and its impact on agricultural production across different climatic zones. Statistical and programming analyses across different geographic areas make it possible to make a comparative assessment of factors affecting production across different regions (Mendelsohn, 1994, p. 12). Two main spatial analogue methods have been developed to account for adaptation in response to changes in climate, i.e., (i) the Future Agricultural Resources Model (FARM) by Darwin et al. (1994, pp. 23-26 and 1995, pp. 95-100), and (ii) the Ricardian approach by Mendelsohn et al. (1994, p. 9). These methods assume costless structural adjustment and adaptation. For example, Mendelsohn et al.

(1994, p. 3) used statistical data and referred to their procedure as the Ricardian approach because of its focus on land values. Specifically, the Ricardian approach uses regression techniques to estimate the effects of various climatic, economic, and other factors on farmland values. On the other hand, Darwin et al. (1994, p. 12) used a global computable general equilibrium (CGE) model with a geographic information system (GIS) model to analyze possible climate change impacts on the U.S. agriculture, taking into account the interaction with non-agricultural sectors and other global regions. The GIS component describes the regional characteristics of land, climate, water, and agricultural suitability. In this approach, climate change is assumed to shift the regional land class and water characteristics, thus altering the production possibilities for a given region. The CGE component, then estimates the resulting economic changes and the effects on regional and global production and price. Therefore, FARM and Ricardian models capture the impacts of climatic factors of various countries on agriculture. Mendelsohn et al. (1994, p. 34) suggested that this method is more advantageous in many ways that the production function approach as: (i) it captures the present value over future streams of profits by using a discount rate, and regional differences in land values or productivity, (ii) it accounts full range of farmers' adaptations, and neutralizes (lower) the impacts more than biophysical crop modeling.

Moreover, Mendelsohn et al. (1994, p. 2 here in after MNS, 1994, p. 1) estimated the impact of climatic factors on agriculture by used of Ricardian approach contesting the traditional production function approach. This approach considered the full adjustment of crops or completely changing pattern of crops or complete adaptability of crops due to changes in climate. This was a significant breakthrough in the method of estimation of climate change impacts on land value. The Ricardian approach assumed the relative prices are unchanged under the partial equilibrium model and allowed the optimal shift of land use from wheat or corn to ultimately retirement housing. The study was based on the implicit assumption that when U.S. grain belt declines, some other regions of the globe would have surplus grains provide to the U.S. and therefore, the prices would remain unchanged. The study used a variety of fundamental factors consisting of geographical, geophysical, demographic, agricultural, and economic in the 48 states in U.S.A. covering 2933 cross sectional observations. Mendelsohn et al. (1994, p. 2) focused on estimating the impact of climatic factors by taking the cross section data on land values, and infinite elastic supply of irrigation water at base year prices, mean temperature and mean precipitation in U.S. agriculture.

After the Mendelsohn et al. (1994, p. 1) study, the validity and robustness of Ricardian approach has animated and international debate among researchers. Cline (1996, p. 12) made one of the first criticisms, which concerns the partial equilibrium nature of this analysis, because it implies no change in prices. Cline (1996, p. 13) argues that as a consequence, underestimation of climate damages and overestimation of climate benefits occurs. Further, several scholars agree that the main weakness of the traditional formulation proposed by Mendelsohn et al. (1994, p. 12), first, approach assumed that output price remains constant. Second, supply of water irrigation is perfectly elastic[26], and third, the testing the results of model is alternative climate scenarios from general circulation models (GCM). Cline (1996, p. 20) critically viewed the impact issues; although, the MNS study adopted and indigenous approach, it failed to recognize better studies which had taken reasonable assumptions on technological adaptation and crops due to climatic changes. He argued that if wheat and corn production were phased out and land use was concentrated on retirement housing, then there would be nothing to feed the people living in the retirements homes. The study, therefore, understated the damage by ignoring large possible welfare loss from a reduction due to decline of grains in the globe was as large as loss of grains in U.S.A. There had been wrong prediction of losses in gross value of the U.S.A's land value due to the doubling of carbon dioxide vis-à-vis, the increase in temperature and the increase in precipitation. Therefore, he concluded that it could be premature to argue that the loss of land value is less under the Ricardian framework than in the prediction of previous studies.

Mendelsohn, R. and Nordhaus, W.D. (1996a, pp. 13-20) and Mendelsohn, R., Nordhaus, W.D and D. Shaw (1996b, pp. 12-17) respond to these criticisms. They pointed out that the Ricardian approach is particularly well suited to a tremendously heterogeneous sectors, because it can rely upon the reduced form of estimation and does not require the impossible

[26]Fisher and Hanemann, 1998, pp. 12-15 and Darwin, 1999, p. 2 demonstrate that the omission of irrigation from the analysis can lead to an incorrect estimation of climate parameters' signs and magnitude.

task of constructing structural models of hundreds of crops in thousands of locations. They agreed that the first point raised by Cline (1996, p. 21) were addition to the analysis, while the second point was wrong. With regard to the first point of Cline (1996, p. 19) they believed that the Ricardian approach was based on the existing pattern of agricultural land rents and land prices, which reflected the long-run equilibrium economic effect of climate and other geophysical and economic variables. However, MNS adopted the partial-equilibrium approach by assuming output prices were an invariant of the climate. In this regard, Cline's (1996, p. 12) point was correct as it led a biased estimation because the partial equilibrium approach underestimated the damages and overestimated the benefits. Secondly, MNS incorporated irrigation in a reduced form with the assumption that availability of water in a region was a function of its climatic and geographical factors such as seasonal precipitation and temperatures, slope, soil erosion, wind erosion, salinity etc. Therefore, the reduced form method of MNS provided unbiased estimates of the impacts of climate on farming, including the irrigation impacts. Thirdly, MNS argued that the average result from GCM model was consistent with a uniform change scenario of 4.5^0C, which was the average predicted temperature change from these global climate models.

Subsequently, MNS conducted study and portrayed the adaptability of farmers in different climatic conditions in 1996 (MNS et al., 1996, p. 14). By using integrated assessment models (IAM) of climate change, study explored a new application of the Ricardian method in order to capture the climate effects in terms of both per acre value of farms and the extent of farmland through adaptation by the farmers. The strength of the agronomic approach was that it tried to integrate science and economics, whereas it weakness lay in its failure to capture the linkage between environment and farmers. It adopted a natural experiment method based on historic analogy (what farmers had already done), instead of prescribing what farmers should do. It tried to capture the observed experiences instead of controlled experiments with farmers. The MNS study conducted in 1999 is different from the study conducted by MNS in 1994, which predicted an inverted U shaped relationship between temperatures with farm values. The model basically described how an environmental factor affected production, which further affected costs, changed how a farmer behaved and net revenue. Long term accumulation of net revenue determined land value. Therefore, environmental changes which were beneficial or harmful to farming, thus increased or decreased the aggregate net revenue and the aggregate land values. Some of the important observations are quite interesting. First, climate has a nonlinear impact on farm values. Second, farm values are more sensitive to temperature effects than precipitation. Third, climate variation tends to be harmful. The only exception to this rule was spring inter-annual temperatures. Fourth, the most interesting result was that a cold and dry winter was highly desirable, probably because it got rid of pests. The study suggested that an average annual temperature of about 63^0F was optimal for agriculture. As one moves away from 63^0F, farm values would decline. A 5^0F increase in temperature, leads to the doubling of the global average CO_2 with a 10^0F increase, including the climate effect on farm acreage reduced the predicted beneficial impact of warming by half. With very large increases of 20^0F, the models predict that farm values fall relative to current conditions rather than increase. The model predicted that as the climate warms up above 63^0F, less land would be suitable for farming so that continued warming above this level would be harmful.

Moreover, Adams et al. (1998a, p. 12) by using of Ricardian approach observed that, i.e., (i) an increase in temperatures, holding other factors constant, decreases crop yields while increase in precipitation lessens or offsets this result, (ii) there are many cases of regional winners and losers from the climate change, given that the likelihood of net reductions in crop yields is the greatest in warmers, low latitude areas and semi-arid areas of the world, (iii) the economic consequences of any yield changes will be influenced by adaptations made by farmers, consumers, government agencies, and other institutions, (iv) adaptation practices captured in both structural and spatial analogue approaches show divergent results for both fundamental biophysical relationships, such as CO_2, fertilization and basic crop yield responses to climate changes, as also the capacity of non-climatic resources, such as soil quality and moisture availability, to support changes in the location of agricultural practices, (v) changes that are harmful for consumers are typically beneficial to producers, (vi) agriculture is linked through trade flows in commodities, inputs, technology, and knowledge in a global system. Therefore, country and region-specific studies can only provide partial and incomplete perspective on likely impacts, (vii) changes in climate are expected to affect the productivity and aggregate demand for factors of production such as water, labour, energy, equipment, and materials. Climate change is analogue to technological change in agriculture, which can increase or decrease the total productivity of factors collectively to another, and (viii) recent research has advanced the understanding of the sensitivity and vulnerability of agricultural systems to climate change. Indirect effects of climate change such as changes in the incidence and severity of agricultural pest and diseases and changes in soil erosion are largely unknown and have not been incorporated into estimates of impacts.

In majority, climate change researchers believe that various sectors of developing nations are more vulnerable to climatic factors than its counter-parts in developed nations (Mendelsohn et al., 1994, pp. 10-12; 1996, pp. 1-5 and 2001, pp. 15-19). Economies with less capital and technology could be more vulnerable to climate change because they have less control over their environments, because more of their economies are in vulnerable sectors, and because they have warmer climates to begin with (Pearce et al., 1996, p. 14). However, a theoretical model was developed in 2001 to examine if development affects the climate sensitivity in the agricultural sector or not (Mendelsohn et al., 2001, p. 12). The study had hypothesized if technology encourages capital to substitute climate, the climate sensitivity function might flatten and move higher with development, so that developing countries would be relatively less vulnerable to climate change. In contrast, if the marginal productivity of technology was higher for farms in ideal climates, technology and climate could be complements. While reflecting on the example of three counties, viz., U.S.A., Brazil and India by taking the development indicators (per capita income) and technology (number of tractors per hectare of land), they compared their climate sensitivities over time. Their observations were two folds. First, Indian and Brazilian climate sensitivity over time has fallen as development has increased. The analysis consequently suggests that development may reduce climate sensitivity. However, this inter-temporal test is an indirect measurement. The analysis does not directly link development to a change in climate sensitivity. It remains possible that other factors also changed monotonically over time could have caused climate sensitivity to change. Second, the Ricardian function for India was more climate sensitive that the American climate response function. These results suggested that development has an important effect on climate sensitivity. Farmers in less-developed countries are currently more climate-sensitive that the farmers in more developed countries. Combining this climate sensitivity to the higher temperatures at low-latitudes suggests that low-latitude agriculture would be hurt if warming occurred today. The results, however, provide a slightly more optimistic picture if warming occurs far into the future. If developing countries can continue to improve their agricultural systems, they are likely to be less climatic sensitive when warming actually occurs. They suggested that government should support more public research and development of agriculture while reducing subsidies and removing of barriers for adaptations.

Though, the Ricardian approach has the potential for addressing the adaptation satisfactorily, yet the issues concerning the cost of adaptation are not completely addressed and fail to capture the impacts fully in various ways. First, it fails to capture the effects of unobservable farms and farmers' characteristics on farm income that may be correlated with climate change. Second, a cross-section or repeated cross-section is often misleading or mis-specified and lead to biased estimation (Guiters, R., 2007, p. 2). Third, it does not account for the effects of factors that do not vary across space and time (Deschenes and Greenstone, 2007, p. 2). Four, the constant relative price assumption used in this approach could bias the estimates (Cline, 1996, p. 23).

(c) Panel Data Approach

The panel data approach is more advantageous in numerous ways than the structural and spatial analogue approach. First, the dependent variable, i.e., land value or net revenue or gross revenue per hectare is an annual measure rather than an average of cross sections as in the case of Ricardian analysis. Second, it is possible to capture the effects of time invariant variable, like soils, and elevations in the panel data. Third, the independent variables of interest are the functions of monthly or yearly realised weather variables rather than the normal climate. Fourth, it is possible to accommodate the short term effects of adaptations, i.e., year to year fluctuations of temperature and precipitation on production or agricultural profits.

By using panel data approach, the economic impact of climate change on U.S. agricultural land has been estimated by incorporating the random year-to-year variation in temperature and precipitation on agricultural profits (Deschenes and Greenstone, 2007, p. 23) Using long-run climate change predictions, study indicates that climate change will lead to a $1.3 billion (2002$), or 4 percent, increase in annual agricultural sector profits.

Additionally, the analysis indicates that the predicted increase in temperature and precipitation will have virtually no effect on yields among the most important crops (i.e., corn for grain and soybean), which suggests that small effects on profits are not due to short-run price increases. Finally, study estimated the effect of climate change in the value of agricultural land range from -$200 billion to $320 billion (or -18 percent to 29 percent), which is even wide range that has been noted in the previous studies.

2.4 Development of Approaches for Measuring the Sensitivity to Climate Change on Agriculture

Climate Change increases the degree of sensitivity for the heterogeneous farming society with least coping capabilities. Occurrence of Climate disaster like drought, flood and cyclone, it affects to the community already living at high risk. This section discusses the evolution of the vulnerability approaches (sensitivity) from simple biophysical context to more complex human, ecological, political and economic context. The term ‘vulnerability’ is used in many different ways by various research communities, such as those concerned with secure livelihoods, food security, natural hazards, disaster risk management, public health global environmental change and climate change (Fussel and Klein, 2006, p. 305)[27]. Broadly, three major approaches have been developed to assess vulnerability, viz., ecological resilience approach, political economy approach and risk hazard approach.

(a) Ecological Resilience Approach

In the globalized society, there are virtually no ecosystems that are not shaped by people, and no human being can survive without the services provide by ecosystems. The systems that are shaped by the interactions between people and ecosystems are the essence of social-ecological system. The ecological resilience approach investigates, how people and nature can best manage in the face of disturbances, surprises, and uncertainty[28]. Ecological

[27] IPCC (2001b, p. 1) define to vulnerability in more complex form that vulnerability is “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity”. It is an integrated measure of the expected magnitude of adverse effects of a system caused by a given level of certain external stresses.

[28] In the ecological resilience approach, resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variable, driving variables and parameters, and still persist (Holling, 1973, p. 17).

resilience approach is one of the strongest concepts to understand the dynamics of social-ecological systems (Anderies et al., 2006, p. 12). Here, dynamic refers to changes and interactions occurring within and between the systems. Some of the strengths that make it unique are, i.e., (i) resilience allows analysis of the changes in social-ecological systems and the determination of their ability to survive the disturbance, (ii) resilience helps to understand the dynamism of systems on multiple scales of interactions, (iii) resilience supports our understanding of how social-ecological systems can cope with, adapt to and shape change for sustainability, (iv) guide the adaptive capacity of humans in social systems, and (v) resilience facilities the integration of other theories for a better understanding of the dynamics in social-ecological systems on multiple scales. Though, ecological resilience approach was developed to analyse ecosystems and was a breakthrough in indicating that there are multiple states within an ecosystem; that the ecosystem is not in a state of equilibrium, but can be in multiple states depending upon resources and agents. This led to the development of the resilience approach and adaptive cycles in which resilience was used to analyse social and then social-ecological systems.

However, ecological resilience approach fails to explain human behavior against uncertainty. The focus of resilience on the ability of systems to cope with changes rather than on normative concepts, and can be seen as a system property, with the implication that, depending on once perspective, achieving resilience may or may not be good for certain kinds of systems (Berkhout, 2008, p. 12). Further, focus on one specific control might reduce other important drivers, which are necessary to manage the system. For instance, water management during flooding can focus on control strategies on maintaining water flow. Maintaining water flow can be difficult as it is highly uncertain, depending upon the amount of rainfall. However, focusing only on maintaining water flow could neglect the response strategies important to adapt to flooding such as building structure to cope with increasing water flow.

(b) Political Economy Approach

The political economy approach emphasizes on socio-political, cultural and economic factors that are responsible for a higher degree of vulnerability. It raised fundamental questions, i.e., (i) what is the human occupancy of hazard zones, (ii) how to people and societies respond to environmental hazards, (iii) what factors influence their choice of adjustments, and (iv) how to mitigates the risk and impacts of environmental hazards. The vast majority of vulnerability studies take a political-economic perspective and suggest a casual structure that concentrates on the differential social impacts and ability to cope with the crisis at hand (Cutter L. Susan, 1996, pp. 529-539). The causes of social vulnerability are explained by the underlying social conditions that are often quite remote from the initiating hazard or disaster event. For example, Watts and Bohle (1993, pp. 117-125) proposed one such explanatory model in their analysis of hunger and famine. In their view, vulnerability is defined by three processes, i.e., entitlement (economic capability), empowerment (political/social reproduction), and political economy (historical/ structural class-based patterns of social reproduction). They suggest that the intersection of these tripartite processes produces the social space of vulnerability. In another formulation, Blaikie et al. (1994, pp. 13-15) examined causality using two alternative models, i.e., the pressure and release mode (PAR) and the access to resource model (ARM). The PAR model provides an explanation of the relationship between processes that give rise to 'unsafe conditions' (e.g., exposure) and their intersection with some type of hazard or disaster event, thus creating a form of social vulnerability. The focus is clearly on the dynamic pressures and underlying driving forces that give rise to vulnerability in the first place. The access to resource model is more a refined explanation of the role of political and economic forces as the root cause of unsafe conditions. Further, model distinguishes between three components on the social side, viz., (i) root cause, (ii) dynamic pressures, and (iii) unsafe conditions, and one component on the natural side, the natural hazard themselves. Root causes include; economic, demographic and political pressure, which affect the allocation and distribution of the resources between different groups of people. Dynamic pressure translates economic and political processes in local circumstance. An unsafe conditions are the specific forms in which vulnerability is expressed in time and space, such as those induced by the physical environment, local economy or social relations (Blaikie et al., 1994, pp. 1-23).

Though, political economy approach has included social, political and economic factors, which were missing in the ecological resilience approach, but it has silent on the following issue, i.e., (i) how vulnerability is linked to underlying causes or pressures have some serious implication and the link can be dismissed, particularly by those who treat disasters as a technical issue, (ii) assumption about the immediate restriction on use of scarce resources while neglecting both the social science causes of vulnerability and more distant root causes, (iii) who is responsible for reducing vulnerability and increasing resilience and social capacity, (iv) it does not address the coupled human-environment system in the sense of considering the vulnerability of biophysical subsystem (as consider in the ecological resilience approach), (v) it provides little detail on the structure of the hazard's causal sequence, including the nested scales of interactions, and (vi) it tends to underemphasize feedback beyond the system analysis.

(c) Risk- Hazard Approach

The risk-hazard (RH) approach bridged the gap between ecological resilience approach and political economy approach by incorporating biophysical vulnerability and social vulnerability. Further, it added two new elements, viz., risk and adaptive capacity. Previous definitions of vulnerability (in the ecological resilience approach and political economy approach) tend to fall into two categories viewed vulnerability either (i) in terms of the amount of (potential) damage caused to a system by a particular climate-related event or hazard, or (ii) as a state that exists within a system before it encounters a hazard event. The former view has arisen from an approach based on assessment of hazards and their impacts, in which the role of human systems in mediating the outcomes of hazard events is downplayed or neglected. Nicholls J. Robert et al. (1999, pp. 69-87) argued that climate change impacts studies are typically examined factors, such as increase in the number of people at risk of flooding based on projections of sea level rise, and thus focused on human exposure to hazard rather than on the ability of people to cope with hazards once they occur.

The risk-hazard approach typically views the vulnerability of a human system as determinants by the nature of physical hazard(s) to which it is exposed, the likelihood, or frequency of occurrence of hazard(s), the extent of human exposure to hazard, and the systems' sensitivity to the impacts of the hazard(s). In other words, vulnerability of any system (natural, social, cultural, political and economic) can be assessed by incorporating the three indicators, exposure, sensitivity and adaptive capacity. It was a major breakthrough in the vulnerability assessment, because previously, biophysical vulnerability and social vulnerability are investigating. Risk-hazard approach include biophysical impacts in system such as droughts, floods, storms, episodes of heavy rainfall, long-term changes in the mean values of climatic variables, potential future shift in climate regimes and so on, whereas, social vulnerability include social as well as political factors such as accessibility of basic amenities (sanitation, pure drinking water, electricity and quality of housing etc.), community participation in the conservation of natural resources, accessibility of the common pool resources, transportation, public health facilities and political representativeness etc. The risk-hazard approach has advantageous compare to ecological and political economy approach as follows: (i) it include all the features of ecological resilience approach, (ii) poverty, hanger, lack of basic amenities are key determinants of social vulnerability, approach include, (iii) the mankind role in the determinants of degree of vulnerability has in center, (iv) it includes the adaptive capacity of the system as well as humans to cope with hazard(s) and reduce the risk in the system, and (v) it capable to include current and future hazard and risk in the model and predict possible future risk associated with natural system and social system.

2.5 Development of Approaches for Measuring the Adaptive Capabilities to Climate Change in Agriculture

Climate change literature generally discuss on mitigation, and adaptation. Mitigation refers to limiting global climate change through reducing the emission of greenhouse gases (GHGs) and enhancing their sinks. On the other hand, adaptation primarily aims to moderating the adverse effects of avoided climate change through a wide range of actions that are targeted at the vulnerable system.[29] Mitigation has traditionally received much greater attention than adaptation in the climate change community, both from a scientific and from a policy perspective because of following reasons, i.e., (i) mitigating climate change helps to reduce impacts on all climate-sensitive systems, whereas the potential of adaptation measures is limited for many systems, (ii) reducing GHGs emission applies the polluter-pays principle, whereas the need for adaptation measures will be greatest in developing countries, which have contributed relatively little to climate change, (iii) GHGs

[29] It may also include taking action to seize new opportunities brought about by climate change.

emission reductions are relatively easy to monitor quantitatively, both in terms of their absolute amount and as deviation from an established baseline, whereas it is much difficult to measure the effectiveness of adaptation in terms of impact avoided, or to ensure that international assistance to facilitate adaptation would be fully additional to existing development aid budget.

Though, mitigation paid more attention among the climate change community, but the role of adaptation cannot underestimate because, i.e., (i) the effect of emission reductions takes several decades to fully manifest, whereas most adaptation measures have more immediate benefits, (ii) adaptation can be effectively implemented on a local or regional scale such that their efficacy is less dependent on the actions of other, whereas mitigation of climate change requires international cooperation, and (iii) most adaptations to climate change also reduce the risk associated with current climate variability, which is a significant hazard in many regions (Fussel and Klein, 2006, p. 304).

Fussel and Klein (2006, p. 304) suggested that effective adaptation to climate change is contingent on the availability of two important prerequisites, i.e., (i) information on what to adapt to and how to adapt, and (ii) resources to implement the adaptation measures. The collection of information about the vulnerable system and the stressors that is exposed to (in terms of scientific research, data collection, or model experiments), and the transfer of resources to vulnerable societies (in terms of financial means, technologies, or expertise) in order to help them to prepare for and cope with un-avoided impacts of climate change are thus necessary elements of a comprehensive climate policy.

In addition, Fussel and Klein (2006, p. 307) explained the importance of adaptation in the agriculture through a hypothetical example. They broadly divided farmers into five categories based on the responses against climate change, viz., dumb farmer, typical farmer, smart farmer, clairvoyant farmers, and reference farmers. First, the basic idea is that a farmer who does not react to changing climate conditions at all (dumb farmer) has a higher degree of vulnerability with zero adaptation capabilities. Second, farmers who adjust with the management practices in reaction to persisting climate change. They are in better position compared to dumb farmer. Third, farmers who use available information (theoretically) on expected climate conditions and adjust to them proactively has much better position to deal with climate change and reduces the extreme degree of vulnerability. Fourth, a farmer who has perfect foresight of future climate conditions and faces on restrictions in implementing adaptation measures. Lastly, 'reference case farmer' comes under unavoidable impacts because after using all precautionary measures an unavoidable impact of changing climate conditions would be affect to the farmer's productivity.

Basically, adaptation to climate change is seen as an investment. Assuming limited resources, it leads directly to the following questions, i.e., (i) how much should be invested in, which adaptation option(s) and, (ii) what time in order to create the highest benefit at reasonable costs and within the available budget (IPCC, 2001c, p. 4). Decision- makers therefore, face a basic economic problem, i.e., optimizing the allocation of resources. UNFCCC (2002, p. 12), along with GSF (2011, p. 12) and Niang-Diop and Bosch (2011, p. 1) suggests three main techniques to be applied in the economic assessment of climate change adaptation options are (i) cost-benefit analysis, (ii) cost-effectiveness analysis, and (iii) Multi-criteria analysis. These three are discusses as follows.

(a) Cost- Benefit Analysis (CBA)

From a purely economic perspective, cost- benefit analysis (CBA) comparable cost and benefits of an intervention over time (GSF, 2011, p. 12). A CBA is able to help decision-makers, which adaptation option is preferred if there is more than one option that makes economic sense to be implemented. Before proceeding CBA for specific climate change adaptation measure, fist we need to sketch a base case or baseline (UNFCCC, 2002, p. 12). This scenario will have to illustrate what will happen without any adaptation. To do this, the present situation has to be projected along a time horizon. This can be 20, 30 or even more years. The focus should be the total cost of climate change in the absence of adaptation (Policy Research Corporation, 2009, p. 14). After taking all precautionary measure, benefit-cost ratio (BCR) can be calculated (ECA, 2009, p. 16). Any BCR above 1 makes sense from an economic point of view as this indicates that benefits are higher that the costs. Although, the CBA provides a powerful instrument for the economic assessment of climate change adaptation options. But is needs to follow all the precautionary measures in the estimation, otherwise false results may be appeared.

(b) Cost-Effectiveness Analysis (CEA)

Cost-effectiveness analysis (CEA) determines how a well-defined objective can be achieved in the most cost-efficient way. However, it has little difference from the CBA. CEA is used only if it is impossible to assign a monetary value to benefits of adaptation options (if both cost and benefit could be measured in monetary values a CBA would be used). For a CEA, the unit in which benefits are measured has to be carefully defined (GSF, 2011, p. 14). Further, the unit cost can be calculated as the ratio to total (discounted) costs to total benefits if- as in the case of CBA- incremental costs and benefits.[30]

In addition, to need for mitigation there are also convincing arguments for a more comprehensive consideration of adaptation as a response measure to climate change. The output indicator of a CEA is therefore also a cost-benefit- ratio (CBR). The most cost-efficient option is the one which the lower CBR, i.e., the lowest cost per unit of benefit.

Though, CEA method has improved from the CBA but it cannot estimate multiple cost and benefits occur in the same unit. For example, better human health and protected habitat for wildlife. The reason is that the outcomes could not be numerically compared.

(c) Multi-Criteria Analysis

When benefits cannot be measured quantitatively or when multiple diverse benefits cannot be aggregated, a Multi-Criteria Analysis (MCA) can be used. Similar to a CBA and CEA, an MCA is able to rank and thus prioritize among multiple adaptation options. However, contrary to a CBA, ranks resulting from an MCA are not based purely on economic calculations by a (qualitative) assessment of criteria such as feasibility, cost effectiveness, cost-benefits, ease of implementation, acceptability to local population and resources required. The MCA differs from CBA and CEA in that rule for the assessment of options according to a set of criteria have to be agreed upon in order to rank options. The reliable quantitative information on this may be difficult to attain, a qualitative expert judgment is the typical way to fill the information gap.

[30] Attainable by comparing a baseline scenario and one or more adaptation scenarios rather than absolute costs and benefits are taken into consideration (GSF, 2011, p. 12)

2.6 Conclusion

The debate on sustainable use of natural resources, population growth, the role of technology in economic growth and individual preferences has a long history, starting from the Malthus's noble argument on biophysical limits to growth. After more than two centuries of Malthus argument, still we are in progress to understand the relationship of human being and nature. There are several unsolved questions still need to answer on current economic growth, i.e., whatever it is sustainable and if it is not then what are the possible solutions to move out from this trap. Judicious use of technology, natural resources, and human capital in the heterogeneous world has possible, what ecological economists suggested to maintain a constant stock of natural resources. Further, nearly three decades ago, the idea of sustainable development/growth was conveyed to estimate/secure for the future generation. But it is far from the dream showed by the sustainability thinkers. The intensity of natural calamities such as climate change has been increased many folds. It urged more complex situation, where current predictions no more valid even for next few years. Although, there is continuous development in the methodological tools & techniques to capture climate change impact on the most and least vulnerable sectors. However, higher degree of uncertainty of climate change always remains one step ahead from the predictions and adaptation strategies. Further, adaptation strategies are highly costly and needs more investment in the agriculture. The degree of current farm crisis is higher in the marginalized farming, i.e., Indian agriculture with least adaptation capabilities.

Chapter- 3

Agriculture Development in India: A State Level Analysis

3.0 Introduction

Agriculture plays vital role in the process of economic development of less developed countries like India. Besides providing food for the nation, agriculture absorbs labor, provides saving, contributes to the market of industrial goods and earn overseas exchange (Tripathi A. and Prasad A.R., 2009, p. 1). Further, agricultural development is an inbuilt part of overall economic development. In India, agriculture has the main source of national income and occupation since independence (GoI, 2014, p. 1). During the first decade of independence, agriculture and allied activities contributed 51.81 percent to India's national income and around 73 percent of the total working population were engaged in agriculture and allied sector (GoI, 2014, p. 1). However, the share of agriculture to national income has declined from 51.81 percent in 1951 to 18.20 percent in 2013-14 (GoI, 2014, p. 2). In spite of this, it is also an important feature of the agriculture that the growth of other sectors and overall economy depends on the performance of agriculture to a considerable extent. Because agriculture provides employment to the majority of rural population, provides raw material and support secondary sector, i.e., growth in industrial sector, provide foods to the 120 hundred millions people (Tripathi A. and Prasad A.R., 2009, p. 1). Founded on these reasons agriculture continues to be a predominant sector in the Indian economy.

Since independence, Indian agriculture has been significantly progressing, it grew at the rate of one percent per annum for sixty years before independence during 1860-1920. Further, it springs up at the rate of about 2.6 percent per annum in the post- independence era 1951-56 (Tripathi A. and Prasad A.R., 2009, p. 1). An increase in total cropped area was the main source of agriculture growth from fifties to eighties (GoI, 2014, p. 28). Even so, after the mid-eighties area under agriculture (particularly for minor food crops) was declined and increase in productivity became the primary source of growth in agricultural production (GoI, 2014, p. 12). Further, there was an increase in production of major food grains, viz., wheat, rice and sugarcane etc. and as a result the dependency on imported food grains was reduced (GoI, 2014, p. 12). Indian agriculture has advanced not only in output and yield terms, but the structural changes have also been emerged. Land reforms, an introduction of agricultural price commission with the objective to ensure remunerative prices to producers, new agricultural strategies, viz., introduction of hybrid seeds, chemical fertilisers, new cultivation & harvesting tools, improved irrigation facilities, agriculture credit & insurance, investment in research and extension services and improvement of rural infrastructure were taking place. All these developments in Indian agriculture are contributed by a series of actions taken by the Indian government in mid-sixties. The dark side of agricultural development is, it increased the disparity among the operational land holders, regional inequality, water scarcity & depletion, water logging and salinity. The agricultural investment statistics also show deceleration trends after post- economic era during 1999-2012. Furthermore, natural calamities, higher interest rates, an increase in the agricultural labourers wage rate, increase in prices of fertilisers, seeds & pesticides and lower minimum support price are increased degree of vulnerability in marginal and small farmers

3.1 Estimation Method

We estimated the growth rate of food grains & non-food grains at national level and net sown area, gross sown area, consumption of fertilisers, number of tractors during post green revolution period of 1966-90 and economic reform period 1991-2012 at the state level by using semi-log quadratic regression model, as follows.

$$Y_t = Y_0(1 + r)^t \ldots\ldots\ldots\ldots\ldots..(1)$$

Where r is the compound (i.e., over time) rate of growth of Y. taking the natural logarithm of equation 1, we can write

$$\ln Y_t = \log Y_0 + t \ln(1 + r) \ldots\ldots(2)$$

Now letting

$$B_1 = \ln Y_0 \ldots\ldots\ldots\ldots..(3)$$

$$B_2 = \ln(1 + r) \ldots\ldots\ldots.(4)$$

We can write equation (2) as

$$\ln Y_t = \beta_1 + \beta_2 T \ldots\ldots\ldots\ldots.(5)$$

Adding this disturbance term to equation (5), we obtain

$$\ln Y_t = \beta_1 + \beta_2 T + U_t \ldots\ldots\ldots\ldots\ldots(6)$$

Model looks like, equation 6 is called semi-log model because only one variable (in the case of regressand) appears in the logarithmic form (Damodar N.Gujrati, 2004, p. 175).

3.2 Change in Land Use Pattern

In the agricultural development history, the changes in land use pattern in the broad sub-agricultural land use categories have observed since green revolution period. Table 3.1 shows the trends of land use pattern change in India over a green revolution period. The present study has taken an average area under the eight sub-categories of land use classification, viz., forest area, area not available for cultivation, permanent posture & grazing land, land under miscellaneous, culturable waste land, fellow land, current fellow and net sown area for the periods, viz., 1966-70, 1971-80, 1981-90, 1991-2000 and 2001-12. It is found that forest cover marginally increased about two percent during 1966-2012 at the cost of land not available for cultivation, permanent pasture & grazing land, land under miscellaneous and culturable waste. In other words, it is found that area has decline by about one percent under land not available for cultivation, permanent pasture & grazing land, land under miscellaneous and culturable waste (Table 3.1). It brought up the question of the reality of afforestation programmes, because plantation which already existed in the land use under misc. and culturable waste land. Further, Net sown area is purely associated with agricultural practices, shows marginally increased by about 1.22 percent during 1966-2012 respectively (Table 3.1). Furthermore an area more than once shows positive outcome of green revolution. Table 3.1 indicates that area more than once use for cultivation increased about two percent during 1966-1990 and continuous increased by about six percent during 1991-2012.

Table 3.1: Trends in Land Use Pattern in India (in '000' Hectares)

Period	1966-70	1971-80	1981-90	1966-90	1991-00	2001-12	1999-2012
TRA	305384	304212	304528	304708	304848	304962	304905
Forest	63581 (20.82)	66060 (21.72)	67037 (22.01)	65559 (21.52)	68612 (22.51)	69729 (22.86)	69170 (22.69)
Not Available for Cultivation	47543 (15.57)	41461 (13.63)	40573 (13.32)	43192 (14.17)	40856 (13.40)	42360 (13.89)	41608 (13.65)
Permanent Posture & Grazing land	13786 (4.51)	12630 (4.15)	11815 (3.88)	12744 (4.18)	11030 (3.62)	10455 (4.43)	10743 (3.52)
Land under Misc.	407 (1.34)	3919 (1.29)	3594 (1.18)	3864 (1.27)	3704 (1.22)	3419 (1.12)	3562 (1.17)
Culturable Waste Land	16345 (5.35)	17274 (5.68)	15801 (5.19)	16473 (5.41)	14294 (4.69)	13284 (4.36)	13789 (4.52)
Fellow land	917 (3.01)	9143 (3.01)	9921 (3.26)	9414 (3.09)	9976 (3.27)	10186 (3.34)	10081 (3.31)
Current Fellow	13011 (4.26)	13435 (4.42)	15174 (4.98)	13873 (4.55)	14023 (4.60)	15168 (4.97)	14596 (4.79)
NSA	137863 (45.14)	140290 (46.12)	140613 (46.17)	139589 (45.81)	142353 (46.70)	140361 (46.03)	141357 (46.36)
More than once	21769 (7.13)	27954 (9.19)	36204 (11.89)	28643 (9.40)	45180 (14.82)	49840 (16.34)	47510 (15.58
GSA	159632	168244	176817	168231	187534	190201	188867

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013**.** Note: TRA = Total Reporting Area, NSA = Net Sown Area, GSA= Gross Sown Area. Parenthesis values are percentage from total reporting area.

3.3 CAGR of Net Sown Area, Gross Sown Area, Net Irrigated Area and Gross Irrigated Area: A State level Analysis

It is noted that after policy reforms in agriculture (green revolution), the total cropped area was increased at the national stage. Estimated compound annual growth rate (CAGR) shows that gross sown area (GSA) was marginally increased 0.24 percent annually during 1991-2012. Nevertheless, net sown area (NSA) was declined by -0.09 percent during the same period. Growth in the irrigation sources (both surface and ground water) net irrigated area (NIA) and gross irrigated area (GIA) were increased by 1.26 & 1.55 percent during 1991-2012 at national level. Disparity in the growth of NSA, GSA, NIA and GIA has observed at the state level. Among the study states, NSA was increased in Gujarat by 0.39 percent during 1991-2012. On the other hand, states like Bihar, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh, Madhya Pradesh and West Bengal NSA was declined by 2.35, 0.38, 0.16, 0.47, 0.25, 11.50, 0.89, 0.30, 1.96 & 0.26 percent. However, GSA shows lower declined trends in CAGR. It was declined in the Bihar, Himachal Pradesh, Kerala, Orissa, Tamil Nadu and Madhya Pradesh by 2, 0.18, 0.58, 1.62, 1.20 and 1.18 percent and in one hand and on the other hand, it was increased in Gujarat, Haryana, Jammu & Kashmir, Karnataka, Maharashtra, Punjab, Rajasthan and West Bengal by 0.53, 0.62, 0.34, 0.28, 0.43, 0.23, 0.23 & 0.55 percent during respectively. The regional disparities have observed in NIA and GIA at state level. Bihar is only the state, which shows a decline in a CAGR of NIA. In Bihar, NIA was declined by 0.41 percent during 1991-2012. On the other hand, remaining states NIA show increased in CAGR during the same period. It was increased in Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Uttar Pradesh, Madhya Pradesh and West Bengal by 2.55, 0.69, 2.22, 1.04, 1.17, 0.34, 1.99, 1.07, 1.43 & 2.83 percent during 1991-2012 (Table 3.1). Moreover, the CAGR of GIA also shows regional variations. GIA was increased in Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Uttar Pradesh, Madhya Pradesh and West Bengal by 0.96, 0.35, 2.94, 1.39, 0.46, 0.40, 1.99, 1.84, 0.43, 2.17, 1.22, 1.42 & 4.63 (Table 3.2).

Possibly there are three main reasons responsible for the positive CAGR of GSA. First, increase in NIA and GIA due to agricultural subsidy in irrigation. State governments in Uttar Pradesh, Punjab, Haryana, Karnataka, Maharashtra and Madhya Pradesh are provided free of cost surface water through canal irrigation. Second, Increase in rural electrification, promoted to use ground water with subsidized electricity or very nominal charges in the absence of strict environmental law. Lastly, price support policy for high irrigational crops like wheat rice and sugarcane. It motivated to the farmers especially small and marginal farmers to grow these crops (Sau, R.K., 1971, pp. 106-116).

Table 3.2: Compound Annual Growth of Net Sown Area, Gross Sown Area, Net Irrigated Area and Gross Irrigated Area during 1991-2012

State	Net Sown Area	Gross Sown Area	Net Irrigated Area	Gross Irrigated Area
Andhra Pradesh	-0.08^{NS} (-0.56)	0.15^{NS} (0.86)	0.48^{NS} (1.63)	0.96* (2.73)
Bihar	-2.35* (-9.12)	-2.00* (-8.68)	-0.41** (-2.10)	0.35** (2.13)
Gujarat	0.39* (6.01)	0.53* (4.03)	2.55* (11.41)	2.94* (11.06)
Haryana	0.003^{NS} (0.08)	0.62* (8.38)	0.69* (8.10)	1.39* (16.45)
Himachal Pradesh	-0.38* (-13.15)	-0.18* (-5.40)	0.35^{NS} (1.63)	0.46* (8.03)
Jammu & Kashmir	0.04^{NS} (1.47)	0.0034* (8.35)	-0.02^{NS} (-0.15)	0.40* (6.41)
Karnataka	-0.16*** (-1.78)	0.28** (2.15)	2.22* (11.06)	1.99* (7.24)
Kerala	-0.47* (-9.56)	-0.58* (-5.65)	1.04* (10.24)	0.69* (2.83)
Maharashtra	-0.25* (-7.37)	0.43* (6.15)	1.17* (5.42)	1.84* (11.50)
Orissa	-11.5* (-7.37)	-1.62* (-3.50)	-0.63^{NS} (-0.86)	-0.22^{NS} (-0.30)
Punjab	-0.03^{NS} (-1.11)	0.23* (5.33)	0.34** (2.41)	0.43* (8.37)
Rajasthan	0.24^{NS} (0.65)	0.84** (1.97)	1.99* (6.35)	2.17* (6.64)
Tamil Nadu	-0.89* (-5.62)	-1.20* (-5.98)	0.30^{NS} (0.92)	-0.18^{NS} (-0.51)
Uttar Pradesh	-0.30* (-6.27)	-0.07^{NS} (-1.31)	1.07* (10.63)	1.22* (12.42)
Madhya Pradesh	-1.96* (-6.76)	-1.18* (-3.17)	1.43* (2.77)	1.42* (2.68)
West Bengal	-0.26* (-4.29)	0.55* (4.78)	2.83* (5.96)	4.63* (6.11)
India	-0.09*** (-1.75)	0.24* (3.05)	1.26* (13.55)	1.55* (12.93

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013. Note: Parenthesis value are t-statistics, *, ** & *** indicates 1, 5 & 10 percent level of significance and NS indicates non- significant.

3.4 Change in Cropping Pattern

Land use pattern, increase in NIA and GIA with use of modern technology and government support price policy leads to change in cropping pattern in favour of food grain crops especially rice and wheat during 1966 to till the mid-eighties. Food grain and non-food grain crops shared the total cropped area by 81.52 & 18.48 percent during 1966-70. It has been changed during 2001-2012 by the 75.21 & 24.79 percent. It is shifted in favour of non-food grain crops (Table 3.3). Regional disparities in the expansion of total cropped area under food grain and non-food crops also found. The total cropped area under food grain crops has increased substantially in the states, viz., Bihar, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal by 3.33, 3.98, 2.20, 0.82, 1.06 & 0.36 percent during 1966-2012, whereas it has marginally increased in Haryana, Jammu & Kashmir and Karnataka by 0.55, 0.14 & 0.7 percent (Table 3.3). On the other hand, it has declined substantially in Andhra Pradesh, Gujarat, Madhya Pradesh and Tamil Nadu by 1.86, 0.82, 3.93 & 1.58 percent. Whereas, it marginally declined in Kerala and Maharashtra by 0.40 & 0.73 percent during 1966-2012 (Table 3.3).

Similarly, the total cropped area under non-food grain crops substantially has increased in Madhya Pradesh, Rajasthan, West Bengal and Andhra Pradesh by the 7.83, 6.11, 6.26, 6.26 & 0.98 percent. Further, it has marginally increased in Haryana, Himachal Pradesh, Jammu & Kashmir, Kerala and Maharashtra by the 0.85, 0.27, 0.65 & 0.09 percent during 1966-2012 (Table 3.4). On the other hand, it has substantially declined in Uttar Pradesh, Tamil Nadu, Punjab and Karnataka by the 15.54, 3.61, 2.36 & 1.87 percent. Further, it has marginally declined in Bihar, Gujarat and Orissa by the 0.96, 0.99 & 0.52 percent.

Moreover, rapid shift in the cropping pattern in favor of food grain crops during 1966 to till mid-eighties has observed. After that, shift in the cropping pattern in favour of non-food grain crops observed up to 2012 (Table 3.3). State level disparities in the shift of food to non-food crops and non-food to food crops has reflection of national level. There are four major reasons for these disparities at national as well as state level. First, adoption of new agricultural technology such as hybrid seeds, chemical fertilisers and mechanical tools etc. Second, coverage of irrigation. Since the starting years of green revolution, coverage of irrigation has increased the cropped area share in favour of irrigation intensive crops such as rice, wheat and sugarcane. With all season irrigation coverage, the gross sown area has increased many folds in the mid-eighties to 2012. Third, Land size, state like, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, Karnataka and Rajasthan have a higher average land size and farmers in these states substantially contributed in the national food stock Lastly, agricultural subsidy. These so-called high yield producing states also have received higher share of the agricultural subsidy during 1966-2012.

However, there is dark side of the green revolution also observed. First, technological change in the mid-eighties caused significantly shift in land utilisation in favour of food grain crops such as wheat and rice at the cost of the area under coarse cereals, pulses and oilseeds. This shift was combined effect of differential rate of technological change among the crops. Second, irrigation bias of new technology causing shift, of land away from dry crops in favour of irrigated crops and the associated policy price- support system as well as market intervention by the government for certain crops (Mruthyunjya and Praduman K., 1989, pp. 159-165). Third, distortions in cropping pattern were reflected in the relatively abundant supply of the same crops (like wheat of which government has surplus stock) and acute shortages of others (like pulses and oilseeds which had to be imported at the huge cost in terms of foreign exchange). Fourth, the input cost has increased many folds (Ranade, C.G., 1980, pp. 23-50). High yielding food grain technology along with fertiliser and irrigation needs more investment in agriculture. With least coverage of institutional credit sources, green revolution pushed in poverty and credit trap to the marginalized Indian farmers. Fifth, emphasis on the agricultural development policy (green revolution) was more on raising the yield of a particular crop per unit of land rather than increasing the total output per unit of land from all crops growth in a year (Dev Mahendra S, 1986, pp. 12-15). Sixth, change in land use pattern. Sharma J.L. (1990, pp. 13-20) examined the inter-state disparities in cropping pattern and agriculture growth. He found that size of land holding has basic factor affecting the structure of cropping pattern across the states. The state with higher agricultural growth rates was having a relatively higher average size of holding except Uttar Pradesh, Punjab and Haryana. Lastly, shift from traditional to unsustainable farm practices. Das (1999, pp. 45-60) argued that traditionally, Indian farmers were small plots of land protected by windbreaks and tree cover. The practices of crop rotation and leaving the field fallow for long periods of time allowed the soil to retain nutrients. However, farmers were then influenced by the green revolution and large farmer who had changed to modern method, such as mono-cropping, in which they cultivated only one type of crop rather than multiple crops, as is done in traditional farming. While mono-cropping allows farmers to grow more of a certain crop that usually of higher market value. It has negative effects on the soil as well. A farmer who applies a mono-cropping system tend to leave their fields fallow for a shorter period of time. Thus, the soil cannot replenish its nutrients. Moreover, farmers that employ mono-cropping methods need higher inputs such as chemical fertilisers, pesticides and improved irrigation facilities.

Table 3.3: Total Cropped Area under Food and Non-Food grains (in '000' Hectares)

Decade	Food grains	Non-Food grains	Total
1966-70	120177 (81.52)	27244 (18.48)	147421 (100.00)
1971-80	124814 (81.53)	28274 (18.47)	153089 (100.00)
1981-90	131573 (80.86)	31143 (19.14)	162717 (100.00)
1991-00	130615 (77.09)	38820 (22.91)	169434 (100.00)
2001-12	122182 (75.21)	40272 (24.79)	162454 (100.00)

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013**.** Note: Parenthesis values are in percent.

Table 3.4: Selected State wise Total Cropped Area under Food grains (in '000' Hectares)

State	1966-70	1971-80	1981-90	1990-2000	2001-12
Andhra Pradesh	9233 (7.68)	9223 (7.39)	8752 (6.65)	7807 (5.98)	7112 (5.82)
Bihar	9597 (7.99)	9922 (7.95)	9741 (7.40)	9404 (7.20)	13827 (11.32)
Gujarat	4879 (4.06)	6783 (5.43)	7609 (5.78)	4229 (3.24)	3961 (3.24)
Haryana	3657 (3.04)	3995 (3.20)	3982 (3.03)	4068 (3.11)	4392 (3.59)
Himachal Pradesh	791 (0.66)	820 (0.66)	876 (0.67)	858 (0.66)	806 (0.66)
Jammu & Kashmir	776 (0.65)	806 (0.65)	875 (0.67)	907 (0.69)	908 (0.74)
Karnataka	7334 (6.10)	6974 (5.59)	7296 (5.55)	7633 (5.84)	7535 (6.17)
Kerala	908 (0.76)	902 (0.72)	742 (0.56)	509 (0.39)	280 (0.23)
Madhya Pradesh	16114 (13.41)	17227 (13.80)	18643 (14.17)	18848 (14.43)	12064 (9.87)
Maharashtra	13205 (10.99)	13361 (10.70)	14776 (11.23)	14566 (11.15)	12535 (10.26)
Orissa	5412 (4.50)	6203 (4.97)	7422 (5.64)	6389 (4.89)	10358 (8.48)
Punjab	3594 (2.99)	4268 (3.42)	5288 (4.02)	5888 (4.51)	6344 (5.19)
Rajasthan	11601 (9.65)	12393 (9.93)	12795 (9.72)	13570 (10.39)	12793 (10.47)
Tamil Nadu	5023 (4.18)	5076 (4.07)	4540 (3.45)	4023 (3.08)	3176 (2.60)
Uttar Pradesh	19154 (15.94)	19306 (15.47)	20819 (15.82)	21210 (16.24)	20763 (16.99)
West Bengal	5811 (4.84)	6329 (5.07)	6216 (4.72)	6639 (5.08)	6347 (5.20)
India	120177	124814	131573	130615	122182

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013**.** Note: Parenthesis values are in percent.

Table 3.5: Selected State wise Total Cropped Area under Non- Food grains (in '000' Hectares)

State	1966-70	1971-80	1981-90	1991-00	2001-12
Andhra Pradesh	2416 (8.87)	2498 (8.84)	3073 (9.87)	4182 (10.77)	3966 (9.85)
Bihar	541 (1.99)	575 (2.03)	526 (1.69)	470 (1.21)	414 (1.03)
Gujarat	3778 (13.870	3839 (13.58)	3846 (12.35)	4339 (11.18)	5187 (12.88)
Haryana	531 (1.95)	582 (2.06)	813 (2.61)	1253 (3.23)	1128 (2.80)
Himachal Pradesh	25 (0.09)	26 (0.09)	24 (0.80)	78 (0.20)	144 (0.36)
Jammu & Kashmir	44 (0.16)	46 (0.16)	63 (0.13)	73 (0.42)	68 (0.81)
Karnataka	2251 (8.26)	2433 (8.61)	2841 (9.12)	3372 (8.69)	2573 (6.39)
Kerala	40 (0.15)	45 (0.16)	39 (0.13)	165 (0.42)	327 (0.81)
Madhya Pradesh	2597 (9.53)	2731 (9.66)	3250 (10.43)	5890 (15.17)	6991 (17.36)
Maharashtra	4705 (17.27)	4461 (15.78)	5287 (16.98)	5862 (15.10)	6627 (17.360
Orissa	402 (1.47)	600 (2.12)	1099 (3.53)	659 (1.70)	384 (0.95)
Punjab	903 (3.31)	952 (3.37)	928 (2.98)	901 (1.70)	621 (0.95)
Rajasthan	1538 (5.65)	1702 (6.02)	2402 (7.71)	4423 (11.39)	4734 (11.76)
Tamil Nadu	1498 (5.50)	1614 (5.71)	1553 (4.99)	1570 (4.05)	761 (1.89)
Uttar Pradesh	5067 (18.60)	5253 (18.58)	4131 (13.26)	2802 (7.22)	1231 (3.06)
West Bengal	647 (2.37)	704 (2.49)	960 (3.08)	1900 (4.90)	3474 (8.63)
India	27244	28274	31143	38820	40272

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013. Note: Parenthesis values are in percent.

3.5 Performance of India Agriculture

The performance of Indian agriculture has been broadly categorised to three periods, viz., Pre-Green Revolution during 1951-65, Post- Green Revolution during 1966- 90 and Economic Reform Period during 1991 to 2012. The current chapter estimates, the growth pattern of area and production in two periods, viz., Post- Green Revolution (1966-90) and Economic Reform Period (1991-2011) by using state as well as national level data.[31] CARG of major food grain crops, viz., rice and wheat shows that it has increased by 0.61 & 2.06 percent annually during post-green revolution period. Further, the CAGR of area of major non-food grain crops viz., sugarcane and total oilseeds has increased by 1.61 & 1.40 percent annually. However, the CAGR of area of cotton in the post- green revolution period declined by -0.27 percent. CAGR of food grain and non-food grain crops has increased by 0.60 & 0.95 percent during post-green revolution period (Table 3.6). CAGR in the economic reform period of major food crops, such as wheat shows that it has increased but decreasing rate. It has increased by 0.83 percent. Furthermore, CAGR of major non-food grain crops viz., sugarcane and total oilseed also has increased but decreasing rate. It has increased by 1.32 & 0.22 percent during economic reform period. CAGR of area of cotton during economic reform period has increased by 1.52 percent during the same period. CAGR of food grain crops in total has declined by -0.44 percent in one hand and on the other hand, CAGR of non-food grain crops in total has increased, but a decreasing rate by 0.61 percent annually during post-green revolution period (Table 3.6).

CAGR of production of major food crops, viz., rice and wheat shows that it has increased by 2.90 & 5.30 percent during post-green revolution period. Further, CAGR of major non-food grain crops, viz., cotton, sugarcane and total oilseeds shows that it has increased by 2.50, 3.09 & 3.28 percent annually during post-green revolution period. Furthermore, CAGR of production of major food grain crops, viz., rice and wheat during the economic reform period has increased but decreasing rate. It has increased by 1.34 & 1.91 percent, respectively. CAGR of production of major non-food grain crops, viz., cotton,

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[31] Due to non- availability of state level data of most of food grain and non-food grain crops during 1951-65, the present study restricted during 1966 to 2012 period.

sugarcane and total oilseeds also shows that it has increased, but rate it has increased by 5.29, 1.40 & 1.98 percent annually (Table 3.6). Similar CAGR of food grain and non-food grain crops in total has found. It has increased, but decreasing rate. It has increased by 1.26 & 1.65 percent in the economic reform period.

Table 3.6: Compound Annual Growth Rate of Area and Production of Major Food and Non- Food grain crops during 1966-90 & 1991-2012

Crop	1966-1990		1991-2012	
	Area	Production	Area	Production
Rice	0.61* (9.20)	2.90* (11.70)	0.09^{NS} (0.86)	1.34* (5.85)
Wheat	2.06* (9.69)	5.30* (16.38)	0.83* (7.08)	1.91* (8.67)
Cotton	-0.27* (-1.94)	2.50* (6.98)	1.52* (4.65)	5.59* (6.19)
Sugarcane	1.61* (7.63)	3.09* (11.70)	1.32* (4.59)	1.40* (3.61)
Total Oilseed	1.40* (9.19)	3.28* (8.73)	0.22* (0.85)	1.98* (3.81)
Total Food grains	0.60* (8.33)	2.93* (14.54)	-0.44* (-3.41)	1.26* (6.40)
Total Non-food grains	0.95* (8.66)	3.02* (13.27)	0.61* (3.07)	1.65* (4.75)

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013**.** Note Parenthesis value are t-statistics, *, ** & *** indicates 1, 5 & 10 percent level of significance and NS indicates non- significant.

3.5.1 CAGR of Area: State Level Analysis

The CAGR of area under rice shows that it is increased in Andhra Pradesh, Haryana, Jammu & Kashmir, Madhya Pradesh, Maharashtra, Punjab, Uttar Pradesh and West Bengal by 0.81, 5.04, 0.89, 0.78, 0.65, 8.85, 1.04 & 0.56 percent during post green revolution (PGR) period, whereas it is declined in Himachal Pradesh, Kerala, Orissa and Tamil Nadu by 0.44, 1.76, 0.20 & 1.48 percent. Further, CAGR of area under rice during economic reform (ER) period shows that it is increased in Gujarat, Haryana, Karnataka and Punjab by 1.67, 2.76, 0.56 & 1.56 percent, whereas it is declined sharply in Bihar, Himachal Pradesh, Jammu & Kashmir, Kerala, Madhya Pradesh, Orissa, Tamil Nadu and West Bengal by 2.85, 0.40, 0.39, 5.01, 5.84, 0.30, 1.08 & 0.32 percent during ER period.

Furthermore, only Punjab and Haryana show an increase in CAGR in one hand and on the other hand decline in Himachal Pradesh, Kerala, Orissa and Tamil Nadu during PGR period and ER period (Table 3.1A & 3.2A).

Subsequently, CAGR of area under wheat shows that it is increased in Bihar, Haryana, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal by 2.64, 3.42, 1.13, 1.28, 1.16, 4.66, 2.47, 1.77, 2.64 & 2.89 percent during PGR period, whereas CAGR is declined in Andhra Pradesh, Karnataka and Tamil Nadu by 1.77, 1.23 & 7.56 percent. Further, CAGR is increased in Bihar, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Punjab and Uttar Pradesh by 0.23, 4.92, 1.51, 0.85, 0.75, 0.84, 2.40, 0.46 & 0.38 percent during ER period, whereas, it is declined in Himachal Pradesh, Orissa and Tamil Nadu by 0.29, 5.12 & 5.13 percent (Table 3.1A & 3.2A).

CAGR of area under cotton shows that it is increased in Andhra Pradesh, Haryana, Orissa, Punjab and Rajasthan by 3.35, 3.64, 13.08, 2.13 & 1.89 percent during PGR period, whereas, it is declined in Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Tamil Nadu, Uttar Pradesh and West Bengal by 10.84, 2.28, 5.20, 7.34, 2.56, 0.79, 1.49, 1.87, 4.95 & 12.42 percent. Further, CAGR during ER period shows that it is increased in Andhra Pradesh, Gujarat, Orissa and West Bengal by 3.42, 1.45 & 22.08 percent, whereas it is declined in Bihar, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh by 0.90, 6.46, 0.90, 2.01, 14.62, 8.94, 1.45, 1.27, 2.29, 5.42 & 6.44 percent during ER period.

Sugarcane is the fourth most important crop (area wise) in India after rice, wheat and cotton. In the current changing consumption pattern leads to increase in demand of goods made by sugarcane. CAGR of area under sugarcane shows that it is increased in Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Orissa, Tamil Nadu and Uttar Pradesh by 0.73, 5.92, 4.64, 3.45, 1.74, 3.01 & 1.76 percent during PGR period, whereas it is declined in Bihar, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Punjab, Rajasthan and West Bengal by 0.84, 1.17, 6.88, 1.31, 1.90, 2.13 & 4.34 percent. Further, CAGR of area under sugarcane during ER period is increased in Gujarat, Maharashtra, Tamil Nadu and Uttar Pradesh by 4.56, 3.98 & 1.21 percent, whereas, it is declined in

Haryana, Jammu & Kashmir, Kerala, Madhya Pradesh, Orissa, Punjab and Rajasthan by 1.99, 15.97, 5.19, 4.12, 3.42, 1.95 & 8.98 percent (Table 3.1A & 3.2A).

CARG of area under total oilseeds shows that it is increased in Andhra Pradesh, Gujarat, Haryana, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan and West Bengal by 1.55, 1.06, 4.22, 2.84, 3.46, 2.76, 2.08, 6.88, 3.55 & 6.03 percent, whereas it is declined in only Uttar Pradesh by 3.81 percent during PGR period. Further, CAGR of area under total oilseeds shows that it is increased in Maharashtra, Rajasthan and West Bengal by 2.53, 1.59 & 1.82, whereas it is declined in Andhra Pradesh, Bihar, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Orissa, Punjab, Tamil Nadu and Uttar Pradesh by 1.94, 3.36, 2.36, 2.52, 14.85, 8.11, 4.28, 8.09, 5.68 & 2.62 percent during the ER period (Table 3.1A & 3.2A).

The green revolution played vital role in the alteration in land use pattern and cropping pattern. CAGR of area under total food grain crops show that it is increased in Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal by 0.62, 0.80, 0.87, 0.96, 1.91, 2.18, 0.47, 0.58 & 0.37 percent during PGR period, whereas it is declined only in Andhra Pradesh, Kerala and Tamil Nadu by 0.29, 1.65 & 0.53 percent. Further, estimated CAGR of area under total food grain crops during ER period show that it is increased in Bihar, Haryana, Punjab and Orissa by 2.64, 0.90, 0.66 & 3.34 percent, whereas it is declined in Andhra Pradesh, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh and West Bengal by 0.61, 0.52, 5.41, 6.83, 1.31, 1.82, 0.22 & 0.46 percent.

Lastly, CAGR of area under non-food grain crops show that it is increased in Andhra Pradesh, Haryana, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan and West Bengal by 1.71, 2.90, 2.56, 1.64, 1.78, 1.11, 5.84, 3.11 & 2.40 percent during PGR period, whereas it is declined in Bihar, Kerala and Uttar Pradesh by 0.32, 0.38 & 1.84 percent. Further, GARG of non- food grain crops show that it is increased in Gujarat, Himachal Pradesh, Kerala, Maharashtra, Rajasthan and West Bengal by 1.73, 7.72, 10.59, 1.60, 1.26 & 6.34 percent, whereas it is declined in Haryana, Karnataka, Orissa, Punjab, Tamil Nadu and Uttar Pradesh by 1.15, 2.52, 3.30, 2.81, 6.39 & 6.29 percent during the ER period (Table 3.1A & 3.2A).

3.5.2 CARG of Production: State Level Analysis

CAGR of area under rice, wheat and sugarcane at the state level shows huge variation at state level. Nevertheless, CAGR of rice, wheat and sugarcane production is increased in the many states except in Kerala, Tamil Nadu and West Bengal. Further, CAGR of rice production is declined in Kerala by 0.63, wheat in Tamil Nadu by 4.99, and sugarcane in West Bengal by 2.77 percent during PGR period. Furthermore, CAGR of cotton production during the same period is increased in Andhra Pradesh, Karnataka, Kerala, Orissa, Punjab and Rajasthan by 10.01, 2.96, 1.89, 13.08, 2.13 & 1.89 percent, whereas it is declined in Bihar, Himachal Pradesh, Jammu & Kashmir, Tamil Nadu, Uttar Pradesh and West Bengal by 10.68, 5.99, 5.55, 1.87, 4.95 & 12.42 percent during PGR period (Table 3.3A). Nevertheless, positive CAGR trends of rice, wheat and sugarcane production did not follow in the ER period. CAGR rice production is increased in Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Punjab, Rajasthan, Uttar Pradesh and West Bengal by 1.84, 3.65, 3.56, 0.67, 1.46, 2.63, 2.40, 0.96 & 1.17 percent, whereas it is declined only in Kerala and Madhya Pradesh by 2.62 & 3.63 percent during ER period respectively (Table 3.4A). Subsequently, CAGR of wheat production shows that it is increased in the majority of states expect Orissa and Tamil Nadu by 4.61 & 4.51 percent during the ER period. Moreover, CAGR of sugarcane production shows vast decline during ER period. It is declined in Jammu & Kashmir, Kerala, Madhya Pradesh, Orissa, Punjab, Rajasthan, by 34.05, 3.33, 1.53, 3.81, 2.96, 1.94 & 7.12 percent, whereas it is increased only in Gujarat, Maharashtra and Uttar Pradesh by 1.70, 3.81 & 0.57 percent during the ER period (Table 3.3A).

CAGR of total oilseeds of production also increased in majority states. It is increased in Andhra Pradesh, Bihar, Haryana, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and West Bengal by 2.86, 1.64, 7.81, 2.65, 4.21, 6.62, 3.93, 7.61, 8.74, 1.06 & 10.27 percent during PGR period, whereas it is declined in Himachal Pradesh, Kerala, Punjab and Uttar Pradesh by 1.68, 4.21, 3.18 & 1.89 percent during the same period (Table 3.3A). Further, CAGR of cotton production during ER period is increased in Andhra Pradesh, Gujarat, Haryana, Jammu & Kashmir, Maharashtra, Orissa and West Bengal by 6.34, 10.12, 2.85, 0.90, 1.45, 14.20 & 22.08

percent, whereas it is declined in Himachal Pradesh, Kerala, Madhya Pradesh, Orissa, Punjab and Rajasthan by 11.10, 16.22, 5.49, 1.27, 2.29, 5.42 & 6.44 percent during the ER period respectively (Table 3.3A).

Due to increase in crop area in favour of food grain crops up to mid- 1980s, production of food grain crops is increased in the majority of the states during a PGR period except Kerala, it is declined by 0.55 percent. CAGR of food grain production shows that it is increased in Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal by 2.56, 2.23, 3.02, 4.32, 1.31, 2.08, 0.99, 2.74, 3.33, 2.22, 5.70, 2.38, 0.92, 3.90 & 3.90 percent during PGR period (Table 3.3A). Further, CAGR of food grain crops production also followed increasing trends during ER period. It is increased in Andhra Pradesh, Gujarat, Haryana, Karnataka, Orissa, Punjab, Rajasthan, Uttar Pradesh and West Bengal by 2.38, 2.77, 2.59, 1.87, 7.15, 1.70, 2.63, 1.08 & 1.08 percent. However, surprisingly, it is declined in Kerala and Madhya Pradesh by 2.85 & 3.91 percent respectively (3.4A).

CAGR of non-food grain crops production also followed similar trends during PGR period. It is increased in Andhra Pradesh, Gujarat, Jammu & Kashmir, Karnataka, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal by 0.97, 5.09, 1.67, 4.20, 2.62, 3.20, 1.21, 5.36, 3.99, 3.09 & 1.59 percent during PGR period respectively (Table 3.3A). Further, CAGR of non-food grain crops production during ER period did not followed the PGR period trends. It is increased in Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal by 1.02, 3.79, 4.06, 1.90, 0.54 & 2.09 percent, whereas it is declined in Kerala and Orissa, by 3.66 & 2.76 percent during the ER period (Table 3.4A).

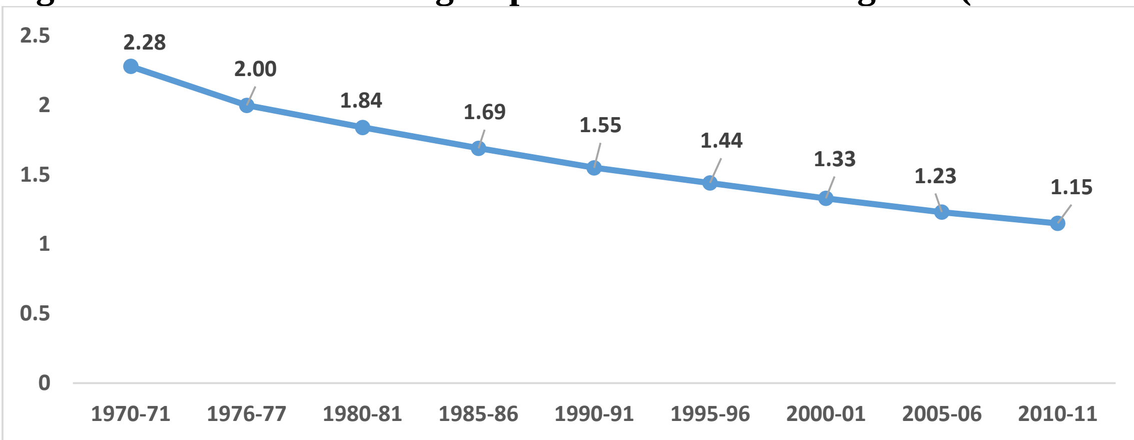
3.6 Determinants of Agriculture Production

The performance of Indian agriculture depends on many numerous factors viz., economic, technological and environmental factors. Economic factors are most important such as size of operational land holding. Technological factors viz., use of machinery (tractors), use of chemical fertilisers and pesticides are employed. Environmental factors such as rainfall and temperature are used. The present chapter investigates change in the use of the various factors at state & all India level during post green revolution and economic reform period.

3.6.1 Economic Factors

As an economic factor, the composition of operational land holdings across classes and social communities plays an important role for agricultural output. India is highly diverse nature in agricultural operations. Since majority of agricultural operational holders are marginal and small with regional difference, their numbers have increased in the subsequent years (GoI, 2013, p. 2). Figure 3.1 shows declined in an average operation land holding size since 1970-71 to 2010-11. There are four possible reasons responsible for decline of land size. First, population growth. India has second most populous country in the world after China and it is continuously increasing (GoI, 2011, p. 12). Second, urbanization in India is in the fastest developing in the macrocosm. Consequently, new shelters and infrastructures require land for enlargement. Therefore, average plot size of land is now limiting year to year. Third, new opportunities in non-farm sector. In the recent year, it is observed that non-farm sector growth is higher compared with farm sector with low risk and higher employment opportunities in all calendar months. Therefore, farmers those are having a small plot of land (, landless small and marginal farmers) are shifting their primary occupation towards non-farm sector. Lastly, high input cost and lower uncertain returns. Other words, the dark side of the green revolution is that it became input intensive to Indian agriculture. It has increased the extra burden on marginal and small farmers; if a farmer unable to inject more inputs, he has to stay away from core farming practices).

Figure 3.1: All India Average Operation Land Holding Size (in Hectare)



Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013.

Additionally, agricultural census data from 1970-71 to 2011 shows that marginalisation in the India agriculture has increased. Marginal farmers were 51 percent in 1970-71, they are increased by 17 percent, i.e., 67 percent in 2010-11 at the cost of large & medium farmers. The large farmer share was declined from 3.9 percent in 1970-71 to 0.7 percent in 2010-11. Subsequently, operated area has shifted from large farmers towards marginal and small farm holders. In 1970-71, 51 percent marginal farmers were owned 9 percent total cropped area. It has increased about 22 percent in 2010-11. On the other hand, 20 percent declined in the large farmer's total operated area during 1970-71 to 2010-11 (Table 3.7).

Table 3.7: Number and Area under Class Wise Operational Land Holdings in India (in Percent)

Distribution of Operational Land Holdings					
Period	Marginal	Small	Semi-medium	Medium	Large
1970–71	51.0	18.9	15.0	11.2	3.9
1980–81	56.4	18.1	14.0	9.1	2.4
1990–91	59.4	18.8	13.1	7.1	1.6
2000–01	62.9	18.9	11.7	5.5	1.0
2005–06	64.8	18.5	10.9	4.9	0.8
2010–11	67.0	17.9	10.0	4.3	0.7
Distribution of Operational Area					
1970–71	9.0	11.9	18.5	29.7	30.9
1980–81	12.0	14.1	21.2	29.6	23.0
1990–91	15.0	17.4	23.2	27.0	17.3
2000–01	18.7	20.2	24.0	24.0	13.2
2005–06	20.2	20.9	23.9	23.1	11.8
2010–11	22.2	22.1	23.6	21.2	10.9

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013.

3.6.1.1 Regional Shift in Average Land Size

State wise shift in the average land size reflects that states having better institutional support such as water resources, investment and non-farm employment opportunities have higher average land size compare to all India level, viz., Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab and Rajasthan, whereas Andhra Pradesh, Bihar, Himachal Pradesh, Jammu & Kashmir, Kerala, Odisha, Tamil Nadu, Uttar Pradesh and West Bengal have lower average land size compare with all India (Table 3.8). It is interesting that state like Uttar Pradesh shows lower average land size compared to all India level in all three periods (Table 3.8). High yield food crops producing states, viz., Punjab Haryana, Tamil Nadu and Kerala show marginal decline in the average land size across three agricultural census period (Table 3.8). On the other hand, states like, Bihar, Madhya

Pradesh, Odisha and Rajasthan have shown sharp decline. It is a serious issue for policy point of view that when average land size is declining in one hand and on the other hand, demand of food items increasing. Will it be trapped with food security?. This food insecurity would be different from previous food crisis raised in the early fifties. In the fifties we are not fully using our natural, institutional, and technological resources. Therefore, by using modern technology and expansion in the total cropped area, we sustain nation's food demand. But now we are at optimum level of agricultural operation. Second, not able to increased total cropped area. Third, larger share on the hands of marginal farmers with high degree of vulnerability. Fourth, political unwillingness in the development of agricultural sector. All these reasons presented adverse conditions in the development of farm sector.

Table 3.8: Selected State wise Average Operational Land Holdings during 1995-96, 2005-06 & 2010-11 (in Hectare)

State	1995-96	2005-06	2010-11
Andhra Pradesh	1.36	1.20	1.08
Bihar	0.75	0.43	0.39
Gujarat	2.62	2.20	2.11
Haryana	2.13	2.24	2.25
Himachal Pradesh	1.16	1.04	0.99
Jammu & Kashmir	0.76	0.67	0.62
Karnataka	1.95	1.63	1.55
Kerala	0.27	0.23	0.22
Madhya Pradesh	2.28	2.02	1.78
Maharashtra	1.87	1.46	1.45
Odisha	1.30	1.15	1.04
Punjab	3.79	3.95	3.77
Rajasthan	3.96	3.38	3.07
Tamil Nadu	0.91	0.83	0.80
Uttar Pradesh	0.86	0.80	0.75
West Bengal	0.85	0.79	0.77
India	1.44	1.23	1.15

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013.

Further, marginal farm size, ownership has increased in the backward states sharply. Marginal farmers were 80.14 percent in Bihar in 1995-96 and it has increased by about 11 percent in 2010-11 to 91.06 percent Subsequently, Uttar Pradesh and West Bengal the total operational holders under marginal farm size was 75.42 & 76.42 percent in 1995-96. It has increased to 79.23 & 82.17 in 2010-11 (Table 3.9). This is much higher from all India level. The lower marginal owners from all India level are in Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Odisha, Punjab and Rajasthan. Among these states, Andhra Pradesh, Maharashtra, Madhya Pradesh and Punjab are high yield states. In other words, the rate of marginalisation in the high yield states is lower and on the other hand, higher marginalisation rate in low yield states observed across the agricultural census period. Furthermore, farm output point of view, it is important that these marginal shareholders are not a real contributor in the national account statistics. They are, in other words called consumer rather than producers. An increase in the family size and decline land size put pressure of food insecurity. Therefore, they grow in majority food crops like rice and wheat for own consumption rather than the profit motive.

Table 3.9: Selected State wise Number and Area under Marginal Operational Land Holding (in percent)

State	1995–96		2005–06		2010–11	
	Number	Area	Number	Area	Number	Area
Andhra Pradesh	59.42	20.20	61.58	22.69	63.95	26.08
Bihar	80.14	36.24	89.64	53.00	91.06	57.44
Gujarat	27.35	5.67	34.01	7.71	36.89	8.59
Haryana	47.16	10.99	47.66	9.66	48.11	9.87
Himachal Pradesh	64.43	23.00	68.27	26.65	69.72	28.48
Jammu & Kashmir	77.92	39.68	81.49	43.99	83.30	46.48
Karnataka	41.95	10.31	48.23	13.33	49.14	15.22
Kerala	93.95	53.27	95.63	57.62	96.33	58.64
Madhya Pradesh	40.38	8.20	40.45	9.92	43.86	12.09
Maharashtra	40.05	10.50	44.60	14.00	48.97	16.06
Odisha	54.08	20.68	59.62	26.74	72.17	39.53
Punjab	18.66	2.94	13.45	2.09	15.57	2.55
Rajasthan	30.03	3.67	33.51	4.85	36.47	5.86
Tamil Nadu	74.28	30.26	76.02	33.50	77.19	35.33
Uttar Pradesh	75.42	33.74	77.95	38.94	79.23	39.27
West Bengal	76.42	42.93	81.16	50.65	82.17	52.48
All-India	61.58	17.21	64.77	20.23	67.04	22.25

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013.

3.6.2 Technological Factors

Technological factors are also equally important and responsible for farm productivity. CAGR of chemical fertiliser & its composition and tractors has been estimated during post green revolution period and economic reform period.

3.6.2.1 Chemical Fertilisers Consumption and Agricultural Productivity

By using chemical fertilisers in the post-green revolution period, India sustains domestic food grains demand. The role of chemical fertilisers is important in the growth of Indian agriculture, as the net area available for cultivation is shrinking, due to the rising demand for land to build new houses, infrastructure and commercial outlets. In fact, the entire increase in farm output in the future may have to come from a rise in productivity. This will require improved technology and increased application of yield-enhancing plant nutrients. Therefore, a growth in fertiliser consumption is of paramount importance to raise food and agriculture production to meet the future requirements of the country. Three key instruments have implemented in the green revolution policy agenda in Indian agriculture; (i) hybrid seeds, (ii) chemical fertilisers, and (iii) improved irrigation. Among these three instruments, chemical fertilisers were a second important instrument. Hybrid seeds required chemical fertilisers to boost plant growth & total output. Therefore, after injection of fertiliser couple with high yielding varieties of rice and wheat since late 1960s, made it possible to produce 15 to 20 tonnes of plant biomass (dry matter) per hectare per year. Therefore, farmers were started use of chemical fertiliser (especially nitrogen) at a massive level. Per hectare consumption of chemical fertiliser has increased four-fold during 1991-2012 from base year of 1965-66. It was 36 kilograms in 1965-66 and has increased 127 kilograms per hectare during 1991-2012. Regional disparities in the fertiliser consumption have also been taken place (Table 3.8). States like Andhra Pradesh, Haryana and Punjab are most high fertiliser intensive states. In 1965-66 fertiliser consumption in these states was 41, 56 & 110 kilograms per hectare and it has increased by 180, 175 & 208 kilograms per hectare during 1991-2012 (Table 3.10). These states are using high yield varieties of rice, wheat and sugarcane, which needs more fertilization coupled with improved irrigation. Andhra Pradesh has topped position for rice productivity per hectare. On the other hand, Odisha, Rajasthan, Madhya Pradesh, Kerala and Maharashtra are still using less. These states are using below 100 kilograms per hectare fertilisers. These regional variations show the scope for rising farm productivity by using fertiliser judiciously.

Table 3.10: Fertilisers Consumption in Selected States during 1966 to 2012 period (Kg/Hectare)

State	1966-67	1966-90	1991-2012	Δ (change)
Andhra Pradesh	41	60	180	120
Bihar	39	46	121	75
Gujarat	26	35	109	74
Haryana	56	67	175	108
Karnataka	45	51	121	70
Kerala	31	44	71	28
Madhya Pradesh	11	18	65	47
Maharashtra	22	29	96	67
Orissa	0.5	9	43	33
Punjab	110	138	208	71
Rajasthan	7	11	42	31
Tamil	56	80	166	86
West Bengal	45	57	138	81
Uttar Pradesh	55	77	140	63
Jammu & Kashmir	24	79	184	105
Himachal Pradesh	12	67	169	102
India	36	54	127	72

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013.Note: Δ indicates change in Fertilisers Consumption during 1966-90 to 1991-2012.

In addition, CAGR shows positive growth in both two study periods, viz., post-green revolution period (PGR) and economic reform period (ERP) in the nitrogen phosphate and potassium based fertiliser’s consumption. It is observed that CAGR of nitrogen based fertiliser has slower in ERP compared with in PGR. It was 9.22 percent in PGR and remained 3.26 percent in ERP (Table 3.11). Similarly, CAGR of phosphorus and potassium based chemical fertilisers shows slower in ERP compared with PGR level. It was 10.22 & 4.24 percent in PGR and remained 9.17 & 5.67 percent in ERP at national level. Further, regional disparities in the consumption of chemical fertilisers have found. Among the study states, Bihar, Haryana, Madhya Pradesh, Punjab, Uttar Pradesh and West Bengal reported more than 10 percent annual growth rate during the PGR period (Table 3.11). However, in the ERP period, CAGR sharply has declined. Even though, the majority of states shows a decline in the consumption of nitrogen, phosphorus and potassium except in Haryana, Punjab and Uttar Pradesh. In these states consumption of potassium based fertilisers has increased sharply in ERP compared with PGR period. It was 9.36, 7.34 & 7.60 percent in PGR period and has increased by 17.84, 8.92 & 7.90 percent in the ERP period (Table 3.11).

There are three major reasons for decline CAGR. First, initially, farmers in the early 1960s have used fertilisers (especially nitrogen based) without consideration of plant requirements. When fertiliser use reached a threshold level or beyond the plant carrying capacity. It has negative consequences in output. Therefore, there is a shift from imbalance towards balance use of chemical fertiliser. Further, Shift from nitrogen based fertilisers towards potassium based fertilisers also found in the higher food grains yield states, viz., Haryana, Punjab and Uttar Pradesh. Second, introduction of new bio-fertiliser and early maturing varieties in arid and semi-arid regions. Lastly, supportive government price policy for nitrogen based fertilisers increased nitrogen based fertilisers consumption markedly during PGR period. A recent report published by the government of India shows that more than 60 percent cropped area under rain-fed conditions. It means water is not available for farming throughout the cropping seasons. Therefore, early maturing varieties and judicious use of chemical fertilisers are best option to cope with adverse climatic conditions.

Though green revolution has much positive impact on Indian agriculture. But it has dark side also. First, farmers were started use of chemical fertilisers (especially nitrogen) at a massive level without considering adverse consequences. Higher use of chemical fertilisers leads to decline net profit. Second, the chemicalisation of agriculture associated with green revolution has brought in its train serious ecological problems such as waterlogging, salinity and alkalinity in the dry or semi-arid regions. Lastly, substitution of chemical fertilisers for organic manure has had an adverse effect on soil health, aggravating instability.

Table 3.11: Selected State wise Compound Annual Growth Rate of Chemical Fertilisers (Nitrogen, Phosphorus and Potassium) Consumption during 1966-90 and 1991-2011

State	1966-90			1991-2012		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
Andhra Pradesh	8.62* 15.41)	9.84* (17.68)	16.42* (8.52)	2.97* (8.26)	4.62* (9.80)	8.16* (13.98)
Bihar	10.40* (22.63)	12.16* (11.40)	12.40* (14.29)	5.41* (5.12)	7.05* (4.64)	12.12* (7.46)
Gujarat	8.61* (17.98)	9.83* (10.99)	9.53* (6.78)	4.67* (9.66)	5.36* (9.21)	7.66* (10.85)
Haryana	11.77* (17.20)	17.70* (16.50)	9.36* (4.47)	3.67* (24.56)	4.74* (14.77)	17.84* (9.84)
Himachal Pradesh	9.67* (17.79)	6.07* (7.79)	9.41* (5.72)	1.49* (7.66)	6.03* (7.36)	7.17* (9.05)
Karnataka	9.19* (24.01)	11.59* (22.07)	12.53* (10.93)	4.07* (10.38)	5.56* (7.36)	6.14* (10.12)
Kerala	5.33* (17.96)	5.62* (11.20)	7.70* (13.72)	2.54* (6.51)	3.19* (7.89)	2.10* (4.63)
Madhya Pradesh	12.51* (16.55)	14.71* (17.58)	13.95* (15.71)	3.10* (4.09)	4.40* (6.46)	6.30* (6.52)
Maharashtra	9.06* (9.69)	9.74* (14.96)	13.57* (5.88)	3.46* (9.69)	6.21* (12.26)	7.14* (9.99)
Orissa	8.70* (15.06)	10.53* (21.11)	12.40* (18.46)	3.90* (9.69)	7.61* (14.89)	6.29* (10.15)
Punjab	10.58* (15.70)	14.68* (12.41)	7.34* (3.22)	2.19* (15.37)	2.87* (8.39)	8.92* (12.19)
Rajasthan	9.20* (19.39)	12.54* (19.76)	8.11* (6.27)	4.24* (17.65)	5.43* (10.53)	7.94* (8.85)
Tamil Nadu	6.18* (11.85)	6.59* (11.43)	8.58* (17.16)	1.93* (8.93)	3.12* (6.44)	2.09* (3.60)
Uttar Pradesh	10.43* (13.61)	11.14* (8.62)	7.60* (4.41)	2.51* (13.96)	5.36* (14.02)	7.90* (9.36)
West Bengal	12.27 (30.00)	16.03* (18.89)	15.82* (7.90)	2.51* (12.98)	4.83* (13.68)	6.15* (11.46)
India	9.22* (23.58)	10.22* (18.92)	9.17* (15.63)	3.26* (15.19)	4.24* (9.73)	5.67* (8.44)

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013. Note: Parenthesis value are t-statistics, *, ** & *** indicates 1, 5 & 10 percent level of significance and NS indicates non- significant.

3.6.2.2 Balance v/s Imbalance Use of Chemical Fertilisers

Since the introduction of chemical fertilisers in the Indian agriculture, the debate on the balanced use of fertiliser and its relation to plant growth are always on concern. In general, the NPK ratio of 4:2:1 is considered to be optimum for India. It is hard to trace the origin of this ratio (Chand R. and Pavitra S., 2015, pp. 1-10). However, it is believed that the ratio is originated from field trials conducted during the 1950s, i.e., in the pre-Green Revolution Period (NAAS, 2009). States like Karnataka, Kerala, Maharashtra, Tamil Nadu and West Bengal have used lower from the recommended ratio of NPK during PGR period. They have used, 3:1:1, 1:1:1, 3:2:1, 3:1:1 & 4:1:1 (Table 3.12). Further, high yield states, viz., Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh have used much higher from the recommended ratio during PGR period. They have used, 32:7:1, 10:6:1, 19:7:1, 21:7:1 & 11:3:1. To maintain the high agricultural growth rate, these states have used more intensive chemical fertilization during the ERP period. During ERP period, farmers have not only increased the share of nitrogen based fertilisers but also increased the share of phosphorus and potassium based fertilisers (Table 3.12).

Though, from the early years of the green revolution period, farmers have adopted intensive chemical fertilization, which was much higher from the recommended ratio. But Chand R. and Pavithra S. (2015, pp. 1-10) criticized that validity of this ideal ratio. They argued that this ratio ignored two important factors. First, during the green revolution period, farmers applied farm- yard manure (bio-fertilisers) and the native soil were rich in phosphorus and potassium content. Second, the response to applied phosphorus and potassium fertilisers was much higher in red and lateritic soils, which clearly indicate that the ratio of NPK would vary for different soil types. Further, the fertiliser norm for a state or country depends upon the cropping pattern, yield levels, crop variety, and soil-specific characteristics which have undergone a sea change over the years. The farm trails conducted in the post-green revolution period confirmed that the response of rice crop to the applied phosphorus was as good as to that of nitrogen, and in fact it was higher in the case of improved varieties of wheat. This finding along with the popularization of improved wheat varieties encouraged the use of Phosphate fertilisers during the post green revolution period (Chand R. and Pavithra S., 2015, pp. 1-2). However, use of fertiliser in

India remained skewed towards Nitrogen based fertilisers. They suggested that the ideal ratio in India based on the current crop pattern and recommendations of SAUs and ICAR institutions was found to be 2.6:1.4:1. This norm implies that N should comprise 52 percent and P and K should constitute 28 and 20 percent, respectively, of the total fertiliser applied in India. These shares are quite different from the share based on the ratio of 4:2:1, which implies that N should constitute 57.8 percent, and P and K should constitute 28.6 & 14 Percent respectively (Nayak, S., 2005, pp. 1-12).

Table 3.12: Selected State wise Consumption and Ratio of Nitrogen, Phosphorus and Potassium during 1966-90 and 1991-2012

State	NPK Ratio (1966-90)	Ratio (1991-2012)
Andhra Pradesh	9:3:1	5:2:1
Bihar	8:2:1	9:2:1
Gujarat	8:4:1	8:3:1
Haryana	32:7:1	42:13:1
Himachal Pradesh	7:1:1	4:1:1
Karnataka	3:1:1	3:2:1
Kerala	1:1:1	1:1:1
Madhya Pradesh	10:6:1	12:7:1
Maharashtra	3:2:1	3:2:1
Orissa	5:2:1	5:2:1
Punjab	19:7:1	32:9:1
Rajasthan	21:7:1	32:13:1
Tamil Nadu	3:1:1	2:1:1
Uttar Pradesh	11:3:1	17:5:1
West Bengal	4:1:1	2:1:1
India	7:2:1	6:2:1

Source: Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2013. Note: Ratio is calculated by k = 1, for Potassium, N = N/K for Nitrogen and P = P/K for Phosphorus.

3.6.2.3 Growth in Use of Tractor

Traditionally, Indian farmers were used bulk for farm management before the introduction of tractor. Tractor has multi-purpose utility equipment. It is not only used in farming, but also used in the non-farm activities. It has labour cost cutting technology and helps to increase farm profits. Table 3.13 shows CAGR of the tractors during 1966-90 and 1991-2012. It is observed that during 1966-90 that growth rate of tractor use in the agriculture were more than 10 percent in Andhra Pradesh, Bihar, Punjab, Haryana, Rajasthan and Uttar

Pradesh. However, during 1991-2012 it has remained about 5 percent, except in Tamil Nadu (Table 3.13).

Table 3.13: Selected State wise Compound Annual Growth Rate of Number of Tractors during 1966-90 and 1991-2012

State	1966-90	1991-2012
Andhra Pradesh	10.79* (49.09)	2.03* (6.74)
Bihar	12.84* (35.93)	4.39* (9.22)
Gujarat	8.14* (15.29)	5.14* (9.04)
Haryana	10.50* (60.01)	0.39* (0.77)
Himachal Pradesh	-2.08* (-0.93)	05.84* (10.39)
Karnataka	7.04* (9.98)	1.53* (2.70)
Kerala	2.57* (5.91)	8.63** (2.14)
Madhya Pradesh	15.66* (15.52)	2.40* (4.29)
Orissa	3.23* (5.30)	7.37* (8.26)
Punjab	12.30* (-0.77)	5.18* (1.60)
Rajasthan	13.84* (47.14)	4.02* (9.43)
Tamil Nadu	7.77* (12.16)	10.49** (2.37)
Uttar Pradesh	13.03* (46.77)	4.18* (11.15)
West Bengal	-7.11** (-2.13)	2.04* (6.32)

Source: Estimated from ICRISAT Database. Note: The values in the parenthesis are t-values. *, ** & *** indicates 1, 5, & 10 percent level of significance.

3.6.3 Environmental Factors

Temperature and rainfall are major environmental determinants, responsible for crop productivity in any piece of land. The distribution of rainfall and temperature is different and vary location to location. In the plains, it is higher and in hilly area, temperature generally remains lower. Due to this, the vegetation is also different like some crops are grown at lower temperature between 15- 21^{0}C and at the same time, some crops grow with temperature between 20- 28^{0}C (IPCC, 2001a, p 254). In other words, temperature is an essential determinant for vegetation growth. However, plant has a minimum threshold level. If temperature (day & night) increased beyond minimum threshold level, surely affects to the growth of the plant. Along with IPCC (2001a, p.1) on global temperature and its negative consequences on global environment as well as human's livelihood several mainstream researchers (Sinha and Swaminathan, 1991, pp. 21-24 ; Singh and Sonatakke, 2002, pp. 1-13 and Sanghi and Mendelsohn, 2008, pp. 15-20) observed that temperature (day & night) adversely affected to the crop productivity and declined net farm revenue.

3.6.3.1 Variations in the Rainfall Distribution Pattern

Sinha and Swaminathan (1991, pp. 21-24); Goswami et al. (2006, pp. 245-250) and Kumar et al. (2015, pp. 1-13) observed that rainfall pattern has shifted from southern parts towards central plains. Means drier regions would be received less rainfall and wetter regions would be received higher rainfall in the coming years. It is confirmed that Gujarat, Karnataka, Maharashtra, Orissa and West Bengal have received surplus rainfall by 103, 43, 20, 93 & 63 millimeter, whereas Andhra Pradesh, Bihar, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh have received less rainfall by -16, -108, -36, -13, -9, -48, -66, -7, -19 and -155 millimeter in the monsoon period during 1966-90 to 1991-2012 (Table 3.14). Further, it is observed that due to climate variability, monsoon rainfall distribution pattern has changed. This regional variations in the monsoon period restricted to the core farmers to change cropping pattern along with sowing period or ready to accept less profit. Goswami et al. (2006, pp. 245-250) observed that less precipitation available for high water intensive khariff crops due to change in monsoon rainfall pattern (Goswami et al., 2006, pp. 245-250). They also observed that rainfall in early Rabi cropping season adversely affected to the Rabi crop, such as wheat. Further, the frequency of heavy and very heavy rain events in central India increased by nearly 50 percent and more than 100 percent during 1951-2000. All India annual rainfall distribution shows that regional variations not only in the monsoon period have increased but it also increased in the annual distribution (Table 3.14).

Table 3.14: Change in Annual and Monsoon Rainfall in Selected States during 1966-90 & 1991-2012 (in Millimeter)

State	Annual Rainfall			Monsoon Rainfall		
	1966-90	1991-2012	Δ (in M.M.)	1966-90	1991-2012	Δ (in M.M.)
Andhra Pradesh	978	962	-16	505	489	-16
Bihar	1221	1051	-170	779	671	-108
Gujarat	1536	1649	113	1228	1331	103
Haryana	603	581	-22	415	379	-36
Himachal Pradesh	1236	1182	-54	692	679	-13
Karnataka	1292	1363	71	770	813	43
Kerala	2575	2837	262	1620	1611	-9
Madhya Pradesh	1051	1017	-34	804	756	-48
Maharashtra	1234	1251	17	898	918	20
Orissa	1306	1457	151	835	928	93
Punjab	642	532	-110	419	353	-66
Rajasthan	582	569	-13	448	441	-7
Tamil Nadu	1025	1029	4	246	227	-19
Uttar Pradesh	979	747	-232	651	496	-155
West Bengal	1220	1308	88	716	779	63
India	1170	1169	1	835	825	-10

Source: Indian Meteorological Department, Government of India, 2013. Note: for the estimation of State level rainfall distribution, geographical location of the meteorological stations have comprised. Δ indicates change in rainfall distribution.

3.6.3.2 Change in Day and Night Temperature

It is observed that states like Gujarat, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Orissa and West Bengal shows that night (minimum) temperature has increased during 1966-90 to 1991-2012. On the other hand, minimum temperature in states like, Bihar, Rajasthan and Uttar Pradesh has declined during the same period (Table 3.15). Further, day (maximum) temperature is important for the vegetative growth of the plants reflects regional variations. It has increased in the states, viz., Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal during 1966-90 to 1991-2012. On the other hand, it has declined in Andhra Pradesh and Bihar. Current findings are match from the Samuel C. (2007, pp. 1-5) study. By using simulation method, his study projected about wheat crop that in Northern India State such as Uttar Pradesh, Punjab, Haryana, Uttarkhand and Himachal Pradesh affected by increasing trends of temperature. Wheat output could plunge by 6 million tonnes with every 1^0C rise in day temperature.

Table 3.15: Selected State wise Change in Mean Minimum and Maximum Temperature during 1966-90 & 1991-2012(in Centigrade)

State	1966-90		1991-2012	
	Minimum Temperature	Minimum Temperature	Maximum Temperature	Maximum Temperature
Andhra Pradesh	21.96	21.85	32.99	32.58
Bihar	19.62	19.44	27.67	27.50
Gujarat	19.76	19.93	26.70	26.85
Haryana	18.14	18.56	31.56	31.85
Himachal Pradesh	13.03	13.75	22.54	23.02
Karnataka	20.32	20.62	25.67	25.93
Madhya Pradesh	19.00	19.26	32.40	30.49
Maharashtra	20.23	20.41	27.75	27.91
Orissa	20.68	19.70	28.49	27.47
Punjab	17.86	18.37	28.65	29.01
Rajasthan	18.82	19.30	31.16	31.61
Tamil Nadu	22.48	22.91	21.63	21.94
Uttar Pradesh	18.78	19.23	32.17	32.51
West Bengal	20.29	20.81	31.00	31.05
India	19.36	19.58	28.60	28.55

Source: Indian Meteorological Department, Government of India, 2013. Note: for the estimation of State level rainfall distribution, geographical location of the meteorological stations has comprised.

3.7 Conclusion

Though, green revolution moved out from the food crisis arisen in the early sixties in some extent, but it also brought regional disparities in the resources use, productivity and cropping pattern. Promotional price policy for some cash crops leads to scarcity in others. Change in an environmental factors, along with economic and technological factors increasing degree of the vulnerability in farm profits in particular and the livelihood of farmers in general.

Chapter- 4

Impact of Climate Change on Agricultural Productivity in India

4.0 Introduction

Climate plays an important role in the farming system, where rainfall, temperature and carbon dioxide are the major natural contributing resources. Suitable climatic conditions show positive trends in agricultural productivity, whereas unfavourable conditions adversely affect to farm system all over the globe (IPCC, 2013, pp. 12-16). The IPCC report predicted that minimum and maximum temperature trends in the South Asian Countries including India will negatively affect to the crops across the agro- climatic regions in majority. Further, higher variation in the annual and monsoon rainfall have increased the degree of vulnerability in the least adaptive sector like, agriculture. Less rainy days, high intensity and shift towards the post monsoon period in the south-west monsoon has signalled the potential impacts of climate change on Indian farm sector (IMD, 1901-2011 database). Studies on rainfall distribution had revealed that the intensity of rainfall increased and rainy days declined at the national level during 1950- 2001 (Goswami et al., 2006, pp. 245-250 and Kumar et al., 2014, pp. 179-197). Further, due to the high intensity of rainfall, water logging, salinity and more intensive flood incidents are becoming a general phenomenon. Basically, rainfall pattern is changing from northeast towards central and northern India (IMD, 2012, p. 12). Therefore, incidences of extreme events are more intensive in central India. Indian Meteorological Department of India, classified that when the monsoon rainfall deficiency exceeds 10 percent and affects more than 20 percent of the country's geographical area, it is categorised as an all-India drought year. However, farming in India is much more sensitive and it adversely affects, even rainfall deficiency exceeds 2-3 percent (Ramanathan et al., 2005, pp. 5326-5333).

The all India long- term temperature records reflect clear picture of increasing temperature trends with regional variations. An increase in temperature during summer season is responsible for heat wave events, which is main responsible factor decline in total mass production in the agriculture. In India, eighteen heat waves were reported during 1980 to 1998. Further, heat wave in 1988 affected ten states and damaged thousands acres of land (GoI, 2012, p. 16). An increased temperature caused an intensification of the water cycle with more extreme variations in weather events and long-lasting droughts (Planning Commission, 2011, p. 12). Furthermore, high night temperature also increases a variety of environmental stresses, viz., heat, drought, salinity and relative humidity in the soil (Peng et al., 2004, pp. 9971-9975).

Moreover, Greg et al. (2011, pp. 205-223) predicted that climate change may increase the number of food insecure children 40-50 million by 2050 in South Asian. Food security gets worse under climate change threatens many millions of people and increased the severity of disparities in cereal yields between developed and developing countries (Parry et al., 2004, pp. 53-67). Furthermore, it is estimated that agriculture output and yield in underdeveloped countries may decline by 15 to 20 percent respectively in the present of climate change on average (Master et al., 2010, pp. 1-35). Subsequently, Oluoko-Odingo (2009, pp. 1-18) observed that a rise in temperature will lead to either drought or flood. It is a reason for the severe shortage of food availability and income of households, lead to poverty and food insecurity. Therefore, the researcher took climate change as one of the main reason of food insecurity and the inability of a national to feed its people through agriculture (Ahmad et al., 2011, pp. 129-137). There is the most serious concern that at the present time more than 870 million populations do not have secure resources to feed their self at a global level. Moreover, 1.2 million people suffer from the deficiency of calories and protein and 2 to 3.5 million population have a micronutrient deficiency (Ramasamy and Moorthy, 2012, pp. 411-22). Malnutrition often leads to disease, devastating the lives of hungry poor people. Particularly, India is home to the largest number of hungry and deprived people in the world, i.e., 360 million undernourished and 300 million poor people. Further, more than 320 million Indian goes to bet even without food every night (Ramasamy and Moorthy, 2012, pp. 411-22). India’s malnutrition level is almost just double compared to many countries in Africa (Dev and Sharma, 2010, pp. 1- 40). Another important fact that in India, food demand will increase just double by 2050 due to high growth rate of population and it may increase the competition for resources such as land, water, capital, labour and other valuable natural resources (Ahmad et al., 2011, pp. 129-137).

4.1 Approaches for Estimation of Climate Change Impact

Since climate is a direct input into the agricultural production process, the agricultural sector has been a natural focus for research. The focus of most previous empirical studies was on United State America, but vulnerability to climate change may be greater in the developing countries like, India and Brazil, where agriculture typically plays a larger economic role. The impact of climate change on developing countries is valuable in understanding the distributional effects of climate change as well as the potential benefits of policies to reduce its magnitude or promote adaptation.

In the literature, there are two important methods for measuring the economic effects of climate change on agriculture, viz., Production function approach and Ricardian approach found. First, the Production function approach is based on controlled agricultural experiments, where specific crops are exposed to varying climates in the laboratory-type setting, such as greenhouse gas and yield then compared across climates (Kumar et al., 2014, pp. 179-97). This approach has an advantage of careful control and randomised application of environmental conditions. However, these laboratory-style outcomes may not reflect the adaptive behaviour of optimising farmers. Some adaptations are modelled, but how well these correspond to the actual farmer behaviour is unclear (Kumar et al., 2014, pp. 179-97). If farmers' actual practices are more adaptive, the production function approach is likely to produce estimates with a negative bias. On the other hand, if the presumed adaptation overlooks constraints on farmers' adaptations or does not take adjustment cost into account, these estimates could be overoptimistic.

Second, Ricardian approach is famous for uncontrolled environment developed by Mendelsohn et al. (1994, p. 3), which attempts to allow full range of compensatory or mitigating behaviours. If markets are functioning well, land prices will reflect the expected present discount value of profit from all, fully adapted uses of land, then, in principle, this approach can account for both the direct impact of climate on specific crops as well farmers' adjustment of production techniques, substitutions of direct crops and even exit from agriculture. However, the success of the Ricardian approach depends on being able to account fully for all the factors correlated with climate and influencing agricultural productivity. Omitted variables such as unobservable farmers or soil quality could lead to a bias of unknown sing and magnitude. The possibility of omitted variables bias and the inconsistent results obtained from Ricardian studies of climate change in the US is leading to a search for new estimation strategies. Basically, a true Ricardian study would be difficult to carry out in a developing country context, because land markets are less likely to be well-functioning and data on land prices are not generally available (William, 2007, pp. 1-15).

More recently, economists studying in US have turned to the panel data approach, using presumably random year to year fluctuations in realised weather across US countries to estimate the effect of weather on agricultural output and profits (Deschens and Greenstone, 2007, pp. 354-82; Schelenkar and Roberts, 2006, pp. 1-50 and Guiteras, 2007, pp. 1-52). The fixed effect approach has the advantage of controlling for time-invariant district level unobservable such as farmer quality or unobservable aspects of soil quality. Furthermore, unlike the production function approach, the use of data on actually field outcomes, rather than outcomes in the laboratory environment, means that estimation from panel data will reflect intra-year adjustments by farmers, such as changes in inputs or cultivation techniques. However, by measuring the effects of annual fluctuations such as crop switching or exit from farming.

4.2 Estimation Method

The present study uses district level agricultural statistics obtained from the International Crops Research Institute for the Semi- Arid Tropics (ICRISAT). The study period of present study has taken during 1966 to 2011. Sixteen major agriculture productive states have been covered for estimation[32]. The selected states represent fourteen agro-climatic zones (Table 4.1A). Further, 291 districts from sixteen states are selected for panel study (Table 4.2A. Rainfall, minimum, maximum temperature datasets obtained from the Meteorological Department of India. Green revolution was a breakthrough in the agricultural development in India. It is boosted agricultural production in many folds, by use of chemical fertilizers, technological tools viz., tractors and pump set for artificial irrigation. Moreover, education has also an important role in agriculture. Highly educated

[32]Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal

cultivators are more smarts and capable to deal with adverse climatic conditions. Therefore, present study has taken irrigated area, fertiliser consumption, use of tractors, use of pump sets for irrigation and rural literacy as the non- climatic determinants. Fifteen major and minor crops food and non- food crops have been taken to examine climate change impact on Indian farm sector[33]. The interpolation and extrapolation have been applied to fill missing values. Furthermore, the study uses panel estimation. Therefore, to use the appropriate method for empirical estimation, Hausman test has been applied to the selection of random or fixed effect model. Moreover, the present study uses time series and cross-sectional data, so, it is usually observed that data sets contain cross-sectional dependence, heteroskedasticity, serial and autocorrelation and unit root problems. Therefore, Im-Pesaran-Shin test for stationarity, Pesaran CD test for cross-sectional dependence, modified Wald test for heteroskedasticity and Wooldridge test for serial correlation and autocorrelation have been applied (Table 4.3A & 4.4A).

Cobb- Douglas (C-D) production function is used by incorporating proxy for independent variables as determinants of crop productivity in India. The model has some advantages compared to other models like simple estimation and easy interpretation. The C-D model assumes that climatic factors are input factors for the growth of crops. This model has been used by various authors to estimate the influence of climatic factors on crop and land productivity in the agriculture (Nastis et al., 2012, pp. 4885-4893) in Greece, Gupta et al. (2012, pp. 10-18) in India. The model assumes that agricultural production is a function of many endogenous and exogenous variables like irrigated area, cultivated area and fertilizers etc. (Nastis et al., 2012, pp. 4885-4893).

4.3 Formulation of Model

In the present study, the proposed regression model assumes that aggregate production for each time period depends on sown area, irrigated area, rainfall, minimum and maximum temperatures, rural literates, tractors, fertilisers and pump sets. In functional form all these variables aggregate with production will be shown as:

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[33]Rice, Wheat, Sorghum, Maize, Barley, Pearl Millet, Finger Millet, Chickpea, Pigeon pea, Pulses, Groundnut, Lime seed Sunflower, Sugarcane and Cotton

$(P)_{it}$ = $f\{(SA)_{it}$, $(IA)_{it}$, $(rainfalls)_{it}$, $(rainfallg)_{it}$, $(rainfallh)_{it}$ $(mintemps)_{it}$, $(mintempg)_{it}$ $(mintemph)_{it}$ $(maxtemps)_{it}$, $(maxtempg)_{it}$ $(maxtempha)_{it}$ $(rurallit)_{it}$, $(tractors)_{it}$, $(fertilizers)_{it}$, $(pumpset)_{it}$, }.............(1).

Where, P is the aggregate production of the respective crop, i is state and t is the time period. Subsequently, SA is sown area, IA is irrigated area, rainfalls is rainfall during sowing period, rainfallg is rainfall during germination period, rainfallh is rainfall during harvesting period, mintemps is minimum temperature during sowing period, mintempg is minimum temperature during germination period, mintemph is minimum temperature during harvesting period, maxtemps is maximum temperature during sowing period, maxtempg is maximum temperature during germination period, maxtemph is maximum temperature during harvesting period (Table 4.5A), rurallit is total rural literates, tractors is number of tractors, fertilizers is fertilizer consumption and pumpset is total pump sets used for irrigation . Further, dividing by SA, equation (1) could be written in yield terms that indicate the production on per hectare basis (land productivity) as:

$(P/SA)_{it}$= $f\{(IA)_{it}$, $(IA)_{it}$, $(rainfalls)_{it}$, $(rainfallg)_{it}$, $(rainfallh)_{it}$ $(mintemps)_{it}$, $(mintempg)_{it}$ $(mintemph)_{it}$ $(maxtemps)_{it}$, $(maxtempg)_{it}$ $(maxtemph)_{it}$ $(rurallit)_{it}$, $(tractors)_{it}$, $(fertilizers)_{it}$, $(pumpset)_{it}$, }.............(2)

After applying a C-D model, equation (2) will take the following specification:

$\log(P)_{it} = \beta_0 + \beta_1\log(IA)_{it} + \beta_2\log(rainfalls)_{it} + \beta_3\log(rainfallg)_{it} + \beta_4\log(rainfallh)_{it} + \beta_5\log(mintemps)_{it} + \beta_6\log(mintempg)_{it} + \beta_7\log(mintemph)_{it} + \beta_8\log(maxtemps)_{it} + \beta_9\log(maxtempg)_{it} + \beta_{10}\log(maxtemph)_{it} + \beta_{11}\log(rurallit)_{it} + \beta_{12}\log(tractors)_{it} + \beta_{13}\log(fertilisers)_{it} + \beta_{14}\log(pumpsets)_{it} + U_{it}$.....................(3)

Where, β_0 is a constant coefficient that is known as Total factor productivity and assumes that the production function is constant returns to scale and a linear production function with homogeneous degree one. It is a white noise error term with zero mean and constant variance and β_1 to β_{14} estimate regression coefficients for the respective variables under the C-D model.

4.4 Final Estimation Method

Based on the model specific test, it is found that fixed effect model is best fit for the final estimation (. Further, it is also found that our data sets infected by serial correlation, autocorrelation, cross- sectional dependence and heteroskedasticity. Therefore, simple ordinary least square (OLS) method is not appropriate for estimation. So study used alternative estimation method viz., Feasible Generalised Least Square (FGLS) method to control serial correlation, autocorrelation, cross-sectional dependence and heteroskedasticity. The method is applied in three stages;

First, the regression coefficients of all fifteen crops yield function f(Xitβ) is estimated by ordinary least square (OLS) estimation. Second, the natural logarithms of the square of estimated residuals from yield function are regressed with explanatory variables to calculate the variable function {h1/2(Xitβ)}. Finally, yield response function calculated as a weighted regression of Yit on f(Xitβ) with weights {h1/2(Xitβ)}. Kumar et al. (2015, p. 5) also followed a similar estimation process to assess the influence of climatic and non-climatic variables on various crops and yield variance.

4.5 Results & Discussion

Rice has the highest mean productivity among the food grain crops (3.28) tonne per hectare, whereas cotton tops on the list (17.50) tonnes per hectare among the non- food grains (Table 4.1). The possible reasons for higher productivity are; first due to increase in the atmospheric carbon dioxide, the majority of C4 crops benefitted initially (Mall et al., 2006, pp. 445-478). Second, there is a positive relationship between cotton productivity and a marginal increase in surface temperature. Basically, it is observed that one-degree centigrade increase temperature from the present level positively affects the cotton crop productivity all over the India (Mall et al., 2006, pp. 445-478). The productivity of wheat, barley and cereal is 1.8, 1.66 and 1.46 tonnes per hectare. Mean maximum & temperature was 32.07 and 19.54 degree centigrade during 1966 to 2011. Mean annual rainfall was 1105.05 millimeters found. Mean rainfall during monsoon season was 870.26 millimeters (Table 4.1). Further, the number of tractors per thousand hectare was 4.17, whereas number of the pump sets per thousand hectare was 29.49 during 1966-2011. The mean consumption of fertilisers (nitrogen, phosphorus & potassium) was 3.70 tons per hectare (Table 4.1).

Table 4.1: Mean of Productivity, Rainfall & temperature at All India level during 1966-2011

Name of the Variable	Unit	Mean
Rice	Ton/Hectare	3.28
Wheat	Ton/Hectare	1.8
Sorghum	Ton/Hectare	1.10
Pearl Millet	Ton/Hectare	0.91
Maize	Ton/Hectare	2.52
Finger Millet	Ton/Hectare	0.71
Barley	Ton/Hectare	1.66
Chickpea	Ton/Hectare	0.77
Pigeon pea	Ton/Hectare	0.73
Rabi Pulses	Ton/Hectare	0.54
Groundnut	Ton/Hectare	1.56
Lime seed	Ton/Hectare	1.34
Soybean	Ton/Hectare	5.49
Sugarcane	Ton/Hectare	5.21
Cotton	Ton/Hectare	17.50
Annual Rainfall	Millimetre	1105.25
Monsoon Rainfall	Millimetre	870.26
Maximum Temperature	Degree Centigrade	32.07
Minimum Temperature	Degree Centigrade	19.54
Tractors	Nos./‘000’Hectare	4.17
Pump set	Nos./‘000’Hectare	29.49
Fertilizer	Ton/Hectare	3.74

Source: Estimated from ICRISAT VDSA database.

4.5.1 Rice

Table 4.2 reveals district year fixed effect, where the irrigated area, rainfall and temperature, minimum & maximum temperature, rural literates, tractors, fertilizers consumption and number of pump sets are found significant at the one percent level of significance. Higher rainfall in the germination period leads to the higher yield of rice whereas; higher rainfall in sowing and harvesting period leads to lower yield. Further, minimum temperature during the sowing period leads to lower yield in one hand and on the other hand, minimum temperature during germination and harvesting period leads lower yield. Furthermore, maximum temperature is crucial for plant growth shows that it affects to the yield adversely in germination period, whereas in sowing period benefitted. Further, non- climatic factors such as sown area, rural literates, tractors, fertilisers and irrigated area positively associated with yield of rice (Table 4.2).

In addition, studies related to temperature and rice productivity observed that a 2^0C rise in temperature and seven percent increase in rainfall would lead to almost 8.4 percent loss in the farm-level net revenue (Kumar and Parikh, 2001b, p. 2). The losses varying between 4 to 26 percent for India under various climate change scenarios. Under the middle scenario of a 2^0C increase in temperature and 7 percent increase in precipitation reported an annual loss of 12 percent of farm-level net revenue in India (Sanghi and Mendelsohn, 2008, pp. 15-20).

4.5.2 Wheat

Wheat is second most important crop among the food grain crops. Non- climatic factors such as sown area, rural literates, tractors, pump sets and fertiliser consumption are positively associated with yield at one percent level of significance. Further, climatic factors, viz., rainfall and minimum & maximum temperatures show heterogeneous relationship with the wheat yield in sowing, germination and harvesting period. Higher rainfall in sowing period leads to higher yield, whereas, higher rainfall in germination and harvesting period leads to lower yield. Subsequently, higher minimum temperature in harvesting period leads to lower yield, whereas, higher minimum temperature in sowing and germination period leads to higher yield. Furthermore, higher maximum temperature in sowing period leads to lower yield, whereas, higher maximum temperature in germination and harvesting period leads to higher yield (Table 4.2). The possible reasons for negative association of rainfall with yield in sowing period is that the shift in monsoon rainfall towards the post monsoon period.

Studies related to wheat productivity observed that in north Indian states such as Uttar Pradesh, Punjab, Haryana, Uttarakhand and Himachal Pradesh is affected by increasing trends of temperature (Goswami et al., 2006, pp. 245-250 and Kumar et al., 2014, pp. 179-197). Further, Guiteras R. (2007, p. 4) predicted that increase in temperature with medium-term (2010-2039), yields reduce by 4.5 to 9 percent, depending on the magnitude and distribution of warming. The study predicted that the impact of long- term climate change (2070-2099) is even more detrimental with predicted yields falling by 25 percent or more. Because these large changes in long- run temperatures will develop over many decades, farmers will have time to adapt their practices to the new climate, likely lessening the negative impacts.

4.5.3 Maize

In India, maize is the third most important cereal crop after rice and wheat. It has major role in the country's food security. Thus, it is important to analyse the consequence of climate change on maize productivity in major maize producing regions in India. The coefficients of FGLS show that the sown area, irrigated area, rural literacy, tractors, fertilizer consumption, and pump sets are positively associated with the maize yield (Table 4.2). It means increase in sown area, irrigated area, rural literacy, tractors and fertilisers consumption leads to increase in the yield of maize. Further, it is found that rainfall and minimum temperature in the sowing period negatively associated with yield of maize, whereas positively associated in germination period. In other words, higher rainfall and minimum temperature in the sowing period leads to lower yield, whereas, higher rainfall in germination and harvesting period leads to higher yield. On the contrary, higher maximum temperature in sowing period leads to higher yield, whereas, higher maximum temperature in germination period leads to lower yield of maize.

The simulation studies on maize crop across the globe observed that maize yield decrease when mean temperatures increase. Kapetanki, G. and Rosenzweig, C. (1997, pp. 251-271) projected that a 4^0C increase in maximum temperature resulted in an average 13.5 percent decrease in yield with no increase in CO_2 (330 ppm) and in a 9.5 percent decrease when temperature change was coupled to evaluated CO_2 (550 ppm). Further, results indicate that maize yield in monsoon season adversely affected, due to rise in atmospheric temperature in all regions, viz., upper Indo- Gangetic plains (UIGP), mid-Indo Gangetic plain (MIGP) and southern plateau (SP) (Byjesh et al., 2010, pp. 413-431).

4.5.4 Barley

Barley has been cultivated in India since ancient times and it considered sacred grains. In India, barley is cultivated on about 6.95 lakhs hectare area with the production of 17.43 lakhs tones and productivity of 2508 kg per hectare (Statistical Abstract, 2013, p. 123). The major barley growing states are; Rajasthan, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, Uttarakhand, Himachal Pradesh, Bihar, Jammu and Kashmir, West Bengal, Chhattisgarh and Sikkim. Among the states, Rajasthan occupies the highest area. The FGLS regression results indicate that yield of barley positively associated with non-climatic factors, viz., sown area, rural literates, tractors, fertilisers, irrigated area and pump sets (Table 4.2). Further, rainfall in sowing, germination and harvesting period negatively associated with the yield of barley. It means, higher rainfall in sowing, germination and harvesting periods lead to lower yield. Furthermore, minimum temperature in sowing period positively associated in one hand and on the other hand, negatively associated in germination and harvesting period with the yield of barley. Moreover, maximum temperature negatively associated with the yield of barley in sowing period, whereas, positively associated with germination and harvesting period (Table 4.2).

4.5.5 Sorghum

Sorghum is the fifth important cereal crop in the sub-tropical and some arid regions of Africa and Asia. It is the second cheapest source of energy and micronutrient after pearl millet. The vast majority of the population in Africa and central Asia depends on it for their dietary and micro-nutrient requirements (ICRISAT, 2016, p. 5). In 1965-66, the share of the area between kharif and rabi cropped area was 62.0 and 38.0 percent respectively. But, these proportions have reserved to 38.0 and 60.0 percent respectively by 2014-15 (State of Agriculture, 2015, p. 17).

The FGLS regression results show that non- climatic factors, viz., sown area, rural literates, irrigated area and pump sets are positively associated with the yield of sorghum, whereas, fertiliser consumption negatively. Climatic factors such rainfall negatively associated in sowing, germination & harvesting period; minimum temperature in germination period and maximum temperature in harvesting period, whereas, minimum temperature positively associated with sorghum yield in sowing & harvesting period and maximum temperature in sowing & germination period. In other words, higher rainfall leads to lower yield in sowing, germination and harvesting period. Similarly, higher minimum temperature in germination periods leads to lower yield, whereas, higher minimum temperature leads to higher yield in sowing and harvesting period. Lastly, higher maximum temperature in sowing and germination period leads to higher yield, whereas, higher maximum temperature leads to higher yield in sowing and germination period (Table 4.2).

4.5.6 Pearl Millet, Finger Millet, Chickpea and Pigeon pea

The pearl millet, finger millet, chickpea and pigeon pea are the major pulses in arid and drier semi-arid regions. These crops are capable of producing a reliable yield under the marginal environmental conditions with least requirement of water for vegetation with higher temperature tolerance capacity (ICRISAT, 2016, p. 6). The FGLS regression results show that sown area, rural literates, tractors, irrigated area and pump sets are positively associated with yield of the pearl millet, whereas fertilisers consumption negatively associated. Further, higher rainfall and minimum temperature in germination period leads to lower yield of pearl millet, whereas, higher rainfall and minimum temperature in sowing and harvesting period leads to lower yield. Higher maximum temperature leads to lower yield in sowing period, whereas, higher maximum temperature in germination and harvesting period leads to higher yield of pearl millet.

Subsequently, yield of finger millet positively associated with sown area, rural literacy, irrigated area and pump sets, whereas, negatively associated with fertilisers consumption. It means, increase in sown area, rural literacy, irrigated area and pump sets least to higher yield of finger millet, whereas increase in fertilisers consumption least to lower yield. Further, rainfall and minimum temperature in harvesting period negatively and in sowing & germination periods positively associated with yield of finger millet. In other words, higher rainfall and minimum temperature in harvesting period leads to lower yield of pearl millet, whereas, higher rainfall in sowing and germination period leads to higher yield. Furthermore, higher maximum temperature in germination period leads to lower yield.

Further, FGLS regression results of chickpea show that sown area, rural literacy, irrigated area, fertilisers consumption and pump sets are positively associated with yield, whereas, tractor is negatively associated with the yield. It means increase in sown area rural literacy, fertilisers consumption, irrigated area and pump sets lead to decline in yield of chickpea. Furthermore, rainfall in sowing and germination periods positively associated with the yield of chickpea, whereas in harvesting period negatively associated. In other words, higher rainfall in sowing and germination period leads to higher yield, whereas, higher rainfall in harvesting period leads to lower yield. Subsequently, minimum temperature in germination period negatively associated, whereas positively associated in sowing and harvesting period. In other words, higher minimum temperature in germination period leads to lower yield, whereas higher minimum temperature leads to higher yield in sowing and harvesting period. Further, maximum temperature negatively associated in sowing and harvesting periods, whereas positively associated in germination period. It means, higher temperature in sowing and harvesting period leads to lower yield.

Moreover, FGLS regression results of pigeon pea show that non- climatic factors, viz., sown area, rural literates, tractors, irrigated area and pump sets positively associated with the yield of pigeon pea and only fertiliser consumption negatively associated. Climatic factors, viz., rainfall and minimum & maximum temperatures show heterogeneous relationship with yield in sowing, germination and harvesting period. It is found that rainfall and minimum temperate negatively associated in sowing and germination periods with yield of pigeon pea, whereas positively associated in harvesting period. It means higher rainfall and minimum temperature in sowing and germination period lead to lower yield, whereas higher rainfall and minimum temperature in harvesting period leads to higher yield. On the contrary, maximum temperate negatively associated in the sowing and harvesting periods, whereas positively associated in the germination period

4.5.7 Rabi Pulses

India is the largest producer and consumer of pulses in the world. Most of the pulses in India are grown in low fertility, problematic soils and unpredicted environmental conditions. Further, more than 87 percent of the area under pulses is rainfed. Drought and heat stress may reduce seed yield by 50 percent, especially in arid and semi- arid regions

(ICRISAT, 2016, pp. 12-15). Another major problem is salinity and alkalinity of soils which is high in both semi-arid tropics and Indo-Gangetic plains (Laxmipati et al., 2013, pp. 145-57).

The FGLS regression results indicate that non-climatic factors, viz., sown area, irrigated area, rural literates, tractors, fertilisers and pump set are positively associated with rabi pulses yield. It means, increase in sown area, irrigated area, rural literates, tractors, fertilisers consumption and pump sets leads to higher yield of rabi pulses. Further, higher rainfall in sowing, germination and harvesting period leads to lower yield. Furthermore, higher minimum temperature in germination period leads to lower yield, whereas, higher minimum temperature in sowing and harvesting periods lead to higher yield (Table 4.2). Lastly, higher maximum temperature in sowing and germination period leads to higher yield, whereas, higher maximum temperature in harvesting period leads to lower yield.

Studies related to pulses yield and climatic factors predicted that recent changes in the global temperature the grain yield is likely to be drastically affected by temperature. Poor drainage/ water logging during the rainy season causes heavy losses, particularly in the states of Uttar Pradesh, Bihar, West Bengal, Chhattisgarh, Madhya Pradesh and Jharkhand (Laxmipati et al., 2013, pp. 145- 57). Subsequently, Ali et al. (2009, pp. 4581–4601) predicted that changes in temperature and their associated impacts on rainfall and the consequent availability of water to crops and extreme events are all likely to affect substantially the potential of pulses production. The most worrying part of the prediction is the estimated increase in winter and summer temperatures by 2.2 ^{0}C and 3.2 ^{0}C respectively by 2050. Such abnormal rise will surely have an adverse impact on pulses production in the form of the reduction in total crop- cycle duration.

4.5.8 Groundnut & Lime Seed

The groundnut or peanut is one of the important legume crops of tropical and semi-arid tropical countries. Where, it provides a major source of edible oil and vegetable protein. The productivity of groundnut varies from 3000 to 3500 kg per hectare in Asia and less than 800 kg per hectare in Africa (ICRISAT, 2016, p. 10). The FGLS regression results show that non-climatic factors, viz., sown area, rural literates, tractors, fertilisers, irrigated area and pump sets are positively associated with the yield of groundnut. Further, climatic factors, rainfall and temperature in the different phase of vegetation shows heterogeneous relationship. Higher rainfall in sowing period leads to lower yield of groundnut, whereas, higher rainfall in sowing and harvesting period leads to higher yield. Furthermore, higher minimum temperature in germination and harvesting period leads to lower yield. Lastly, higher maximum temperature in germination period leads to lower yield, whereas, higher maximum temperature in harvesting period leads to higher yield of groundnut (Table 4.2).

Moreover, FGLS results of Lime seed show that non-climatic factors, viz., sown area, rural literates, tractors, fertilisers, irrigated area and pump sets are positively associated with the yield of Lime seed at one percent level of significance. It means, higher sown area, rural literates, tractors, fertilisers, irrigated area and pump sets leads to higher yield of lime seed (Table 4.2). Climatic factors, viz., rainfall and minimum & maximum temperatures show heterogeneous associated with the yield in the sowing, germination and harvesting period. Higher rainfall in germination period leads to lower yield, whereas, higher rainfall in sowing and harvesting period leads to higher yield of lime seed. Further, higher minimum temperature in sowing period leads to higher yield, whereas, higher maximum temperature in harvesting period leads to higher yield of lime seed (Table 4.2).

Studies on groundnut predicted that increase in maximum temperature would be reduce the crop duration (Gadgil, 1995, pp. 649-659). This study was used PNUTGRO model to determine the sowing window for rainfed groundnut. Variation in the model yield with sowing date showed that the broad sowing window of 22nd June to 17th August is the optimum for minimising the risk of failure. It was also shown that incidence of locally triggered pests/diseases, viz., leaf miner and late leaf spot tikka is low when showing is postponed to after mid- July and thus does not involve many risks. It was also seen that pod filling state was critical to moisture availability. In totality, the sowing dates are shifting June towards the end of June to mid- august. Hundal and Kaur (1996, pp. 13-18) examine climate change impact of groundnut yield in Punjab. The study projected that if all the climatic variables were to remain constant and temperature increase of 1, 2 and 3^{0}C from the present level would reduce the grain yield by 8.7, 23.2 and 36.2 percent.

4.5.9 Soybean, Sugarcane and Cotton

Soybean, sugarcane and cotton crops are equally important in terms of domestic consumption as well as export. Soybean and cotton are C4 category crops and initially benefit if carbon dioxide levels increased. However, it is observed that if carbon dioxide level is increased beyond 550 ppm adversely affect the yield of soybean (Lal et al., 1999, pp. 53-70). The FGLS regression results show that non- climatic factors, viz., sown area, rural literates, tractors, irrigated area and pump sets are positively associated with yield of soybean, whereas fertilisers negatively associated. It means, higher sown area, rural literates, tractors, irrigated area and pump sets are leads to higher yield of soybean, whereas, higher fertiliser leads to decline yield (Table 4.2). Further, higher minimum temperature in germination period leads to higher yield. Furthermore, higher maximum temperature in sowing and germination period leads to higher yield, whereas, higher maximum temperature leads to lower yield in harvesting period (Table 4.2).

Subsequently, non-climatic factors are positively associated with yield of sugarcane. However, climatic factors show heterogeneous association with yield. Higher rainfall in sowing and germination period leads to higher yield of sugarcane. On the contrary, higher minimum temperature in sowing and germination period leads to lower yield, whereas, higher minimum temperature in harvesting period leads to higher yield. Lastly, higher maximum temperature in sowing and harvesting period leads to lower yield, whereas higher maximum temperature in germination period leads to higher yield (Table 4.2).

Moreover, FGLS regression results of cotton are similar as sugarcane. However, heterogeneous association in climatic factors found. Higher rainfall in all vegetation periods, viz., sowing, germination and harvesting leads to higher yield of cotton. Further, higher minimum temperature in sowing period leads to higher yield, whereas, higher minimum temperature in harvesting period leads to lower yield. On the contrary, higher maximum temperature in sowing and germination period leads to lower yields, whereas, higher maximum temperature leads to higher yield of cotton.

In addition, the projection results observed that 50 percent increased yield for soybean for a doubling of CO_2 in central India, however, a 3^0C rise in surface air temperature almost cancels out the positive effects of a doubling of the carbon dioxide concentration. A decline in daily rainfall amount by 10 percent restricts the grain yield to about 32 percent (Lal et al., 1999, pp. 53- 70). The long term prediction revealed that there was an inter-annual variation in soybean yield due to variation in rainfall pattern. The distribution of rainfall rather than the amount during the soybean growing season is important for soybean yield. Further, the significant decrease in soybean yield (as high as 96 percent) when the rainfall receded during the initiation of flowering to maximum pod stage is observed. The yield reduction was 56 percent when a drought spell of around 2 weeks occurs during the mid-vegetative stage. There was a significant decrease in yield (37 percent) from the maximum, when the drought spell occurs in some parts of the growing season (Mohanthy et al., 2015, pp. 39-44). Furthermore, the projected results indicate that a decrease (ranging between 20 to 35 percent) in soybean yield when the effect of the rise in surface air temperature during soybean growing season was considered (Mohanthy et al., 2015, pp. 39-44).

Sugarcane has cover highest sown area under non- food grain crops. Studies about sugarcane productivity across the Globe indicated that increase in maximum temperature adversely affected to the sugarcane yield (Deressa et al., 2005, pp. 524- 38). The study observed that an increase in temperature by 2^0C and precipitation by 7 percent (doubling of CO_2) has negative impacts on sugarcane production. The difference, however, is negligible as the reduction in average net revenue per hectare was 26 percent under irrigation compared to 27 percent under dry land farming. This is an indication that irrigation is not a very effective adaptation measure for mitigating climate change damage on sugarcane farming.

Table 4.2: Yield with District Level and District Year Fixed Effects

Coefficients	GLS	GLS	GLS	GLS
Panels	Homoskedastic	Homoskedastic	Homoskedastic	Homoskedastic
Correlation	No Autocorrelation	No Autocorrelation	No Autocorrelation	No Autocorrelation
Number of Observation	13340	13340	13340	13340
Wald chi2(7)	5617.00	8627.87	2556.45	2653.93
Pro> chai2	0.0000	0.000	0.000	0.000
Variables	Rice	Wheat	Maize	Barley
lsownarea	0.0361981* (0.000)	0.0179091* (0.000)	0.01347* (0.000)	0.0441264* (0.000)
lruralliterates	0.005317^{NS} (0.512)	0.1463767* (0.000)	0.0681545* (0.000)	0.0061488 ^{NS} (0.479)
ltractors	0.0842766* (0.000)	0.0419295* (0.000)	0.0596111* (0.000)	0.0309319* (0.000)
lfertilisers	0.063198* (0.000)	0.0164573* (0.000)	0.0541538* (0.000)	0.0031643^{NS} (0.489)
lirrigatedarea	0.0116889* (0.000)	0.0078484* (0.003)	0.0057789*** (0.084)	0.020951* (0.000)
lpumpsets	0.002120* (0.001)	0.001210* (0.001)	0.073331* (0.002)	0.001012* (0.002)
lrainfalls	-0.0291123* (0.002)	0.016842*** (0.061)	-0.0554587* (0.000)	-0.0291293* (0.000)
lrainfallg	0.1142275* (0.000)	-0.0527025* (0.000)	0.2297323* (0.000)	-0.0930204* (0.000)
lrainfallh	-0.0290034* (0.000)	-0.0084838* (0.005)	0.0141562 ^{NS} (0.187)	-0.0734019* (0.000)
lmintemps	-3.33499* (0.000)	0.8235449* (0.000)	-1.418709* (0.000)	2.129654* (0.000)
lmintempg	3.527046* (0.000)	0.3865033* (0.000)	2.900149* (0.000)	-0.9676408* (0.000)
lmintemh	1.310819* (0.000)	-1.263153* (0.000)	0.2866359*** (0.062)	-3.569695* (0.000)
lmaxtemps	5.30625* (0.000)	-4.859563* (0.000)	1.080872* (0.000)	-3.185716* (0.000)
lmaxtempg	-7.268147* (0.000)	1.487796* (0.000)	-0.8932652* (0.001)	2.747089* (0.000)
lmaxtemph	0.3104195^{NS} (0.203)	2.320126* (0.000)	-0.034858 ^{NS} (0.884)	1.348061* (0.000)
Constant	0.5246937 ^{NS} (0.115)	4.985634* (0.000)	-6.856209* (0.000)	4.771069* (0.000)

Source: Estimated from ICRISAT VDSA database, Note: *, **, *** & NS indicates 1, 5, 10 and non-significant percent level of significance. Note: Parenthesis figures are p- values.

Table 4.2: Yield with District Level and District Year Fixed Effects

Coefficients	GLS	GLS	GLS	GLS
Panels	Homoskedastic	Homoskedastic	Homoskedastic	Homoskedastic
Correlation	No Autocorrelation	No Autocorrelation	No Autocorrelation	No Autocorrelation
Number of Observation	13340	13340	13340	13340
Wald chi2(7)	2216.92	2891.21	1646	2432.35
Pro> chai2	0.000	0.000	0.000	0.000
Variables	Sorghum	Pearl Millet	Finger Millet	Chickpea
lsownarea	0.0502107* (0.000)	0.0405713* (0.000)	0.0035104^{NS} (0.246)	0.0220117* (0.000)
lruralliterates	0.0976711* (0.000)	0.0765993* (0.000)	0.0044465^{NS} (0.639)	0.0220117* (0.000)
ltractors	0.0467187* (0.000)	-0.058185* (0.000)	0.026691* (0.000)	-0.0502374* (0.000)
lfertilisers	-0.001075^{NS} (0.837)	-0.046451* (0.000)	-0.0823264* (0.000)	0.00722* (0.000)
lirrigatedarea	0.0019187* (0.000)	0.0135127* (0.000)	0.0311031* (0.000)	0.0025813** (0.049)
lpumpsets	0.003120* (0.002)	0.006123* (0.001)	0.002120* (0.002)	0.008120* (0.001)
lrainfalls	-0.1380805* (0.000)	0.0763734* (0.000)	0.1296655* (0.000)	0.0024683^{NS} (0.262)
lrainfallg	-0.0299503* (0.000)	-0.1379047* (0.000)	0.1482179* (0.000)	0.0012216^{NS} (0.542)
lrainfallh	-0.033348* (0.000)	0.0163722* (0.000)	-0.0322447* (0.003)	-0.0137974* (0.000)
lmintemps	0.8262612* (0.000)	0.3509454* (0.000)	0.2646072^{NS} (0.331)	0.4582799* (0.000)
lmintempg	-0.4889605* (0.000)	-1.960067^{NS} (0.325)	2.267756* (0.000)	-0.5356864* (0.000)
lmintemh	1.192819* (0.000)	0.6430025* (0.000)	-0.6423352* (0.000)	0.468155* (0.000)
lmaxtemps	1.778966* (0.000)	-0.5455736* (0.000)	1.449924^{NS} (0.701)	-1.978374* (0.000)
lmaxtempg	0.1050803^{NS} (0.608)	1.157296^{NS} (0.138)	-1.930098* (0.000)	2.164674* (0.000)
lmaxtemph	-1.181591* (0.000)	0.666468* (0.001)	0.1019313^{NS} (0.564)	-0.9352988* (0.000)
Constant	-5.585571* (0.000)	0.2275909^{NS} (0.656)	-5.186719* (0.000)	2.657139* (0.000)

Source: Estimated from ICRISAT VDSA database, Note: *, **, *** & NS indicates 1, 5, 10 and non-significant percent level of significance. Note: Parenthesis figures are p- values.

Table 4.2: Yield with District Level and District Year Fixed Effects

Coefficients	GLS	GLS	GLS	GLS
Panels	Homoskedastic	Homoskedastic	Homoskedastic	Homoskedastic
Correlation	No Autocorrelation	No Autocorrelation	No Autocorrelation	No Autocorrelation
Number of Observation	13340	13340	13340	13340
Wald chi2(7)	2536.09	2913.85	1198.27	724.90
Pro> chai2	0.000	0.000	0.000	0.000
Variables	Pigeon pea	Rabi Pulses	Groundnut	Lime Seed
lsownarea	0.0108885* (0.000)	0.0454248* (0.000)	0.0335034* (0.000)	0.2062478* (0.000)
lruralliterates	0.0802067* (0.000)	0.1399465* (0.000)	0.0864878* (0.000)	0.0466787* (0.000)
ltractors	0.0237457* (0.000)	0.0357921* (0.000)	0.0182599* (0.000)	0.0379163* (0.000)
lfertilisers	-0.0118631* (0.004)	-0.0171683* (0.000)	0.0116384* (0.000)	0.0062715 NS (0.331)
lirrigatedarea	0.0063185* (0.009)	0.0313467* (0.000)	0.0066773* (0.009)	0.0882548* (0.000)
lpumpsets	0.008010* (0.002)	0.002102* (0.001)	-0.001210* (0.001)	0.002312* (0.002)
lrainfalls	-0.0114073 NS (0.175)	-0.0120722** (0.014)	-0.0545288* (0.002)	0.0281344* (0.000)
lrainfallg	-0.1551506* (0.000)	-0.0155464* (0.000)	0.0173237* (0.000)	-0.0292699* (0.000)
lrainfallh	0.0047535 NS (0.232)	-0.0145438* (0.001)	-0.0028728NS (0.190)	0.0210424* (0.000)
lmintemps	-0.2280271 NS (0.275)	0.0116377NS (0.930)	1.195546 NS (0.513)	0.2486417* (0.001)
lmintempg	-1.43487* (0.000)	-0.3125152* (0.003)	-1.020003* (0.000)	0.2295019 NS (0.204)
lmintemh	1.220439* (0.000)	1.381638* (0.000)	-0.2959421* (0.001)	-1.647893 NS (0.137)
lmaxtemps	-0.0345769 NS (0.866)	0.5772755* (0.004)	0.4322754 NS (0.126)	-0.462712 NS (0.127)
lmaxtempg	2.144871* (0.000)	2.021134* (0.000)	-1.590921* (0.000)	-0.2733834 NS (0.278)
lmaxtemph	-0.6843189* (0.000)	-2.912606* (0.000)	1.708665* (0.000)	1.349418* (0.000)
Constant	-1.065286* (0.0070	-0.0451373 NS (0.894)	-1.021631* (0.0030	2.212033* (0.000)

Source: Estimated from ICRISAT VDSA database, Note: *, **, *** & NS indicates 1, 5, 10 and non-significant percent level of significance. Note: Parenthesis figures are p- values.

Table 4.2: Yield with District Level and District Year Fixed Effects

Coefficients	GLS	GLS	GLS
Panels	Homoskedastic	Homoskedastic	Homoskedastic
Correlation	No Autocorrelation	No Autocorrelation	No Autocorrelation
Number of Observation	13340	13340	13340
Wald chi2(7)	2865.00	2082.70	929.59
Pro> chai2	0.000	0.000	0.000
Variables	Soybean	Sugarcane	Cotton
lsownarea	0.0218453* (0.000)	0.0414201* (0.000)	0.3322953* (0.000)
lRuralliterates	0.0704269* (0.000)	0.0904157* (0.000)	0.0598945* (0.020)
ltractors	0.0146958** (0.016)	0.0117384* (0.001)	0.1373432* (0.000)
lfertilisers	-0.0235933* (0.000)	0.0643189* (0.000)	0.0955652* (0.000)
lirrigatedarea	0.1184721* (0.000)	0.0074896* (0.000)	0.1706641* (0.000)
lpumpsets	0.006121* (0.002)	0.008123* (0.004)	0.007021* (0.005)
lrainfalls	0.2334905* (0.000)	0.0153832* (0.007)	0.0967235* (0.000)
lrainfallg	0.219518* (0.000)	0.0616254*** (0.078)	0.0765081*** (0.054)
lrainfallh	-0.2102691* (0.000)	-0.0162232 NS (0.356)	0.2778901* (0.000)
lmintemps	-0.6808835 NS (0.144)	-0.2942952* (0.000)	0.7436698 NS (0.159)
lmintempg	2.033109* (0.000)	-0.6732476* (0.000)	-0.8950487 NS (0.267)
lmintemh	-0.2438377 NS (0.339)	0.6012012* (0.000)	-2.996396* (0.000)
lmaxtemps	1.394691* (0.003)	-0.6800829* (0.000)	-5.775244* (0.000)
lmaxtempg	2.724653* (0.000)	2.31709* (0.000)	-4.927765* (0.000)
lmaxtemph	-5.346676* (0.000)	-1.743536* (0.000)	1.59081* (0.000)
Constant	-0.2702988 NS (0.661)	0.2726597 NS (0.458)	-2.23268* (0.000)

Source: Estimated from ICRISAT VDSA database, Note: *, **, *** & NS indicates 1, 5, 10 and non-significant percent level of significance. Note: Parenthesis figures are p- values.

4.6 Marginal Effect

The huge heterogeneity in the exogenous and endogenous variable included in the panel regression estimation. It is hard to explain in classical way, i.e, one percent increase in independent variable leads to increase some percent in the dependent variable. Therefore, we estimate crop specific marginal impact of climatic factors, viz., rainfall and minimum & maximum on yield of the crop by using following equation (4).

$$E\left[\frac{dy}{dx}\right] = Y \times \left[\frac{\Delta AMAXT}{\Delta y}\right] + Y \times \left[\frac{\Delta AMINT}{\Delta y}\right] + Y \times [\frac{\Delta RAINFALL}{\Delta y} \text{......(4)}$$

Where, $E\left[\frac{dy}{dx}\right]$ is marginal effect of minimum & maximum temperature and rainfall on the crop productivity, Y is coefficient value, ΔAMAXT is mean maximum, ΔAMINT & maximum temperature and ΔARAINFALL rainfall, and Δy is mean productivity of the crop.

The estimated marginal effect shows that one percent (millimeter) increase in rainfall leads to increase the yield of rice, maize, sorghum, finger millet, lime seed, soybean, sugarcane and cotton by 0.25, 2.50, 1.86, 2.17, 0.22, 0.65, 0.17 & 0.38 percent, whereas one percent increase in rainfall has reduced the yield of wheat, barley, pearl millet, chickpea, pigeon pea, rabi pulses and groundnut by 0.36, 3.16, 0.93, 0.19, 3.26, 1.15 & 0.38 percent. Further, marginal effect of minimum temperature on crop yield shows that one percent (1^0C) increase in minimum temperature has increase the yield of rice, maize, sorghum, pearl millet, finger millet, chickpea, rabi pulses and soybean by 8.95, 31.41, 3.10, 35.18, 22.25, 9.92, 39.11 & 3.94 percent, whereas yield of wheat, barley, pigeon pea, groundnut, lime seed, sugarcane and cotton reduces by 0.58, 51.70, 11.84, 1.51, 17.06, 1.37 & 3.51 percent respectively (Table 4.3). Furthermore, marginal effect of maximum temperature on crop yield shows that one percent (1^0C) increase in maximum temperature has increase the yield of maize, barley, pigeon pea, groundnut and lime seed by 4.45, 32.05, 62.65, 11.31 & 14.68 percent, whereas, one percent (1^0C) increase in maximum temperature reduces the yield of rice, wheat, sorghum, pearl millet, finger millet, chickpea, rabi pulses, soybean, sugarcane and cotton by 16.15, 18.74, 91.53, 43.64, 31.20, 18.66, & 7.17 percent (Table 4.3). The total marginal effect of rainfall, minimum temperature and maximum temperature shows that the yield of rice, wheat, barley, sorghum, pearl millet, finger millet, chickpea, lime seed, soybean, sugarcane and cotton decline by 6.94, 19.68, 22.81, 86.57, 9.40, 21.47, 2.16, 2.57, 1.86 & 19.83 percent, if one percent increase in rainfall and minimum & maximum temperature, whereas, yield of maize, finger millet, pigeon pea, rabi pulses and groundnut increase by 38.38, 17.11, 47.55, 19.30 & 9.42 percent (Table 4.3).

Table 4.3: Marginal Effect of Rainfall and Minimum & Maximum Temperature on Crop Productivity

Crops	Rainfall	Minimum Temperature	Maximum Temperature	Total
Rice	0.25	8.95	-16.15	-6.94
Wheat	-0.36	-0.58	-18.74	-19.68
Maize	2.52	31.41	4.45	38.38
Barley	-3.16	-51.70	32.05	-22.81
Sorghum	1.86	3.10	-91.53	-86.57
Pearl Millet	-0.93	35.18	-43.64	-9.40
Finger Millet	2.17	22.25	-7.31	17.11
Chickpea	-0.19	9.92	-31.20	-21.47
Pigeon pea	-3.26	-11.84	62.65	47.55
Rabi Pulses	-1.15	39.11	-18.66	19.30
Groundnut	-0.38	-1.51	11.31	9.42
Lime Seed	0.22	-17.06	14.68	-2.16
Soybean	0.65	3.94	-7.17	-2.57
Sugarcane	0.17	-1.37	-0.66	-1.86
Cotton	0.38	-3.51	-16.70	-19.83

Source: Estimated from ICRISAT VDSA database, Note: Total Climate Change effect estimated during the period 1966 to 2011.

4.7 Projected Impact of Climate Change

The effect of climate change on crop yields has been projected for four-time periods, viz., 2040, 2060, 2080 and 2100 by using equation (5).

$$\Delta y = \left\{\left(\frac{\delta \mathrm{y}}{\delta \mathrm{ARF}}\right) \times \Delta\ ARF + \left(\frac{\delta \mathrm{y}}{\delta \mathrm{AAMAXT}}\right) \times \Delta AAMAXT + \left(\frac{\delta \mathrm{y}}{\delta \mathrm{AAMINT}}\right) \times \Delta AAMINT\right\} \ldots\ldots (5)$$

Where, Δy is change in crop productivity; $\Delta\ ARF$ is increase in annual actual rainfall; $\Delta AAMAXT$ is increase in annual average maximum temperature and $\Delta AAMINT$ is increase in annual average minimum temperature in different scenarios. $\left(\frac{\delta \mathrm{y}}{\delta \mathrm{ARF}}\right), \left(\frac{\delta \mathrm{y}}{\delta \mathrm{AAMAXT}}\right)\ and \left(\frac{\delta \mathrm{y}}{\delta \mathrm{AAMINT}}\right)$ are estimated by model equations (Gupta et al., 2012, pp. 10-18).

The IPCC was predicted that surface temperature would increase by 0.5, 0.75, 1.0 and 1.5 ^{0}C in the given period and rainfall would be increased 4, 5, 6 and 7 millimeters (as per various emissions scenarios of IPCC, 2003, p. 3). Further, IPCC revised projection in the fifth assessment report (2012, the summary of policy makers). It predicted that surface temperature would increase 1, 2, 3 and 4 ^{0}C and -7.5, -10, -15 and -20 mm in South Asia including India. Therefore, the study includes both two projection scenarios (2003 and 2012). The projected results indicate that the yield of rice, wheat, barley, sorghum, pearl millet, chickpea, rabi pulses and cotton would be declined by 4.83, 10.96, 9.53, 37.57, 16.76, 13.89, 4.14 & 7.71 in 2040 (projection scenario I), whereas, yield of rice, wheat, sorghum, pearl millet, finger millet, chickpea, soybean, sugarcane and cotton would be decline by 13.56, 16.31, 103.40, 19.04, 12.49, 12.49, 24.79, 10.07, 2.63 & 21.30 percent (projection scenario II) in 2040.

Subsequently, yield of rice, wheat, barley, sorghum, pearl millet, chickpea, rabi pulses soybean, sugarcane and cotton would be declined by 6.38, 16.15, 17.60, 57.82, 19.81, 19.40, 0.18, 0.16, 0.32 & 12.39 percent in 2060 (projection scenario I). The degree of climate change would be an increase in (projection scenario II). The yield of rice, wheat, sorghum, pearl millet, finger millet, chickpea, soybean, sugarcane and cotton would be declined by 25.86, 34.43, 198.51, 42.75, 14.11, 50.55, 16.89, 4.40 & 40.70 in 2060 (projection scenario II) if no adaptation and mitigation measures taken place. Further, yield of rice, wheat, barley, sorghum, pearl millet, soybean, sugarcane and cotton would be declined by 7.92, 21.34, 25.67, 78.07, 22.86, 24.92, 0.31, 0.66 & 17.06 percent in 2080 (projection scenario I), whereas, yield of rice, wheat, sorghum, pearl millet , chickpea, soybean, sugarcane and cotton would be decline by 38.78, 51.65, 297.77, 64.13, 21.16, 75.82, 25.34, 6.60 & 61.05 percent in 2080 (projection scenario II). Moreover, yield of rice, wheat, barley, sorghum, pearl millet, chickpea, soybean, sugarcane and cotton would be declined by 13.51, 31.22, 25.73, 121.20, 36.82, 38.23, 2.26, 1.16 & 21.30 percent in 2100 (projection scenario II), whereas, yield of rice, wheat, barley, sorghum, pearl millet, chickpea, soybean, sugarcane and cotton would be declined by 56.19, 68.57, 398.58, 103.10, 39.34, 106.05, 35.75, 8.11 & 79.64 percent in 2100 (Table 4.4).

Table 4.4: Projected Results for the Period 2040, 2060, 2080 and 2100

Crops	Projection Scenario I				Projection Scenario II			
	2040	2060	2080	2100	2040	2060	2080	2100
Rice	-4.83	-6.38	-7.92	-13.51	-13.56	-25.86	-38.78	-56.19
Wheat	-10.96	-16.15	-21.34	-31.22	-16.31	-34.43	-51.65	-68.57
Maize	20.15	31.63	43.11	55.71	1.28	15.14	22.72	14.58
Barley	-9.53	-17.60	-25.67	-25.73	29.88	43.98	65.96	113.80
Sorghum	-37.57	-57.82	-78.07	-121.20	-103.90	-198.51	-297.77	-398.58
Pearl Millet	-16.76	-19.81	-22.86	-36.82	-19.04	-42.75	-64.13	-103.10
Finger Millet	10.61	16.51	22.42	26.51	-12.49	-14.11	-21.16	-39.34
Chickpea	-13.89	-19.40	-24.92	-38.23	-24.79	-50.55	-75.82	-106.05
Pigeon pea	15.33	24.78	34.22	59.33	81.15	146.02	219.02	297.95
Rabi Pulses	-4.14	-0.18	3.79	3.09	9.50	13.26	19.89	6.97
Groundnut	3.77	5.84	7.91	12.81	13.38	24.88	37.32	50.52
Lime Seed	3.95	3.57	3.20	6.49	4.51	10.12	15.18	28.76
Soybean	0.00	-0.16	-0.31	-2.26	-10.07	-16.89	-25.34	-35.75
Sugarcane	0.01	-0.32	-0.66	-1.16	-2.63	-4.40	-6.60	-8.11
Cotton	-7.71	-12.39	-17.06	-25.91	-21.30	-40.70	-61.05	-79.64

Source: Estimated from ICRISAT VDSA database.

3.8 Conclusion

Though, expansion of irrigated area, use of technological instruments, viz., chemical fertilisers, tractors, pump sets have moderating the degree of adverse impacts of climate change. However, change in monsoon rainfall pattern towards the post monsoon period is potentially affecting to the both two major cropping seasons, viz., khrif and rabi in India. Further, rise in minimum and maximum temperatures even in the winter season, adding an additional layer of the adverse impacts of climate change. The estimated FGLS results during 1966-2011 indicate that high yield, high irrigational crops are at higher risk rather than low yield crops. Because of higher water- crop demand, farmers are over-utilising water resources (mainly ground water) in the absence of strict environmental law. It is observed in the simulation based studies that maximum temperature adversely affected to the yield of all study crops if it is increased up to 4^0C. This is confirmed by the projection results that when a maximum temperature increase up to 4^0C, the yield of rice, wheat, barley, sorghum, pearl millet, chickpea, soybean, sugarcane and cotton would be declined by 13.51, 31.22, 25.73, 121.20, 36.82, 38.23, 2.26, 1.16 & 21.30 percent in 2100 (projection scenario II), whereas, yield of rice, wheat, barley, sorghum, pearl millet, chickpea, soybean, sugarcane and cotton would be declined by 56.19, 68.57, 398.58, 103.10, 39.34, 106.05, 35.75, 8.11 & 79.64 percent in 2100 (Table 4.4). Based on the empirical and projection results, there is needed a comprehensive copping plan to deal with the current farm crisis.

Chapter- 5

Assessment of Climatic Vulnerability at Community Level

5.0 Introduction

The climate change is adversely affecting all over the world directly or indirectly (IPCC, 2013, p. 124). Therefore, assessment of the potential impacts of climate change in different parts of the world often using vulnerability as a framing device has increased over the past two decades (Malone and Engle, 2011, pp. 1-15). However, diversity in the definitions and methodologies for assessing vulnerability always creates confusion because the degree of vulnerability depends on social, cultural, political, economic and natural structure of the respective location or society (Fussel, 2007, pp. 155-167). The component which is valid for one location does not valid for other location (Fussel, 2007, pp. 155-167). Further, the concept of vulnerability is complex to define, and most often it is conceptualized as consisting of components that include exposure and sensitivity to perturbations or external stress and the capacity to adapt (Adger, 2006, p. 12). The Third Assessment Report (TAR) of the IPCC defines vulnerability as a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (McCarthy et al., 2001, p. 995). Furthermore, it is defined as "the degree to which a system is susceptible or unable to cope with adverse effects of climate change, including climate variability and extremes, and vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Brenkert and Malone, 2005, pp. 57-102).[34]

In the most common sense, vulnerability conveys the idea of susceptibility to damage or harm. Although, the scientific use of the word "vulnerability" has its origins in geography, natural hazards research and the analysis of food insecurity and famine (Liverman, 1999, p. 7). However, nowadays, it is spread across the region and groups. Researchers have been estimated social, cultural vulnerability by using a vulnerability standard definition which

[34]Mathematically, it is expressed as: $= f(E_i, S_i , A_i)$, here, exposure refers to "the nature and degree to which a system is exposed to significant climatic variations", sensitivity refers to "the degree to which a system is affected either adversely or beneficially, by climate related stimuli" and adaptive capacity is defined as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with consequences" (IPCC, 2001b, p. 1).

consists three core components viz., exposure, sensitivity and adaptive capacity (Brenkert and Malone, 2005, pp. 57-102).

Moreover, researchers primarily worked for the developing world issues related with poverty, unemployment, discrimination, malnutrition in 70s. Basically, they have assessed social vulnerability (Hewitt, 1983, pp. 1-15). The social vulnerability refers to those characteristics of a society that render its members subject to harm and loss in a disaster. Therefore, social vulnerability is one of the constitutive features of disaster risk, defined as the latent probability of future loss and damage associated with the occurrence of the physical event and the exposure of social elements to its impacts (Lavell, 2011, p. 7). When it is confirmed that climate change has potential impact on livelihood security, then the question, urge which technique is appropriate for the study because the magnitude always vary from region to region. In the other words, the debate is centered on how to characterise vulnerability in theory and practice.

In the literature, various theoretical methods are discussed for the assessment of vulnerability. Eakin and Luurs (2006, pp. 364-65) have discussed three approaches of vulnerability assessment, viz., (i) ecological resilience approach, (ii) political economy approach, and (iii) risk- hazard approach. First, the ecological resilience approach which suggests that the ability of a system to absorb shock and disturbance, but still maintain the same relationship with the system that controls the system's behaviour (Holling, 1973, pp. 1-23). Resilience approaches tends to give more importance to implications for social and economic changes across the broader geographic space, considering human activities as just one of the driving forces and humans themselves as one of the affected species in the earth. Second, the political economy perspective of vulnerability emphasizes on socio-political, cultural and economic factors that together explain differential capabilities to recuperate from the past impacts and cope or adapt to future threats (Blakie et al., 1994, pp. 15-24). Third, Risk hazard approaches tend to consider negative outcomes as functions of both biophysical risk factors and potential loss of a specified exposed population (Brooks, 2003, pp. 8-12). Similarly, (Adger, 2006, pp. 268-281) suggested two major research traditions of vulnerability such as the analysis of vulnerability as a result of lack of entitlements and the analysis of vulnerability due to natural hazards. Entitlement based vulnerability focused exclusively in the social realm of institutions, well-being and on class, social status and gender as important variable (Sen, 1981, pp. 25-30). Second, research tradition on natural hazards (Burton et al., 1978, pp. 36-42), which focusses on physical science, engineering and social science to explain the linkages between system elements.

The gap between these two research traditions on hazards were successfully bridged by Blaikie and his colleagues (1994, pp. 15-24) in their 'Pressure and Release' model of hazard. They proposed that physical or biological hazards represent the pressure characteristics of vulnerability. But the pressure comes from the cumulative progression of vulnerability, from root causes through local geography and social differentiation. The analysis is also comprehensive in seeking to explain physical and biological hazards through deliberately omitting technological hazards. More recently, a new approach emerged called synthesis- orientation. This approach attempted to understand the vulnerability of natural and social systems in a holistic manner. It portrays vulnerability as the property of social ecological system. This approach proposed by Turner et al. (2003a, pp. 8074-8079) seeks to analyse the elements of vulnerability (exposure, sensitivity and adaptive capacity) bounded system at a particular time of period.

5.1 Vulnerability Assessment and Approaches

The climate change literature provides two main distinct epistemological approaches to conceptualising vulnerability. One approach views vulnerability as the "end point" in terms of the amount of (potential) damage caused a particular climate related event. The second approach considers vulnerability as the "starting point" i.e., as a state that exists within a system before it encounters a hazard event (Brooks, 2003, pp. 15-19). The end point approach is found in earlier studies of integrated assessment modelling of climate change impacts (Kelly and Koldstad, 1999, pp. 171-197). In this approach, vulnerability is understood as a residual of climate change impacts minus adaptation. This approach emphasises the physical dimensions of vulnerability. In this approach, assessment of vulnerability is the end point of an analytical sequence that begins with projections of future emission trends, moves on to the development of climate scenario and then progress through biophysical impact studies and the identification of adaptive options (O'Brien et al., 2004b, pp. 303-313). On the other hand, ‘starting point’ approach to the assessment of vulnerability to climate change has its origins in studies that assessed the vulnerability of social groups to food security and famine (Sen, 1981, pp. 25-30) and vulnerability to natural hazards (Cutter, 1996, pp. 529-539). This approach also draws on entitlement literature regarding access to resources on the political economy literature for the means of claiming factors that lead to vulnerability (Adger, 1999, pp. 268-281). Further, social capital literature for the means of claiming entitlements and pursuing coping mechanisms (Adger, 1999, pp. 268-281). Thus, the starting point approach diagnoses inherent social and economic processes of marginalisation and inequalities as the causes of climate vulnerability and seeks to identify ways to address these processes (O’Brien et al., 2004b, pp. 303-313).

5.1.1 Vulnerability in the Agriculture Sector

Agriculture is the key sector for providing economic and social development in developing countries because of the world’s poor people depend on agriculture as a main source of household income (FAO, 2003, p. 12). In India, around 50 percent population still depends on agriculture and allied activities either directly or indirectly form. Agricultural activity is highly sensitive to changing weather conditions (12^{th} Five Year Plan Document, Volume- II, p. 7). The climate change is expected to present both risks and opportunities for agricultural system in different parts of the world (IPCC, 2014b, p. 124). Extreme climate variability (drought, floods and frost) can destroy the economies and welfare of poor rural families because they lack technologies, social protection mechanisms (such as benefits, insurance and savings) and adequate protection for their crops and animals (Gupta et al., 2012, pp. 1-10). Moreover, agriculture in developing countries like India is more vulnerable to the impacts of climate variability and change (Kumar et al., 2015, pp. 23-30). Small-scale farmers are among the first to feel the impacts of climate change in developing countries because of their greater dependence on the natural resources (GoI, 2012, p. 13). In view of the vulnerability of agriculture sector, studies have assessed the vulnerability of agriculture to climate change at various temporal and spatial scales (Kumar et al., 2015, pp. 1-10). The field of climate vulnerability assessment has emerged to address the need to quantify how communities will adopt to changing environmental conditions. Various researchers have tried to bridge the gap between the social, natural, and physical sciences and contributed new methodologies that confront this challenge (Polsky et al., 2007, p. 12).

In addition, the studies on vulnerability to climate change in India can be grouped into three categories. The first set of studies is based on climate modelling and deals with the impacts of climate change on different crops and vulnerability of different regions and sectors (Sinha and Swaminathan, 1991, pp. 33-45; Lal et al., 1998, pp. 101-114; Lal et al., 1999, pp. 53-70 and Kumar and Parikh, 2001, pp. 147-154). The first category of studies deals with the impacts of climate change on different crops, their productivity and yield under different climate change scenarios for different regions. Mall et al. (2006, pp. 445-478) provides an excellent review of climate change impact studies on Indian agriculture, mainly from the perspective of physical impacts. The available evidence suggests a significant drop in the yield of important cereal crops like paddy and wheat under the impact of climate change. However, studies on the biophysical impacts of climate change deals with important commercial crops like sugarcane, cotton and sunflower in the Indian context are scarce. Moreover, mix impact of climate variability has been observed in various studies in India (Aggarwal, 2009, p. 148; Sinha and Swaminathan, 1991, pp. 33-45; Aggarwal and Mall, 2002, pp. 331-343; Kumar and Parikh, 2001b, pp. 147-154 and Rathore et al., 2001, p. 5). Above studies show that agriculture gets affected both negatively and positively by different levels of temperature change depending on the crop varieties and geographic location. For example, many studies have noted that a doubling of CO_2 in the atmosphere of the present level will have positive impacts on the yields of rice, wheat and soybean. However, a temperature rise beyond 3^0C of the pre- industrial level will wipe out the positive impact of climate change on these crops.

The second set of studies has examined the vulnerability of different geographical units such as districts and states to the impacts of climate change either using secondary or using both climate modelling and secondary data (Aggarwal and Mall, 2002, pp. 331-343; Sanghi and Mendelsohn, 2008, pp. 123-125; Jacoby et al., 2010, pp. 12-16 and Mathew S., et al., 2012, pp. 12-19). The studies have focused on the vulnerability to climate change at different spatial scales in India using secondary data and some studies combining secondary data with climate projections. One of the earliest studies in India was by

Brenkart and Malone (2005, pp. 1-19), where they have examined vulnerability to climate change using a set of indicators at the state level. State level results indicate a wide range of vulnerabilities for India and reiterate the need to formulate differential strategies to reduce vulnerability and build resilience. Individual states show a wide range of sensitivities to food security. For example, the states of Kerala and Sikkim are more sensitive than Punjab. However, Punjab has the highest ecosystem sensitivity, mainly because of the pollution caused by the use of chemical fertilizers. Sharma and Pattwardhan (2008, pp. 1-16) examine the vulnerability of coastal districts to tropical cyclones adapting the cluster analysis method. In addition, these types of studies constitute an improvement over the first category of studies as they consider socio- economic factors also for analysing the vulnerability to climate change instead of considering only the impacts of climate change. Further, Ravindranath et al. (2011, pp. 210-211) developed vulnerability profile for the agricultural water and forest sectors in the North-East region for current and projected future vulnerability to climate change. The outcome of the study indicates that the majority of the districts in North-East India is subject to climate-induced vulnerability currently and in the near future.

The third set of studies have examined vulnerability and adaptation to climate change in India at the community and household level (Pandey et al., 2011, p. 2; Aulong et al., 2012, p. 1; Chaliha et al., 2012, pp. 179-200 and Haldar et al., 2012, pp. 665-673). These studies have addressed questions such as who are the most vulnerable and what are the important features of their vulnerability. These studies have focused on identifying and ranking both the households that are vulnerable and households that have the highest adaptive capacity to climate change. The households living away from the district headquarters are highly vulnerable to the impacts of climate change in comparison to households lining near to the district headquarter (Pandey et al., 2011, pp. 151-160). Further, the distance from the district headquarters and the geographic positioning are important factors in determining vulnerability of the households or communities (Aulong et al., 2012, pp. 12-19). Similarly, the bio-physical features have the greatest impact on the vulnerability of the communities to climate change (Chaliha et al., 2012, pp. 130-135). It is evident from the above discussion that many studies have tried to assess vulnerability and adaptive capacity to climate change at various spatial scales, but very few attempted to consider how farming households are adapting to the impacts of climate change at the farm level.

Apart from these set of studies, four different aspects of vulnerability assessment such as social, cultural, political and economic are discussed. Therefore, a systematic assessment shows a coverage of vulnerability. Fussel (2006, pp. 301-329) describes four different stages of vulnerability assessment of climate change viz., impact assessment, first generation vulnerability assessment, second generation vulnerability assessment and adaptive policy assessment. Basically, these four are related to the vulnerability function as we discussed earlier. First, impact assessment evaluates the potential effects of several climate change scenarios, compare to a (hypothetical) constant climate scenario, and one or more impact studies. This type of assessment looks at the long term impacts of climate change on natural and human systems. This type of assessment method was used by IPCC assessment reports. Second, first generation vulnerability assessments raise awareness of the (potential) vulnerability of sensitive systems to climate change. They may also assess the relative importance of various non- climatic factors. They help to prioritize further research and determine the need for mitigation and adaptation measures to reduce adverse effects. Third, second generation vulnerability assessments are conducted to estimate realistically the vulnerability of different regions or sectors and to assess the potential of adaptations to reduce the adverse impact of climate variability and change. Last, adaptation policy assessment primarily focuses on the requirements of the stockholders for policy development and facilitation of decision making process.

5.1.2 Measuring Vulnerability

There are numbers of methods available in the literature viz., participatory methods, simulation based and indicator based method. Therefore, quantification of the method before applying on the data must be clear. Some other methods like vulnerability resilience indicator prototype method which has used national level proxies on sensitivity and adaptive capacity. These were scaled against global data to get the overall national baseline of vulnerability and resilience for each of the countries (Brenkert and Malone, 2005, pp. 57-102). Further, livelihood vulnerability index (LVI) used several indicators to assess the impacts of climate change and variability among households (Hahn et al., 2009, pp. 74-

80). Dynamic international vulnerability assessment (DIVA) integrated global model for coastal system assessed the biophysical and socio-economic development (Hinkel J. at al., 2009, pp. 384-395). Multi-criteria decision analysis (MCDA) interested with adaptive capacity and sensitivity through the analytic hierarchy process (AHP) and combines a livelihoods framework with MCDA to weigh household attributes according to their relative importance in driving household vulnerability (Eakin et al., 2008, pp. 112-127 and Aulong et al., 2012, p. 113). Moreover, econometric approaches use household level socio economic survey data to analyse the vulnerability levels of different social groups (Hoddinott and Quisumbing, 2003, pp. 25-30). However, among these different methods, one of the widely used methods for vulnerability assessment is the indicator based approach. Research continues on the development of quantitative indicators of climate variability and adaptation to climate- related hazards at the multiple scale analysis (Hahn et al., 2009, pp. 74-80). However, the major limitation of the indicator based approach it its inability to capture the complex temporal and social dynamics of the various systems being measured (Luers et al., 2003, pp. 255-267). On the other hand, the indicator based approach is valuable for monitoring trends and exploring conceptual frameworks. Further, composite indices capture the multi-dimensionality of vulnerability in a comprehensible form.

5.2 Measurement of Vulnerability Index in the Study Area

Data on farmer's perception on coping and adaptation strategies against climate vulnerability has been collected. Further, the indicator based approach is used for vulnerability assessment. The indicator based approach uses a specific set or combination of indicators (proxy indicators) and measure vulnerability by computing indices, average or weighted averages for those selected variables. This approach can be applied any scale, such as household, district and at country level. The indicator based approach consists three core elements viz., exposure, sensitivity and adaptive capacity. Further, combining three main indicators, composite climate vulnerability and livelihood vulnerability indexes have been computed based on field level survey data. The major components and sub-components shown in the Appendix 5.1A & 5.2A).

The CVI method is used in this study based on the IPCC vulnerability framework. Exposure index in the study is measured based on the perception of the respondents on declining rainfall in the monsoon period. Increase in temperature and frequency of drought that they have experienced. Further, due to lack of climate change data at village/ village level. The indicator based method on the perception of the people to represent the sensitivity at household level is used. Further, agricultural and socio-economic sensitivity indicators are indexed.[35] Subsequently, adaptive capacity on climate risks has been described as a function of indicator method like accessibility of information technology, wealth, financial and institutional resources (Smith and Wandel, 2006, pp. 282-292). For this purpose, both indicators of particular adaptation actions by farming households to deal with climate risks such as changing crops and planting dates, use of climate information, access to crop insurance, the literacy level of the head of household[36].

Further, climate vulnerability index (CVI) uses a balanced, weighted average approach (Sullivan et al., 2002, p. 5), where each sub component contributes equally to the overall index score and equal weights are applied to all the three major components. Because each component is measured on a different scale, it is necessary to standardise each with separate index. Further, if the expected outcome of a factor is positively related with vulnerability, standardisation index is obtained (Iyenger and Sudharsan, 1982, pp. 1-5 and Kumar et al., 2015b, p. 12) as follows:

$$CZI_f = \frac{K_i - K_{min}}{K_{max} - K_{min}} \text{..............................(1)}$$

Here CZI_f is the original sub component for village f and $K_{max} - K_{min}$ is the maximum and minimum maximum values respectively. For each sub component determined using data from all the ten villages. For variables that represents frequencies such as percentage of farmers who have changed their crops, the minimum value was set at 0 and maximum

[35]Perceived high impact of drought on agriculture which is the only source of income, crop diversity index, households below poverty line, average numbers of dependents and indebtedness

[36] We have used Iyengar and Sudarsan (1982, p. 2) method to work-out a composite index from the multivariate data. The methodology is statistically sound and well suited for the development of composite index of vulnerability to climate change also. This method has been chosen because it is simple to compute and our purpose, i.e. to develop a tool to assess deferential vulnerability of the communities where the socio-economic differences are less.

value at 100. Further, if predicted value of a sub- component is negatively associated with vulnerability, the standardisation index is calculated as follows:

$$CZI_f = \frac{K_i - K_{max}}{K_{min} - K_{max}} \text{.........(2)}$$

After each component was standardised, the mean of each sub components is estimated by using the following equation to calculate the value of each major component.

$$K_h = \frac{\sum_{i=1}^{n} indexK_f^i}{n} \text{ .... (3)}$$

Where k_h is one of the three components of the village h, exposure (EXP), sensitivity (SENS) and Adaptive capacity (ADP), index K^i_f represents the sub components indexed by i, that make up for each major component, and n is the number of sub components in each major component. Once the values for the exposure, sensitivity and adaptive capacity for a village level were calculated, the three contributing factors were combined using the following equation form Hahn et al., (2009) to obtain the village level vulnerability index (CVI).

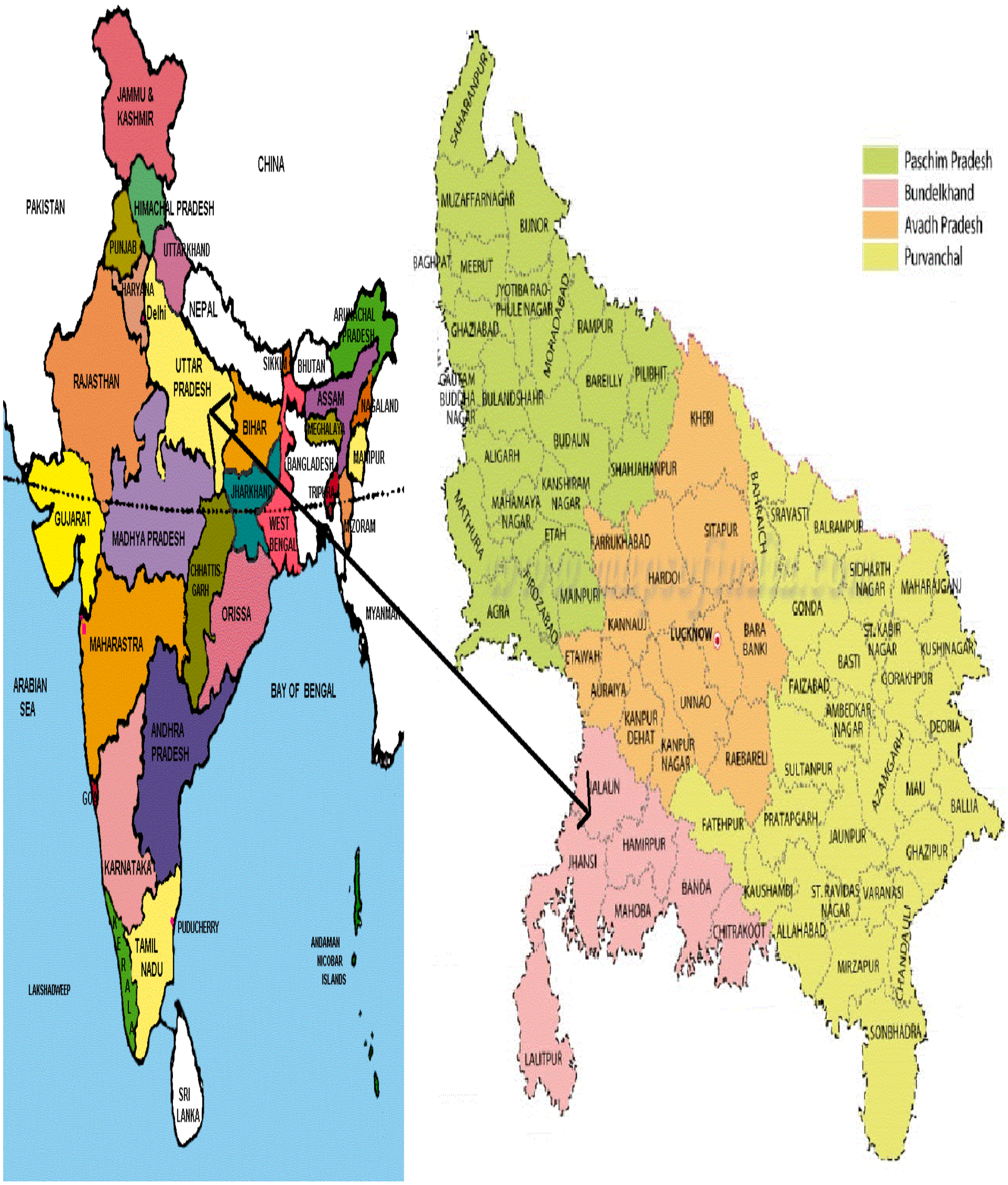
$$CVI_d = (E_d \ - A_d) * S_d \text{........................ (4)}$$

Where CVI_d is the climate vulnerability index score for the village d (obtained using the IPCC vulnerability framework), E_d is the calculated exposure score for the village d, A is the adaptive capacity score for the village d, and S is the sensitivity score for the village d. We scaled the CVI based on the results obtained from vulnerability index score i.e. 0 (least vulnerable) to 1 (most vulnerable).

5.3 Socio-economic and Agronomic Profile of the Study Households

The present study is conducted in the agro, socio-economic heterogeneous districts of the Bundelkhand part of Uttar Pradesh, viz., Jhansi and Jalaun. The selection of the districts is based on the agro, socio-economic profile of the households. Jhansi district is much rich in terms of natural resources like water and soil quality. The crop productivity of wheat, chickpea and other kharif pulses in Jhansi also is higher compared to those of Jalaun district. On the other hand, Jalaun district has lower farm productivity and water resources for irrigation with inferiors soil quality (Statistical Diary, Uttar Pradesh, 2014, pp. 12-35).

Figure 5.2: Map of the Study Area

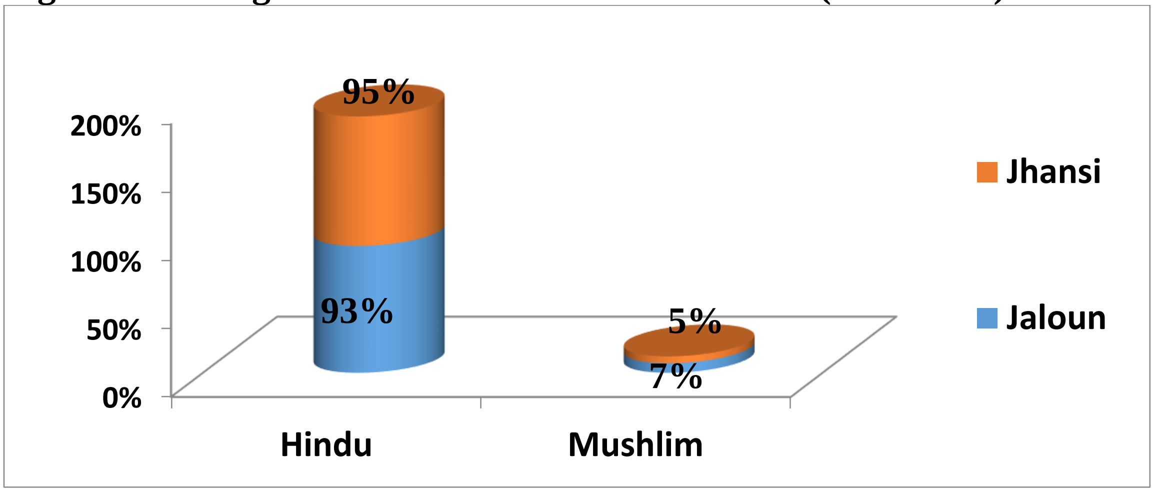


Source: Google Map

5.3.1 Social Profile of the Households

This section includes a brief profile of the religious and social category based distribution of the surveyed households. The field survey was conducted in 200 households by using the proportionate sampling method during May, 2015. Further, 100-100 samples from the each district are collected. The surveyed districts, Jhansi and Jalaun are mostly Hindu dominated and principal spoken languages, are Bundeli and Hindi. In the Jhansi out of 100 households, 95 percent registered for the Hindu community and rest 5 percent belongs to the Muslim community. Further, the marginal difference has observed in the Jalaun district in the religion profile. Out of 100 households, 93 percent registered for the Hindu community and the rest of 7 percent belongs to Muslim community (Figure 5.3).

Figure 5.3: Religion wise Profile of the Households (in Percent)



Source: Estimated from the Field Survey Data.

Half of the surveyed households, i.e., 50 percent belong to Other Backward Classes, followed by 32 & 18 percent belonging to General and Scheduled Caste in the Jalaun district respectively. The social structure in the Jhansi district is found slightly different. In the Jhansi district, 45 percent households belong to the Other Backward Classes, followed by 33, 19 and 3 percent belonging to the Scheduled Caste, General Caste and Scheduled Tribes respectively (Table 5.5). Further, in total, 45.50 percent households belong to the Other Backward Classes, followed by 25.50, 25.50 & 1.50 percent households belonging to the General Caste, Scheduled Caste and Scheduled Caste respectively containing both districts.

Table 5.5: Social Category wise Households Profile (in Numbers)

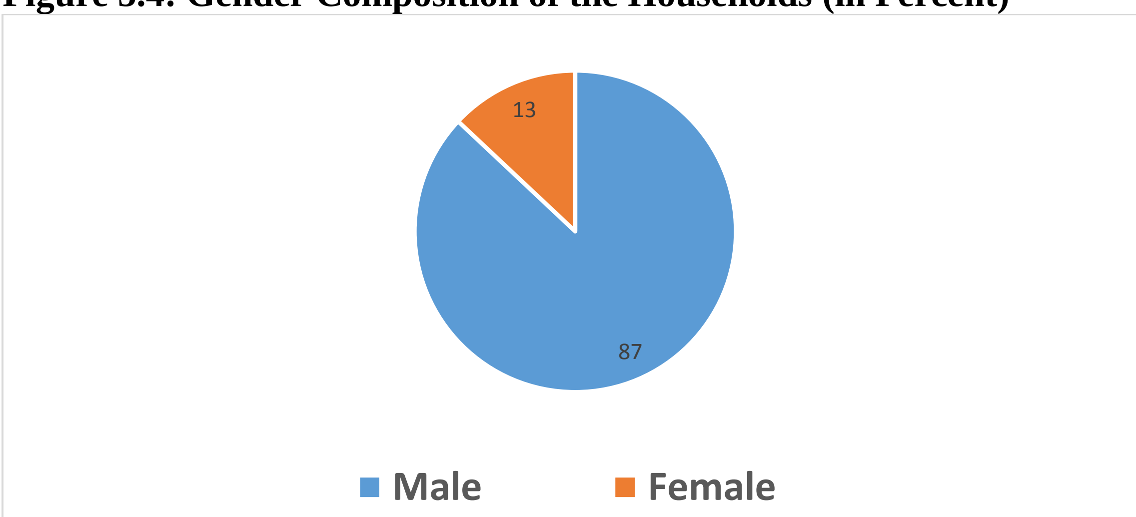
District/Caste	General	Other Backward Caste	Scheduled Caste	Scheduled Tribes	Total
Jalaun	32 (32.00)* (62.75)**	50 (50.00)* (52.63)**	18 (18.00)* (35.29)**	0 (0.00)* (0.00)**	100 (100.00)* (50.00)**
Jhansi	19 (19.00)* (37.25)**	45 (45.00)* (47.37)**	33 (33.00)* (64.71)**	3 (3.00)* (100.00)**	100 (100.00)* (50.00)**
Total	51 (25.50)* (100.00)**	95 (47.50)* (100.00)**	51 (25.50)* (100.00)**	3 (1.50)* (100.00)**	200 (100.00)* (100.00)**

Source: Estimated from the Field Survey Data. Note: Figures in parentheses are percentage of total. *Row percentage and ** Column percentage.

5.3.2 Demographic Profile of the Households

Farm practices in India still male dominated occupation. Field level studies in the farm sector argued that female- headed households are highly vulnerable (Vincent, 2007, pp. 12-24 and Hahn et al., 2009, p. 74-80). Therefore, it is essential to understand the linkage between farm productivity, livelihood vulnerability and gender. Majority of head of households belong to the male gender category, i.e., 87 percent and only 13 percent are female- headed households (Figure 5.4).

Figure 5.4: Gender Composition of the Households (in Percent)



Source: Estimated from the Filed Survey Data.

Male dominancy at individual level also found (Table 5.6). 336 out 607 (55.35 percent) individuals are male in the Jalaun district, whereas 44.65 percent are female individuals. Similarly, in the Jhansi district, 55.82 percent and 44.41 percent female are found (Table 5.6).

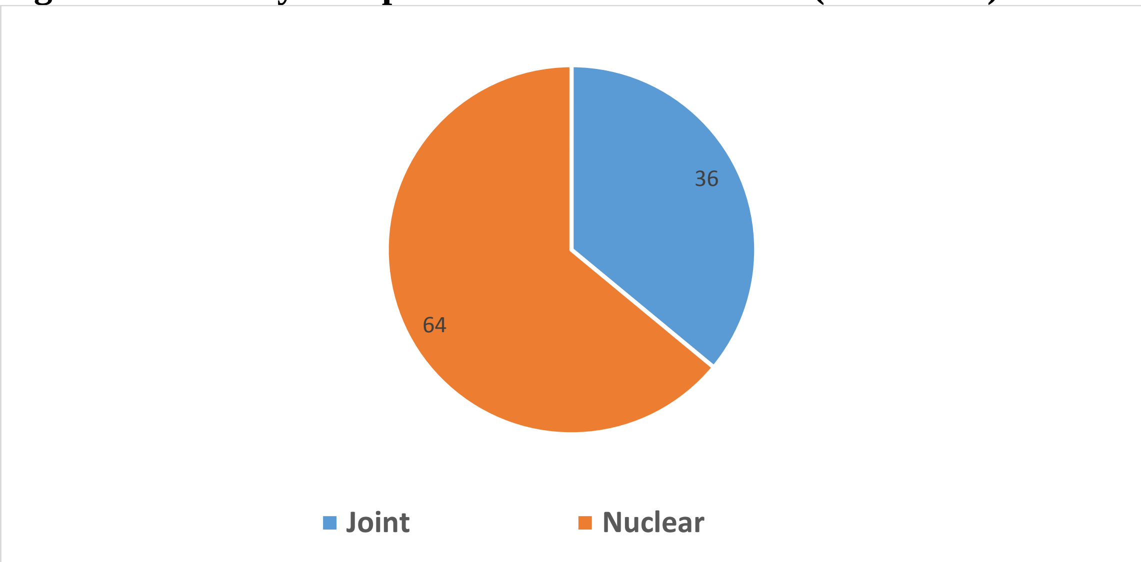
Table 5.6: Gender Composition of the Individuals

District	Gender		Total
	Male	Female	
Jalaun	336 (55.35)* (48.98)**	271 (44.65)* (49.45)**	607 (100.00)* (49.19)**
Jhansi	350 (55.82)* (51.02)**	277 (44.18)* (50.55)**	627 (100.00)* (50.81)**
Total	686 (55.59)* (100.00)**	548 (44.41)* (100.00)**	1,234 (100.00)* (100.00)**

Source: Estimated from the Filed Survey Data. Note: Figures in parentheses are percentage of total. *Row percentage **Column percentage.

Apart from the gender composition of the surveyed households, family structure is also an important indicator for the social condition assessment. Hahn et al. (2009, pp. 74-80) argued that households belong to the joint family are less vulnerable to the climate induced vulnerability. The majority of households belongs to the nuclear family structure, i.e., 64 percent, and only 36 percent households are living in the joint family (Figure 5.5).

Figure 5.5: Family Composition of the Households (in Percent)



Source: Estimated from the Filed Survey Data.

5.3.3 Basic Household Amenities

Basic household amenities includes good house, drinking water, sanitation, cooking advances and electricity. The housing conditions in a society reflect social and economic status of the household. Improved drinking, sanitation and cooking facilities are key indicators of the healthier livelihood conditions along with better house. For the housing condition, nature of the houses are categorised into the three sub-categories, viz., Kuchha, Semi-pucca and Pucca. The Kuchha houses are the houses made from the mud, thatch, lime and other low quality materials. Semi-pucca houses use both low quality and high quality materials and covered with tiled roofs. In the Semi-pucca houses, the quantity of high quality materials is much lower. Pucca houses are the one made with high quality materials. The majority of households (63 percent) lives in the Pucca houses, followed by 19 percent in the Semi-Pucca houses. The percentage of households living in the kuchha houses are slightly higher, i.e., 19 percent (Table 5.7).

The drinking water facilities are categorised into the three sub-categories, viz., hand pump, public tab and pipe water. According to the 69th NSSO classification, hand pumps, public tab and pipe water categories are come under improved drinking water facilities. Because of the present study, surveyed households belong to the rural areas, majority of households (60.50 percent) a using hand pump, followed by the public tab (35.50 percent) as a source of drinking water. The percentage of households using pipe water are lower, that is only 3 percent (Table 5.7).

The improved sanitation facilities reduced the health expenditure and increased savings of the households. Broadly sanitation facilities are divided into the three sub-categories, viz., dry latrine, flush and open field. It is still a reality in India that the majority of rural households are using open field for the sanitation. Thanks to the government and Non-Government Organisations (NGOs), those are creating awareness among the rural as well as urban households for the linkages between sanitation and health. Sanitation and health are closely associated with each other. Improved sanitation facilities not only save time but also reduce health expenditure. Among the surveyed households, 46 percent are still using open field, followed by 42.50 percent flush and 11.50 percent dry latrine sanitation facilities (Table 5.7).

Females are normally the victims of chronic diseases due to use of non- renewable resources for the cooking purpose (IPCC, 2014a, p. 45). The cooking devices are categories in the three sub-categories, viz., Gas (a renewable source), Chulha and Ageethi (non-renewable source). More than half (56.50 percent) of households are still using non-renewable resources (Chulha 56 percent & Ageeth 0.50 percent). The percentage of the households using renewable resources is 43.50, which is higher and increased the degree of adaptive capacity (Table 5.7).

The electricity has nowadays become an essential item for the survival. The majority of the household devices are controlled by the electricity. In the rural areas, farmers are using electricity for various purposes, i.e., for cooking, cooling, lighting and irrigation. The majority of the households has electricity connection, i.e., 72.50 percent. The percentage of the households don't have electricity connection is only 27.50 percent (Table 5.7).

Table 5.7: Basic Household Amenities in Survey Area (in Numbers)

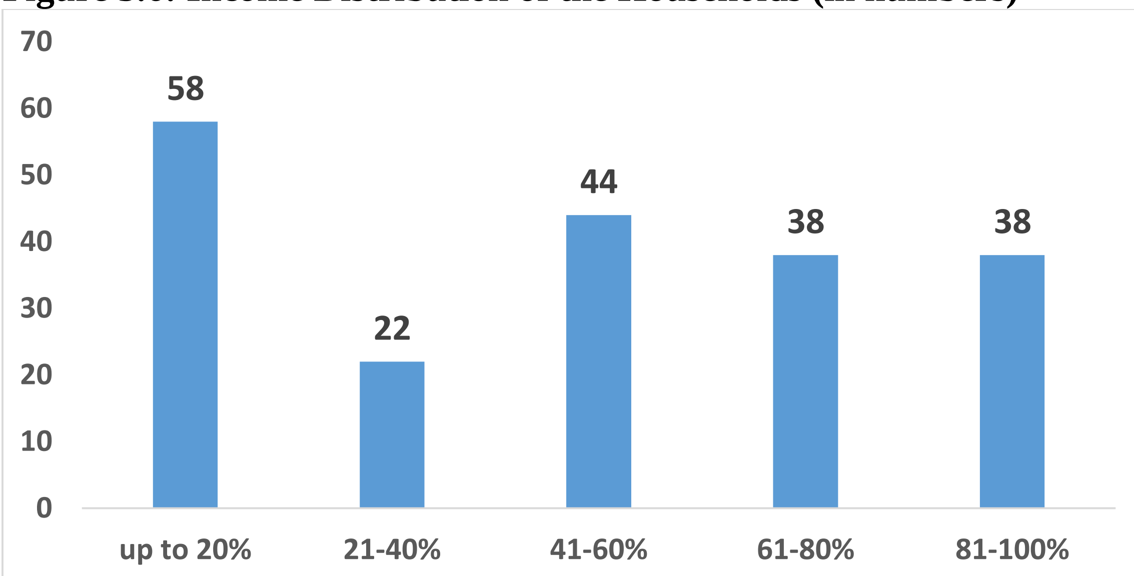
Nature of House	Kuchha 38 (19.00)	Semi-Pucca 36 (18.00)	Pucca 126 (63.00)	Total 200 (100.00)
Drinking Facilities	Hand Pump 121 (60.50)	Public Tab 73 (36.50)	Pipe Water 6 (3.00)	200 (100.00
Sanitation Facilities	Dry Latrine 23 (11.50)	Flush 85 (42.50)	Open Field 92 (46.00)	200 (100.00)
Cocking Device	Gas 87 (43.50)	Chulha 112 (56.00)	Ageethi 1 (0.50)	200 (100.00)
Electricity Connection	Yes 145 (72.50)		No 55 (27.50)	200 (100.00

Source: Estimated from the Filed Survey Data. Note: Parentheses values are in percentage.

5.3.4 Income Profile of the Households

Income level of households also plays a vital role in the determination of agro, socio-economic status in the society. Higher incomes can provide better nutrition, housing, sanitation, drinking water and education. For the facilitation of analysis, the households are sub- divided into the five income groups based on the income distribution, viz., up to 20, 21-40, 41-60, 61-80 and 81-100 percent. It is found that 58 households earning only up to 20 percent income (Figure 5.6). In other words, 29 percent households are earning only up to 20 percent income. Further, 22 households have an income within the range of 21-40 percent, whereas 44 household having income within the range of 41-60 percent. Furthermore, 38 households having income 61-80 and remaining 38 households having income 81-100 within the range.

Figure 5.6: Income Distribution of the Households (in numbers)



Source: Estimated from the Field Survey Data.

This demonstrates that the low level of economic status of the households. The disparities in the income among the income groups also found (Table 5.8). Nearly 30 percent households earned 41,224.10 Rupees annually, whereas 11 percent households earned 66, 545.60 Rupees only. Similarly, 22 percent households earned 97, 318. 20 Rupees, whereas 19 percent households earned 1, 77, 342 Rupees and remaining 19 percent earned 4, 10, 184 Rupees annually (Table 5.8).

Table 5.8: Income Group wise Distribution of Mean, Minimum, Maximum and Standard Deviation (S.D.) of Annual Income of the Households

Income Group (in Percentage)	Mean Annual Income (Rs.)	Minimum Annual Income (Rs.)	Maximum Annual Income (Rs.)	S.D. Annual Income (Rs.)
Up to 20%	41224.10	18000	50000	9855.17
21-40%	66545.60	60000	78000	6515.38
41-60%	97318.20	80000	120000	12934.13
61-80%	177342.00	123000	220000	300910.10
81-100%	410184.00	225000	1200000	195688.90

Source: Estimated from the Field Survey Data.

5.3.5 Educational Profile of the Households

Among the socio-economic factors, education is the most basic factor in determining the socio-economic status of individual in the society. Better education leads to better employment opportunities in the modern technical era. Education helps in the improving socio-economic status of the individual. Educated person has better understanding about the health. It increases the awareness not only to health but also for increase the skills to anticipate health hazards. Educational level is classified into the nine sub-categories, viz., illiterate, literate without schooling, literate below primary, junior, secondary, diploma, graduate and post graduate. Nearly 50 percent individuals are either illiterate or not taken formal education. Further, 22.85 percent individuals have educational qualification up to junior level and only 9.81 & 7.54 percent have taken education up to secondary and senior secondary level. The individuals have the educational qualification up to diploma, graduate and post- graduate only is 0.32, 7.46 & 2.19 percent respectively. This shows that the education level of the surveyed households is very poor (Table 5.9).

The disparities in the educational level on gender basis also found. The illiteracy rate among female is higher that of males by 10 percent. The percentage of illiterate females and males is 53.14 & 46.86 respectively. Table 5.8 shows that disparity in the high educational level. Educational level up to senior secondary clearly states that only 23.66 percent females. Further, graduation and post-graduation level the degree of disparity has increased. More than two-third males are graduate and only 34.78 females are graduates. However, diploma holder females have not found in the surveyed households (Table 5.9).

Table 5.9: Gender wise Educational level of the Individuals

Educational Level	Gender of Individual		Total
	Male	Female	
Illiterate	194 (46.86)* (28.32)**	220 (53.14)* (40.07)**	414 (100.00)* (33.55)**
Literate without Schooling	16 (44.44)* (2.34)**	20 (55.56)* (3.64)**	36 (100.00)* (2.92)**
Literate Below Primary	82 (49.70)* (11.97)**	83 (50.30)* (15.12)**	165 (100.00)* 13.37)**
Junior	172 (60.99)* (25.11)**	110 (39.01)* (20.04)**	282 (100.00)* (22.85)**
Secondary	70 (57.85)* (10.22)**	51 (42.15)* (9.29)**	121 (100.00)* (9.81)**
Senior Secondary	71 (76.34)* (10.36)**	22 (23.66)* (4.01)**	93 (100.00)* (7.54)**
Diploma	4 (100.00)* (0.58)**	0 (0.00)* (0.00)**	4 (100.00)* (0.32)**
Graduate	60 (65.22)* (8.76)**	32 (34.78)* (5.83)**	92 (100.00)* (7.46)**
Post Graduate	16 (59.26)* (2.34)**	11 (40.74)* (2.00)**	27 (100.00)* (2.19)**
Total	685 (55.51)* (100.00)**	549 (44.49)* (100.00)**	1,234 (100.00)* (100.00)**

Source: Estimated from the Field Survey Data. Note: Figures in parentheses are percentage of total. *Row percentage **Column percentage.

5.3.6 Occupational Profile of the Individuals

Education induced occupation in the modern era is the most effective tool to reduce social discrimination in the Indian society. Occupational status also appears to indicate a reliable and powerful characteristic of households by its correlation with other social and economic factors. As far as the main occupation is concerned in the rural India is farming. Table 5.10

shows that the positive relationship between occupational status and educational level. It means higher education level leads to higher percentage participation in the self-employed rather than agriculture labour and casual labour. Further, individuals have an education level up to junior, secondary, senior secondary, graduate, diploma and post-graduate have self-employed by 16.67, 24.79, 35.48, 75.00, 26.09 & 37.04 percent. In majority individuals belong to the illiterate category are agricultural labour and non-agricultural labour (Table 5.10). Higher educational level reduced the occupational participation in the agricultural and casual labour. The individuals have education level, secondary, senior secondary, diploma, graduate and post-graduate, the percentage of occupational participation in the agriculture level have only 11.45, 8.40, 0.00, 5.34 & 1.53 percent (Table 5.10).

Table 5.10: Education wise Occupational Status of the Individuals

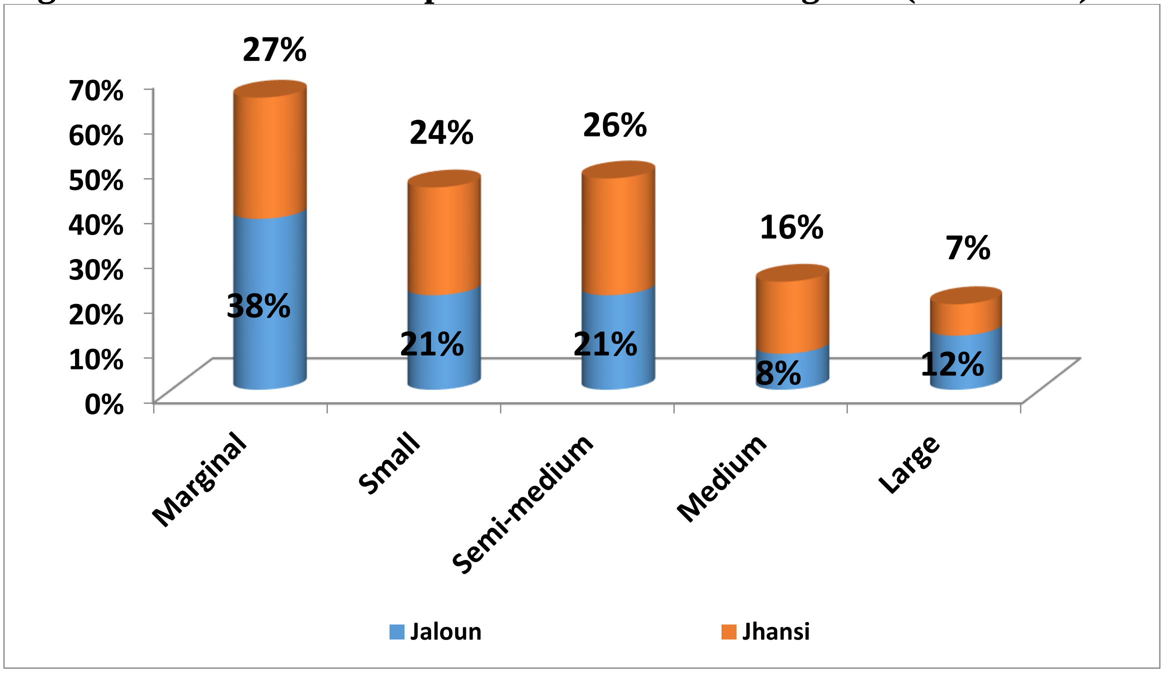
Educational Level	Self employed	Agriculture labour	Casual labour	Unemployed	Total
Illiterate	60 (14.53)* (25.42)**	43 (10.41)* (32.82)**	27 (6.54)* (29.67)**	283 (68.52)* (36.52)**	413 (100.00)* (33.50)**
Literate without schooling	5 (13.89)* (2.12)**	2 (5.56)* (1.53)**	5 (13.89)* (5.49)**	24 (66.67)* (3.10)**	36 (100.00)* (2.92)**
Junior	47 (16.67)* (19.92)**	34 (12.06)* (25.95)**	23 (8.16)* (25.27)**	178 (63.12)* (22.97)**	282 (100.00)* (22.87)**
Secondary	30 (24.79)* (12.71)**	15 (12.40)* (11.45)**	14 (11.57)* (15.38)**	62 (51.24)* (8.00)**	121 (100.00)* (9.81)**
Senior Secondary	33 (35.48)* (13.98)**	11 (11.83)* (8.40)**	3 (3.23)* (3.30)**	46 (49.46)* (5.94)**	93 (100.00)* (7.54)**
Diploma	3 (75.00)* (1.27)**	0 (0.00)* (0.00)**	0 (0.00)* (0.00)**	1 (25.00)* (0.13)**	4 (100.00)* (0.32)**
Graduate	24 (26.09)* (10.17)**	7 (7.61)* (5.34)**	4 (4.35)* (4.40)**	57 (61.96)* (7.35)**	92 (100.00)* (7.46)**
Post- graduate	10 (37.04)* (4.24)*	2 (7.41)* (1.53)**	0 (0.00)* (0.00)**	15 (55.56)* (1.94)**	27 (100.00)* (2.19)**
Total	236 (19.14)* (100.00)**	131 (10.62)* (100.00)**	91 (7.38)* (100.00)**	775 (62.85)* (100.00)**	1, 233 (100.00)* (100.00)**

Source: Estimated from the Field Survey Data. Note: Figures in parentheses are percentage of total. *Row percentage **Column percentage.

5.3.7 Agronomic Profile of the Households

In the rural India, about 70 percent population still has engaged in the farm and allied activities (GoI, 2014, p. 3). In majority, farmers belong to the marginal and small operational land holding category. Therefore, this section estimates agronomic profile of the surveyed households. Land holding size determines the cropping pattern, crop productivity and livelihood pattern of the household. Among the surveyed households, majority farmers belong to the marginal and small operation land holding size, i.e., 27 & 38 percent of Jhansi district and 24 & 21 percent of Jalaun district respectively (Figure 5.7). Hahn et al. (2009, pp. 74-80) argued that lower operational land size also has reason for the higher climate induced vulnerability. Figure 5.7 also shows that because of the majority of households belong to the marginal and small operational land size, the degree of climate-induced vulnerability is also higher.

Figure 5.7: District wise Operational Land Holding Size (in Percent)



Source: Estimated from the Field Survey Data.

Most of the marginal operational households belong to Other Backward caste and Scheduled caste i.e., 60 & 26.15 percent respectively. The percentage of small farmers (land size 2 to 4 hectares) belong to the General, Other Backward caste and Scheduled caste category is 35.56, 40.00 & 24.44 percent respectively. Similarly, the percentage under semi-medium households belong to the General, Other Backward caste, Scheduled caste and Scheduled Tribes is 34.04, 40.43, 23.40 & 2.13 percent respectively. Lastly, the share of the medium and large farmers among the social categories is lower. In the General social category, only 19.61 & 3.92 percent households are medium and large farmers. Further, in the Other Backward caste social category, only 11.58 & 8.42 percent surveyed households are medium and large farmers. The households belong to the scheduled caste only 5.88 & 17.65 percent are medium and large farmers (Table 5.11).

Table 5.11: Social Category wise Operational Land Size

Caste /Land Holding Size	Marginal	Small	Semi-medium	Medium	Large	Total
General	7 (13.73)* (10.77)**	16 (31.37)* (35.56)**	16 (31.37)* (34.04)**	10 (19.61)* (41.67)**	2 (3.92)* (10.53)**	51 (100.00)* (25.50)**
Other Backward Caste	39 (41.05)* (60.00)**	18 (18.95)* (40.00)**	19 (20.00)* (40.43)**	11 (11.58)* (45.83)**	8 (8.42)* (42.11)**	95 (100.00)* (47.50)**
Scheduled Caste	17 (33.33)* (26.15)**	11 (21.57)* (24.44)**	11 (21.57)* (23.40)**	3 (5.88)* (12.50)**	9 (17.65)* (47.37)**	51 (100.00)* (25.50)**
Scheduled Tribes	2 (66.67)* (3.08)**	0 (0.00)* (0.00)**	1 (33.33)* (2.13)**	0 (0.00)* (0.00)**	0 (0.00)* (0.00)**	3 (100.00)* (1.50)**
Total	65 (32.50)* (100.00)**	45 (22.50)* (100.00)**	47 (23.50)* (100.00)**	24 (12.00)* (100.00)**	19 (9.50)* (100.00)**	200 (100.00)* (100.00)**

Source: Estimated from the Field Survey Data. Note: Figures in parentheses are percentage of total. *Row percentage **Column percentage.

5.4 Livelihood Vulnerability Index

The sustainable livelihood approach looks at five types of household's assets viz., natural, social, financial, physical and human capital (Chambers and Conway, 1992, pp. 1-24) is an approach used to design, development programme at the community level (Hahn et al., 2009, pp. 74-80). This approach has been used very successfully for assessing the ability of households to withstand shocks such as epidemics or civil conflict. Climate change adds complexity to household livelihood security. The sustainable livelihood approach to a limited extent addresses the issue of sensitivity and adaptive capacity to climate change. But a new approach for vulnerability assessment that integrates climate exposures and accounts for household adaptation practices is needed in order to evaluate comprehensively the livelihood risks resulting from climate change.

CVI constructed in the previous section linked to the livelihood vulnerability index (LVI) to understand the differential impacts of climate change on community. The LVI uses multiple indicators to assess exposures to natural disasters and climatic variability, social and economic characteristics of the households that affect their adaptive capacity and current health, food and water resource characteristics that determine their sensitivity to climate change impacts. The two stages are adopted viz., first express the LVI as a composite index comprises of seven major components, while the second aggregates the seven into IPCCs three contributing factors to vulnerability such as exposure, sensitivity and adaptive capacity. LVI has numerous advantages for the policy implementation. First, LVI presents a framework for grouping and aggregating indicators at the district level. Second, it avoids the pitfalls associated with using secondary data. Third, it reduces the dependence on climate models, which are still presented as too large scale to provide accurate projections at levels useful for community development planning (Patz et al., 2005, pp. 310-317 and Sullivan, C. and Meigh, J., 2005, pp. 69-78). Fourth, the LVI approach focuses on quantifying the strength of current livelihood and health systems as well as the capacity of communities to alter these strategies in response to climate related exposures. Lastly, the LVI is designed to help the policy makers and public health practitioners with a practical tool to understand demographic, social and health factors contributing to climate vulnerability at the community or household level. It is designed to be flexible so that development planners can refine and focus their analysis to suit the needs of each geographic area. In addition, to the overall composite index, sectoral vulnerability scores can be segregated to identify potential areas for intervention.

5.4.1 Calculating the LVI: IPCC Framework Approach

An alternative method for calculating the livelihood vulnerability index is developed based on the IPCC vulnerability definition (Hahn et al., 2009, pp. 74-80.). The organization of the three major components of the IPCC framework are exposure, sensitivity and adaptive capacity. Further, exposure of the population is measured by the number of natural disasters like drought, heat waves that have occurred in the past five years. Responses of the respondents are used to estimate exposure index (Table 5.1A). Similarly, sensitivity has been calculated by using number of questions asked to the respondents like use of natural capital, health, water, sanitation, food and livelihood facilities nearer to the home. At last, number of variables related to adaptive capacity has been measured (Table 5.1A). Further, each sub component is explained in details to exposure, sensitivity and adaptive capacity mechanisms. Basically, livelihood vulnerability has much broader complications compare to climate vulnerability as it includes several factors, where many of them are included in the climate vulnerability index. Health, sanitation, drinking water, employment, dependence on environment resources, nature of family, size of family, social status in the society are key determinants for livelihood security or vulnerability (Vincent, 2007, pp. 12-24). These factors are hardly collected from the secondary data. Therefore, the above mentioned variables are collected from field to prepare LVI. Although, livelihood vulnerability index based on indicator approach is explore degree of vulnerability but this does not generalised at national level. Because, the degree of vulnerability is vary from location to location (Vincent, 2007, pp. 12-24).

5.4.2 Measurement of the Livelihood Vulnerability Index (LVI)

Indicator based approach is used to measure the livelihood vulnerability index based on Hahn et al. (2009, Pp. 74-80) and IPCC framework. Therefore, first, sub components based indicator indexes are estimated. Second, equal weightage to all indicators are given. Third, average of all sub components is estimated. Finally by using equation three composite livelihood vulnerability composite index is estimated.

5.4.3 Village Wise Exposure Index

Exposure to adverse climatic conditions like drought, floods, heat waves which are nowadays common in the Bundelkhand region. Though, study region is similarly exposed to risk of drought. The level of exposure is dependent on how farmers perceive the risk of droughts and the time they have faced droughts. Within the region, with similar exposure to climate hazards, the sensitivity of particular farm units to climate impacts will vary considerably, as well the capacity of agricultural producers to adapt in relation to a wide variety of socio-economic, institutional and physical variables (Easterling, 1996, pp. 1-54; Brklanchich et al., 1997, pp. 12-15 and Eakin, 2000, pp. 112-127).

The exposure index results show that Pahladpur village is highly exposed from climatic factors in the Jalaun district, i.e., 0.963, whereas in Jhansi district, Dunora and Birora villages are highly exposed, 0.900 (Table 5.12). It is found that 95 percent farmers in the Pahladpur village perceived that rainfall and water level have been declined in one hand and on the other hand, temperature (95 percent) and intensity of droughts (100 percent) have been increased over the last five years (Table 5.3A). Similarly, in the Dunora and Birora villages more than 60 percent farmers perceived that the distribution of rainfall has declined. Due to decline in annual rainfall and back-to-back drought episodes, the storage capacity of surface water resources also have declined. This creates water scarcity for agriculture in particular and domestic use in general. The main reason behind high exposure in Dunora and Birora villages is that these villages do not have access to the canal irrigation system, which is only available source of irrigation to the marginal farmers, when drought occurred. On the other hand, Amra, Gadvai and Nimoni villages are well connected with the canal irrigation system in the Jhansi district.

Table 5.12: Village wise Sub Components Values for the Exposure Indicator

District	Village	Sub Components				
		Rainfall	Temperature	Drought	Water level	Exposure Index
	Karson	0.900	0.900	0.900	0.850	0.888
	Kaithi	0.950	0.950	0.950	0.850	0.925
	Pahladpur	0.950	0.950	1.000	0.950	0.963
	Biriya	0.650	0.900	0.850	1.000	0.850
	Aata	0.400	0.800	0.800	1.000	0.750
Jalaun		0.770	0.900	0.900	0.930	0.875
	Dunora	0.700	1.000	0.950	0.950	0.900
	Nimoni	0.750	0.950	0.900	0.950	0.888
	Amra	0.421	1.000	0.940	0.895	0.814
	Gadvai	0.333	0.950	0.950	1.000	0.808
	Birora	0.600	1.000	1.000	1.000	0.900
Jhansi		0.561	0.980	0.948	0.959	0.862

Source: Estimated from Field Survey Data.[37]

5.4.4 Village Wise Sensitivity Index

In the rural area of Bundelkhand region, people mostly depend on natural capital for their livelihoods. They use wood for cooking purposes. Due to deforestation for various purposes, the stock of natural capital has declined over the years (Department of Economics and Planning, Uttar Pradesh). It increases degree of vulnerability and become more sensitive for those are depends on them (Hahn et al., 2009, pp. 74-80). In Jalaun district, Karson (0.900) village is highest sensitive to natural capital deceleration. It is found that 90 percent farmers in the Karson village perceived that stock of natural capital has declined over the last five years in the Jalaun district (Table 5.3A). Basically, Karson village is located in the Orai block, which has epicenter of all administrative activities. Therefore, massive urbanization in the last five years taken place. Further, it is found that land not available for cultivation has declined, which is the main source of natural capital

[37]In the 5.11, rainfall represent, percentage of households feel that rainfall is declining over the last five years, temperature represents percentage of households perceive that summer days become hotter, drought represents, percentage of households perceives that increasing of frequencies of drought over the last five years and water level represent percentage of households perceive that water level decline over the last five years.

for the cooking purposes. On the other hand, farmers in Gadvai village (0.710) of Jhansi district perceived that natural capital stock has declined over the last five years.

Drinking water has an important source of livelihood security. The pipe water is far from the dream in the rural areas of Bundelkhand region. The sensitivity index scores indicate that in the Pahladpur village of the Jalaun district highest households are using hand pump water for the drinking purpose, i.e., 0.950. It is found that hand pump is the only source of drinking water for the 95 percent households in the Pahladpur village (Table 5.3A). Subsequently, in the Birora village of Jhansi district households are highly sensitive in terms of source of drinking water. The sensitivity index score is 0.800. In the Birora village, 80 percent households are using hand pump as a main source for the drinking purpose.

An average crop diversity index also estimated to explore the degree of sensitivity for food commodities. Basically, crop diversification negatively associated with food sensitivity. Lowest value shows highest sensitivity, whereas highest value means lowest sensitivity. It is found that Kaithi village shows lowest sensitivity index score, i.e., 0.362 in Jalaun district, whereas in Jhansi district, Gadvai village has a lowest sensitivity score, i.e., 0.303. Farmers in these villages least diversified their cropping pattern. The main reasons are less agricultural land, family size, location of the farmland, education level and current consumption pattern. In other words, only 36 percent in Kaithi village and 30 in Gadvai village farmers have diversified their cropping pattern and taking more than one cropping in the calendar year (Table 5.3A).

Irrigational sources are key determinants for the modern agricultural practices. Therefore, study looking to farmer’s sensitivity from irrigation. In India, after green revolution movement, area share of irrigation increases tremendously (around 60 percent, State of Agriculture, 2012, p. 12). However, still around 40 percent area remains untouchable from irrigational sources (State of Agriculture, 2012, p. 12). In addition, small and marginal farmers do not able to install tube-well or Bore-wells[38]. Further, in India,

[38]Banking system is much complicated in India. Study found that majority of farmers belongs to small and marginal land category do not able to repay loans due to crop damages. Therefore, banks are not ready to give loans to the small and marginal farmers.

majority of irrigation covered divided into two broad categories viz., surface and ground water. Surface water is hand on government sources. Furthermore, the Bundelkhand has largest canal channels in the Uttar Pradesh. But due to, decline rainfall (Drought over the last three years), surface water is not sufficient to feed agriculture, water requirement (Department of Agriculture, Uttar Pradesh). Therefore, the present study is taken in account dependency of farmers on government sources for irrigation. The Karson and Aata villages show highest sensitivity index scores, i.e. 0.850 & 0.850 in the Jalaun district, whereas in the Jhansi district, Amra village highly sensitive from the irrigation sources, i.e., 0.730 (Table 5.12). Nearly 85 percent farmers in the Karson and Aata villages revealed that canal water is not sufficient to fill the agricultural water demand, whereas in Amra village 73 percent farmers revealed that due to insufficient water available for irrigation has restricted to least crop diversification and increases the degree of sensitivity (Table 5.3A).

Dependency on head of household also has contributing factor in the livelihood sensitivity. Basically, in the rural areas generally large family size and less employment opportunities are found (12th five Year Plan Document, Volume- II, p. 7). It is found that Aata village is highly sensitivity score, i.e., 0.707 in the Jalaun district, whereas in the Jhansi district, Dunora village shows highest dependency score, i.e., 0.658. In other words, more than 70 percent in Aata village and nearly 65 percent in the Dunora village households are living in the joint family (Table 5.3A).

Modern health facilities are helping to cope with the adverse impact of climate related disasters. Therefore, improved medical facilities have to provide in remote area always key willingness of local government. The recent government was started free emergency medical facilities in the rural area through 108 ambulances. However, many of them in rural areas do not aware. Households are uses 108 medical facilities considered less vulnerable compare with those are not used. Therefore, it has negative association with sensitivity index score. It means highest health sensitivity score leads lower sensitivity. Biriya village shows highest sensitivity index score, i.e. 0.80 in the Jalaun district, whereas in the Jhansi district, Amra village has highest health sensitivity index score, i.e., 0.940. In other words, in the Biriya village only 20 percent and in the Aata village only 6 percent households are using 108 emergency medical services (Table 5.3A).

To provide sanitation facility for all class of households has key motive of the present central government. Clean India movement, tries to insure full sanitation facilities, even in remote areas. So, the present study includes availability of sanitation facilities in the sensitivity index. It is found that households belong to the Karson and Gadvai villages are having least modern sanitation facilities. The sensitivity index scores are, 0.550 & 0.571 (Table 5.13). In these villages, nearly 45 percent households are only having modern sanitation facilities, whereas remaining 55 percent households are either using open field or dry latrine for the sanitation purpose (Table 5.3A).

Housing condition of the respondents protect from environmental calamity. Therefore, study present includes nature of house as an important variable to estimate livelihood sensitivity index. The sensitivity index scores show that Biriya village in Jalaun district and Gadvai village in the Jhansi district are highly sensitive. The sensitivity scores are 0.400 & 0.191. In other words, in the Biriya village 60 percent and in Gadvai village 81 percent households do not have the Pucca house (Table 5.3A).

Moreover, the households belongs to BPL category also deprives from necessary requirement like, sanitation, health, food and water. Biriya village, i.e., 0.400 in Jalaun district shows highest sensitivity. It means 40 percent households are belong to BPL category (Table- 5.13). On the other hand, Dunora village shows i.e. 0.350 highest sensitivity index score in the Jhansi district. It Means 35 percent households in the Dunora village belong to the BPL category (Table 5.3A). The overall sensitivity index shows that Biriya village in the Jalaun district and Gadvai village in Jhansi district are highly sensitivity, i.e., 0.518 & 0.531 respectively (Table 5.13).

Table 5.13: Village wise Sub Components Values for the Sensitivity Index

District	Village	Sub Components									
		Natural Capita	**Water**	**Food**	**Irrigation**	**Dependency**	**Health**	**Toilet**	**Nature of House**	**BPL**	**Sensitivity Index**
	Karson	0.900	0.650	0.450	0.850	0.649	0.000	0.550	0.300	0.300	0.517
	Kaithi	0.750	0.600	0.362	0.250	0.591	0.250	0.500	0.250	0.300	0.428
	Pahladpur	0.550	0.950	0.483	0.450	0.579	0.200	0.400	0.050	0.150	0.424
	Biriya	0.650	0.400	0.463	0.450	0.650	0.800	0.450	0.400	0.400	0.518
	Aata	0.550	0.450	0.396	0.850	0.707	0.700	0.250	0.350	0.300	0.506
Jalaun		0.680	0.610	0.431	0.570	0.635	0.390	0.430	0.270	0.290	0.479
	Dunora	0.400	0.300	0.477	0.050	0.658	0.600	0.500	0.050	0.350	0.376
	Nimoni	0.250	0.600	0.414	0.450	0.638	0.650	0.400	0.150	0.000	0.395
	Amra	0.470	0.630	0.358	0.730	0.630	0.940	0.526	0.053	0.158	0.499
	Gadvai	0.710	0.660	0.303	0.570	0.590	0.900	0.571	0.191	0.286	0.531
	Birora	0.350	0.800	0.433	0.650	0.600	0.550	0.450	0.100	0.300	0.470
Jhansi		0.436	0.598	0.397	0.490	0.623	0.728	0.489	0.109	0.219	0.454

Source: Estimated from the Field Survey Data.[39]

5.4.5 Village wise Adaptive Capacity Index

The potential impact of climate change is higher in the villages, which are highly exposed to climate change and variability. In other words, these villages have experienced greater change in climate and variability. But we do not have the option to stop or regulate changes

[39]In the Table 5.12, Natural capital represents, percentage of households using only forest based energy for cooking purposes. Water represents, percentage of households using hand pump water for drinking. Food represents, average crop diversity Index. Irrigation represents, percentage of households depends on government sources for Irrigation, Dependency represent, percentage of households depends on head of household, Health represents, percentage of households using 108 free medical facility, Toilet represents, percentage of households do not have toilet facilities, Nature of House represent, percentage of households do not have Pucca house and BPL represent, percentage of households belongs to BPL category.

in climatic variables. Because farmers are generally did farming in the open environmental conditions not in the control environment. Therefore, adaptation to climate change is suggested to minimize the impact of climate change and enhance livelihood security. Scoones, I. (1998, p. 1-22) categorized adaptation techniques in the five categories viz., human, natural, financial, social and physical capitals to combat climate variability. To construct an adaptive capacity index (ACI) we aggregated all sub- indicators viz., female-headed households, educational level, source of income, burden of loan, changes cropping pattern, awareness about information technology and the nature of family. Female- headed households have a positive relationship with livelihood vulnerability in rural India is assumed. In other words, higher female-headed adaptive capacity index score leads to lower adaptive capacity, whereas, lowest adaptive capacity index score leads to higher adaptive capacity. It is found that Kaithi village in the Jalaun district has the highest female headed adaptive capacity index score, i.e., 0.300, whereas in the Jhansi district, Amra village shows highest adaptive capacity index score, i.e., 0.316. In other words, in the Kaithi village, 30 percent households are headed by females, whereas in Amra village 31 percent households are headed by females.

Education also has an important role in the livelihood security. It increases the degree of adaptive capacity. In other words, higher educational level increased the degree of adaptive capability, whereas, illiteracy reduces the degree of adaptive capability. By assuming this, it is found that Kaithi village (0.250) has the least adaptive capability in Jalaun district, whereas in Jhansi district, Dunora (0.200) and Birora (0.200) villages have least adaptive capability (Table 5.13). In other words, in the Kaithi village 25 percent and 20 percent in Dunora and Birora, head of households do not attained school (Table 5.14).

The dependence on the agriculture solely for income also increases the degree of livelihood vulnerability and has a similar relationship with vulnerability as illiteracy. It is found that Karson village in the Jalaun district and Dunora village in the Jhansi district has least adaptive capacity scores, i.e. 0.070 & 0.086 (Table 5.14). It means that in the Karson village only seven percent and in Dunora village only 9 percent households are solely dependent on agriculture as a source of income (Table 5.3A).

Indebtedness also has a major determinant factor to livelihood vulnerability. With the rapid decline in land size, climate change, lower coverage of institutional credit sources, the burden of indebtedness have increased the degree of livelihood vulnerability study villages. It also has a similar relationship with livelihood vulnerability as education and dependence on the agriculture for income. It is found that Biriya (0.100) and Aata (0.100) villages in the Jalaun district and Birora (0.000) village in the Jhansi district have least loan adaptive capacity scores. It means in these villages, households having least burden of loan. Further, in Biriya and Aata villages only 10 percent households having burden of loan, whereas in Birora village, no one having the burden of loan out of 20 households (Table 5.3A). On the other hand, households belong to the Kaithi village in Jalaun district and Gadvai village in the Jhansi district have burden of loan. The adaptive capacity index score, i.e., 0.450 & 0.150 respectively. In these villages, 45 & 15 percent households having burden of loan (Table 5.3A). Households in these villages reveal that they are not in the position to re-pay loans because the entire crop they grown in the rabi cropping season in 2015 damages by the unexpected and unseasonal rainfall.

On the contrary, change in cropping pattern, use of information technology and households belongs to the joint family increases the degree of adaptive capability. In other words, higher adaptive capacity index score leads to higher adaptive capability and lower livelihood vulnerability. It is found that Karson village in the Jalaun district and Amra in the Jhansi district has changed their cropping pattern. The cropping pattern change adaptive capacity index scores are, i.e., 0.450 & 0.947 respectively (Table 5.14). It means in the Karson village 45 percent and in the Amra village 95 percent households have changed their cropping pattern to cope with climate change and variability over the last five years (Table 5.3A).

It is argued in by the several researchers that uncertainty about the future changes in climate also has one step ahead from the current adaptation and coping measures (Easterling, 1996, pp. 1-54; Brklanchich et al., 1997, pp. 12-15 and Eakin, 2000, pp. 112-127). They also argued that by using information technology, farmers can reduce the degree of vulnerability. Therefore, present study is taken Kisan Call Centre as an information tool, which increases the adaptive capacity of the farmers. It is found that households belong to the Kaithi village in the Jalaun district and Amra village in Jhansi district are highest taking information from the Kisan Call Centre to reduce the degree of livelihood vulnerability. The adaptive capacity scores are, i.e., 0.600 & 0.474 (Table 5.14). In other words, 60 percent households in the Kaithi village and 48 percent in the Amra village households are taking information about climate from the Kisan Call Centre (Table 5.3A).

Further, Brooks (203, p. 12) argued that farmers living in joint family would be treated as a major adaptation measures. It provides extra manpower without any cost. It is found that in Biriya village of Jalaun district and Amra village of Jhansi district have highest adaptive capacity in terms of households living in joint family. The adaptive index scores are, i.e., 0.500 & 0.842 (Table 3.14). In other words, 50 percent households in Biriya village and 84 percent in Amra village households are living in the joint family (Table 5.3A).

Table 5.14: Village wise Sub Components Values of the Adaptive Capacity

District	Village	Adaptive Capacity							
		Female Head	**Illiteracy**	**Income**	**Loan**	**Cropping pattern**	**IT**	**Joint Family**	**Adaptive Capacity**
	Karson	0.050	0.400	0.070	0.350	0.450	0.250	0.400	0.281
	Kaithi	0.300	0.250	0.076	0.450	0.000	0.600	0.300	0.282
	Pahladpur	0.250	0.400	0.048	0.200	0.050	0.350	0.100	0.200
	Biriya	0.150	0.300	0.072	0.100	0.200	0.150	0.500	0.210
	Aata	0.050	0.350	0.090	0.100	0.300	0.550	0.400	0.263
Jalaun		0.160	0.340	0.071	0.240	0.200	0.380	0.340	0.247
	Dunora	0.050	0.200	0.086	0.050	0.900	0.200	0.050	0.219
	Nimoni	0.000	0.300	0.165	0.105	0.100	0.500	0.300	0.210
	Amra	0.316	0.300	0.111	0.143	0.947	0.474	0.842	0.448
	Gadvai	0.095	0.250	0.201	0.150	0.857	0.429	0.810	0.399
	Birora	0.050	0.200	0.100	0.000	0.900	0.100	0.500	0.264
Jhansi		0.102	0.250	0.133	0.090	0.741	0.341	0.500	0.308

Source: Estimated from Field Survey Data[40]

[40]In the Table 5.13 Female headed represent, percentage of female- headed households. Illiteracy represent, percentage of head of household does not attained school. Income represent, percentage of households solely dependent on agriculture as source of income. Loan represent, average number of households who have burden of loan. Cropping pattern represent, percentage of households changed their cropping pattern. IT

5.4.6 The Livelihood Vulnerability Index

The livelihood vulnerability analysis of ten villages of the two districts, viz., Jalaun and Jhansi shows that in the Jalaun district, Pahladpur village is highly exposed, Karson village highly sensitive and Biriya village is least adaptive capacity. The overall livelihood vulnerability index scores show that due to least adaptive capacity Biriya village has the highest livelihood vulnerability score, i.e., 0.356 respectively (Table 5.15). Further, in the Jhansi district, Dunora and Birora villages are highly exposed, Gadvai village is highly sensitive and Birora village has highest adaptive capacity. The composite livelihood vulnerability index score shows that Birora village has the highest livelihood vulnerability in the Jhansi district respectively (Table 5.15).

Table 5.15: Village wise Livelihood Vulnerability Index

District	Village	Exposure Index	Sensitivity Index	Adaptive Capacity	Livelihood Vulnerability Index
	Karson	0.888	0.517	0.262	0.324
	Kaithi	0.925	0.428	0.279	0.276
	Pahladpur	0.963	0.424	0.216	0.317
	Biriya	0.850	0.518	0.162	0.356
	Aata	0.750	0.506	0.240	0.258
Jalaun		0.875	0.478	0.247	0.300
	Dunora	0.900	0.376	0.248	0.245
	Nimoni	0.888	0.395	0.195	0.274
	Amra	0.814	0.499	0.382	0.216
	Gadvai	0.808	0.531	0.330	0.254
	Birora	0.900	0.470	0.225	0.310
Jhansi		0.862	0.454	0.308	0.252

Source: Estimated from Field Survey Data.

5.5 Measurement of Climate Vulnerability Index

The climate vulnerability index also consists three major sub-components, viz., exposure, sensitivity and adaptive capacity. The sub-components for the estimation of exposure index

represent, percentage of households call Kisan Call Centre and Joint Family represent, percentage of households live as a joint family are same as used in the livelihood vulnerability index (Table 5.12). Sensitivity and adaptive capacity indexes are estimated by using table 5.2A.

5.5.1 Sensitivity Index

For the purpose of calculation sensitivity at the village level, present study used key indicators which reflect production sensitivity through crop diversity and agriculture as a source of income, number of dependents in the family on head of household and indebtedness. Therefore, present study includes these indicators to examine the sensitivity to climate change. It is found that Karson village highly sensitive, followed by Aata village, i.e., 0.617 & 0.613 in the Jalaun district, whereas in Jhansi district, Dunora village is highly sensitive followed by Nimoni village, i.e., 0.624 & 0.560 (Table 5.16). Upon looking deeper, we found that differentiated the highly sensitive village from other villages in the Jalaun district, higher dependence on agriculture as the only source of income (70 percent), least crop diversification (only 45 percent households belong to the Karson village are diversified their cropping pattern and majority of households grow single crop in a year) and higher dependency on the head of households (65 percent). Further, we found that households belong to the Dunora village are highly sensitive from drought (90 percent), Heat waves (100 percent) increase in temperature (85 percent) and highest dependency on head of household (66 percent) (Table 5.4A). Finally, the composite sensitivity index score shows that Jalaun district is highly sensitive compared to Jhansi district. The sensitivity scores are, i.e., 0.600 & 0.530 (Table 5.16).

Table 5.16: Village wise Sub Components Values for Sensitivity Indicator

District	Village	Sub Components							
		Drought	Heat Waves	Temperature	Agricultural Income	Average Crop Diversity	BPL Card	Dependency on HH	Sensitivity Index
Jalaun	Karson	0.900	1.000	0.950	0.070	0.450	0.300	0.649	0.617
	Kaithi	0.950	1.000	0.900	0.076	0.362	0.300	0.591	0.597
	Pahladpur	1.000	0.900	0.800	0.048	0.483	0.150	0.579	0.566
	Biriya	0.850	0.950	0.850	0.072	0.463	0.400	0.650	0.605
	Aata	0.800	1.000	1.000	0.090	0.396	0.300	0.707	0.613
Jalaun		0.900	0.970	0.900	0.071	0.431	0.290	0.635	0.600
	Dunora	0.950	1.000	0.850	0.086	0.477	0.350	0.658	0.624
	Nimoni	0.900	0.950	0.850	0.165	0.414	0.000	0.638	0.560
	Amra	0.940	1.000	0.150	0.111	0.358	0.158	0.630	0.478
	Gadvai	0.950	1.000	0.190	0.201	0.303	0.286	0.590	0.503
	Birora	1.000	0.850	0.100	0.100	0.433	0.300	0.600	0.483
Jhansi		0.948	0.960	0.428	0.133	0.397	0.219	0.623	0.530

Source: Estimated from Field Survey Data.[41]

5.5.2 Adaptive Capacity

The adaptive capacity of households to deal with climate vulnerability assessed by using differential adaptation strategies, viz., crop insurance, change in current cropping pattern, switch to non-farm activities, through improved irrigation, plantation surrounded of the field, use of early maturing seed varieties, farming experience and use of information technology (Table 5.17). Karson village shows highest adaptive capacity, followed by Aata village, i.e., 0.350 & 0.338 in the Jalaun district, whereas in the Jhansi district, Amra village shows highest adaptive capacity, followed by Gadvai village, i.e., 0.409 & 0.388

[41]In the table 5.15, we estimate sensitivity index by using sub components. drought sub component represents percentage of households that perceived high impact of drought on the farming system, heat wave represents percentage of households perceived that heat waves are become more frequent, temperature represents percentage of households perceived that temperature has been increasing over the last five years, income represents percentage of survey population reporting agriculture as the only source of income, average crop diversity index, BPL represents percentage of households belongs to BPL category and Dependency on HH represents average number of dependents on Head of household (unemployed).

respectively (Table 5.17). Upon looking deeper found that differentiated the highly adaptive capacity of Karson village from other villages in the Jalaun district, 65 percent households are using early maturing varieties. It is found that in the rabi cropping season mainly farmers grow wheat crop. It is found that farmers are mainly grow HW 2004 (Amar) - Tall as an early maturing varieties, when they have insufficient irrigation facility and lower soil fertility. This variety of wheat crops require least irrigation (two time irrigation is sufficient) and fertilizers. The ideal sowing period recommended by National rainfed area authority is 15-30 October. The average productivity of wheat if farmers uses this variety of seeds is 15-20 quintal per hectare. One the other hand, if farmers grow HW 2004 (Amar)- dwarf during 15 October- 10 November, the productivity is increased by 30-35 quintal per hectare. But this variety (HW 2004 (Amar)- dwarf requires improved irrigation, higher chemical fertilisers and better soil quality. Further, 45 percent farmers taking information about climate change, balance use of fertilisers, suitable seed varieties and information about rainfall and sowing period and 35 percent farmers have changed their cropping pattern as well as an occupation from agriculture (as main) to non-farm activities. Further, in the Amra village of Jhansi district, it is found that 95 percent farmers have taking information on various farm issues as discussed earlier, 90 percent farmers have increased the share of irrigated area and have 100 percent all season irrigation facilities, 52 percent farmers are using early maturing varieties and 47 percent farmers planted trees surrounded the fields to cope with climate change and variability over the last five years (Table 5.4A). After the discussion with the households, it is found that in Amara village that farmers were planted Eucalypts trees sounded the fields. It not only helps in the copping to climate change and variability but also generate extra income. Lastly, the composite index score shows that Jhansi district has highest adaptive capacity compared to Jalaun district, i.e., 0.368 & 0.313 (Table 5.17).

Table 5.17: Village wise Sub Components Values for the Adaptive Capacity Indicator

District	Village	Sub Components								
		Crop Insurance	**Cropping Pattern**	**Non-farm activities**	**Improved irrigation**	**Plantation**	**Early mature**	**Illiterates**	**Information Technology**	**Adaptive Capacity Indicator**
	Karson	0.050	0.350	0.350	0.250	0.300	0.650	0.400	0.450	0.350
	Kaithi	0.050	0.450	0.350	0.200	0.550	0.450	0.250	0.000	0.288
	Jalaun	0.100	0.200	0.450	0.100	0.700	0.300	0.400	0.050	0.288
	Biriya	0.000	0.100	0.200	0.600	0.600	0.400	0.300	0.200	0.300
	Aata	0.050	0.100	0.300	0.600	0.400	0.600	0.350	0.300	0.338
Jalaun		0.050	0.240	0.330	0.350	0.510	0.480	0.340	0.200	0.313
	Dunora	0.000	0.050	0.050	0.850	0.600	0.400	0.200	0.900	0.381
	Nimoni	0.000	0.105	0.150	0.750	0.500	0.450	0.300	0.100	0.294
	Amra	0.000	0.143	0.000	0.890	0.474	0.520	0.300	0.947	0.409
	Gadvai	0.000	0.150	0.000	0.850	0.952	0.048	0.250	0.857	0.388
	Birora	0.000	0.000	0.100	0.750	1.000	0.000	0.200	0.900	0.369
Jhansi		0.000	0.090	0.060	0.818	0.705	0.284	0.250	0.741	0.368

Source: Estimated from the Field Survey Data[42]

5.5.3 The Climate Vulnerability Index

By using equation (4), the composite climate vulnerability index is estimated (Table 5.18). It is found that Kaithi village (0.925) is highly exposed, Karson village (0.617) is highly sensitive and Karson village (0.350) has the highest adaptive capacity in the Jalaun district respectively (Table 5.18). However, Pahladpur village is highly vulnerable from the climate change and variability. Basically, Pahladpur and Kaithi villages have much similar climate vulnerability scores, i.e., 0.382 & 0.380. However, higher exposure score, i.e.,

[42]Similarly, table 5.16 shows sub components of the adaptive capacity index. Here, crop insurance represents, percentage of farmers having crop insurance, cropping pattern represents, Percentage of households changes their cropping pattern, non-farm activities represents percentage of households switch to non-farm activities, improved irrigation represents percentage of households using improved irrigational facilities, plantation represents percentage of households planted tress surrounded of the field, early mature variety represents percentage of households are using early maturing varieties, illiterate represents percentage of head of households belongs to illiterate education level (we take illiterate as a base) and information technology represents, percentage of households call Kisan Call Centre. Moreover, minimum value and maximum values we taken 0 and 100 for exposure, sensitivity and adaptive capacity index estimation.

(0.963) of Pahladpur village compares with Kaithi (0.925) increased the degree of vulnerability. Further, composite exposure, sensitivity and adaptive capacity index scores show that Dunora and Birora villages (0.900) are highly exposed, again Dunora village (0.624) is the highly sensitive and Amra village (0.409) has highest adaptive capacity in the Jhansi district (Table 5.18). The overall composite climate vulnerability index score shows that due to higher exposure, sensitivity and least adaptive capacity, Dunora village is highly vulnerable to the climate change and variability among the surveyed villages (Table 5.18).

Table 5.18: Village wise Climate Vulnerability Index

District	Village	Major Components			
		Exposure	Sensitivity	Adaptive Capacity	Climate Vulnerability Index
	Karson	0.888	0.617	0.350	0.332
	Kaithi	0.925	0.597	0.288	0.380
	Pahladpur	0.963	0.566	0.288	0.382
	Biriya	0.850	0.605	0.300	0.333
	Aata	0.750	0.613	0.338	0.253
Jalaun		0.875	0.600	0.313	0.337
	Dunora	0.900	0.624	0.381	0.324
	Nimoni	0.888	0.560	0.294	0.333
	Amra	0.814	0.478	0.409	0.194
	Gadvai	0.808	0.503	0.388	0.211
	Birora	0.900	0.483	0.369	0.256
Jhansi		0.862	0.530	0.368	0.262

Source: Estimated from Field Survey Data.

5.6 Conclusion

Bundelkhand region originally has highly exposed, sensitive and least adaptive capacity to cope with climate change. This statement confirmed through the present study. The livelihood and climate vulnerability profile of the ten villages of the two most diversified agricultural profile districts, i.e., Jalaun and Jhansi show that villages have least crop insurance, least income & crop diversification, higher dependency on head of household, lowest basic amenities and fewer source of non-farm employment. At Individual level, farmers are adopted several coping strategies to moderate degree of vulnerability, viz., use of early maturing varieties, improved irrigation, plantation of the trees surrounded the field. These differential adaptation strategies not only moderating the degree of vulnerability (livelihood and climate) but also generating extra source of income, such as plantation of eucalyptus trees are protecting to crop from the heat waves, reducing farm temperature in one hand and on the other hand, when farmer sale these plants would receive extra income.

Chapter 6

Assessment of Adaptation Strategies at Household Level

6.0 Introduction

The variability in climate, re-composition in the socio-economic environments and changes in agricultural vagaries are increasing the degree of vulnerability. Due to this, farming system across the globe is being adversely affected. The literature claimed that if no preventive, as well as curative measures are not taken by the end of this century agriculture practices are not possible in some parts of Africa and Asian. Further, the temperature reached threshold level and the frequencies of the extreme events, viz., flood and drought already affecting large section of the society (Smith et al., 2000, pp. 223-51; Brooks et al., 2005, pp. 151-63 and Hulme et al. 2011, pp. 764-65). Furthermore, the degree of vulnerability in the absence of new adaptation strategies will increase in the Africa and Asia continent respectively (Hulme et al. 2011, pp. 764-65). Studies highlight the importance of adaptation measures, which delivers substantially the potential adverse impacts of climate change and in strengthening the benefits associated with the changes in climate (Helms et al., 1996, pp.). Rosenzweig and Parry (1994, pp. 12-16) suggested that there is great potential to increase food production under climate change in many regions of the world if adaptation is taken into consideration. Subsequently, Downin (1999, pp. 365-80) showed that adaptation has the potential to reduce food deficits in Africa from 50 to 20 percent. In India, it is estimated that private adaptation reduced the potential damages from 25 to 15-23 percent (Mendelsohn and Dinar, 1993, pp. 328-41).

6.1 Adaptive Capacity and Adaptation

Adaptive capacity is the potential or ability of a system, region or community to adapt to the effects or impact of climate change (Smith et al., 2006, p. 881). Enhancement of adaptive capacity represents a practical means of copping with changes and uncertainties in climate including variability and extremes. In this way, enhancement of adaptive capacity reduces vulnerability and promotes sustainable development (Smith et al., 2000, pp. 223-51). On the other hand, adaptation is referred in broader sense of adaptive capacity. It is an adjustment in the ecological, social or economic systems in response to actual or expected climate change and their effects or impacts. This term refers to changes in processes, practices, or structure to moderate or offset potential damages or to take advantages of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions or activities to climate change and variability. Further, adaptation refers both to the process of adapting and to the condition of being adapted. The term has specific interpretations in particular disciplines. In ecology, for example, adaptation refers to changes by which an organism or species becomes fitted to its environment (Abercrombie et al., 1997, pp. 4-9); whereas in the social sciences, adaptation refers to adjustments by individuals and the collective behaviour of socio-economic systems (Hardesty, 1983, pp.). Furthermore, Smith et al. (2000, pp. 12-19) in a broad interpretation of adaptation to include the adjustment in natural or human systems in response to experienced or future climatic conditions or their effects or impacts, which may be beneficial or adverse. Basically, adaptation is important in the climate change issue in two ways. First, the assessment of vulnerability impact and second, the development and evaluation of response options.

Adaptation strategies are broadly categorised into two categories, viz., autonomous and planned. The adaptation that does not constitute a conscious response to climate stimuli but is triggered by ecological changes in natural systems and key market or welfare changes in human systems refers autonomous adaptation. Further, autonomous adaptation is the reaction of a farmer to change perception patterns, in that she/he changes crops or uses different harvest and planting dates. Farm level analysis have shown that large reductions in adverse impacts from climate change are possible when adaptation is fully implemented (Mendelsohn and Dinar, 1999, pp. 6-9). Short- term adjustments are seen as autonomous in the sense that no other sectors (e.g. policy research etc.) are needed in their development and implementation. The root cause of climate change is uncertainty about them. Therefore, a rational farmer has a wider sense about adaptation strategy, which best fit for his land. Changing sowing dates, multi-cropping system, changes cropping pattern from high water consuming crops to less water consuming crops and use early maturing varieties are some of the best practices identified at individual level.

Planned adaptation strategies are conscious policy options or response strategies, often multi-sectoral in nature, aimed at altering the adaptive capacity of the agricultural system or facilitating specific adaptations. For example, deliberate crop selection and distribution strategies across the different agro-climatic zone, substitution of new crops for the old one and resource substitution induced by scarcity (Easterling, 1996, pp. 56-71). Further, planned adaptation strategies are referred long- term adaptations. Major structural changes to overcome adversity such as changes in land use to maximise yield under new conditions; application of new technologies; new land management techniques and water use efficiency related techniques. Reilly and Schimmelpfenning (1999, p. 786) suggested some of the planned strategies, such as water supply and irrigation system, new crop varieties, other inputs (fertiliser, tillage methods, grain drying, other field operations), increased training and education, identification and promotion of micro climatic benefits and environmental services of trees and forests, agro biodiversity and soil and land management.

6.2 Climate Change and Adaptive Capacity

This is a well-recognised statement that in near future temperatures level accelerated from the current level (IPCC, 2013, p. 1). As a result, sea level and variability in the rainfall pattern would change extremely. Further, levels of greenhouses gases (GHGs) would be increased due to anthropogenic causes in the majority. It increases the degree of vulnerability in health, livelihood, and farming. In totality, the hydrological, demographic structure would change extremely due to current anthropogenic activities globally. Therefore, it requires new adaptation as well as mitigation efforts to moderate these impacts. Broadly research about adaptation strategies categorised in the three categories. First, studies are focused on the human health keep in centre to three main aspects, viz., exposure, sensitivity and adaptive capacity of human systems in explaining impacts (e.g. mortality and other kinds of damages) due to climate change related hazards (Adger et al., 2004, pp. 12-19; O'Brien et al., 2004b, pp.564-70 and Brookes et al., 2005, pp.321-43). Further, these studies also classified into two categories, viz., generic and specific. Generic adaptive capacity includes factors such as education, health, income, institutional, political and cultural which tend to be related to development in general (Adger et al., 2004, pp.12-15 and Sharma and Patwardhan, 2008, pp. 703-17). Specific adaptive capacity refers to certain adaptation interventions that specifically aim to reduce the impact of particular climate hazard. For example, a cyclone warning system is an intervention aimed at the forewarning population at risk due to a cyclone (Sharma and Patwardhan, 2008, pp. 703-

17). Further, construction of dams to control flood in the area and enhance irrigation intensity for better farming are specified for the specific purpose.

Second, studies examine adaptive capacity which is driven by theoretical models and framework of vulnerability and adaptation (Vincent, 2007, pp. 1-7; Brenkert and Malone, 2005, pp. 234-40 and Adger and Vincent, 2005, pp. 12-16). The main features of these studies are follows. First, these studies used the indicators for vulnerability and adaptive capacity based on available scientific knowledge in the form of frameworks, theories or models about a vulnerable system of interest in the selection and aggregation of indicators (Hinkel J., 2011, pp. 198-208). Second, exposure, sensitive and adaptive capacity are three indicators for assessment vulnerability of the system. Third, studies are capable of capturing social, demographical and geological aspects to any system. Fourth, if a system has a low adaptive capacity and high exposure & sensitivity than system called highly vulnerable. However, this research does not aim to identify the processes, determinants of drivers of adaptive capacity and vulnerability in each system. They are rather taken as 'given' and used as the basis for the rating or ranking analysis (Smith and Wandel, 2006, pp. 282-92).

Third, studies focused on the differential adaptive capacity among farmers and examine the factors that distinguish farmers with low adaptive capacity from farmers with higher adaptive capacity in Africa, India, Nepal and Mexico (Seo and Mendelsohn, 2006, pp. 1-6; Maddison, 2006. pp. 34-45; Wang et al., 2008, pp. 12-19 and Aulong et al., 2012, p. 1). Studies conducted in Africa on adaptation to climate change drawn following conclusions. First, farmers having access to credit, free extension services, farming expertise, mixed crop and livestock rearing in farms, private ownership of property, a proper perception of climate change, better education, opportunities for both farm and non-farm income increases adaptive capacity. Means higher adaptive capacity. Second, on the other hand, if farmers having small land holding size, low income, less income diversification opportunities, lack of farm infrastructures, traditional practices, no crop diversification, high intensity of calamities decline the adaptive capacity and increases the degree of agricultural vulnerability. However, factors affecting adaptive capacity of farmers differ from place to place (Frankhauser et al., 1999, pp. 67-78). Therefore, macro level adaptation strategies are not appropriate to deal with climate change (Manandhar, S.

et al., 2011, pp. 21-30). For example, the meteorological department is forecast deficit rainfall but this forecast not actually for all agro-climatic zones. The agricultural system of some regions is highly affected due to deficit rainfall and some are marginally affected. The reason being they have higher irrigation intensity, diversified cropping and income.

These studies leave two important questions unanswered. First, these studies have been conducted in the African countries. Whether, findings are valid in other than Africa. Exposure, sensitivity and adaptive capacity of the system (Health, Agriculture, and Livelihood) differ place to place. Therefore, the comparison is not possible. In general, it is not necessary that indicator which used in the Africa is valid for India or else, where latitude and longitude also centre point of these studies. Africa is situated low latitude and highly exposed from temperature. On the other hand, high latitude countries like US, New Zealand and Russia are less affected by the same level of temperature rises. In some crop cases, they are benefitted and able to grow a crop which is not possible earlier. Second, the specific interventions are taken to moderate degree of vulnerability and enhance adaptive capacity are really benefitted to the farmers. MGNREGA is one of the major specific policy interventions to improve economic condition of the farmers. It covers soil, water conservation, infrastructure development and provides extra income other than traditional sources. But after implementation of nine years some states in India are not equally benefitted. Means the adaptive capacity is generated from the MGNREGA is lower and higher.

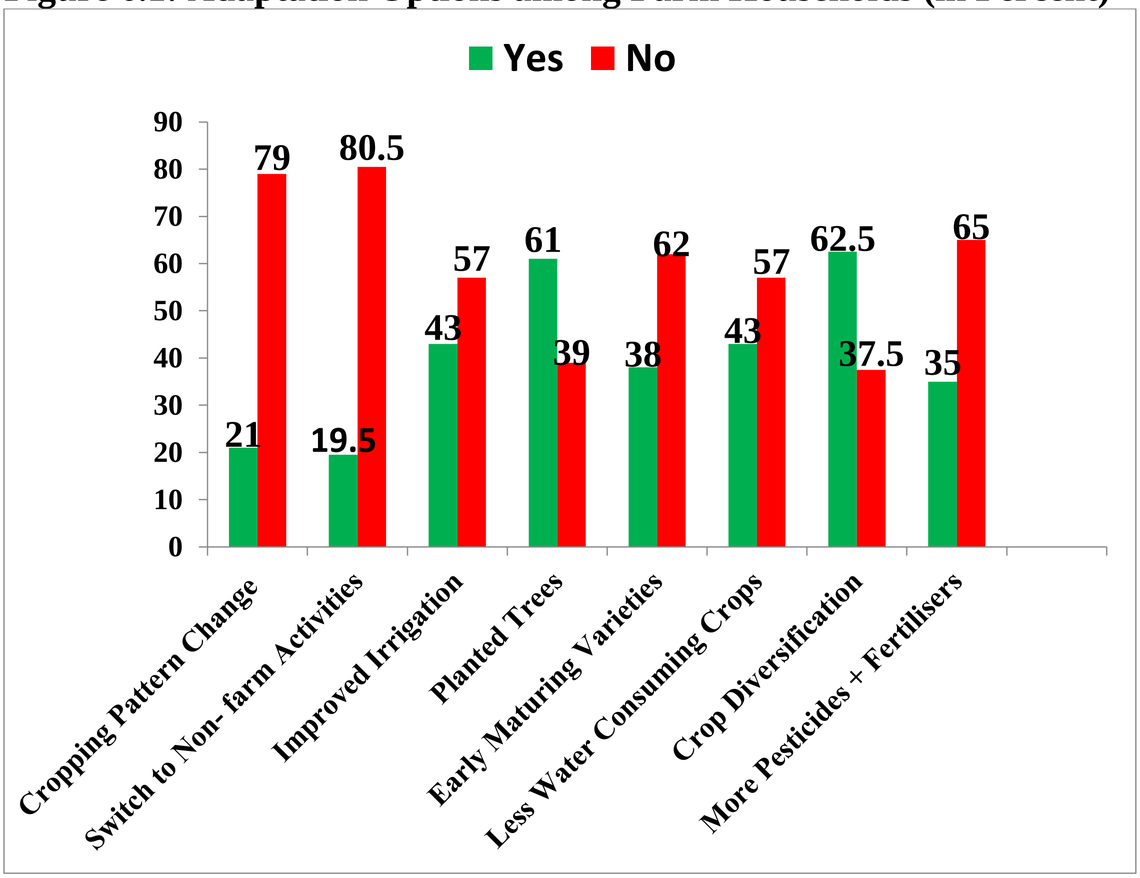
6.3 Adaptation Strategies in Agriculture

Adaptation to climate change in agriculture aims to minimise farmers’ vulnerability by improving their ability to cope with the impact of climate change, which is also known as adaptive capacity (Smith and Wandel, 2006, pp. 282-92). Adaptive capacity is often limited, particularly in poor rural areas, where people live on subsistence agriculture and generally have little formal education. Therefore, people have to be provided with climate change related information and given access to social, economic, institutional and technical resources. It is extremely important that new adaptation strategies and measures should be increased to build up capacity of a system to overcome external shocks or change. The assessment of farm level adoption of adaptation strategies is important as a tool for managing a variety of risks associated with climate change in agriculture. Studies on adaptation in agriculture explored following adaptation strategies. First, farming experience have a long history of responding to climate change by developing a wide range of management practices such as pre-monsoon dry seeding, stubble mulching, crop rotation and intercropping to cope with climate change. Second, construction of micro water harvesting system across the country in response to abrupt climate fluctuations such as drought. It provides water in the off rainy season not only agriculture but also domestic consumption. Further, it also helps to reduce consumption of ground water and increase ground water table. Third, crop diversification, such as mixed crop-livestock farming system, using different seed varieties, changing planting and harvesting dates, mixing less productive, drought- resistant varieties and high- yield water sensitive crops (Bradshaw et al., 2004, pp. 119-41). Increased productivity in one hand and on the other hand, reduces resource requirement and harnessing from climate change. Bradshaw et al., (2004, pp. 119-41) assessed the adoption of crop diversification of Canadian prairie agriculture for the period 1994-2002, reflecting upon its strengths and limitation for managing a variety of risks including climate ones. Fourth, improved irrigation intensity helps to reduce agricultural vulnerability. It is evidenced in the Indian agriculture system after green revolution. With the help of improving irrigational technology, the cropped area of high irrigation intensive crops increased tremendously. It also reduced the dependency of monsoon rainfall, which is highly sensitive, erratic in nature (Mendelsohn and Dinar 2003, pp. 328-41). The study explored the importance of water availability in the Ricardian model by estimating the role of irrigation as an adaptation measure against unfavourable climatic conditions. Fifth, demographic condition also is a major determinants of agricultural productivity. Low lying and up-lying areas have different conditions. In the low- lying areas farmers are generally given preference to food crops, viz., rice, wheat, sugarcane etc., on the other hand, in up- lying areas horticultural crops, apple, tea, mangoes and peanuts are produced. Sixth, institutional access to credit, seeds, fertilisers are key contributing factors to reduce vulnerability in the agriculture sector. Investment in the agriculture in terms of infrastructure development, viz., check dams, expansion of canal irrigation and relaxation in the credit norms helps to increase agricultural productivity. This helps to small and marginal farmers which are resource intensive in nature. Further, agriculture insurance positively associated with agricultural productivity in the unfavourable conditions. Twelve five-year plan of India observed that young generation does not want to stay in the agriculture sector. Due to, deceleration in profits and production, agriculture insurance provides a safety net to the farmers and protects profits.

6.4 Adaptation Options among Farm Households

Farmers across villages were asked if they had responded to the changing climate variability through adaptation and copping measures. Farmers reported as they have used multiple adaptation actions to deal with climate variability. Major nine different adaptation and copping actions were taken by farmers in the study region in response to drought and climate variability are summarised (Figure 6.1).

Figure 6.1: Adaptation Options among Farm Households (in Percent)



Source: Estimated from Field Survey Data.

6.4.1 Cropping Pattern Change

The Bundelkhand region experienced continue drought episodes last three years. Due to this, majority of surface water sources dried. High water consuming crops are resource intensive and require huge water, i.e., rice and wheat. Therefore, surveyed farm households responded that in a pace of climate variability, they are changing cropping pattern. Even in the khariff season, they have grown chickpea and khariff pulses. Farmers reported that pulses have comparable higher net profits over those of traditionally grown wheat and other crops under drought-prone rainfed upland conditions. This has attracted more cultivation of pulses resulting in increasing the area under pulses cultivation rather than wheat. In the study area, uplands are more and such lands are more vulnerable to droughts situation when crops such as upland wheat which cannot withstand moisture and stress are grown. Hence, in such lands, farmers prefer to grow pulses which unlikely wheat can withstand moisture stress to some extent. This not only reduces the vulnerability of drought but also enhances the profitability of the farmers and higher yield. After discussion with the farmers, it is observed that many of the upland and medium land, wheat varieties cultivated in the area has decreased drastically over the years and replaced with pulses cultivation. Furthermore, the cropping pattern change in favour of kharif pulses has observed in marginal and small, followed by semi-medium farmers in majority of the villages (Table 6.1). In the Pahladpur village, marginalised (44.44 percent marginal, 22.22 percent small and 22.22 percent semi-medium) farmers have changed their cropping pattern in majority, whereas in the Karson village, large farmers (57.14 percent) have changed the cropping pattern (Table 6.1). Upon deeper sense, the main reason for changing cropping pattern is livelihood security. For marginalised farmers agriculture have only source of income, whereas, large farmers have an engaged in the permanent employment, i.e., government jobs and business.

Table 6.1: Land Size wise Cropping Pattern Change in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	2 (28.57)	0 (0.00)	1 (14.29)	0 (0.00)	4 (57.14)	7 (100.00)
	Kaithi	3 (33.33)	4 (44.44)	0 (0.00)	2 (22.22)	0 (0.00)	9 (100.00)
	Pahladpur	4 (44.44)	2 (22.22)	2 (22.22)	1 (11.11)	0 (0.00)	9 (100.00)
	Biriya	3 (75.00)	1 (25.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (100.00)
	Aata	1 (50.00)	0 (0.00)	1 (50.00)	0 (0.00)	0 (0.00)	2 (100.00)
Jhansi	Dunora	2 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (100.00)
	Nimoni	0 (0.00)	0 (0.00)	1 (100.00)	0 (0.00)	0 (0.00)	1 (100.00)
	Amra	1 (50.00)	0 (0.00)	1 (50.00)	0 (0.00)	0 (0.00)	2 (100.00)
	Gadvai	1 (33.33)	2 (66.67)	0 (0.00)	0 (0.00)	0 (0.00)	3 (100.00)
	Birora	1 (33.33)	0 (0.00)	1 (33.33)	0 (0.00)	1 (33.33)	3 (100.00)
	Total	18 (42.86)	9 (21.43)	7 (16.67)	3 (7.14)	5 (11.90)	42 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.4.2 Switch to Non- Farm Activities

Switch to non- a farm activity is also an important adaptation strategy. Better management of livestock and farm revenue would reduce a degree of agricultural vulnerability. There is a huge demand for milk made products in the urban areas. It provide an extra source of income, when reduction occurred in agriculture production. To the extent that non-agricultural income sources are less climate-sensitive than the farm activities. Further, diversification of incomes out of agriculture might be a promising adaptation strategy in the face of adverse impacts of a changing climate. Engaging in multiple activities is an important way of promising flexibility and countering risk and uncertainty arising due to rainfall fluctuations in agricultural production and can be compensated by income from more secondary activities. However, this again depends on the off-farm activities available in the area. For most of the small and marginal farmers in the study area, income diversification activities such as working as a construction labour is a low- return copping strategy. Although, they help in moderating the risks from the loss in crops due to climate-related risks such as drought, using off-farm activities as a fallback option itself can be highly correlated to agricultural productivity. When all experience about yield (and thus income) decline simultaneously, then demand both agricultural wage labour and off-farm goods and services will likely also fall (Jayachandran, 2006, pp. 538-75). Further, it is found that marginal farmers in Pahladpur (44.44 percent) and Aata (66.67 percent) villages, followed by Kaithi (28.57) have diversified their occupation and an engaged in the non-farm activities (Table 6.2). Subsequently, semi-medium farmers in the Kaithi village (51.43 percent), followed by Pahladpur have switch to non-farm activities for the livelihood security. Again it is found that large farmers belong to the Karson village also diversified their occupation pattern (71.43 percent). Basically, Karson village is situated in the Orai block of the Jalaun district and Orai is an epicenter of all administrative and economic activities. Therefore, there are large extent opportunities are available in the non- farm sector. This is main reason that farmers in the Karson village have switch to non-farm activities. It not only increasing the income, but also reducing risks compare to agriculture.

Table 6.2: Land Size wise Switch to Non- Farm Activities in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	0 (0.00)	1 (14.29)	1 (14.29)	0 (0.00)	5 (71.43)	7 (100.00)
	Kaithi	2 (28.57)	0 (0.00)	5 (71.43)	0 (0.00)	0 (0.00)	7 (100.00)
	Pahladpur	4 (44.44)	1 (11.11)	2 (22.22)	2 (22.22)	0 (0.00)	9 (100.00)
	Biriya	2 (50.00)	2 (50.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (100.00)
	Aata	4 (66.67)	0 (0.00)	2 (33.33)	0 (0.00)	0 (0.00)	6 (100.00)
Jhansi	Dunora	0 (0.00)	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (100.00)
	Nimoni	1 (33.33)	1 (33.33)	0 (0.00)	1 (33.33)	0 (0.00)	3 (100.00)
	Amra	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
	Gadvai	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (100.00)
	Birora	0 (0.00)	0 (0.00)	1 (50.00)	1 (50.00)	0 (0.00)	2 (100.00)
	Total	13 (33.33)	6 (15.38)	11 (28.21)	4 (10.26)	5 (12.82)	39 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.4.3 Improved Irrigation

Subsidy on irrigation tools, such as bore-well and electricity also provides by the government to meet water- crop demand in the Bundelkhand region. Due to this, marginalised farmers have benefitted in majority. Apart from these initiatives, individual water conservation practices also observed in the study villages, like construction of minor check dams and contour bonds. These practices help farmers to increase the yield because they have access to water even in the eventually of water shortage due to less rainfall in the region. These are useful in a relatively short period drought. In a case of a prolonged drought these water structures themselves be affected by rainfall shortage. It is found that marginal farmers in Dunora (83.33 percent), Aata (62.50 percent), Biriya (62.50 percent), followed by Pahladpur (44.44 percent) and Kaithi (31.25 percent) have improved irrigation. In these village, farmers have practices differential water management practices to conserve water in the off rainy season. It is found that conservation of ponds and collection of rain water in the low-land areas are major practices. On the contrary in the semi-medium and large farmers, it is found that they have improved irrigation through the extraction of ground water resources. In Karson village (60 percent) large farmers have increased the irrigated area by digging new bore-wells (Table 6.3). Similarly, Semi-medium farmers in the Aata (37.50 percent) and Kaithi (31.25 percent), followed by Karson (13.33 percent) farmers have increased the irrigated area by using ground water resources (Table 6.3). The reason behind differential use of water resources (surface and ground water) is the demand of water and input cost. Marginal farms have required less water compare to large farmers and operational cost also higher of ground water resources.

Table 6.3: Operational Land Size wise Improved Irrigation in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	3 (20.00)	1 (6.67)	2 (13.33)	0 (0.00)	9 (60.00)	15 (100.00)
	Kaithi	5 (31.25)	4 (25.00)	5 (31.25)	2 (12.50)	0 (0.00)	16 (100.00)
	Pahladpur	8 (44.44)	3 (16.67)	4 (22.22)	3 (16.67)	0 (0.00)	18 (100.00)
	Biriya	5 (62.50)	3 (37.50)	0 (0.00)	0 (0.00)	0 (0.00)	8 (100.00)
	Aata	5 (62.50)	0 (0.00)	3 (37.50)	0 (0.00)	0 (0.00)	8 (100.00)
Jhansi	Dunora	5 (83.33)	1 (16.67)	0 (0.00)	0 (0.00)	0 (0.00)	6 (100.00)
	Nimoni	2 (40.00)	1 (20.00)	1 (20.00)	1 (20.00)	0 (0.00)	5 (100.00)
	Amra	1 (50.00)	0 (0.00)	1 (50.00)	0 (0.00)	0 (0.00)	2 (100.00)
	Gadvai	1 (33.33)	2 (66.67)	0 (0.00)	0 (0.00)	0 (0.00)	3 (100.00)
	Birora	1 (20.00)	0 (0.00)	2 (40.00)	1 (20.00)	1 (20.00)	5 (100.00)
	Total	36 (41.86)	15 (17.44)	18 (20.93)	7 (8.14)	10 (11.63)	86 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.4.4 Planted Trees

The Bundelkhand region is completely rainfed. Heat waves in the summer season are predominantly affected by the crop growth. To cope with heat waves, plantation surrounding fields reduced farm temperature and protect from heat waves in one hand and on the other hand it has increased the income also. It is found that marginal farmers have planted trees surrounding the field in the majority (Table 6.4). More than 60 percent farmers belong to the marginal operation land size have planted trees in the Aata and Dunora villages respectively (Table 6.4), whereas in Pahladpur (42.86 percent), Nimoni (40 percent), Kaithi (26.67 percent) and Biriya (25 percent) farmers have planted the trees surrounding the field (Table 6.4). The participation of large farmers in this adaptation strategy remain lowest. It is found that only 26.67 percent in the Kaithi village, large farmers have planted the trees surrounding the field (Table 6.4). After discussion with the farmers, it is found that farmers have planted different- different varieties of plants, viz., eucalyptus, citrus and mango.

Table 6.4: Land Size wise Planted Trees in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	0 (0.00)	1 (50.00)	1 (50.00)	0 (0.00)	0 (0.00)	2 (100.00)
	Kaithi	4 (26.67)	4 (26.67)	1 (6.67)	2 (13.33)	4 (26.67)	15 (100.00)
	Pahladpur	6 (42.86)	1 (7.14)	4 (28.57)	3 (21.43)	0 (0.00)	14 (100.00)
	Biriya	3 (25.00)	7 (58.33)	1 (8.33)	1 (8.33)	0 (0.00)	12 (100.00)
	Aata	5 (62.50)	0 (0.00)	2 (25.00)	1 (12.50)	0 (0.00)	8 (100.00)
Jhansi	Dunora	8 (66.67)	2 (16.67)	1 (8.33)	1 (8.33)	0 (0.00)	12 (100.00)
	Nimoni	4 (40.00)	4 (40.00)	1 (10.00)	0 (0.00)	1 (10.00)	10 (100.00)
	Amra	3 (30.00)	2 (20.00)	4 (40.00)	1 (10.00)	0 (0.00)	10 (100.00)
	Gadvai	4 (21.05)	5 (26.32)	5 (26.32)	4 (21.05)	1 (5.26)	19 (100.00)
	Birora	1 (5.00)	4 (20.00)	7 (35.00)	3 (15.00)	5 (25.00)	20 (100.00)
	Total	38 (31.15	30 (24.59	27 (22.13)	16 (13.11)	11 (9.02)	122 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.4.5 Early Maturing Varieties

The temperature in the Bundelkhand region reached the threshold level. The region also experienced continue droughts during last three decades. These changes are reduced growing period. Therefore, early maturing varieties are major adaptation strategy has been observed in among the farm households. After discussion with the farmers, it is found that traditional crop seed varieties are not suitable to current climate change scenario. Therefore, shorter duration varieties are best option to cope with adverse climate conditions. Short duration variety of wheat (HW 2004, Amar) has less vulnerable to the shortening of growing seasons than long duration varieties which need water over a longer period of time. This short duration wheat variety requires less water (only two time water is sufficient) and fertilisers and ready to cultivation in 85 days with 15-20 quintal per hectare production. It is found that marginal farmers are adopter of early maturing varieties at large extent. In Pahladpur village 66.67 percent farmers belong to the marginal operation land size adopted early maturing varieties to maintain current cropping pattern, whereas in Biriya, Aata and Dunora nearly 50 percent marginal farmers have adopted early maturing varieties of seeds respectively (Table 6.5). Similarly, in the Biriya village (50 percent) farmers belong to the small operation land size have using early maturing varieties (Table 6.5). The adoption of early maturing varieties in the large farmers remain lower in the study villages. It is found that only Karson village, farmers belong to large operation land size (61.54 percent) have using early maturing varieties respectively (Table 6.5).

Table 6.5: Land Size wise Early Maturing Varieties in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	3 (23.08)	0 (0.00)	2 (15.38)	0 (0.00)	8 (61.54)	13 (100.00)
	Kaithi	3 (33.33)	1 (11.11)	5 (55.56)	0 (0.00)	0 (0.00)	9 (100.00)
	Pahladpur	4 (66.67)	2 (33.33)	0 (0.00)	0 (0.00)	0 (0.00)	6 (100.00)
	Biriya	4 (50.00)	4 (50.00)	0 (0.00)	0 (0.00)	0 (0.00)	8 (100.00)
	Aata	6 (50.00)	1 (8.33)	4 (33.33)	1 (8.33)	0 (0.00)	12 (100.00)
Jhansi	Dunora	4 (50.00)	1 (12.50)	1 (12.50)	2 (25.00)	0 (0.00)	8 (100.00)
	Nimoni	2 (22.22)	3 (33.33)	1 (11.11)	3 (33.33)	0 (0.00)	9 (100.00)
	Amra	1 (10.00)	1 (10.00)	6 (60.00)	2 (20.00)	0 (0.00)	10 (100.00)
	Gadvai	0 (0.00)	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (100.00)
	Birora	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (100.00)
	Total	27 (35.53)	14 (18.42)	19 (25.00)	8 (10.53)	8 (10.53)	76 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.4.6 Less Water Consuming Crops

Because of Bundelkhand region is completely rainfed, the access of water resources in the marginal farmers is lower. After discussion with the farmers, it is found that only large farmers have owned ground water resources and marginal, small farmers have dependent on them for irrigation. They did not provide water to the marginal farmers when they required due to social and political reasons. Therefore, marginal farmers have preferred less water consuming crops to avoid crop damage due to water scarcity and higher temperature. It is found that more than 50 percent marginal farmers in the Pahladpur and Dunora villages have growing less water consuming crops, whereas in the Kaithi and Aata village, more than 40 percent marginal farmers have growing less water consuming crops respectively (Table 6.6). Further, among the survey village, only in the Nimoni village 40 percent farmers belong to small operational land size have growing less water consuming crops. An interestingly it is found that nearly 70 percent farmers belong to large operational land size in the Karson village also growing less water consuming crops (Table 6.6).

Table 6.6: Land Size wise Less Water Consuming Crops in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	2 (15.38)	0 (0.00)	2 (15.38)	0 (0.00)	9 (69.23)	13 (100.00)
	Kaithi	4 (40.00)	2 (20.00)	4 (40.00)	0 (0.00)	0 (0.00)	10 (100.00)
	Pahladpur	5 (55.56)	1 (11.11)	2 (22.22)	1 (11.11)	0 (0.00)	9 (100.00)
	Biriya	3 (33.33)	4 (44.44)	1 (11.11)	1 (11.11)	0 (0.00)	9 (100.00)
	Aata	4 (44.44)	1 (11.11)	3 (33.33)	1 (11.11)	0 (0.00)	9 (100.00)
Jhansi	Dunora	4 (50.00)	1 (12.50)	1 (12.50)	2 (25.00)	0 (0.00)	8 (100.00)
	Nimoni	3 (30.00)	4 (40.00)	2 (20.00)	1 (10.00)	0 (0.00)	10 (100.00)
	Amra	3 (23.08)	2 (15.38)	6 (46.15)	2 (15.38)	0 (0.00)	13 (100.00)
	Gadvai	1 (20.00)	2 (40.00)	1 (20.00)	1 (20.00)	0 (0.00)	5 (100.00)
	Birora	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (100.00)
	Total	29 (33.72)	17 (19.77)	22 (25.58)	9 (10.47)	9 (10.47)	86 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.4.7 Crop Diversification

The commonly used adaptation method among the farmers is crop diversification. By using crop rotation, multi- cropping, increase the share of horticulture crops, farmers have diversified their cropping pattern. This method is more appropriate in the pace of climate variability, less water availability and absence of an alternative source of income. It is found that more than 50 percent marginal farmers have diversified their cropping pattern in the Pahladpur, Aata and Dunora villages, followed by Kaithi (33.33 percent) and Biriya (33.33 percent) respectively (Table 6.7). Subsequently, small farmers in the Biriya village (55.56 percent), followed by Nimoni (35.29 percent) and Kaithi (33.33 percent) respectively (Table 6.7). Semi- medium farmers are also diversified their cropping pattern in favour of less climate vulnerable crops, viz., chickpea, pigeon pea and finger millets. It is found that more than 25 percent semi- medium farmers in Karson, Kaithi, Aata and Amra villages have diversified their cropping pattern (Table 6.7), whereas 55.33 percent large farmers in the Karson village also followed same strategy to deal with climate change respectively (Table 6.7).

Table 6.7: Land Size wise Crop Diversification in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	3 (20.00)	0 (0.00)	4 (26.67)	0 (0.00)	8 (53.33)	15 (100.00)
	Kaithi	4 (33.33)	4 (33.33)	3 (25.00)	1 (8.33)	0 (0.00)	12 (100.00)
	Pahladpur	8 (57.14)	2 (14.29)	3 (21.43)	1 (7.14)	0 (0.00)	14 (100.00)
	Biriya	6 (33.33)	10 (55.56)	1 (5.56)	1 (5.56)	0 (0.00)	18 (100.00)
	Aata	10 (55.56)	1 (5.56)	5 (27.78)	2 (11.11)	0 (0.00)	18 (100.00)
Jhansi	Dunora	10 (58.82)	2 (11.76)	2 (11.76)	3 (17.65)	0 (0.00)	17 (100.00)
	Nimoni	5 (29.41)	6 (35.29)	2 (11.76)	3 (17.65)	1 (5.88)	17 (100.00)
	Amra	2 (20.00)	2 (20.00)	4 (40.00)	2 (20.00)	0 (0.00)	10 (100.00)
	Gadvai	0 (0.00)	1 (33.33)	2 (66.67)	0 (0.00)	0 (0.00)	3 (100.00)
	Birora	0 (0.00)	0 (0.00)	1 (100.00)	0 (0.00)	0 (0.00)	1 (100.00)
	Total	48 (38.40)	28 (22.40)	27 (21.60)	13 (10.40)	9 (7.20)	125 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.4.8 More Pesticides and Fertiliser Consumption

Pesticides and chemical fertiliser are major determinants for vegetation of the plant. However, balance versus unbalance use of these artificial additives always in the centre of debate, where less educated people are handling. Basically, these additives exceed photosynthesis process of plant and enhanced mass production. However, farmers' uses beyond the plant requirement, it shorten crop duration, reduces gain size and ultimately result came out less production. It is found that more than 50 percent marginal farmers have increased use of chemical pesticides and fertilisers in the Dunora village (Table 6.8). Further, nearly 50 percent marginal farmers in the Biriya and Aata villages also increased the use of chemical pesticides and fertilisers over the last five years respectively (Table 6.8). Furthermore, Karson village remain topped position in the large farmers. It is found that 75 percent large famers have increased the consumption of chemical pesticides and fertilisers to increase the farm productivity respectively (Table 6.8).

Table 6.8: Land Size wise More Pesticides and Fertiliser Consumption in Survey Villages (in Numbers)

District	Village	Marginal	Small	Semi-medium	Medium	Large	Total
Jalaun	Karson	0 (0.00)	1 (25.00)	0 (0.00)	0 (0.00)	3 (75.00)	4 (100.00)
	Kaithi	2 (40.00)	1 (20.00)	2 (40.00)	0 (0.00)	0 (0.00)	5 (100.00)
	Pahladpur	1 (20.00)	1 (20.00)	1 (20.00)	2 (40.00)	0 (0.00)	5 (100.00)
	Biriya	1 (50.00)	1 (50.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (100.00)
	Aata	1 (50.00)	0 (0.00)	1 (50.00)	0 (0.00)	0 (0.00)	2 (100.00)
Jhansi	Dunora	2 (66.67)	1 (33.33)	0 (0.00)	0 (0.00)	0 (0.00)	3 (100.00)
	Nimoni	1 (33.33)	2 (66.67)	0 (0.00)	0 (0.00)	0 (0.00)	3 (100.00)
	Amra	2 (20.00)	1 (10.00)	6 (60.00)	1 (10.00)	0 (0.00)	10 (100.00)
	Gadvai	4 (23.53)	5 (29.41)	3 (17.65)	4 (23.53)	1 (5.88)	17 (100.00)
	Birora	1 (5.26)	4 (21.05)	6 (31.58)	3 (15.79)	5 (26.32)	19 (100.00)
	Total	15 (21.43)	17 (24.29)	19 (27.14)	10 (14.29)	9 (12.86)	70 (100.00)

Source: Estimated from Field Survey Data. The Parentheses values are row percentage.

6.5 Determinants of Multiple Adaptation Strategies: Logistic Regression Analysis

In this section, study examines the adaptive capacity and factors responsible for adaptation strategies of farmers. Therefore, the study employed logistic regressions, where dependent variable is an adaptation actions in binary form (i.e., a farmers reported in terms of yes/no, whether they take that particular action). Study fitted six logistic regressions for the adaptation actions undertaken by the farmers in the study area. The explanatory variables include household characteristics such as education, age, household size, farm income, non-farm income; physical resources of the households such have land owned, types of land, area irrigated, access to additional water sources; income and wealth; human resources such as number of family members, number of dependent persons, access to climate information, perception on climate change, perception on frequency of drought, perception on declining rainfall and increasing temperature.

6.5.1 Functional forms Model for Estimation

For the five major adaptation measures, study has conducted logistic regressions separately using the indicators influence the adaptation actions. In each case, given a sample size of 200 households, the degree of freedom by dropping those independent variables that gave insignificant results and for which there was no prior expectation based on theory of casual relationship between dependent and independent variable. The functional form of logistic regression are as follows.

Cropping Pattern Change = *f*(Income, Education, BPL, Rainfall, Temperature, Irrigated Area)............................(1)

Switch to Non-Farm Activities = *f(*source of Income, Land Size, Nature of Household, Education level, Access to Credit).........................(2)

Improved Irrigation Facilities = *f*(Irrigated Area, Education, BPL, Access to Credit, Access to Climate Information, Access to Crop Insurance).............................(3)

Early Maturing Variety (wheat) = *f(*Total Income, Irrigated Area, Education, BPL, Nature of Household, Access to Credit, Access to Climate Information, Access to Crop Insurance, Temperature, Rainfall)....................(4)

Less Water Consuming Crops = *f*(Education, Access to Climate Information, Temperature, Rainfall...(5)

The empirical model defined is:

$$L_i = ln\left(\frac{P_i}{P_i}\right) = B_1 + B_2X_i + U_i$$

Where, L_i is the unobserved response on adaptation strategy, Xi is the matrix of explanatory variables, viz., education, BPL, insurance, credit, climate information, nature of family etc. B_2 is unknown parameters, B_1 is the intercept and U_i is the error term.

6.5.2 Results and Discussion

The logistic regression results for cropping pattern change as an adaptation strategy shows that temperature, rainfall and education level have positive association with cropping pattern change adaptation strategy (Table 6.9) and the coefficients are significant at one percent level. Although, BPL and irrigated area also positively associated with cropping pattern change, but not statistically significant up to five percent level (we have taken up to five percent acceptance). Further, the calculated odd ratio of temperature shows that there is 12.77 times higher probability to change cropping pattern, followed by 4.13 times if farmer feel that rainfall has declined. Similarly, increase in education level from secondary towards post- graduation, there is 3.43 times higher probability to change cropping pattern respectively (Table 6.9).

Table 6.9: Logistic Regression Results of Cropping Pattern Change for Adaptation

Cropping (Yes = 1, No = 0)	Coefficient	Z	P>z	Odd Ratio
Education (Below Secondary = 1, above = 0)	1.231586**	2.44	0.015	3.43
BPL (Yes = 1, No = 0)	0.194917^{NS}	0.34	0.734	1.22
Temperature (Yes = 1, No = 0)	2.546916**	2.4	0.016	12.77
Rainfall (Yes = 1, No = 0)	1.418127***	1.78	0.075	4.13
Irrigated Area (Yes = 1, No = 0)	0.538687^{NS}	0.94	0.346	1.71
Constant	1.392012^{NS}	0.68	0.494	1.39
Pseudo R^2	0.1803			

Source: Estimated From Field Survey Data. Note, *, ** and *** indicate 1, 5, 10 percent level of significance and NS indicates non- significant level.

The role of income, land size, nature of family, education level and access to credit in the switch to non-farm activities is estimated. It is found that only nature of family is positively associated with the dependent variable (switch to non-farm activities), whereas income, land size, education level and access to credit are negatively associated respectively (Table

6.10). Further, nature of family is only statistically significant. Therefore, the calculated odd ratio results show that households belong to the joint family, there is 1.85 times higher probability to switch in non-farm activities respectively (Table 6.10).

Table 6.10: Logistic Regression Results of Switch to Non-Farm Adaptation Action

Non-Farm Activities (Yes= 1, No= 0)	Coefficient	Z	P>z	Odd Ratio
Income (Continuous; INR)	8.58E-07^{NS}	0.69	0.492	1.00
Land Size (Continuous; in Acres)	-0.10313^{NS}	-0.8	0.426	0.90
Nature of Family (Joint = 1, Nuclear = 0)	0.615289***	1.8	0.071	1.85
Education Level (up to secondary = 1, above = 0)	-0.17714^{NS}	-0.44	0.660	0.84
Access to Credit (Yes = 1, No =0)	-0.18341^{NS}	-0.49	0.624	0.83
Constant	-2.036155*	-3.33	0.001	0.13
Pseudo R^2	0.0232			

Source: Estimated From Field Survey Data. Note, *, ** and *** indicate 1, 5, 10 percent level of significance and NS indicates non- significant level.

Further, the role of education level, households belong to below poverty line (BPL), access to credit, information about climate and access to crop insurance in improved irrigation facilities is estimated. It is found that education level, access to credit are negatively associated with dependent variable (improved irrigation), whereas households belong to the BPL and have information about climate are positively associated with dependent variable. However, it is found that BPL and access to crop insurance are only statistically significant. Therefore, estimated odd ratio results show that households belong to above poverty line (APL), there is 14.74 times higher probability to improved irrigation, whereas households have access to crop insurance, there is 2.48 times higher probability to improved irrigation respectively (Table 6.11).

Table 6.11: Logistic Regression Results of Improved Irrigation Adaptation Action

Improved Irrigation (Yes = 1, No = 2)	Coefficient	Z	P>z	Odd Ratio
Education (up to secondary = 1, above = 0)	-0.13057^{NS}	-0.34	0.737	0.88
BPL (Yes = 0, No = 1)	2.690801*	6.33	0.001	14.74
Access to Credit (Yes = 1, No =0)	-0.10826^{NS}	-0.32	0.752	0.90
Information about Climate (Yes = 1, No = 2)	0.380601^{NS}	1.07	0.287	1.46
Access to Crop Insurance (Yes = 1, No = 2)	0.90782*	2.5	0.012	2.48
Constant	-2.31596*	-3.94	0.001	0.10
Pseudo R^2	0.2328			

Source: Estimated From Field Survey Data. Note, *, ** and *** indicate 1, 5, 10 percent level of significance and NS indicates non- significant level.

Furthermore, the role of income, irrigated area, education level, households belong to the below poverty line (BPL), nature of family, access to credit, information about climate, access to crop insurance, temperature and rainfall in growing early maturing variety (wheat) is estimated. It is found that income, irrigated area, access to credit, access to crop insurance, temperature and rainfall are negatively associated with the dependent variable, i.e., early maturing variety, whereas education level, BPL, nature of family, information about climate are positively associated. However, only education level, BPL and rainfall are statistically significant (Table 6.12). Therefore, calculated odd ratio results show that there is 2.32 times higher probability to use early maturing variety if head of households having education level above from secondary, whereas there is 2.58 times higher probability to use early maturing variety if households belong to APL respectively (Table 6.12).

Table 6.12: Logistic Regression Results of Early Maturing Variety (Wheat) Adaptation Action

Early Maturing Variety (Yes = 1, No = 0)	Coefficient	Z	P>z	Odds Ratio
Income (Continuous; INR)	-9.49E-07^{NS}	-0.91	0.361	1.00
Irrigated Area (Yes = 1, No = 0)	-0.75585***	-1.8	0.071	0.46
Education (up to secondary = 1, above = 0)	0.838724**	2.3	0.021	2.31
BPL (Yes = 0, No = 1)	0.954676**	2.01	0.044	2.58
Nature of Family (Joint = 1, Nuclear = 0)	0.224031^{NS}	0.72	0.472	1.25
Access to Credit (Yes = 1, No=0)	-0.10242^{NS}	-0.31	0.758	0.90
Information about Climate (Yes= 1, No= 2)	0.039019^{NS}	0.1	0.916	1.04
Access to Crop Insurance (Yes= 1, No= 2)	-0.40573^{NS}	-1.08	0.282	0.66
Temperature (Yes= 1, No= 0)	-0.79083**	-2.03	0.043	0.45
Rainfall (Yes= 1, No= 0)	-2.01563*	-4.44	0.001	0.13
Constant	0.566063^{NS}	0.89	0.376	1.76
Pseudo R^2	0.1695			

Source: Estimated From Field Survey Data. Note, *, ** and *** indicate 1, 5, 10 percent level of significance and NS indicates non- significant level.

Lastly, the role of education level, information about climate, rainfall and temperature in the growing less water consuming crops is estimated. It is found that education level and rainfall are positively associated with dependent variable, i.e., less water consuming crops, whereas information about climate and temperature are positively associated with dependent variable respectively (Table 6.13). However, information about climate and temperature only statistically significant up to 10 percent level of significance. Therefore, the calculated odd ratio results show that there is 1.49 times higher probability to grow less water consuming crops if households having information about climate, whereas there is 1.07 times higher probability to grow less water consuming crops if households perceived that temperature continuously increasing over the years respectively (Table 6.13).

Table 6.13: Logistic Regression Results of Less Water Consuming Crops Adaptation Action

Less Water Consuming Crops (Yes= 1, No= 0)	Coefficient	Z	P>z	Odds Ratio
Education (up to secondary= 1, above= 0)	-0.13571^{NS}	-0.35	0.729	0.87
Information about Climate (Yes= 1, No= 2)	0.401219*	1.04	0.02	1.49
Rainfall (Yes= 1, No= 0)	-0.36595^{NS}	-0.76	0.449	0.69
Temperature (Yes= 1, No= 0)	0.06581***	0.18	0.86	1.07
Constant	-1.47115*	-3.3	0.001	0.23
Pseudo R^2	0.0079			

Source: Estimated From Field Survey Data. Note, *, ** and *** indicate 1, 5, 10 percent level of significance and NS indicates non- significant level.

6.6 Conclusion

This is an attempt to understand the adaptation strategies undertaken by farmers in the study region to adapt the climate variability and change. It examined the different adaptation and copping actions to current climate risks by farming households and drives of differential adaptive capacity at the household level. The study observed farmers in the study region restored to nine different adaptations and copping actions to tackle drought and climate variability. First, Education is observed key indicator to tackle with climate variability at household level. The respondents have education above secondary level likely more adaptive capacity compare with below secondary. Second, BPL category is use based on ration card have in the surveyed farm households. It is observed that above BPL category, farmers have higher adaptive capacity to change cropping pattern, early maturing varieties and improved irrigation facilities. Third, perception about climate change also positively & significantly associated with adaptation strategies. It is observed in the predicted binary logistic results that farmers have information about climate have likely to more adaptive capacity than those don't have information. Fourth, perception about increase in temperature also has been observed positive association with cropping pattern change and early maturing varieties. Fifth, access to agriculture insurance leads to improved irrigation facility. It is notably important that agriculture insurance provides safety net to farmers against any natural disaster. It is observed that farmers those have agriculture insurance are ready to grow high irrigation intensive crops rather than change cropping pattern change or diversify the crops.

In the light of current adaptation practices, farming in the Bundelkhand region are highly vulnerable from climate variability. Deceleration in the land size, rainfall and acceleration in temperature and population size, low education level, less access to insurance, modern technology, credit are also major contributing factors in this direction.

Chapter- 7

Summary and Conclusion

7.0 Introduction

Agriculture is potentially affected, highly vulnerable and least adaptable to cope with the environmental externalities, i.e., climate change. Further, heterogeneous agro-climatic condition, land size and resource use increases the degree of the potential impact of climate change on farm productivity as well as farmers. The threshold level of temperatures has reached for the majority of the crops in low latitude countries like India. In India, continuous decline in mean land size, majority of the cropped area under rainfed conditions, variability in climatic factors, decline in agricultural investment, higher dependency on farming for employment, uneducated farmers in majority shows that agriculture no more profitable business if no adaptation measures take place.

The thesis has made an attempt to study the present status of Indian agriculture. Firs, how agriculture situation has been changed after an adoption of the ambitious green revolution strategy. Second, how climatic factors, viz., rainfall and temperatures are affecting to the crop productivity in India. Third, how climate change is increasing the degree of livelihood and climate vulnerability in the surveyed villages of Bundelkhand region in Uttar Pradesh. Finally, how farmers are responding to cope with climate change in the surveyed village. The study has used primary and secondary data to analyse various objectives of the study. Secondary data are used to analyse the growth of major food and non- food crops during the post green revolution (1966-90) and economic reform period (1991-2012). Further, change in economic (land size), technological (number of tractors, consumption of fertilisers) and environmental factors (rainfall and temperatures) has laso analysed during the post green revolution period (PGR) and economic reform period (ERP). Furthermore, by using ICRISAT database, the potential impact of rainfall and temperatures on crop productivity is also analysed. Primary data are used to examine the degree of livelihood and climate vulnerability among the surveyed farmers. Further, differential adaptation strategies followed by surveyed farmers to cope with climate change is also analysed.

7.1 Summary and Conclusion of the Study

The chapter one entitled **"Climate Change: Issues and Challenges"** explores the impact of climate change on farm productivity and livelihoods of farmers. Based on the existing review of literature. Some important observations are as follows. First, farming in the high latitudes that are cooler that the optimum temperature, warming would cause net revenues to go up. On the other hand, farming in low latitudes that are warmers that the temperatures, warming would cause net revenues to fall. These results imply that countries that happen to be in relatively cool regions of the world are likely to get benefit from the warming, those countries that happen to be in relatively warm regions of the world are likely to be harmed by warming. Further, the predicted results show that the effect of climate change in Europe is likely to increase the productivity of agricultural and forestry systems, because increasing CO_2 concentration directly increase resource use efficiency of plants, and because warming do provide more favourable conditions for the plants in northern Europe. On the contrary, estimated results show that an increase 2^0C in mean temperature decreased rice yield by about 0.75 ton/hectare in high yield areas and 0.6 ton/hectare in the low yield coastal regions in the low latitude countries including India. Further, 0.5^0C increase in winter temperature would reduce wheat crop duration of seven days and reduced yield by 0.45 ton/hectare, and 10 percent reduction in wheat production in the high yield states of Northern India.

Second, higher dependency on south-west monsoon in one hand and on the other hand, variability in rainfall pattern and shift towards the post monsoon period is increasing the degree of vulnerability in the Kharif season across the agro-climatic zones in India.

Third, it is found that to cope with climate change, farmers started differential adaptation strategies, viz., crop rotation, less water consuming crops, short-duration crops, improved irrigation facilities, use of hybrid seeds and crop insurance in the Bundelkhand region part of Uttar Pradesh.

Therefore, agriculture needs special attention. Because agriculture provides employment to the majority of rural population, provides raw material and support secondary sector, i.e., growth in industrial sector, provides foods to the 120 hundred million people.

The chapter two entitled **"Climate Change and Economic Development: Perspectives and Approaches"** address the debate on environment versus economic growth as well as development of approaches for measuring the impacts of climate change on agriculture.

First, Malthus and followers argued that with scarce natural resources and the exponential growth in population, we cannot achieve economic growth indefinitely. Further Malthusian was suggested two solutions, viz., preventive and positive checks. The preventive checks consist of voluntary limitations of population growth. On the other hand, the positive check to population is to a direct consequence of the lack of a preventive check. In other words, when society does not limit population growth voluntarily, diseases, famines and wars reduce population size and establish the necessary balance with resources.

Second, however, neoclassical economists in majority believed that there is no such kind of resource depletion as pointed by the Malthusian economists. Instead, the real issue of significance is to understand the circumstances under which technological progress would continue to ameliorate resource scarcity.

Third, in contrast to neoclassical economists, ecological economists believed that the human economy is a subsystem of the ecosystems. Limits to economic growth could no longer be argued solely on the basis of the possibility of running out of conventional resources as Malthusian believed. Further, technology could not be viewed as the ultimate means of circumventing ecological limits as neoclassical economists advocated.

Fourth, the sustainability economists in the ecological prospective argued that uncertainty about the future changes in ecology is core issue. The problem is not that changes will occur, but rather that we do not know for sure how and when these changes will occur and we do not know what the implications of these changes will be on future resource availability.

Fifth, there is continuous development in the methodology to capture the impact of climate change starting from structural modelling approach to panel data approach, which provide advantages to the future researchers to capture real time impact of climate change on farm productivity as well as livelihoods of the farmers.

Therefore, it is important to understand the externalities occur due to over exploitation of natural resources. The views on limits to economic growth and environmental degradation clearly states that inclusive and sustainable development is the only way to move out from the current tragedy of commons.

The chapter three entitled **"Agriculture Development in India: A State Level Analysis"** made an attempts to examine the performance of Indian agriculture. Further, change in key determinants, viz., economic, technological and environmental during post green revolution and economic reform period are analysed.

First, it is found that forest cover marginally increased about two percent during 1966-2012 at the cost of land not available for cultivation, permanent pasture & grazing land, land under miscellaneous and culturable waste. Further, the net sown area is purely associated with agricultural practices, shows marginally increased by about 1.22 percent during 1966-2012 respectively. Furthermore an area more than once shows positive outcome of the green revolution. It indicates that area more than once is used for cultivation increased about two percent during 1966-1990 and continuous increased by about six percent during 1991-2012.

Second, the CAGR of gross sown area (GSA) has marginally increased by 0.24 percent annually during 1991-2012, whereas CAGR of net sown area (NSA) shows that it has declined by -0.09 percent annually. Further, with the support of government and well as community participation, the CAGR of net irrigated area (NIA) and gross irrigated area (GIA) increased by 1.26 & 1.55 percent during 1991-2012 respectively. Furthermore, disparities in growth of GSA, NSA, NIA and GIA have found at the state level. NSA has declined in Bihar, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh, Uttar Pradesh, Madhya Pradesh and West Bengal, whereas, it has increased marginally in Gujarat during 1991-2012. Similarly, GSA has declined in Bihar, Himachal Pradesh, Kerala, Orissa, Tamil Nadu and Madhya Pradesh, whereas it has increased in Gujarat, Haryana, Jammu & Kashmir, Karnataka, Maharashtra, Punjab, Rajasthan, and West Bengal. Furthermore, NIA has increased in all states except Bihar, whereas GIA has increased in all states.

Third, cropping pattern was in favour of food grain crops, especially rice and wheat from post green revolution period to mid-eighties and after words it has changed in favour of non-food grains. Further, regional disparities in the total cropped area for food and non-food grains have found. The cropped area under total food grains has increased in Bihar, Orissa, Punjab, Rajasthan, Uttar Pradesh, West Bengal, Haryana, Jammu & Kashmir and Karnataka, whereas, it declined in Andhra Pradesh, Gujarat, Madhya Pradesh, Tamil Nadu, Kerala and Maharashtra during 1966-2012. Furthermore, the total cropped area under non-food grains has increased in Madhya Pradesh, Rajasthan, West Bengal, Andhra Pradesh, Haryana, Himachal Pradesh, Jammu & Kashmir, Kerala and Maharashtra during 1966-2012.

Fourth, the mean operational land size shows a continuous decline during 1970-71 to 2010-11. It also shows that marginalization has increased rapidly. Marginal farmers were 51 percent in 1970-71 and they are increased by 17 percent, i.e., 67 percent in 2010-11. Further, the operated area has shifted in favour of marginal and large farmers. In 1970-71, 51 percent marginal farmers have owned 9 percent cropped area and it has increased about 22 percent in 2010-11. Furthermore, marginal farmers have increased in the backward states, i.e., Bihar and Uttar Pradesh sharply due to rapid increase in population. In 1995-96, marginal farmers were 80.14 percent and increased by 11 percent in 2010-11. Similarly, the total marginal farmers were 75.42 & 76.42 percent in 1995-96 and it has increased by 79.23 & 82.17 percent in 2010-11 in Uttar Pradesh and West Bengal. The rate of marginalization in the high yield states is lower. Moreover, the regional shift in mean land size also found. Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab and Rajasthan states have higher mean land size, whereas Andhra Pradesh, Bihar, Himachal Pradesh, Jammu & Kashmir, Kerala, Odisha, Tamil Nadu, Uttar Pradesh and West Bengal have lower mean land size.

Fifth, per hectare consumption of chemical fertilisers has increased fourfold during 1991-2012. High yield states such as Andhra Pradesh, Haryana and Punjab have consumed at a higher rate, whereas low yield states, Odisha, Rajasthan, Kerala, Madhya Pradesh and Maharashtra have consumed at a lower rate.

Sixth, there had been imbalance use of nitrogen, potassium and phosphorus fertilisers have found during PGR and EPR. States like, Karnataka, Kerala, Maharashtra, Tamil Nadu, and

West Bengal had lower imbalance, whereas, Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh had higher imbalance from the recommended ratio during 1966-2012. Seventh, the higher rate of technological tools adoption, i.e., tractors was observed in all states. It means, the input cost in agricultural labourers has shifted in favour of technological tools, viz., tractors.

Eighth, variability in the environmental factors, viz., rainfall and temperatures was observed during 1966-2012. It is found that rainfall variability has increased in Gujarat, Karnataka, Maharashtra, Orissa, and West Bengal, whereas it has declined in Andhra Pradesh, Bihar, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. Further, maximum temperature was increased in Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal, whereas, it was declined in only Andhra Pradesh and Bihar. Furthermore, minimum temperature was increased in Gujarat, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Orissa, and West Bengal, whereas, it was declined in Bihar, Rajasthan and Uttar Pradesh.

Though, green revolution moved out from the food crisis arisen in the early sixties in some extent, yet it brought regional disparities in the resource use, productivity and change in cropping pattern. Promotional price policy for some crops lead to scarcity in others. Change in environmental factors, along with economic and technological factors increased the degree of vulnerability in the farm profits, in particular and the livelihoods of farmers in general.

The fourth chapter "**Impact of Climate Change on Agricultural Productivity in India**" estimates the climate change impact on fifteen major and minor food & non- food grain crops. The calculated marginal effect of rainfall and temperature shows that majority of the crops are potentially affected. Further, increase in temperature up to 1.5^0C and rainfall up to 7 millimeter would adversely affect by the end of this century to the majority of the crops.

First, rice has the highest mean productivity among the food grain crops, i.e., 3.28 tonnes per hectare, whereas, cotton tops on the list of non- food grains, i.e., 17.50 tonne per hectare. The mean minimum & maximum temperature was 19.54^0C and 32.07^0C during 1966-2011 respectively. The annual and monsoon rainfall was 1105.05 and 870.26

millimeter. Further, the number of tractors per thousand hectares was 4.17, whereas the number of pump sets per thousand hectares was 29.49 during 1966-2011.

Second, majority of crops are positively associated with non-climatic factors, viz., sown area, rural literates, tractors, fertilisers, irrigated area and number of pump sets except sorghum, pear millet, finger millet, chickpea, pigeon pea, rabi pulses and soybean. These crops are negatively associated with fertilisers.

Third, rainfall in the sowing period negatively associated with yield rice, maize, barley, sorghum, rabi pulses and groundnut, whereas positively associated with yield of wheat, pearl millet, finger millet, chickpea, lime seed, soybean, sugarcane and cotton. Further, rainfall in the germination period negatively associated with yield of wheat, barley, sorghum, pearl millet, pigeon pea, rabi pulses and lime seed, whereas positively associated with the yield of rice, maize, finger millet, chickpea, groundnut, soybean, sugarcane and cotton. Furthermore, rainfall in the harvesting period negatively associated with the yield of rice, wheat, barley, sorghum, finger millet, chickpea, rabi pulses, groundnut, soybean and cotton.

Fourth, minimum temperature in sowing period is positively associated with the yield of majority crops except from, rice, maize and sugarcane. Further, minimum temperature in the germination period positively associated with the yield of majority crops except for, barley, sorghum, chickpea, pigeon pea, rabi pulses, groundnut and sugarcane. Similarly, minimum temperature in the harvesting period is positively associated with the yield of majority crops except from, wheat, barley, finger millet, groundnut and cotton.

Fifth, maximum temperature in the sowing period is positively associated with the yield of rice, maize, sorghum, raib pulses and soybean, whereas, negatively associated with the yield of wheat, barley, pearl millet, chickpea, sugarcane and cotton. Further, maximum temperature in germination period is positively associated with the yield of wheat, barley, chickpea, pigeon pea, rabi pulses, soybean and cotton, whereas, negatively associated with the yield of rice, maize, finger millet, groundnut and cotton. Furthermore, maximum temperature in the harvesting period positively associated with the yield of wheat, barely, pearl millet, groundnut, lime seed and cotton, whereas, negatively associated with the yield of sorghum, chickpea, pigeon pea, rabi pulses, soybean and cotton.

Sixth, the calculated marginal effect of rainfall, minimum & maximum temperature indicates that in the absence of any adaptation measures, i.e., irrigation, fertilisers and pump sets, etc., the productivity of rice, wheat, barley, sorghum, pearl millet, chickpea, lime seed, soybean, sugarcane and cotton is declined by -6.94, -19.68, -22.81, -86.57, -9.40, -21.47, -2.57, -1.86 & -19.83 percent during 1966-2011.

Seventh, the projected results shows that if the minimum temperature increase up to 1^0C, maximum temperature increase up to 1.5^0C and rainfall increase up to 7 millimeter, the productivity of rice, wheat, barley, sorghum, pearl millet, finger millet, chickpea, soybean, sugarcane and cotton would be decline by -13.51, -31.51, -121.20, -36.82, -38.23, -2.26, -1.16 & -17.06 percent by the end of century.

Eighth, the projected results also show that if the minimum temperature increased up to 1.5^0C, maximum temperature increase up to 4^0C and rainfall decline up to 20 millimeter, the productivity of rice, wheat, sorghum, pearl millet, finger millet, chickpea, soybean, sugarcane and cotton would be decline by -56.19, -68.57, -398.58, -103.10, -39.34, -106.05, -35.75, -8.11 & -79.64 percent by the end of century.

Expansion of irrigated area, use of technological factors, viz., chemical fertilisers & pesticides, tractors and pump sets have moderated the degree of adverse impacts of climate change. However, changes in the monsoon rainfall pattern towards the post monsoon period is potentially affecting to the both major cropping seasons, viz., kharif and rabi in India. Further, rise in minimum and maximum temperatures even in the winter season, adding an additional layer of the adverse impacts of climate change. The results show that high yield, higher irrigational crops are at a higher risk rather than low yield crops, viz., kharif pulses and minor cereals.

The fifth chapter **"Assessment of Climatic Vulnerability at Community Level"** develops the livelihood and climate vulnerability indices by using agro, socio-economic conditions of the surveyed households. Education, basic amenities, exposure from the climatic factors, viz., rainfall and temperature, higher dependency on agriculture, lack of non-farm employment opportunities and minimum use of modern technology in the farming have increased the degree of vulnerability among the surveyed households.

First, majority of surveyed households are belong to the Hindu region and headed by male counterparts. Further, more than 60 percent households live in the pucca houses, followed by 19 percent in the semi- pucca houses by using hand pump as a main source of drinking water. Furthermore, 46 percent households are still using open field, followed by 42.50 percent flush and 11.50 dry latrines for the sanitation. Moreover, more than half (56.50 percent) of households are still using non- renewable resources for the cooking purpose and still 27.50 percent households do not have electricity in their house.

Second, heterogeneity in the income distribution is observed among the surveyed households. 29 percent households earns only up to 20 percent income. Another, 11 percent households have an income within the range of 21-40 percent, whereas, next 22 percent households earns within the range of 41-60 percent. Next, 19 percent households earns with the range of 61-80 percent and remaining 19 percent households earns within the range of 81-100 percent. In other words, mean income of nearly 30 percent households is Rs. 41, 224.10, whereas, 11 percent households earned Rs. 66, 545.60 only. Further, 22 percent earns Rs. 97,318.20, whereas, 19 percent earned Rs. 1, 77, 342 and remaining 19 percent earned Rs. 4, 10, 184 annually.

Third, nearly 50 percent individuals are either illiterate or not taken formal education. Further, 22.85 percent individuals have educational qualification up to junior level and only 9.81 & 7.54 percent have taken education up to secondary and senior secondary level. Furthermore, the individuals have the educational qualification up to diploma, graduate and post- graduate only is 0.32, 7.46 & 2.19 percent respectively. This shows that illiteracy and low education level of the surveyed households is high.

Fourth, disparities in the education level on gender basis also significant. The illiteracy rate among females is higher than those of males by 10 percent. Illiterate females and males are 53.14 & 46.86 percent respectively. It is also found that when education is increasing the disparity in the education level also increases among the males and females.

Fifth, there exist positive relation between education level and occupational. It is found that individuals have an education level up to junior, secondary, senior secondary, graduate, diploma and post-graduate, the level of self-employment is 16.67, 24.79, 35.48, 75, 26.09 & 37.04 percent respectively. Majority of individuals belong to illiterate category are agricultural and non-agricultural labour.

Sixth, the agronomic profile of the surveyed households indicates that majority of the farmers belong to the marginal and small operational land size, i.e., 35 & 22.50 percent. Further, the majority of marginal operational households belong to the OBC and SC, i.e., 60 & 26.15 percent respectively. The percentage of small farmers belong to the General, OBC and SC is 35.56, 40 & 24.44 percent. The share of the medium and large farmers among the social categories is lower. It is found that in General category, only 19.61 & 3.92 percent households are medium and large farmers, whereas, in the OBC, only 11.58 & 8.42 percent surveyed households are medium and large farmers.

Seventh, Pahladpur village is highly exposed by the climatic factors, such as increase in temperature, decrease in rainfall and decline in ground water level. Further, Karson village highly sensitive due to dependence on natural resources (90 percent), using hand pump as a main source of drinking water (65 percent), less crop diversification (45 percent), dependency on government sources of irrigation (85 percent), dependency on head of household (65 percent), none using modern health facilities (zero percent), open defecation (55 percent), only 30 percent households having pucca house and households belong to the below poverty line (30 percent). Furthermore, Biriya village has least adaptive capacity. It is found that only 15 percent households headed by females, 30 percent households have not taken formal education, seven percent solely depends on agriculture, 10 percent have the burden of loan, only 20 percent have changed the cropping pattern, 15 percent have taken information form the Kisan Call Centre (KCC), and 50 percent lives in the joint family structure. The overall livelihood vulnerability index scores show that due to least adaptive capacity, Biriya village has the highest livelihood vulnerability score, i.e., 0.356 respectively.

Eight, the estimated climate vulnerability index shows that Kaithi village (0.925) is highly exposed, Karson village (0.617) is highly sensitive and Karson village (0.350) has the highest adaptive capacity in the Jalaun district. Whereas, Pahladpur village is highly vulnerable by the climate change and variability. Basically, Pahladpur and Kaithi villages have much similar climate vulnerability index scores, i.e., 0.382 & 0.383. However, Pahladpur and Kaithi are high degree of vulnerability. Finally, due to higher exposure, sensitivity and least adaptive capacity, Dunora village is highly vulnerable to the climate change and variability.

Therefore, the livelihood and climate vulnerability profile in the ten villages of two most diversified agricultural districts, i.e., Jalaun and Jhansi depicts that these villages have least crop insurance, least income & crop diversification, higher dependency on head of household, lowest basic amenities and fewer sources of non-farm employment.

The sixth chapter **"Assessment of Adaptation Strategies at Household Level"** examines the different adaptation strategies applied by the farmers to cope with climate change in the Bundelkhand region of Uttar Pradesh.

First, farmers are applying numerous types of adaptation strategies, such as cropping pattern change, switch to non-farm activities, improving irrigation, planting trees in the surrounding of the fields, early maturing varieties of seeds, less water consuming crops, crop diversification and more pesticides and fertilisers. More than 20 percent farmers have changed their cropping pattern, nearly 20 percent switch to non-farm activities, 43 percent improved irrigation, 61 percent planted trees surrounded the fields, 38 percent used maturing varieties of seeds, 43 percent have used less water consuming variety of crops, nearly 63 percent diversified their cropping pattern and 35 percent increased the consumption of chemical fertilisers and pesticides to cope with climate change.

Second, it is found that in the majority, marginal, small and semi-medium farmers have followed differential adaptation strategies in the surveyed village, whereas medium and large farmers have least adaptation. Karson is only village, where large farmers have the changed cropping pattern (57.14 percent), switch to non- farm activities (71.43 percent), improved irrigation (60 percent), used early maturing varieties of seeds (61.54 percent), less water consuming crops (69.23), crop diversification (53.33), more consumption of fertilisers and pesticides (75 percent).

Third, it is found that exposure from the rainfall and temperature has forced to the highly educated farmers (education qualification above from the secondary level) to change cropping pattern.

Fourth, households living in the joint family structure are inclined to switch non-farm employment activities, because farm income does not sufficient to the livelihood security.

Fifth, households belong to the above poverty line (APL) and insured from the national *Fasal Bima Yojna* have better the coverage of all season irrigation facilities.

Sixth, households belong to the APL category and have educational qualification above from the secondary level more inclined to use an early maturing variety of wheat to moderate adverse impact of climate change.

Seventh, households have better information on continuous increase in temperature over the last five years are more habituated to use less water consuming crop varieties to deals with climate change.

In the light of current adaptation practices, farming in the surveyed villages is highly vulnerable to the climate change. Marginalization in the land size in, decline in rainfall and the increase in temperatures, continuous increase in population, low education level, less access to insurance, modern technology and institutional credit adding an additional layer of the adverse impacts of climate change.

7.2 Policy Recommendations

Some of the recommendations are important to cope with climate change in India as well in Bundelkhand region of Uttar Pradesh.

First, the green revolution has changed the cropping pattern. In the post green revolution period majority of the cropping pattern has been shifted in favour of rice, wheat, sugarcane and cotton at the cost of minor cereals, pulses and some other non-food grain crops. Due to this, surplus production in major cereals and scarcity in pulses and minor cereals have a major reason for the current food crisis. Therefore, there is need of promotion to enhance the share of minor cereals and pulses. Further, pulses are high temperature tolerance and needs fewer resources for the vegetation. In the raifed areas (more than 60 percent cropped area under rainfed conditions in India), it is recommended that pulses are the best option to deal with climate change.

Second, the price support policy has a potential role in the cropping pattern. Therefore, it is recommended that price support policy for the minor cereals and pulses before the sowing period would be helpful. It not only increase the farm- profits, but also reduce resource input cost.

Third, FGLS results confirm that temperature and rainfall are potentially affecting the crop productivity during 1966-2011. Therefore, there is need of temperature tolerance and less water consuming crop varieties to deal with climate change.

Fourth, it is found that information about climate change education has a potential role to moderate the climate change impacts. However, due to illiteracy, farmers are hardly aware about the future climatic conditions, such as rainfall and temperatures. Therefore, agro-climatic zone specific awareness centers nearby villages should be open and farmers to be trained accordingly.

Fifth, it is found that farmers started differential adaptation practices to cope with climate change, such as more fertilisers and pesticides consumption, without knowing the soil requirement. Therefore, it is recommended that creating the soil health card should be compulsory and connected with AADHAR card. So administrator can monitor and recommend best possible solutions. This measure reduces the input cost and leads to farm sustainability.

7.3 Limitations of the Study

There are few limitations of the present study:

First, present study analyses the performance of Indian agriculture during post green revolution period. However, there is a need to present pre-green revolution performance and then compares with post green revolution (PGR) and economic reform period (ERP).

Second, there are three main environmental factors, which are affecting to the crop productivity, viz., rainfall, temperature and carbon dioxide. The present study is only taken rainfall and temperature. The availability of data on CO_2 on temporal and spatial basis is almost nil.

Third, there are seven districts in Bundelkhand region of Uttar Pradesh. The present study has taken only two districts. Therefore, based on the results of various factors in ten village of two districts, are not able to generalise the livelihood and climate vulnerability results.

Fourth, the macro level study at all India level do no cover all districts in all the states during 1966-2011.

7.4 Further Scope of the Study

The present study has not meant to answer all questions those have emerged during the recent research process. However, some of them seem to be worth mentioning in order to be addressed by contemporary studies. There are three stages to analyse the impact of climate change on agriculture sector, i.e., potential impact by using historical data of agricultural determinants including environmental factors, vulnerability impact by either historical data or filed survey data, and adaptation impact using agro, socio- economic datasets. The present study analyses the all three stages by using secondary and primary data with fewer sample size. The present study analyses the potential impact on crop productivity during 1966-2011 and only included 291 districts and fewer determinants of crop productivity. So there is need to increase the time period and also include remaining districts in the future study, so generalization can possible.

The present study collected only 200 samples from the two districts out of thirteen districts in Bundelkhand region. Based on this small sample size generalization of vulnerability and adaptation strategies is not possible. Therefore study can be developed by including more districts with large sample size.

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Appendices

Table 3.1A: CARG of Area of Major Food and Non- Food grain Crops during 1966-90

States	Rice	Wheat	Cotton	Sugarcane	Total Oilseed	Food grain	Non-food grain
Andhra Pradesh	0.81* (3.55)	-1.77** (-2.40)	3.35* (8.75)	0.73*** (1.87)	1.55* (3.74)	-0.29** (-2.18)	1.71* (5.00)
Bihar	0.09^{NS} (0.53)	2.64* (5.38)	-10.84* (-9.70)	-0.84* (-3.14)	-0.17^{NS} (0.54)	0.15^{NS} (1.03)	-0.32*** (-1.78)
Gujarat	0.38^{NS} (1.16)	0.13^{NS} (0.15)	-2.28* (-5.12)	5.92* (14.28)	1.06* (2.49)	0.40^{NS} (0.35)	-0.12^{NS} (-0.33)
Haryana	5.04* (16.95)	3.42* (15.11)	3.64* (13.87)	-0.66^{NS} (1.57)	4.22* (4.65)	0.28^{NS} (1.33)	2.90* (10.40)
Himachal Pradesh	-0.44* (3.08)	1.13* (8.29)	-5.20* (-6.95)	-1.17* (-3.22)	-0.03^{NS} (-0.14)	0.62* (8.98)	-0.28^{NS} (-1.38)
Jammu & Kashmir	0.89* (7.53)	1.28* (7.71)	-7.34* (-6.52)	-6.88* (-13.65)	2.84* (9.39)	0.80* (13.37)	2.56* (8.98)
Karnataka	0.15NS (0.95)	-1.23* (2.95)	-2.56* (-4.81)	4.64* (20.67)	3.46* (9.47)	0.37^{NS} (1.32)	1.64* (7.93)
Kerala	-1.76* (-7.95)	-	-0.79** (-1.92)	-0.10^{NS} (-0.39)	-0.38^{NS} (-1.30)	-1.65* (-8.91)	-0.38** (-1.79)
Madhya Pradesh	0.78* (17.25)	1.16* (4.10)	-1.49* (7.80)	-1.31** (-2.21)	2.76* (8.75)	0.87* (11.34)	1.78* (6.46)
Maharashtra	0.65* (5.94)	-0.09^{NS} (-0.19)	0.15^{NS} (0.75)	3.45* (9.33)	2.08* (8.29)	0.96* (5.63)	1.11* (6.07)
Orissa	-0.20** (-1.85)	4.66* (3.49)	13.08* (6.41)	1.74* (5.09)	6.88* (22.83)	1.91* (12.26)	5.84* (23.67)
Punjab	8.85* (27.03)	2.47* (14.14)	2.13* (6.56)	-1.90* (-4.32)	-3.89* (-8.29)	2.18* (26.51)	0.04^{NS} (0.18)
Rajasthan	0.72NS (1.16)	1.77* (4.38)	1.89* (5.00)	-2.13** (-2.39)	3.55* (6.13)	0.47** (2.12)	3.11* (8.34)
Tamil Nadu	-1.48* (-5-50)	-7.56* (-4.69)	-1.87* (-4.07)	3.01* (8.87)	0.31^{NS} (1.26)	-0.53* (-2.81)	0.18^{NS} (0.78)
Uttar Pradesh	1.04* (8.20)	2.64* (16.22)	-4.95* (-8.70)	1.76* (7.90)	-3.81* (-7.27)	0.58* (8.96)	-1.84* (-5.47)
West Bengal	0.56* (4.74)	2.89** (2.01)	-12.42** (-6.12)	-4.34* (-6.37)	6.03* (15.57)	0.36** (2.39)	2.40* (7.29)

Source: Department of Economics & Farmers' Welfare, Ministry of Agriculture, Government of India, New Delhi, India. Note: Estimated by using Semi- log model. Parentheses Values are t- values, *, ** & *** indicate 1, 5, 10 percent level of significance and NS indicates non-significant.

Table 3.2A: CARG of Area of Major Food and Non- Food grain Crops during 1991-2012

States	Rice	Wheat	Cotton	Sugarcane	Total Oilseed	Food grain	Non-food grain
Andhra Pradesh	0.36^{NS} (0.75)	-0.39^{NS} (-0.65)	3.42* (5.38)	0.34^{NS} (0.79)	-1.94* (-6.00)	-0.61** (-2.12)	-0.33^{NS} (-1.22)
Bihar	-2.85* (7.64)	0.23** (2.47)	-0.90*** (-1.73)	1.02^{NS} (1.18)	-3.36* (-9.52)	2.64* (5.79)	-0.47^{NS} (-0.89)
Gujarat	1.67* (7.19)	4.92* (4.43)	4.56* (18.31)	2.11* (4.80)	0.05^{NS} (0.38)	-0.43^{NS} (-0.79)	1.73* (11.74)
Haryana	2.76* (9.24)	1.51* (13.19)	-0.48^{NS} (1.29)	-1.99** (2.65)	-0.69^{NS} (-1.36)	0.90* (7.04)	-1.15* (-3.24)
Himachal Pradesh	-0.40* (-6.31)	-0.29* (-4.98)	-6.46** (-2.67)	-1.11^{NS} (-1.63)	-2.36* (-11.61)	-0.52* (-9.79)	7.72* (3.18)
Jammu & Kashmir	-0.39** (-2.69)	0.85* (5.21)	-0.90* (-1.73)	-15.97* (-4.24)	-1.75^{NS} (-0.85)	0.06^{NS} (0.76)	-1.46^{NS} (-0.85)
Karnataka	0.56** (1.84)	0.75* (2.72)	-2.01* (-3.10)	0.55^{NS} (0.67)	-2.52* (-3.75)	-0.03^{NS} (-0.16)	-2.52* (-5.48)
Kerala	-5.01* (-32.91)	-	-14.62* (-11.77)	-5.19* (-5.60)	-14.85* (-12.89)	-5.41* (-35.50)	10.59* (4.31)
Madhya Pradesh	-5.84* (6.50)	0.84* (7.05)	-8.94* (-4.37)	-4.12* (-4.07)	-8.11* (-3.01)	-6.83* (-4.49)	-1.52^{NS} (-0.92)
Maharashtra	-0.03^{NS} (0.47)	2.40* (3.96)	1.45* (4.37)	3.98* (4.31)	2.53* (6.39)	-1.31* (-.79)	1.60* (6.05)
Orissa	-0.30* (-3.29)	-5.12* (-3.02)	14.20* (9.27)	-3.42* (-3.21)	-4.28* (-5.54)	3.34* (4.48)	-3.30* (-4.38)
Punjab	1.56* (11.30)	0.46* (11.08)	-1.27** (-2.54)	-1.95** (-2.17)	-8.09* (-17.37)	0.66* (10.06)	-2.81* (-5.33)
Rajasthan	-1.19NS (-1.68)	0.75^{NS} (1.62)	-2.29* (-3.48)	-8.98* (-8.88)	1.59* (2.27)	-0.07^{NS} (-0.15)	1.26** (2.03)
Tamil Nadu	-1.08* (-2.71)	-5.13* (-3.98)	-5.42* (6.49)	1.21*** (2.00)	-5.68* (-18.11)	-1.82* (-6.45)	-6.39* (-16.14)
Uttar Pradesh	0.19NS (1.07)	0.38* (5.58)	-6.44* (9.18)	0.71* (4.41)	-2.62* (-7.39)	-0.20** (-2.50)	-6.29* (-7.18)
West Bengal	-0.32** (-2.06)	0.57^{NS} (1.08)	22.08* (9.59)	-0.20^{NS} (-0.21)	1.82* (6.56)	-0.46* (-3.45)	6.34* (5.35)

Source: Department of Economics & Farmers' Welfare, Ministry of Agriculture, Government of India, New Delhi, India. Note: Estimated by using Semi- log model. Parentheses Values are t- values, *, ** & *** indicate 1, 5, 10 percent level of significance and NS indicates non-significant.

Table 3.3A: CARG of Production of Major Food and Non- Food grain Crops during 1966-90

States	Rice	Wheat	Cotton	Sugarcane	Total Oilseed	Food grain	Non-food grain
Andhra Pradesh	3.30* (9.80)	1.93^NS (1.23)	10.01* (9.12)	0.31^NS (0.79)	2.86* (4.40)	2.56* (9.22)	0.97* (2.80)
Bihar	2.08* (3.04)	5.50* (6.09)	-10.68* (-5.85)	-0.10^NS (-0.16)	1.64* (3.33)	2.23* (4.78)	0.30^NS (0.61)
Gujarat	3.15** (2.72)	2.38** (2.28)	-1.21^NS (-1.15)	8.53* (18.12)	2.41^NS (1.59)	3.02*** (1.88)	5.09* (9.73)
Haryana	8.26* (13.44)	6.46* (18.21)	4.92* (14.22)	-0.03^NS (0.06)	7.81* (7.06)	4.32* (10.99)	0.61* (1.17)
Himachal Pradesh	-0.27NS (-0.58)	2.62* (4.45)	-5.99* (-3.91)	-1.41^NS (-1.27)	-1.68*** (-1.86)	1.31* (4.42)	-1.51^NS (-1.44)
Jammu & Kashmir	2.34* (5.09)	2.30* (4.71)	-5.55* (-4.01)	-5.55^NS (0.12)	2.65* (3.23)	2.08* (5.79)	1.67** (2.39)
Karnataka	0.96* (3.04)	0.51^NS (0.43)	2.96* (4.00)	4.27* (16.07)	4.21* (8.23)	0.99** (1.80)	4.20* (17.70)
Kerala	-0.63* (2.68)	-	1.89* (4.09)	0.67NS (1.14)	-4.21* (-7.55)	-0.55* (-2.55)	0.53^NS (0.95)
Madhya Pradesh	2.42* (3.96)	4.56* (8.98)	0.21^NS (0.35)	0.29NS (0.44)	6.62* (15.15)	2.74* (6.80)	2.62* (5.05)
Maharashtra	2.77* (4.45)	3.72* (3.88)	0.15^NS (0.75)	4.85* (11.07)	3.93* (5.44)	3.33* (5.10)	2.40^NS (1.68)
Orissa	1.01** (2.00)	6.30* (3.82)	13.08* (6.41)	2.83* (8.24)	7.61* (18.01)	2.22* (5.08)	3.20* (12.01)
Punjab	12.76* (20.99)	5.39* (17.14)	2.13* (6.56)	0.79*** (1.81)	-3.18* (-5.90)	5.70* (25.66)	1.21* (3.19)
Rajasthan	2.76*** (1.87)	5.24* (11.78)	1.89* (5.00)	2.95NS (1.56)	8.74* (9.14)	2.38* (3.75)	5.36* (5.17)
Tamil Nadu	0.98** (2.34)	-4.99* (-4.43)	-1.87* (-4.07)	4.32* (10.01)	1.06** (2.46)	0.92** (2.39)	3.99* (10.06)
Uttar Pradesh	5.36* (10.18)	5.88* (18.46)	-4.95* (-8.70)	3.21* (10.08)	-1.89* (-3.71)	3.90* (12.29)	3.09* (9.83)
West Bengal	2.49* (6.31)	4.38** (2.22)	-12.42* (-6.12)	-2.77* (-3.72)	10.27* (16.72)	3.90* (12.29)	1.59* (3.52)

Source: Department of Economics & Farmers' Welfare, Ministry of Agriculture, Government of India, New Delhi, India. Note: Estimated by using Semi- log model. Parentheses Values are t- values, *, ** & *** indicate 1, 5, 10 percent level of significance and NS indicates non-significant.

Table 3.4A: CARG of Production of Major Food and Non- Food grain Crops during 1991-2012

States	Rice	Wheat	Cotton	Sugarcane	Total Oilseed	Food grain	Non-food grain
Andhra Pradesh	1.84* (3.48)	2.55* (2.81)	6.34* (7.34)	0.69NS (1.30)	2.38* (5.17)	1.02** (2.34)	-1.89*** (-1.85)
Bihar	-1.21^NS (-1.09)	0.17^NS (0.39)	-0.63^NS (0.52)	1.11^NS (0.99)	0.52^NS (0.99)	1.00^NS (1.04)	-0.36^NS (-0.86)
Gujarat	3.65* (4.00)	6.37* (4.69)	10.12* (6.80)	1.70* (5.18)	2.77* (3.13)	3.79* (9.38)	3.40* (2.52)
Haryana	3.56* (14.69)	2.70* (12.27)	2.85* (3.17)	-0.61^NS (-0.86)	2.59* (14.91)	0.14^NS (0.27)	0.86^NS (1.12)
Himachal Pradesh	0.67*** (1.90)	-0.40^NS (-0.46)	-11.10* (-3.25)	-0.56^NS (-0.32)	-0.11^NS (0.25)	-0.65^NS (-0.41)	-1.15^NS (-1.07)
Jammu & Kashmir	0.17^NS (0.39)	1.60^NS (1.72)	0.90* (1.73)	-34.05* (-8.03)	0.45^NS (1.39)	-1.26^NS (-0.53)	-0.12^NS (-0.05)
Karnataka	1.46** (2.45)	2.13** (2.43)	0.10^NS (0.08)	0.44^NS (0.41)	1.87* (3.09)	0.31^NS (0.31)	-2.44* (-3.57)
Kerala	-2.62** (-2.25)	-	-16.22* (-11.99)	-3.33* (-2.93)	-2.85** (-2.55)	-3.66* (-3.25)	-12.19* (-8.05)
Madhya Pradesh	-3.63* (-5.35)	3.51* (14.64)	-5.49* (-2.90)	-1.53** (-2.21)	-3.91* (-3.09)	-0.98^NS (-0.83)	-5.22** (-1.85)
Maharashtra	0.51^NS (1.13)	3.96* (4.40)	1.45* (4.37)	3.81* (3.19)	0.44^NS (0.77)	4.06* (3.79)	5.23* (7.54)
Orissa	0.78^NS (1.10)	-4.61** (-2.37)	14.20* (9.27)	-2.96** (-2.47)	7.15* (6.44)	-2.76* (-2.77)	-3.51* (-2.59)
Punjab	2.63* (14.41)	1.30* (6.65)	-1.27** (-2.54)	-1.94** (-2.07)	1.70* (11.37)	-1.17^NS (-1.66)	-7.91* (-9.21)
Rajasthan	2.40** (2.25)	2.42* (4.36)	-2.29* (-3.48)	-7.12* (-6.26)	2.63* (3.41)	1.90* (2.04)	4.24* (4.49)
Tamil Nadu	-0.43^NS (-0.34)	-4.51* (-4.50)	-5.42* (-6.49)	1.21^NS (1.65)	-0.59^NS (-0.57)	0.99^NS (1.37)	-2.77** (-2.52)
Uttar Pradesh	0.96** (2.51)	1.66* (7.99)	-6.44* (-9.18)	0.57** (2.40)	1.08* (5.47)	0.54** (2.31)	-2.12* (-4.66)
West Bengal	1.17* (5.56)	1.55* (3.27)	22.08* (9.59)	1.66^NS (1.35)	1.08* (5.47)	2.09* (5.40)	3.34* (7.70)

Source: Department of Economics & Farmers' Welfare, Ministry of Agriculture, Government of India, New Delhi, India. Note: Estimated by using Semi- log model. Parentheses Values are t- values, *, ** & *** indicate 1, 5, 10 percent level of significance and NS indicates non-significant.

Table: 4.1A: Agro-climatic Zones and Geographical distribution of the States

Agro-climatic Zones	States
Western Himalayan Region	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
Eastern Himalayan	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, West Bengal
Lower-Gengatic Plain	West Bengal
Middle- Gangatic Plain	Uttar Pradesh
Upper Gangetic Plain	Uttar Pradesh, Bihar
Trans-Gangetic Plain	Chandigarh, Delhi, Haryana, Punjab, Rajasthan
Eastern- Plateau and Hills	Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra
Central- Plateau and Hills	Madhya Pradesh, Rajasthan, Uttar Pradesh
Western- Plateau and Hills	Madhya Pradesh, Maharashtra
Southern- Plateau and Hills	Andhra Pradesh, Karnataka, Tamil Nadu
East-Coast Plains and Ghat	Andhra Pradesh, Orissa, Pondicherry, Tamil Nadu
West-Coast Plains and Ghat	Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu
Gujarat- Plains and Hills	Gujarat, Dadra & Nagar Haveli, Daman & Diu
Western Dry Region	Rajasthan
Island Region	Andaman & Nicobar Islands, Lakshadweep

Source: Adopted from Department of Economics & Farmers' Welfare, Ministry of Agriculture, Government of India, New Delhi, India.

Table 4.2A: Name of the States and Districts

States	Districts
Andhra Pradesh	Srikakulam, Vishakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Nellore, Kurnool, Anantpur, Cuddapur, Hyderabad, Nizamabad, Medak, Mahabubnagar, Nalgonda, Warangal, Khammam, Krishna Nagar, Adilabad
Assam	Cachar, Darrang, Dibrugarh, Goalpara, Kamrup, Karbi Anglong, Lakhimpur, North Cachar Hill, Nowgong, Sibsagar
Bihar	Champaran, Muzaffarpur, Darbhanga, Saharsa, Purenea, Saran, Patna, Monghys, Bhagalpur, Shahabad, Gaya
Gujarat	Ahmedabad, Amreli, Banaskantha, Baroch, Baroda, Bhavnagar, Busal, Bangs, Jamnagar, Junagarh, Kaira, Katch, Mehsana, Panch Mahal, Rajkot, Sabar Kanta, Surat, Surendra Nagar
Haryana	Hisar, Gurgaon, Jind, Mahendragarh, Ambala, Rohtak
Himachal Pradesh	Bilaspur, Chamba, Kanga, Kinnaur, Kullu, Lajauli & Spiti, Solan, Mandi, Shimla, Sirmaur,

Karnataka	Banglore, Kator, Tumkur, Mysore, Mandya, Harar, Shimoga, Chickmagalur, Chitadurga, Bellary, Dharwad, Belgaum, Bijapur, Bidar, Raichur, Gulbarga, Dakshina Kannara, Uttara Kannara
Kerala	Coorg, alapuzha, Kannur, Ernakulam, Koltayam, Kozhikoda, Palkkad, Palkkad, Kollam, Thrisur, Thiruvantpuram,
Maharashtra	Bombay, Thane, Raigad, Ratnagiri, Nasik, Dhulia, Jalgaon, Ahmad Nagar, Pune, Satara, Sangli, Solapur, Kolhapur, Aurangabad, Parbhari, Beed, Nanded, Ormanabad, Buldhara, Akola, Amravati, Yeotmal, Wardha, Nagpur, Bhandhara, Chandarpur
Madhya Pradesh	Jabalpur, Bagalpur, Chindwara, Narsingpur, Seoni, Mandla, Sagar, Damoh, Tikamgarh, Chatarpur, Panna, Reva, Sidhi, Satna, Shahdal, Gwaliar, Shivpur, Guna, Datia, Morena, Bhind, Indore, Ratlam, Ujjain, Mandsaur, Dewas, Shar, Jhabua, Khargore, Khandwa, Sohore, Raisen, Vishisa, Betul, Rajgarh, Shajapur, Hosangabad
Orissa	Balasore, Bolangir, Cuttak, Dhankanal, Gunjan, Kalahandi, Keonjhar, Korapat, Mayurbhanj, Pulbari, Puri, Sambhalpur, Sundergarh
Punjab	Gurdaspur, Ammritsar, Kapurthala, Jalandhar, Hoshiyarpur, Roop Nagar, Ludhiyana, Ferozpur, Bhatinda, Sungrur, Patiala
Rajasthan	Ajmer, Alwar, Banswara, Barmer, Bharatpur, Bhilwara, Bikaner, Bundi, Chittorgarh, Churu, Dungarpur, Ganganagar, Jaipur, Jaisalmer, Jalore, Jhalawar, Jhanjhunu, Jodhpur, Kota, Nagour, Pali, Sawaimadhopur, Sikar, Sorohi, Tonk, Udaipur
Tamil Nadu	Chengaltty, South Arcot, Cuddalor, Vellore, Salen, Coimbatore, Tiruchirapalli, Tanjavur, Madurai, Ramanthapuram, Tirunelvei, Nilgiris, Kanyakumari
Uttar Pradesh	Saharanpur, Mazaffar Nagar, Meerut, Bulandsahar, Aligarh, Mathura, Agra, Mainpuri, Etah, barely, Badaun, Moradabad, Sahajhanpur, Pilibhit, Rampur, Bijnor, Farukhabad, Etawah, Kanpur, Fetehpur, Allahabad, Jhansi, Jalaun, Hamirpur, Banda, Vanarasi, Mirzapur, Jaounpur, Gazipur, Balia, Gorakhapur, Deoria, Basti, Azamgarh, Lucknow, Unnao, Rai bareli, Sitapur, Hardoi, Kheri, Faizabad, Gonda, Bahraich, Sultanpur, Pratapgarh, Barabanki
West Bengal	24 Pargana, Nadia, Murshidabad, Burdwan, Birbhum, Bankura, Hoogly, Hawrah, Jalpaigudi, Darjeeling, Malda, Cooch Behar, Purulia, Midnapur

Source: Estimated from ICRISAT database.

Table 4.3A: Im-Pesaran-Shin Unit-Root Test for Stationary

Productivity	P-Value	Irrigated Area	P-value	Sown Area	P-value
Rice	0.001	Rice	0.002	Rice	0.001
Wheat	0.002	Wheat	0.001	Wheat	0.000
Sorghum	0.003	Sorghum	0.003	Sorghum	0.002
Pearl Millet	0.004	Pearl Millet	0.005	Pearl Millet	0.000
Maize	0.006	Maize	0.007	Maize	0.006
Finger Millet	0.002	Finger Millet	0.005	Finger Millet	0.003
Barley	0.001	Barley	0.006	Barley	0.000
Chickpea	0.009	Chickpea	0.003	Chickpea	0.001
Pigeon pea	0.001	Pigeon pea	0.003	Pigeon pea	0.000
Rabi Pulses	0.002	Rabi Pulses	0.000	Rabi Pulses	0.000
Groundnut	0.002	Groundnut	0.000	Groundnut	0.002
Lime seed	0.006	Lime seed	0.000	Lime seed	0.000
Soybean	0.007	Soybean	0.002	Soybean	0.000
Sugarcane	0.005	Sugarcane	0.0004	Sugarcane	0.003
Cotton	0.002	Cotton	0.000	Cotton	0.000

Source: Estimated from CRISAT database. Note: Null Hypothesis is datasets contain unit root. It is confirm through p- value that datasets do not have unit root problem.

Table 4.3A: Im-Pesaran-Shin Unit-Root Test for Stationary

Rainfall in Sowing	P-value	Rainfall in Germination	P-value	Rainfall in Harvesting	P-value
Rice	0.002	Rice	0.002	Rice	0.001
Wheat	0.006	Wheat	0.005	Wheat	0.002
Sorghum	0.001	Sorghum	0.001	Sorghum	0.003
Pearl Millet	0.009	Pearl Millet	0.003	Pearl Millet	0.009
Maize	0.001	Maize	0.002	Maize	0.006
Finger Millet	0.002	Finger Millet	0.000	Finger Millet	0.002
Barley	0.003	Barley	0.001	Barley	0.001
Chickpea	0.005	Chickpea	0.002	Chickpea	0.003
Pigeon pea	0.003	Pigeon pea	0.000	Pigeon pea	0.007

Rabi Pulses	0.001	Rabi Pulses	0.010	Rabi Pulses	0.001
Groundnut	0.010	Groundnut	0.002	Groundnut	0.003
Lime seed	0.002	Lime seed	0.002	Lime seed	0.007
Soybean	0.000	Soybean	0.005	Soybean	0.003
Sugarcane	0.005	Sugarcane	0.006	Sugarcane	0.005
Cotton	0.008	Cotton	0.008	Cotton	0.006

Source: Estimated from CRISAT database. Note: Null Hypothesis is datasets contain unit root. It is confirm through p- value that datasets do not have unit root problem.

Table 4.3A: Im-Pesaran-Shin Unit-Root Test for Stationary

Minimum Temperature in Sowing	P-Value	Minimum Temperature in Germination	P-value	Minimum Temperature in Harvesting	P-value
Rice	0.001	Rice	0.002	Rice	0.008
Wheat	0.002	Wheat	0.000	Wheat	0.004
Sorghum	0.003	Sorghum	0.002	Sorghum	0.003
Pearl Millet	0.005	Pearl Millet	0.003	Pearl Millet	0.010
Maize	0.000	Maize	0.001	Maize	0.010
Finger Millet	0.000	Finger Millet	0.008	Finger Millet	0.003
Barley	0.006	Barley	0.000	Barley	0.006
Chickpea	0.000	Chickpea	0.000	Chickpea	0.002
Pigeon pea	0.007	Pigeon pea	0.010	Pigeon pea	0.004
Rabi Pulses	0.000	Rabi Pulses	0.003	Rabi Pulses	0.006
Groundnut	0.008	Groundnut	0.000	Groundnut	0.003
Lime seed	0.000	Lime seed	0.002	Lime seed	0.005
Soybean	0.004	Soybean	0.000	Soybean	0.000
Sugarcane	0.000	Sugarcane	0.003	Sugarcane	0.010
Cotton	0.003	Cotton	0.000	Cotton	0.003

Source: Estimated from CRISAT database. Note: Null Hypothesis is datasets contain unit root. It is confirm through p- value that datasets do not have unit root problem.

Table 4.3A: Im-Pesaran-Shin Unit-Root Test for Stationary

Maximum Temperature in Sowing	P-Value	Maximum Temperature in Germination	P-value	Maximum Temperature in Harvesting	P-value
Rice	0.001	Rice	0.001	Rice	0.001
Wheat	0.002	Wheat	0.002	Wheat	0.002
Sorghum	0.003	Sorghum	0.000	Sorghum	0.004
Pearl Millet	0.002	Pearl Millet	0.004	Pearl Millet	0.002
Maize	0.004	Maize	0.000	Maize	0.010
Finger Millet	0.004	Finger Millet	0.003	Finger Millet	0.002
Barley	0.000	Barley	0.000	Barley	0.010
Chickpea	0.010	Chickpea	0.002	Chickpea	0.002
Pigeon pea	0.002	Pigeon pea	0.000	Pigeon pea	0.003
Rabi Pulses	0.000	Rabi Pulses	0.010	Rabi Pulses	0.010
Groundnut	0.001	Groundnut	0.002	Groundnut	0.004
Lime seed	0.000	Lime seed	0.002	Lime seed	0.003
Soybean	0.007	Soybean	0.003	Soybean	0.000
Sugarcane	0.000	Sugarcane	0.000	Sugarcane	0.002
Cotton	0.004	Cotton	0.010	Cotton	0.009

Source: Estimated from CRISAT database. Note: Null Hypothesis is datasets contain unit root. It is confirm through p- value that datasets do not have unit root problem.

Table 4.4.A: Hauseman Test, Pesaran CD Test, Wald Test and Wooldridge Test

Model Crop	Hausman Test for Random Effect Model	Pesaran CD test for Cross Sectional Dependence	Modified Wald test for Heteroskedasticity	Wooldridge test for Serial Correlation and Auto-correlation
	Prob>chi2	Pr- Value	Prob>chi2	Prob>chi2
Rice	0.0021	0.0020	0.0000	0.0017
Wheat	0.0020	0.0039	0.0025	0.0015
Sorghum	0.0030	0.0031	0.0054	0.0013
Pearl Millet	0.0028	0.0023	0.0034	0.0016
Maize	0.0029	0.0027	0.0065	0.0016
Finger Millet	0.0000	0.0045	0.0056	0.0076
Barley	0.0027	0.0032	0.0038	0.0034
Chickpea	0.0032	0.0043	0.0013	0.0041
Pigeon pea	0.0054	0.0024	0.0045	0.0017
Rabi Pulses	0.0032	0.0046	0.0057	0.0018
Groundnut	0.0038	0.0000	0.0018	0.0098
Lime seed	0.0029	0.0021	0.0026	0.0081
Soybean	0.0031	0.0034	0.0018	0.0000
Sugarcane	0.0041	0.0027	0.0017	0.0017
Cotton	0.0040	0.0018	0.0019	0.0000

Source: Estimated from CRISAT database. Note: Null Hypothesis for fixed effect model in Hausman test is: fixed effect is best fit model, for Pesaran CD test for cross sectional dependence is: residuals are not correlated, for Modified Wald test for Heteroskedasticity is: Homoskedasticity or constant variance, Wooldridge test for serial correlation and auto-correlation is: no correlation. It is confirm through Prob>chi2 and Pr- value that data sets contain cross sectional dependence, heteroskedasticity and serial correlation & auto-correlation.

Table 4.5A Classification of Sowing, Germination and Harvesting Periods

Crop	Sowing	Germination	Harvesting
Rice	May-June	July-August	September-October
Wheat	October-November	December-February	March-April
Sugarcane	January-February	March-July	August-November
Pearl Millet	June-July	August-September	October
Maize	March-April	May-August	September-December
Lime Seed	October-November	December-February	March-April
Groundnut	June-July	August-September	October- November
Chickpea	October-November	December-January	February-March
Soybean	June-July	August	September-October
Sorghum	September-October	November-February	March-April
Finger Millet	May-June	July-August	September-December
Pigeon Pea	June	July-October	November-January
Rabi Pulses	October-November	December-February	March-April
Barley	November	December-March	April-May
Cotton	April-May	May-August	September-October

Source: Indian Council of Agriculture Research, New Delhi, India.

Table 5.1A: Major and sub components for Livelihood Security Index

Major Component	Sub Components
Exposure	Percentage of households feel that rainfall is decline over the last five years
	Percentage of households perceive that summer days become more hotter
	Percentage of households perceives that increasing of frequencies of drought over the last five years
	Percentage of households perceive that water level decline over the last five years
Sensitivity (Natural Capital, water, health and Food)	Natural Capital- Percentage of households using only forest based energy for cooking purposes
	Water- percentage of households using Hand Pump water for drinking
	Food- Average crop diversity Index
	Percentage of Households depends on government sources for Irrigation
	Percentage of Households depends on head of household
	Health- Percentage of households using 108 free medical facility
	Percentage of households do not have toilet facilities
	Percentage of households do not have Pucca house
	Percentage of households belongs to BPL category

Adaptive Capacity (socio-demographic profile, livelihood strategies	Percentage of female- headed households
	Percentage of head of household does not attained school
	Percentage of households solely dependent on agriculture as source of income
	Average number of households who have burden of loan
	Percentage of households changed their cropping pattern
	Percentage of households call Kisan Call Centre
	Percentage of households live as a Joint family

Source: Estimated from Field Survey Data & Adopted from Hahn et al., 2009.

Table 5.2A: Major Indicators for constructing the Climate Vulnerability Index (CVI)

Major Components	Sub Components
Exposure	Percentage of households feel that rainfall is decline over the last five years
	Percentage of households perceive that summer days become more hotter
	Percentage of households perceives that increasing of frequencies of drought over the last five years
	Percentage of households perceive that water level decline over the last five years
Sensitivity	Percentage of households that perceived high impact of drought on the farming system.
	Percentage of households perceived that heat waves are become more frequent.
	Percentage of households perceived that temperature has been increasing over the last five years
	Percentage of survey population reporting agriculture as the only source of income
	Average crop diversity index (range: 0-1)
	Percentage of households belongs to BPL category
	Average number of dependents on Head of household (unemployed)
Adaptive Capacity	Percentage of farmers having crop insurance
	Percentage of households changes their cropping pattern
	Percentage of households switch to non-farm activities
	Percentage of households using improved irrigational facilities

	Percentage of households planted tress surrounded of the field
	Percentage of households are using early maturing varieties
	percentage of head of households belongs to illiterate education level (we take illiterate as a base)
	Percentage of households call Kisan Call Centre

Source: Estimated from Field Survey Data. Note: The inverse of (the number of crops grown by a household +1) e.g. a household that grows rice, cotton will have a crop diversity index = 1/(2+1) = 0.33.

Table 5.3A: Percentage distribution of sub-components of exposure, sensitivity and adaptive capacity for Livelihood Vulnerability Index

Sub-Component	Karson	Kaithi	Pahladpur	Biriya	Aata	Jalaun district	Dunora	Nimoni	Amra	Gadvai	Birora	Jhansi district
Exposure												
Rainfall	90	95	95	65	40	77	70	75	42	33	60	56
Temperature	90	95	95	90	80	90	100	95	100	95	100	98
Drought	90	95	100	85	80	90	95	90	94	95	100	95
Water level	85	85	95	100	100	93	95	95	90	100	100	96
Sensitivity												
Natural Capita	90	75	55	65	55	68	40	25	47	71	35	44
Water	65	60	95	40	45	61	30	60	63	66	80	60
Food	45	36	48	46	40	43	48	41	36	30	43	40
Irrigation	85	25	45	45	85	57	5	45	73	57	65	49
Dependency	65	59	58	65	71	64	66	64	63	59	60	62
Health	00	25	20	80	70	39	60	65	94	90	55	73
Toilet	55	50	40	45	25	43	50	40	53	57	45	49
Nature of House	30	25	05	40	35	27	5	15	5	19	10	11
BPL	30	30	15	40	30	29	35	0	16	29	30	22
Adaptive Capacity												
Female Head	5	3	25	15	5	16	5	0	32	10	5	10
Illiteracy	4	25	4	3	35	34	20	30	30	25	20	25
Income	7	8	5	7	9	7	9	17	11	20	10	13
Loan	35	45	20	10	10	24	5	11	14	15	0	9
Cropping pattern	45	0	5	20	30	20	90	10	95	86	90	74
IT	25	60	35	15	55	38	20	50	47	43	10	34
Joint Family	4	30	10	50	40	34	5	30	84	81	50	50

Source: Estimated from Field Survey Data. Note: Figures are in percent.

Table 5.4A: Percentage distribution of sub-components of exposure, sensitivity and adaptive capacity for Climate Vulnerability Index

Sub-Component	Karson	Kaithi	Pahladpur	Biriya	Aata	Jalaun district	Dunora	Nimoni	Amra	Gadvai	Birora	Jhansi district
Exposure Index												
Rainfall	90	95	95	65	40	77	70	75	42	33	60	56
Temperature	90	95	95	90	80	90	100	95	100	95	100	98
Drought	90	95	100	85	80	90	95	90	94	95	100	95
Water level	85	85	95	100	100	93	95	95	90	100	100	96
Sensitivity												
Drought	90	95	100	85	80	90	95	90	94	95	100	95
Heat Waves	00	100	90	95	100	97	100	95	100	100	85	96
Temperature	95	90	80	85	100	90	85	85	15	19	10	43
Agricultural Income	07	8	5	7	9	7	9	17	11	20	10	13
Average Crop Diversity Index	45	36	48	46	40	43	48	41	36	30	43	40
BPL Card	30	30	15	40	30	29	35	0	16	29	30	22
Dependency on Head of Household	65	59	58	65	71	64	66	64	63	59	60	62
Adaptive Capacity												
Crop Insurance	5	5	10	0	5	5	0	0	0	0	0	0
Cropping Pattern Change	35	45	20	10	10	24	5	11	14	15	0	9
Non - Farm Activities	35	35	45	20	30	33	5	15	0	0	10	6
Improved Irrigation	25	20	10	60	60	35	85	75	89	85	75	82
Plantation	30	55	70	60	40	51	60	50	47	95	100	71
Early Maturing Varieties	65	45	30	40	60	48	40	45	52	5	0	28
Illiterates	40	25	40	30	35	34	20	30	30	25	20	25
Information Technology	45	0	5	20	30	20	90	10	95	86	90	74

Source: Estimated from Field Survey Data. Note: Figures are in percent.

Structured Schedule

Section- 1

General Information

1. Name of the Respondent:……………………..
2. Name of the District:………………………….
3. Name of the Tahsil:……………………………
4. Name of the Block:……………………………
5. Name of the Village:………………………….
6. Nature of Family:…………………………….
7. Number of Family Members:………………..
8. Caste of the Respondent:…………………….
9. Religion of the Respondent:…………………
10. Land Size:…………………………………….

Household Profile

Name of the Family Member	Age	Gender @	Education Qua. &	Occupational Status %	Secondary Occupation	Marital status *	Annual Income

@ (Male-1, Female-2)
# (General-1, OBC-2, SC-3, ST-4, Others-5)
$ (Hindu-1, Muslim-2, Christian-3, Others-4)
& (illiterate-1, Literate without formal schooling-2, literate below primary-3, Junior-4, Secondary-5, Senior Secondary-6,
Diploma/Certificate-7, Graduate-8, Post Graduate-9)
% (self-employed- 1, Agricultural labour-2, Non-Agricultural labour-3)
*(Married-1, Unmarried-2, and Widow-3)

Q.1 Nature of the House

1. Kutch ☐ 2. Semi-Pukka ☐
3. Pukka ☐ 4. Any other, please specify……………..

Q.2 What is the main source of Drinking Water?

1. Hand pump ☐ 2. Public tap ☐
3. Pipe water ☐ 4. Any other, please specify………………..

Q.3 Sanitation Facility

1. Dry latrine ☐ 2. Flush ☐

3. Open field ☐ 4. Public sanitation facility ☐

5. Any other, please specify…………………………………….

Q.4 Do you own a Ration Card?

1. Yes ☐ 2. No ☐

Q. 5 If yes, then which type of Ration Card you own?

1. BPL ☐ 2. APL ☐

3. Antyodya ☐ 4. Any other, please specify…………..

Q. 6 You have Electricity Connection

1. Yes ☐ 2. No ☐

Q. 7 How many hours per day you are getting Electricity?

…………………………………………………………

Q. 8 Cooking Device

1. Gas ☐ 2. Chulha ☐

3. Angeethi ☐ 4. Any other, please specify………

Q. 9 Household Assets

Items	Answer		If yes then how many	Purchase Value
	Yes	No		
Car and Jeep				
Bicycle				
Motorcycle				
Bullock Cart				
Fodder cutting machine				
Tractor				
T.V.				
Refrigerator				
A.C.				
Mobile Phone				
Water pump				
Any other				

Q. 10 Do you know about free Medical Facilities?

1. Yes ☐ 2. No ☐

Q. 11 If yes, then which type of facility you have used?

………………………………………………………

Section-2

(A) Land holding

Type-I (Irrigated land)	Nature of Land	Area (in Acres)	Present Value
	Owned		
	Lease In		
	Lease Out		
Type- II (Non-Irrigated)	Owned		
	Lease In		
	Lease Out		
Type-III (Fallow land	Owned		
	Lease In		
	Lease Out		
Total Value of land holding………………………………………………………			

Agriculture

(B) Cropping Pattern (2014-15)

Q.12 Cropping Pattern

Name of the Crop	Area (in Acre)	Production (in Quintal)

Q.13 Are you taking multiple Cropping Season?

1. Yes ☐ 2. No ☐

Q.14 if yes, then how much Cropping Season you are taking?

1. One ☐ 2. Two ☐ 3. Three ☐

Q.15 Are you using whole land for Food grains Crops?

1. Yes ☐ 2. No ☐

Q.16 If no, then what you do with remaining Land?

1. Vegetable ☐ 2. Horticultural Crops ☐

3. Apiculture Crops ☐

4. Any other, please specify……………….

Q. 17 Do you have grain storage space in your Home?

1. Yes ☐ 2. No ☐

Q. 18 If yes, then storage capacity is sufficient

1. Yes ☐ 2. No ☐

Section-3
Agriculture Inputs

(B) Irrigation

Name of the Crop	Source of Irrigation		Irrigation agency	Number of Irrigation		Cost per hours	Total Costs
	Surface	Ground	Government	Private			

Q.19 If you are depends on Government Sources, whether water is available on time

1. Yes ☐ 2. No ☐

Q.20 Water provided by Government Agency is enough to feed your requirement?

1. Yes ☐ 2. No ☐

Q.21If you are depends on Private Sources, then water is available on time?

1. Yes ☐ 2. No ☐

(C) Seeds

Name of the Crop	Nature of the seeds	Source		Area	Quantity	Price per K.G.		Total Value
		Government	Private			Govt.	Pri.	

Q. 22 Before applying seeds in the Field, you have treated?

1. Yes ☐ 2. No ☐

Q.23 if yes, then which techniques you are followed

1. Bio- treatment ☐ 2. Chemical- treatment ☐

Q. 24 How much cost you bear for one K.G. seeds for treatment?

1. Bio-treatment…………………………………

2. Chemical-treatment………………………….

(E) Fertilizers Consumption

Q.25Fertilizers Consumption

Name of the Crop	Area	Source		Types of Fertilizer		Quantity of Fertilizer	Price per Q.	Total Value
		Gov.	Priv.	Bio.	Chem.			

Q. 26 Do you know about suitable mix of NKP?

1. Yes ☐ 2. No ☐

Q. 27 if yes, then you are follows suitable mix conditions

1. Yes ☐ 2. No ☐

Q. 28 if no, then how to ensure that quantity you are using is sufficient?

……………………………………………………………………………….

Q. 29 How many days prior to harvest were the chemical fertilizers are applied?

……………………………………………………………………………….

Q. 30 Do you observed that after regular uses of chemical fertilizers, quality of soil is declining

1. Yes ☐ 2. No ☐

Q. 31 Do you observed that after regular uses chemical fertilizers water quality is declining

1. Yes 2. No

Q. 32 Are you taking proper precaution at the time of chemical fertilizers injected in the soil?

1. Yes 2. No

Q. 33 After injection of chemical fertilizers, in case of vegetable/ fruits, how many day after you harvest to the crop……………………………………………………………

(F)Pesticides

Name of the Crop	Area	Source		Types of pesticides		Quantity of pesticides	Price per 100 ml	Total Value
		Gov.	Priv.	Bio	Chem.			

Q. 34 Which types of safety you have taken at the time of use of chemical pesticides

…………………………………………………………………….

Q. 35 Is there any camp is organized by agricultural department for awareness and safety

measures in last one year

1. Yes 2. No

Q. 36 Do you observed that after regular uses of chemical pesticides, quality of soil is declining

1. Yes 2. No

Q. 37 Do you observed that after regular uses chemical pesticides water quality is declining

1. Yes 2. No

Q. 38 Are you taking proper precaution at the time of chemical pesticides injected in the soil?

1. Yes ☐ 2. No ☐

Q. 39 After injection of Chemical Pesticides, in case of Vegetable/ fruits, how much day after you harvest to the crop…………………………………………………

(G)Cultivators Tool

Name of Crop	Area	Ownership		Name of the Cultivators tool	Price per Hours	Total Value
		Self	Private			

Q. 40 Reasons behind less use of Technical Cultivation Tools

1. Decline land size ☐
2. Non- availability on time ☐
3. High cultivation cost ☐
4. Any other, please specify……………………………

(H)Labour

Name of the Crop	Area (in Acre)	Quantity of labor	Nature of the labour		Wages per labor		Total Value
			Hired	self	Male	Female	

Q. 41 Labour is available on time and as much you required?

1. Yes ☐ 2. No ☐

(I)Livestock Assets

Livestock	How many	Grazing space		Annual income
		Stalled	Open	
Poultry				
Pigs				
Goats				
Cows				
Bullocks				
Buffaloes				
Sheeps				
Other				

(J)Loan

Name of the Crop	Source		Total amount	Interest rate	Amount		Unpaid amount after due date
	Banks /SHGs	Private			Paid	Unpaid	

(K) Institutional Source

Q. 42 Do you know about Kisan Call Centre

1. Yes ☐ 2. No ☐

Q. 43If yes, then information as you required easily received

1. Yes ☐ 2. No ☐

Q. 44 Information provided by Kisan Call Centre is appropriate

1. Yes ☐ 2. No ☐

Q. 45 Has government is established any weather station in your area

1. Yes ☐ 2. No ☐

Q. 46 If yes, then it is provided information on regular basis

1. Yes ☐ 2. No ☐

Section- 4

Farmer's Perception on Climate Change

Q. 47 Do you feel that weather pattern in your area is changing over the last five years?

1. Yes ☐ 2. No ☐

Q. 48 If yes, then is there any significant impact occurring in your area

1. Yes ☐ 2. No ☐

Q. 49 If Yes, which climatic factor is affecting your farming?

1. Rainfall ☐ 2. Temperature ☐
3. Both ☐ 4. Any other………………

Q. 50 Do you observed that distribution of rainfall is significantly change over the last five years

1. Yes ☐ 2. No ☐

Q. 51 If yes, then what changes happened?

1. Less rainy days ☐ 2. High intensity ☐
3. Less rainfall ☐ 4. Any other, please specify…………

Q. 52 Has Rainfall is distributed within monsoon season (June-September)?

1. Yes ☐ 2. No ☐

Q. 53 If no, then rainfall distribution occurring

1. During Pre-Monsoon period ☐
2. Post Monsoon Period ☐
3. Any other, please specify……………………………………

Q. 54 Do you observed that frequency of droughts is increasing over the last five years?

1. Yes ☐ 2. No ☐

Q. 55 If yes, then which types of consequences you are observed?

1. Responsible for death of human/livestock ☐
2. Decline surface water level ☐
3. Responsible for decline in agricultural production ☐
4. Any other, please specify……………………………………………………….

Q. 56 Do you observed that mean temperature is increasing over the last five years?

1. Yes ☐ 2. No ☐

Q. 57 If yes, then which consequences you found?

1. Responsible for crop fire
2. Responsible for crop failure
3. Decline crop duration
4. Any other, please specify………………………………………………………

Q. 58 Do you think that frequency and intensity of heat waves is increases over the last five years?

1. Yes 2. No

Q. 59 Do you observed that intensity of pest is increases over last five years?

1. Yes 2. No

Q. 60 Do you think that planting dates are changing over the last five years in your area?

1. Yes 2. No

Section- 5

Copping Strategies against Climate Change

Q. 61 Do you covered your cropping pattern from Insurance?

1. Yes 2. No

Q. 62 If yes, name of the source

1. Government 2. Banks

Q. 63 Do you know about National Agriculture insurance Scheme

1. Yes 2. No

Q. 64 If no, then why don't you have crop insurance?

1. Not important 2. Too expensive
3.Don't know about the scheme 4.Complicated process
5. Any other, please specify………………………….

Q. 65 If yes, then when crop is lost due to climatic factor, is compensation is provided on time

1. Yes 2. No

Q. 66 Is the Compensation sufficient against agricultural lost?

1. Yes 2. No

Q.67 If you secured your crop through banks insurance, then how much you spend

Name of the Crop	Season	Premium	Total amount for crop

Q. 68 when rainfall is distributed in deficit, then which techniques you followed

1. Changes Cropping Pattern
2. Switching to more non-farm income
3. Improved irrigation facilities
4. Increases use of water and soil conservation techniques
5. Uses of new HYV
6. Any other, please specify………………………………………..

Q. 69 when temperature is increases then how to sustain your farming?

1. Planted trees surrounded of the field
2. Uses early maturing varieties
3. Uses temperature tolerance varieties

Q.70 When water level is decline due to less rainfall and high temperatures, then what will do?

1. Increase in depth of bore well
2. Switch less water consuming crops
3. Uses more fertilizers
4. Any other, Please specify……………………………………..

Q. 71 Are you adjusting the timing of irrigation in recent years to deal with less rainfall in your area?

1. Yes 2. No

Q. 72 Intensity of pest is increases in your areas, then how to tackle them?

1. Uses more pesticides
2. Followed crop diversification
3. Uses mixture of Bio and Chemical pesticides
4. Uses pest tolerance varieties
5. Any other, Please specify……………………………

Signature of the Respondent