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Impact of Climate Change on Agricultural Productivity and Food Security Resulting in Poverty in India

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Abstract

"Tackling Climate Change is closely linked to poverty alleviation and economic development; I would call them different sides of the same coin."

- *Paul Polman, CEO, Unilever*

Climate change has been considered to have catastrophic effects on planet Earth. It has become a major barrier to developing economies, like India where agriculture accounts for 55 per cent of its total working population (Registrar General 2013) and constitutes about 14.1 per cent of its GDP (GoI, 2013). Moreover, due to the alteration in climate, crop productivity is being affected adversely resulting in food and livelihood security issues. This study is based on state level data of 4 major seasonal Indian crops- Rice, Wheat, Cotton, Sugarcane which comprise of Food and Cash crops for the time span of 2004 to 2013. 7 agriculturally intensive states with varied climatic conditions have been taken into consideration for the study. States under tropical zones include West Bengal, Maharashtra, Uttar Pradesh, Gujarat, while the subtropical regions are Andhra Pradesh, Tamil Nadu and Karnataka. This thesis makes an attempt to analyze the impact of climate change on Indian Agriculture and food security. It also examines the implications of climate change on food security and evaluates the multiple benefits of mitigation and adaptation. Cobb Douglas production function will be incorporated in this model to simulate this impact of climate change on agricultural productivity. Majority of the crops taken into consideration are expected to be adversely affected by the future climatic conditions. Local adaptation practices have also been scrutinized, highlighting the role of institutional support, national adaptation strategies and resilience at different scales.

Keywords: Agricultural Productivity, Climate Change, Institutions, Panel Data, Government Policies, Food Security, Poverty

JEL Classification: C32, C33, Q18, Q54, Q58,

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Chapter 1: Introduction

Agriculture in India: An Overview

Agriculture plays a dominant role in the Indian economy and supplements the socio economic fabric of the country. It captures around 14% of the total GDP and is a source of employment to approximately 55% of the Indian population barring caste, creed, gender and origin. The performance of the agriculture sector has always had a huge impact on the trend of India's GDP. Presently, the primary sector employs nearly 58% of the rural population of the country. According to FAO, (2010), India is a leading producer of fruits, vegetables, milk, spices and several other food grains and second biggest producer of rice and wheat. Indian agriculture not only serves the nation with food grains but also contributes heavily towards the exports. It is the seventh largest agricultural exporter and delivers processed food to more than 120 countries across the globe. Tea, sugar, oilseeds, tobacco and spices are some of the major export commodities. According to Tripathi and Prasad, (2009), all sectors in India are significantly contingent on the agricultural sector and thus, constant improvement in this sector is important for the betterment of overall growth of the economy. Agriculture is a major supplier of raw materials for industry. Examples include cotton and jute for textiles, sugar and vegetable oil. Almost half of the total manufacturing sector is dependent on agriculture directly or indirectly.

While the growth of Indian economy has been quite impressive, the country still struggles with two major problems. Firstly, the widespread poverty and hunger is posing great challenges to the country's food security. India's poor population amounts to more than 300 million people. This issue gets elevated by the lack of awareness within farmers with worse off financial conditions (GOI, 2005) coupled with inadequate infrastructural facilities in rural areas. According to Srivastava, (2012), a very high percentage (46 per cent) of the children between three and six are malnourished which justifies the requirement for an increase in crop production that in turn will improve food security, having a positive effect on the overall economy. Secondly, Indian farmers are vulnerable to the effect of changing climate as approximately 60 per cent of cultivated land is rain fed and dependent on the monsoon season.

This study attempts to establish a relationship between agriculture and variation in climate. It also aims at analyzing the effect of agriculture on food security, proposing relevant solutions for the issues faced by this sector. In this chapter, Section one describes the commencement of Indian Agriculture and challenges. Section two highlights the history of Indian agriculture and how it emerged. Section three establishes a link between climate change, agriculture and food security. Section four addresses the problem of food security and poverty resulting from the problem of unavailability and insufficiency of agricultural produce. Section five presents the motive to carry out this research and captures the main idea of the thesis. It then proceeds to outline the essential research questions this thesis attempts to address.

1.1. Agriculture: An overview of commencement

At the dawn of civilization, man essentially survived by either hunting wild animals or by identifying and consequently, consuming edible plants. Herds of men flocked from one part of the world to the other in search of food once they had depleted the mentioned resources in their former habitations. But through all these wanderings, as man consistently devised new ways of survival, as he expanded his knowledge of nature's edible bounty- both flora and fauna alike- and yet nonetheless struggled to make ends meet, he finally began considering it worthy to have his quintessential flora and fauna always at his disposal. It was thus on a quest of a convenient survival that the nomadic lifestyles gave way to a system that led to settlement: on the first hand, he began gathering and cultivating food extensively, on the other hand, he also perfected the domestication of animals, in an epoch in which dogs were the only hunters and cattle was not reared but consumed.

This influx of harvest not only led to an increase in population, flourishing thus the first civilizations known to man, but it also resulted in the change of habitation of the first *homo sapiens*. Rather than living in primitive caves like animals, man now began to constructively move to permanent and semi-permanent establishments near its site of harvesting. One of the first examples of such villages can be traced back to Jericho, a village birthed near 9000 B.C that is even presently a site of habitation. Another early record of settlement, stemming from agriculture, is Catal Huyak on the Konya Plain in Turkey whose earliest traces date back to 6500 BC, similar to the aforementioned Jericho town.

Be it then in the Euphrates Valley or in ancient paranoiac Egypt, inhabitations went on a rise under the flagship of agriculture. Man started developing the first techniques of cultivation; he gained a deeper knowledge of the workings of the nature and began intensively taking advantage of the same. This is evident in the case of the people of Egypt, who apprehended the predictable flooding cycle of the river Nile that used to leave the land fertile upon inundation, giving way to a boom in agriculture. Moreover, this agriculture leading to a proportionate increase in settlements, equally resulted in the establishment of practices and crafts other than cultivation and harvesting. These settlements, these sites became the point of initiation of all crafts such as copper smiting, rope making etc. Therefore, with the assurance of a regular and a consistent food supply thanks to their new-found agricultural practices, rather than the nomadic wanderings that resulted in sporadic periods of hunger, these settlements eventually gave way to civilizations and the world as is depicted upon the canvas of our history began to take shape.

And, while the rest of the world was reaping the benefits of agriculture, in India too, a similar situation was transpiring. Let us now delve profoundly into the very fiber of Indian agriculture.

1.2. Ancient Indian Agriculture

The agriculture in India originated in 9000 BC when implements and new techniques to sustain agriculture were being developed. Those who were contingent on the agriculture as a source of living, prospered. The Neolithic epoch (9000 BC) consisted of agro pastoralism which was composed of three stages: threshing, planting two to six crops in a row and storing the crops in the granaries. Cultivation concentrated around the Kashmir Valley in 5000 BC. The Bronze Age Civilization, also called the Indus Valley Civilization developed by the basin of the river Indus surrounded by abundance of agricultural land. Peas, Dates, Rice and Sesame were some of the food grains popular in this era. Agriculture completely relied on rainfall and monsoon and the rain water was collected in the massive rocks designed to be used during the dry season. The settlement grew by 4500 BC and mixed farming became the main source of income for the Indus valley economy. Drainage and sewage systems were developed accompanied by a well-established irrigation plan.

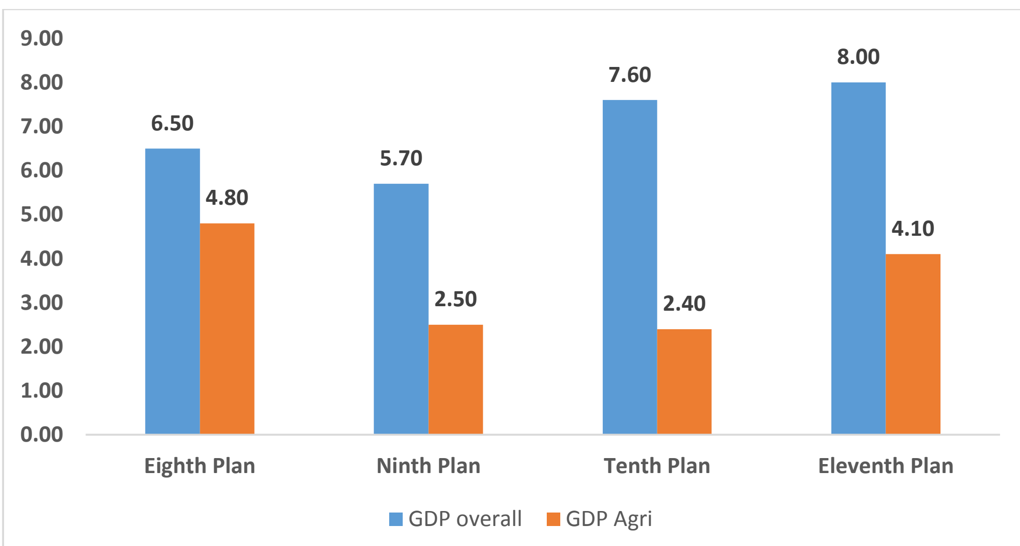
Persian and Muslim invasion was seen during the Middle-ages introducing the system of Landlords and middlemen. This structure led to the introduction of myriad of crops and strong management system. The Islamic rule paved way for agricultural trade introducing the Indian farmers to the western world. Then, the British raj soon overtook all the others in 1757. Their conduct towards administering Indian agriculture was castigated by agricultural economists all around the world. In the beginning, the country managed to export cotton, opium, wheat, rice and indigo under the British rule prevalent from 1757 to 1947. Moreover, India discovered and began the farming of sugarcane and certain spices. In this era, sugar and sugarcane production was only limited to India, reaching out to the rest of the world in the 19^{th} century. There was an increase in the cultivable land until the nineteenth century resulting in 1 percent per annum rise in the agricultural productivity. Between 1870 and 1920, crop prices rose three times as an extensive irrigation system developed with the help of community effort and private investments. However, cultivation of cash crops had deleterious effects on the farmers as the British trade policies were harsh on the poor farmers. Simultaneously, the Cotton and jute industries in Britain expanded tremendously.

Post- independence, improvement in agriculture sector and economic planning were prominent due to which area under cultivation and average yield per hectare increased rapidly. The government focused on improving the supply of food and cash crops. New programs were introduced in order to boost the production of food grains and to address the shortages. Technological progress in the early 1960s also contributed to the growing yield. The ‘Grow More Food’ Campaign in 1940s, the ‘Integrated Production Program’ in the 1950s and the ‘Five year plans’ focused on setting up high agriculture goals were being followed. Several other production revolutions like the Yellow Revolution (1986-1990), Operation flood (1970-1996), Blue revolution (1973-2002) etc. commenced after the evident success of the Green Revolution in the

1960s. Agriculture exports increased at 10.1 percent per annum in the 1990s and contract farming became popular raising the profit margins of the farmers. More stress was laid upon the use of fertilizers, high yielding varieties and changing cropping patterns and agricultural practices.

The beginning of the economic reforms in India in 1991 brought about volatility in the agriculture sector and its contribution towards the Gross Domestic Product. The figures have varied from 4.8 percent during 1992-1996 (Eighth Five Year Plan) to 2.40 percent in 2002-2006 (Tenth Five Year Plan).The share of agriculture and the distribution of population working in the sector reduced drastically post 1996. Even though there was a shift in the distribution of the working population from the agriculture to the industry and the service sector, maximum employment was still generated by the agriculture sector.

Figure 1.1: Agriculture Growth Rate during Different Plan Periods



Source: Central Statistics Office

As can be analyzed from the above-mentioned table, the average yearly performance of the agriculture sector went up to 5 percent whereas the GDP of the country grew to 9 percent between 2008 and 2014. On the other hand, the growth rate of the agriculture sector fell to 3 percent between

2008 and 2014 leading to a 2 percent decrease in the GDP. Agriculture and the allied sectors had the maximum volatility during this phase. From 2005 to 2014, the coefficient of variation of the agriculture sector was 0.69 percent which proved to be much higher than the coefficient of variation of the overall GDP of the economy which was only 2.7 percent. Factors that contribute to the slow growth in this sector are lack in financial backing, low literacy levels and insufficient marketing of products. Also, reduction in the area of the farms has reduced productivity. Delay in adopting latest technologies in most of the regions which has led to this decline. Lack of irrigation services still prevail in most of the regions and hence farmers are required to depend on the rainfall which, thanks to its unpredictability, cannot be deemed a reliable source.

As a matter of fact, according to Central Statistical Organization, (1998), a large part of the area under cultivation in India relies on rainfall. The rain-fed agriculture is still popular in the western and the southern parts where food grains like oilseeds, cotton and grains are grown. Eastern region of India is concentrated with rice production which also has a great dependence on the rainfall. The southwest monsoon is usually expected in June-July. Due to the increased reliance on rainfall, agricultural productivity is highly affected by varying climate.

That said, we now consider it opportune to further outline the salient features of climatic change and its effect on agricultural production.

1.3. Agriculture and Climate Change

An age-old phenomenon, climate change can happen due to increasing population levels, innovation, high living standards, technological progress, industrialization, increasing infrastructure, reduction of trees and agricultural land, etc. According to the results of IPCC, (2013), the level of Greenhouse Gases has surpassed the highest levels of concentrations on earth over the last 800,000 years. This greenhouse effect, in turn, is causing increased rainfall, frequent hot extremes, floods, droughts, cyclones and gradual recession of glaciers. Rise in precipitation levels has been observed in Northern Europe, eastern parts of North America, South America, Northern Asia as well as Central Asia. Tropics and Sub tropics have been facing severe and long lasting droughts since 1970s whereas areas like Sahel, Southern Africa and Central Asia have parched lands (Aggarwal, 2008). According to the IPCC Fourth Assessment Report, intensification of activities performed by humans since 1750 has resulted in atmospheric concentrations of Carbon-dioxide, Methane and Nitrous Oxide around the world. The level of greenhouse gases has now exceeded the preindustrial values that existed thousands of years ago.

Climate change may not always have a negative effect on agriculture, especially in case of high latitude and high-income countries where agriculture cultivation is complimented by advanced technological implements and resources, leading to higher productivity of land. However, this climate change is a major barrier to developing economies, like India where agriculture accounts for 55 per cent of its total working population (Registrar General 2013) and constitutes about 14.1 per cent of its GDP (GoI 2013).

India is highly susceptible and risk-prone to climate change more so than many other countries in the world. In the last few years the India's vulnerability to climate change has increased because of population growth, poverty, high differentials in access to housing, good infrastructure and adequate. The effects of climate fluctuations and the vulnerability of the small and medium farmers to these climate conditions make it daunting for the institutions and the policy makers. Moderate variations in the weather during the crucial stages of crop development can also have a major impact on the yield. While cost of inputs, types of implements used, availability of irrigation water, rainfall and commodity prices can also be some of the other factors that lead to an alteration in the yield, it is estimated that severe climate changes leading to natural and manmade calamities like floods, droughts, cyclones, hailstorms, landslides, etc. impact the agriculture productivity most unfavorably.

The World Bank in 2013 predicted that there will be a 10 percent yearly increase in the average intensity of monsoon and a 15 percent annual change in the precipitation levels, for an increase in the global warming mean of 4 percent. According to the report, the north-western region of India will be highly vulnerable to droughts whereas the southern part will face increased rainfall.

What's worse is that this gradual change in climate is expected to increase the frequency and intensity of current hazards and the prospect of extreme events, acting as a catalyst to the emergence of new hazards like sea-level rise and new vulnerabilities with differential geographic and socioeconomic impacts. The increase in vulnerabilities would further result in higher susceptibility of poor and other communities which contribute to one fourth and half of the population of most Indian cities. Climate variations have started to degrade India's economic growth rates, adversely affecting the livelihood of millions of people. Keeping in mind its importance for the survival of civilizations, it is indispensable for the agriculture institutions, government and the policy makers to address these issues and strengthen the agriculture sector maintaining its growth as it is an increasingly important strategic, economic and political concern.

Furthermore, due to this alteration in climate, crop productivity is being affected adversely resulting in food and livelihood security issues (Tripathi, 2014). This climate change coupled with the increasing poverty and unavailability of food leading has led to the immensity of food security challenges which further poses a threat to the nation, in its entirety.

While in the recent years the growth of Indian economy has been quite impressive, yet poverty and hunger are widespread. India is the world's second largest producer of rice, wheat and cotton and is leading in the production of spices, pulses and (World Bank 2012). Nearly 75% of India's households are dependent on rural incomes derived from the agriculture lands. However, the agricultural productivity is impeded by water shortages and recurrent droughts, while environmental degradation and vulnerability pose challenges to the country's food security as a whole.

Let us analyze this in greater detail in the following section.

1.4. Food Security and Agriculture

"No society can surely be flourishing and happy, of which the far greater part of the members are poor and miserable"

-Adam Smith

The World Food Summit stated,1996, *"Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"*

Food security has four dimensions: food availability, food accessibility and food utilization and stability over time.

Food Availability: Food availability is concerned with the production and supply of crops. Agriculture plays an indispensable role in the economic growth of a country. It not only provides the nation with food, but is also responsible for generating employment, savings, supporting all the other sectors of the economy and earning foreign exchange for the country. Agriculture is a source of employment to 55% of the Indian population. The food grain production in India has increased tremendously however, malnutrition and poverty levels continue to shoot up as a result of biotic, abiotic and sociopolitical situations (Gahukar, 2011). Being highly dependent on monsoon for agriculture yield, the country remains vulnerable to issues relating to paucity and unavailability of food. There are several other factors that contribute to the magnitude of the problem. These can be increasing population levels and the growing pressure on the limited land for cultivation, poor government policies and public distribution system, etc. The agricultural sector in India is also expected to suffer due to variations in the temperature in the coming years. The IPCC report, (2007), states that there can be a 0.45 tonnes per hectare reduction in the wheat yield due to a 0.5 degree Celsius rise in the temperature during winters. Further, water shortages accompanied by thermal stress would lead to a drop in the rice productivity.

Food Accessibility: Economic and physical access to food relates to the issue of affordability. IPCC Fourth Assessment Report states that there will be approximately 200-600 million hunger stricken people around the world by 2080. In 1990-1991, the GDP at factor cost had increased at seven percent per annum, whereas it amplified at five percent per annum in 2013-2014, however, there has only been slight improvement in the amount of undernourished people from 210.1 million in 1990 to 194.6 million in 2014. Food accessibility is not only a problem limited to the rural households but it also extends to the urban areas. Poor households from the rural areas migrate to the urban cities looking out for employment opportunities. Ramachandran (2014) states that poverty and hunger drives the rural population to the urban slums. These people undertake menial jobs in order to meet the basic necessities and are exploited in terms of wages. Food is the main expenditure for urban poor and this section of the society is the worst hit by any increase in the food grain prices followed by production shocks due to change in the climate conditions. Malnutrition is highly prevalent in children below five years of age in major metropolitan cities such as Karnataka, Madhya Pradesh, Meghalaya, Bihar, and Uttarakhand.

Food Utilization:

"Food is properly used; proper food processing and storage techniques are employed; adequate knowledge of nutrition and child care techniques exists and is applied; and adequate health and sanitation services exist." – USAID.

This focuses on the importance of non-food inputs. It takes into consideration the quality of food people eat and its nutritional value. It also encompasses the process of preparing the food, distribution, health-care, water supply and sanitation conditions. This aspect can be measured with the help of immunization chart, health and demographic surveys, etc.

Stability over time: Stability means supply of sufficient food at all times. Sudden shocks in the climate and other factors affecting agricultural productivity should not destabilize the supply of food grains. This factor includes stability of food availability, accessibility and utilization. Instable prices of food grains and the ability to bare the magnitude of risk arising out of adverse weather conditions, unemployment and economic and political instability majorly affect the stability of the aspect of food security.

Food security continues to pose a major threat to the Indian economy and has so far been high on the list of agendas of the government. The Millennium Development Goal that targeted 50 percent reduction in the proportion of people suffering from hunger failed as about 12 Indian states were marked as 'alarming' according to the Global Hunger Index. It has significantly pulled down the growth rate of the country. Several agriculture economists argue that food security issue goes hand in hand with low demand. The Global Food Security Index and the Global Hunger Index indicate India among the African countries in terms of hunger and undernourishment. It shows 40 percent children in India are stunted and underweight (Pandey, 2015) making it extremely important for the country to make efforts in ameliorating nutrition and food security.

1.5. Research Question

Until now, it has been our objective to demonstrate how Agriculture has played a crucial role in the growth and economic well-being of the nation. Even though the share of agriculture sector has reduced in the total GDP, the sector still stands strong and is of utmost importance to all the other sectors. We have also mentioned that the increasing dependence of the farmers on uncertain monsoon makes agriculture productivity in India vulnerable. Climate change not only influences the eco system including the forests, sea levels and rivers but also the socio-economic system consisting of agriculture and fisheries. Further, there is a dire need to produce sufficient amount of food grains to meet the demands of the multiplying population and to save the farmers who solely depend on agriculture for their livelihood. Thus, it is imperative to carry out a research on effect of climate change on the agriculture due to the drastic changes in precipitation and temperature.

This study makes an attempt to analyze the impact of climate change on Indian Agriculture and food security, which consequently results in poverty. It examines the implications of climate change for poverty alleviation and evaluates the multiple benefits of mitigation and adaptation. The thesis also highlights the role of institutional policies. This brings us to the following research questions:

1) **What is the impact of climate change on agricultural production in 7 agriculturally rich states of India?**

2) **Does the impact of climate change on agriculture productivity differ from region to region?**

3) **How is agricultural productivity linked to food security? What are the steps for mitigation and adaptation?**

Throughout the course of this thesis, it will be our intention to analyze these questions, to bring to light in greater depth, the interrelatedness of climate change, agriculture, food security issues, to offer valid arguments and justifications in their response and to equally propose solutions to these problems that currently pose a threat to our survival on a national level.

Chapter 2: Literature Review

The importance of referring to economic literature is paramount if one wishes to unearth the very fiber of actuality. It demonstrates the nature and the scope of climate change, agricultural productivity and food security in India, laying the foundation for analyzing the interrelationships between the three. Analyzing the literature in context to our topic will help us in displaying the effect of uncertain climate shocks on productivity of principal crops in India, from which stems the pervasive incapability among Indian farmers to produce significantly lower than their production frontiers. It will be our aim to present how the production levels are much less than the optimal amount of output leading to lower profit margins.

In the first section of this chapter of four parts, past works on agricultural productivity and climate variations are cited. Section two revisits the literature on food security as a rising problem in terms of declining productivity levels. The next section reviews the literature on climate change and food security. The review presented in the paper is restricted to the research related to the area selected for study.

2.1. Literature on Indian Agriculture and Climate Change

There have been very limited studies on the impact of climate change on Indian agriculture till date, the results of which differ extensively. This can be due to the application of different techniques and assumptions in every study. Most of the research on impact of climate change on agricultural productivity has been carried out for developed countries. It is accepted that developing countries are more vulnerable to climate variations and have adaptation issues due to the scarcity of capital, limited capital resources, poor technological implements, scarce arable land and high dependence on agriculture (Mendelsohn et al., 2006; Stern, 2006; Nelson et al., 2009).

According to the results computed by Aggarwal (2009), there can be a 3 to 7% decrease in the productivity of wheat, soybean, mustard, groundnut and potato due to a 1 degree Celsius rise in the temperature. Consequently, a predicted rise in the temperature between 2.5 degree and 4.9 degree Celsius by the year 2099 would lead to 10 to 40 percent destruction of these crops. IPCC

Fourth assessment report, Climate Change 2007, on the other hand forecasts that there is a 2 to 5 percent chance of decline in the wheat and rice production in India for a rise in temperature between 0.5 and 1.5 degree Celsius. Further, studies have found that between 2010 and 2035, there is a possibility of decline in the productivity by 4.5 to 9 percent. This fall in the productive levels can amount to 1.5 percent of the Gross Domestic Product of the country. Indian agriculture sustains the livelihood of approximately 55 percent of the total population of the country and therefore, it seems obvious that any small variation in the climate will influence agriculture productivity and thus, the food security of several people dependent on agriculture for livelihood. Due to increasing carbon dioxide emissions and release of Greenhouse Gases, there is a high possibility of the occurrence of global warming in the near future. Weather shocks and changes in precipitation will have an impact on productivity resulting in alteration in prices, demand and supply, profitability and trade. These changes can become a major challenge and hinder the capability of the country to feed its multiplying population.

In the previous years, agriculture sector in India has been hard hit by extreme natural calamities such as droughts, floods, heat waves and cyclones (Goswami et al., 2006) causing fall in the productivity of food grains, aggravating the vulnerability of marginal and small farmers, leading to food insecurity and poverty (Birthal et al.2014). Estimating the effect of these natural disasters, Bhandari et al. (2007) found that in a drought year, there is a significant decline of 24 to 58 percent in the household income in the eastern region of India and a 12 to 33 percent jump in the poverty levels among rural households dependent on farm activities.

The Indo- Gangetic plains in India experienced a steep fall of more than 4 million tonnes in the yield of wheat due to an increase in the temperature by 3 to 6 degree Celsius in the month of March, 2014. This meant a 1 degree Celsius increase in the temperature every day for the entire cropping season. A similar event took place in the year 2002, when drought destroyed more than 10 percent of the total food produced, decreasing the area under cultivation of rain-fed crops. Increased rainfall during kharif season can have severe adverse effects on productivity grounds. Crops like wheat, sorghum, maize have higher chances of getting affected by the changing climatic conditions and precipitation levels. Further, there have been predictions on the possibility of occurrence of extreme weather conditions by 2070. Sudden shocks in the magnitude and the time of rainfall and the recurrence of natural calamities may lead to instability in agricultural sector. The average temperature during in both Kharif and Rabi cropping seasons are expected to increase till 2070 by 0.4 degree Celsius to 2.0 degree Celsius and 1.1 degree to 4.5 degree Celsius respectively. S.A Khan et al., (2009). Kumar and Parikh (2001) predicted that climate change would have a huge impact on the production of rice and wheat by 2060, which would in turn affect the livelihood and food security one million people in India. Excessive rainfall and drastic weather changes have adversely affected the production of Jowar, impacting the life of those dependent on farm in Karnataka, according to Kaul and Ram (2009).Geethalakshmi *et al.* (2011), on the other hand, found that there has been a 41% decline in the rice production as a result of an increase in the temperature by 4 degree Celsius in Tamil Nadu.

Many studies argue that global warming is not only a consequence of human activities and industrial waste generation but is also a result of rice production and animal waste coming from agriculture. It is responsible for 68 percent of the total CH4 emission (S.A Khan et al.,(2009)). International researchers announced that India and China are the major producers of Paddy and are highly responsible for the high methane levels globally. However, Bhattacharya and Mitra (1998) estimated that the rice production in India was only responsible for 4.2 Tg emission of methane per annum. Agriculture in India is assumed to have a negligible effect on the overall increase in the amount of greenhouse gases. This is attributable to the minimal use of fertilizers and low soil fertility levels in the country (S.A Khan et al., (2009)). Nitrous Oxide has been proved to have a long lasting effect on greenhouse gases and thus, can be accountable for knocking down the stratospheric ozone layer (Rodhe, 1990).

Although weather conditions affect the crop productivity to a considerable extent, soil fertility, varieties of seeds, pests and diseases are some of the other factors that are dependent on climate variation (S.A Khan et al., (2009)). Any change in the weather conditions, especially a rise in the temperature or variation in the precipitation level makes water bodies a suitable habitat for pests. Multiplying pests and widespread diseases are a great cause of concern for agricultural farmers. They bring about large losses to the agricultural yield under various climatic conditions. Pest interaction with crops might result in an increase in the carbon dioxide content, affecting the productivity levels. Thus, farms need to take into consideration these factors and prepare adaptation techniques before planning the cultivation of crops. Additionally, two third of the landholdings in the rural India have a landholding capacity of less than 1 hectare. This implies that the majority of the population in rural areas is vulnerable to the meteorological changes due to lack of knowledge, low accessibility to technology, paucity of resources, leading to lack of adaption techniques.

2.2. Indian Agriculture, food security and poverty

The Food and Agricultural Organization of the United Nations (FAO) defines food security as- *"A situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life"*.

Food insecurity happens to people when they do not have sufficient food to satisfy their hunger, they have bounded diet, are keen to have adequate food and shift to begging, snatching, hunting, becoming dependent on government programmes (Cook and Frank, 2008). Cook and Frank (2008) added that marginal disposable income, scarcity of resources and socio economic resources are factors contributing to the problem of food insecurity of a country. Many researchers found an interrelationship between food security and factors like water, agriculture growth, prices of food grains, energy and environment change (Gustafson, 2013; Hanumankar, 2014; Henningsson et al, 2004). A large proportion of the population in developing countries is dependent on agricultural activities for livelihood. According to World Bank, agriculture is the main source of income for 2.5 billion people, out of which 1.3 billion people are landless and marginal laborers. Approximately 86 percent of the poor rural population of the world is employed in the agriculture sector (ECG, 2011) thus, making agriculture productivity important for the economic growth of a nation.

According to FAO report, (2008), there can be two main implications of changing agricultural patterns and productivity on food security in developing countries. Firstly, variations in the productivity affect food security at a national as well as at a global level. Due to high dependency of the country on its own food production and its scarce financial and technological resources to import/export to other countries, it is difficult for these low income, developing countries to deal with a shortage in the supply of food grains. Secondly, there is a higher risk for the agricultural producers in rural areas to tackle any variations in the food supply as they are solely dependent on agriculture for their livelihood.

The problem of food security is crucial especially in India which accounts for 17 percent of the world's total population and is the second most populated country in the world, after China. A large section of the society in India is unable to obtain adequate calories and is undernourished. They suffer from nutrient deficiencies. According to The National Family Health Survey, 2005-2006, the body mass index of 28 percent of the men and that of one third of the married women in the country is below normal readings. Additionally, it reports that overweight and anemia are common among the married population of the country. While 15 percent of the married women are obese, anemia is common in 24 percent of the married men.(CIRCUS, 2006; Drèze et al., 2008; Drèze, 2004) compared the child mortality rates in India to that of Africa and argued that India is falling behind several African countries in terms of child nutrition and welfare. A large percentage of children between three months and three years are suffering from anemia. India currently has 212 million undernourished people which amount to the largest in the world. There has been a 38 percent rise in the undernourishment level ranging from 172.4 million in 1990-1992 to 237.7 million in 2005-2007 (Upadhyay and Palanivel, 2011).

India has been facing an alarming threat of food insecurity ever since the independence when majority of the agriculture policies and plans emphasized on reducing the problem of hunger, food security, malnutrition and poverty. In the first fifteen years, the government of India focused on reducing the food grain prices to make it affordable for one and all. The stress gradually shifted to macro level food security and then to household food security, scrutinizing the seriousness of the problem. Though India could not completely eliminate the problem of hunger and poverty as done by China, its experience and accomplishment in reduction of poverty has been commendable.

Taking into account the situation of farming in India in the 1950s, Amartya Sen (1964) believed that there existed a negative relationship between the productivity levels and farm holding size.

Further, Collective farming didn’t seem to be fruitful in India and agricultural sector was in the dire need of land reforms. (Saini, 1971).In the 1950s and 1960s, the government introduced several revolutionary land reforms. The Zamindar (landlord) system was abolished and in 1971, average land holdings increased leading to higher production yields. Government provided incentives and subsidies to the farmers to boost the production. In the 1960s, the Green Revolution in India introduced the country to a myriad of high yielding seeds, chemical and organic fertilizers and advanced technology to boost the productivity of the land. It ameliorated the food supply globally and improved the efficiency of agricultural labor. However, Indian agriculture had a setback due to the drought in 1960, increasing 16 percent of the country’s dependence on imports of cereals (Acharya, 2009). Indian agriculture flourished in the subsequent years, becoming the second largest producer of agricultural output.

Despite a splendid growth in the agricultural sector leading to high economic development of the country, malnutrition, hunger and poverty prevail in India, exceedingly. Additionally, the multiplying population of the country and the increasing pressure on land does not seem to keep pace with the agricultural production. According to Mellor (2001) increase in the agricultural productivity stimulates economic growth and helps in the reduction of poverty in urban and rural areas. A similar idea was proposed by Datt and Ravallion (1998) and Ravallion and Datt (1999). Chakravarty and Dand, (2005), carried out a study in which Indian states were marked on a food insecurity map indicating the degree of food security existing in the state. They divided the economy into rural and urban areas. The results indicated Madhya Pradesh, Orissa, Pondicherry and Chandigarh to be the ‘most insecure’ urban areas whereas Bihar and Jharkhand were marked as the ‘most insecure’ rural areas. These results were computed using 17 indicators of food security, including food availability, food accessibility and food absorption. Timmer in (1995), states that poverty can be reduced by increasing the agriculture related business activities and also, by raising the need for manufacturing output. Stringer (2001), explains that agriculture plays a crucial role in the welfare of the society. It acts as a buffer, a safety net and as an economic stabilizer” (p.7.) (Self and Grabowski (2007)). According to a research by Reddy, (2016), there needs to be a rise in the production of oilseeds, pulses and meat products as there is a lack in the protein levels of the general population of the country. He suggests that improvement in the agricultural production and improvement in the technology and techniques of production would regulate the food supply of the country fulfilling the requirement of “food availability”. It would also increase the adaptability of the small and marginal farmers to any meteorological changes.

Agriculture in India is the main source of livelihood for the majority of the population and an important source of raw material and labor for the industrial sector. Prolonged existence of poverty and hunger in the rural areas forces the agricultural laborers to shift from the rural to the urban base, resulting in cheap labor for the manufacturing sector, spurring growth in the economy (Provided the marginal product of labor is not equal to zero). This can also lead to increase in the urban poverty due to the exploitation of these laborers for minimal wages. This makes the landless, small and marginal agricultural workers most vulnerable. Lack of resources, knowledge, advanced technology and high dependence on rainfall makes them even more sensitive to climate variations.

2.3. The Effect of Climate Change and Agriculture on food security

The previous section highlighted the importance of agriculture in the context of food security and poverty. It also underlined the sensitivity of agricultural sector to the volatility and uncertainty in the climate. More than 60 percent of the population in India is dependent on the primary sector for living. This explains that the livelihood of a large number of rural and urban households stand in danger in case of frequent changes in the climate affecting the agricultural productivity. The consequences of meteorological changes can be seen both in urban and rural areas leading to food insecurity and poverty. Variations in the climate have affected food productivity and water availability in India. Tien Shiao et al., (2015), mentions that 54 percent of India faces a water shortage leading to 600 million people under the risk of acute shortage of water supply. Additionally, agriculturally rich states, such as, Punjab and Haryana where rice and wheat productivity is the main source of livelihood have been facing a huge risk of water shortage. Lobell et al. (2012), states that wheat production can be adversely affected in case there is a rise in the temperature over 34 degree Celsius.

Not only does this meteorological variation affect productivity of crops and water resources, but it also has serious repercussions on the economic and financial resources of the poor and the small and landless farmers. Prolonged duration of a particular cropping season resulting in the destruction of the crop may have serious implications on the income of the farmer. Another prominent reason for the vulnerability of the farmers is the high reliance of Indian agriculture on monsoon. Currently, the rain fed land in India hardly supports the farmers dependent on it. Reduced profits, decrease in the productivity of the land, small land holdings and heavy dependence on monsoon for productivity pressurizes the small farmers to move to the urban slums where they resort to menial and low paid jobs, lacking job security. Growing inflation in the country and higher prices of food grains in the urban areas also adds up to the problem of poverty. Statistics show that 30 percent of the children in India belonging to the age group of 5 years and below are undernourished in well-developed states of Bihar, Uttar Pradesh and Karnataka. (Chakrabarty, 2016).

Climate change not only influences the primary sector, including plants and livestock, water availability, environment, fisheries and forests but also socio economic factors, human health, electricity, infrastructure, roads, storage, trade etc., having an indirect effect on the economy and the political structure, leading to instability in the food chain. Thus, it is one of the major factors affecting food security directly and indirectly. As mentioned in the introduction, there are four dimensions to food security: food stability over time, availability, accessibility and utilization. Other than these, food security relies upon several other factors such as food processing, food distribution, marketing, acquisition and consumption. Extreme climate changes and occurrence of natural calamities can lead to disruption in the transport systems, leading to delays in the delivery and consequently food unavailability. FAO (2010) states, climate variations are likely to have a considerable impact on the food security around the world in the near future. Extreme weather changes and uneven precipitation levels have been predicted across the world. It is projected that the wet areas will become wetter and the dry ones drier in the immediate future.

More stress has been laid upon the food security issue as it is majorly dependent on agricultural productivity which is a factor of climate change. Climate change may cause drastic changes in the weather and rainfall monthly, yearly or between the seasons (Chakrabarty, 2016). The geographical location of India makes it more prone to different natural calamities.

Approximately 8 percent of the geographical area under area is vulnerable to earthquakes, floods, cyclones and droughts (Samra et al. 2006).

In 1877, the El Nino event caused death of six to ten million people as a result of drought in the Central and Southern regions of India (McMichael et al. 2004). An acute cold wave struck in the Northern and North-Eastern part of India in 2002-2003 which consequently affected the productivity of perennial and seasonal crops. (Singh, 2004) The IPCC Fourth Assessment report states that the wetlands in India have become extremely vulnerable to change in the precipitation levels and warming of temperature. Further, there is a high possibility of the greater occurrence of cyclones in the country. The number of heat waves in a day and the number of hot days in a year have increased significantly leading to high death rate in the country due to the increased temperature (Cruz et al. 2007). Large part of agriculture in India is dependent on water bodies and ground water for irrigation purposes. These sources of water greatly rely on climate change giving rise to diseases like malaria, dengue, and cholera. According to IPCC, further variability in climate and precipitation could result in the spread of malaria across the arid region in Asia. As a result of rise in the sea water level and increase precipitation levels, higher chances of flooding may lower the capacity of food utilization by giving rise to numerous diseases (Ramachandaran, 2014). According to her, there is a likely chance of 20 percent of the snow melting on the Himalayan Range by 2030, increasing the chances of floods in that region. IPCC further predicts an 80 percent rise in the sea level affecting the states in low lying coastal areas.

Keeping in mind the above-mentioned factors, statistics, as well as the magnitude of the problem of food security and poverty, there is a dire need to mitigate the impact of climate change on food security and agriculture. In the chapters that succeed, we would be analyzing the same in greater detail.

Chapter 3. Research Methodology

3.1. Data Sources

This study is based on state level data of 4 major seasonal Indian crops- Rice, Wheat, Cotton, Sugarcane which comprise of Food and Cash crops for the time span of 2004 to 2013 obtained from various sources. Seven agriculturally intensive states with varied climatic conditions have been considered for the study covering both, tropical and subtropical zones in India. Maharashtra, West Bengal, Uttar Pradesh and Gujarat fall under the category of tropical zones whereas Andhra Pradesh, Tamil Nadu and Karnataka come under the subtropical zones. The data obtained can be divided into two parts: agricultural and meteorological variables. These have been obtained from the following sources:

Agricultural Data- Crop wise productivity in kilogram per hectare, crop wise gross irrigated area in thousand hectares, total forest area in thousand hectares, total number of tractors used on the land, total consumption of fertilizers in kilogram per hectare and number of agricultural workers are the agricultural variables taken into account. The yield per hectare data for the four crops has been taken from different sources. Cotton productivity in kg per hectare has been taken from The Central Institute for Cotton Research (CICR), Indian Council of Agricultural Research, database. Productivity of wheat and rice has been obtained from Agricultural Statistics at a Glance,(2014), Ministry of Agriculture, Government of India. The data on Agricultural yield of sugarcane was available on Status Paper on Sugarcane, Directorate of Sugarcane Development, Ministry of Agriculture, Government of India.

Crop wise irrigated area, total forest area and fertilizer consumption data has been extracted from the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare database. The data on tractors has been obtained from Tractor Manufacturers Association (TMA), India database. Crop wise irrigated area, total forest area and fertilizer consumption have all been considered in thousand hectares since the dependent variable, that is, agricultural productivity is also measured in kilogram per hectare.

Meteorological Data- State-wise Annual Rainfall and state-wise maximum and minimum temperatures have been taken into consideration as the climate variables. State-wise Annual rainfall data for the respective years (2004-2013) has been obtained from the database of the India Meteorological Department (IMD). District-wise monthly temperature data was taken from India Meteorological Department (IMD), Pune Branch, India. Due to absence of state-wise annual data, the figures were converted from district wise average maximum and minimum temperatures to state-wise average maximum and minimum temperatures using excel. Then, the monthly data was converted to average annual data.

This study incorporated the data of only 7 states in India belonging to different zones: tropical and sub-tropical as well as different geographical locations. While Andhra Pradesh, Tamil Nadu and Karnataka are situated in the south of India, Maharashtra and Gujarat lie in the west. West Bengal is located in the east and Uttar Pradesh is in the north. All states in India have not been incorporated in the model because of 2 major reasons: Firstly, there exists a massive difference in the temperature of every state, so, the results would not have been robust. Secondly, not every state is agriculturally intensive.

3.2. Empirical Model

The relationship between climate change and agricultural productivity for the years 2004-2013 is assessed by running an econometrics model using Panel Regression. The data collected is for seven agriculturally rich states. Agricultural productivity in kg per hectare is chosen to be the Dependent variable whereas average annual maximum and minimum temperatures, gross irrigated area, fertilizer consumption, agricultural workers, number of tractors, total forest area, farm harvest price, average annual rainfall are the Explanatory variables. These variables have been further segregated into exogenous and endogenous variables. While gross irrigated area, fertilizer consumption, agricultural workers and the number of tractors are the endogenous factors, total forest area, farm harvest price are the exogenous variables that affect the dependent variable. The theory related to panel regression and its application is explained in the following section.

Consider the panel regression equation:

$$Y_{sn} = \beta_1 X_{sn} + \beta_2 L_{sn} + \beta_3 T_{sn} + \beta_4 W_{sn} + u_n + v_{sn} \qquad (3.1)$$

Where,

$$E[v_{sn}|X_{sn}, L_{sn}, T_{sn}, W_{sn}] = 0 \qquad (3.2)$$

In case explanatory variables are observed, in all the above equations; coefficients can be computed using multiple regression. However, in case when the explanatory variable is unobserved, an external variable Z_s is introduced which relates to the endogenous variable, say, X_{sn}.In this case however it is uncorrelated to all exogenous variables (L_{sn}, T_{sn}, W_{sn}) and the idiosyncratic error term v_{sn}.

$$corr(Z_{sn}, v_{sn}) = 0 \qquad (3.3)$$

$$corr(Z_{sn}, X_{sn}) \neq 0 \qquad (3.4)$$

By using panel data we can control for the sources that cannot be measured or are not observable and are sources of heterogeneity that vary between individuals but do not differ with time. It can also control for omitted variables. The panel data has three basic models: the random effects model, the fixed effects model and the OLS model. The random effects model exists when there exists heterogeneity over the years and within the cases. The fixed effects on the other hand does not vary with time but there is variability within the cases. The OLS, which is the third model does not take into account the time factor.

This regression analysis has been conducted using STATA to find out the best fit in our model. Linear regression with panel-corrected standard errors (PCSEs) has been used in the model to remove the effect of heteroskedasticity and multicollinearity. Linear regression with panel-corrected standard errors is used in time series model for cross sectional data using OLS to calculate the values for the parameters. This model by default assumes that the errors are heteroskedastic and correlated. According to research, panel regression for micro econometric data is usually over estimated since it shows all kinds of temporal and cross sectional correlations. These dependencies can lead to biased results. To avoid these biases and to get valid results, linear regression with panel-corrected standard errors has been introduced to avoid possible correlation in residuals.

In literature, the relationship between climate change and agriculture productivity has been commonly estimated by using two methods: the production function method and the Ricardian method. The production function approach uses the production function and accommodates various environmental inputs to examine the impact of these inputs on the production (Callway et al., (1982); Decker et al., (1986); Adams et al., (1988), (1990); Adams, (1989); Rind et al., (1990); Rosenzweig and Parry, (1993). The major drawback of the production function method is that it fails to take into account the substitutions that farmers make in order to cope up with the uncertain climate shocks. The Ricardian approach on the other hand, incorporates value of farmland or net rent on which the impact of climate is assessed (Mendelsohn et al., 1994). This approach takes into consideration both, the impact of climate change on productivity of crops as well as the substitutions that farmers resort to as an adaptation strategy towards change in the climate. However, according to De Salvo et al.(2013), the production function approach is used to estimate the effect of climate change on one particular crop, a group of crops or a particular ecosystem in both short and long term, whereas the Ricardian approach is applied to estimate the impact on the whole agricultural sector or a particular branch. This regression analysis will first show the impact of climate change on each food and cash crop and then on the productivity of all the crops using the production function approach.

Cobb Douglas production function is incorporated in this model to analyze the effect of climate change on agricultural productivity. The functional form of the equation may be written as:

$$(TProd)_{sn} = f\{FC_{sn}, GAI_{sn}, AW_{sn}, Tract_{sn}, FAR_{sn}, HP_{sn}\} \quad (3.5)$$

Where, TProd stands for total productivity for each crop. s denotes the number of states for every crop and n is the considered time period. FC is the total fertilizer consumption, GAI stands for gross area irrigated, AW is the total number of agricultural workers and Tract are the total tractors used on the land. FAR is the crop wise share of forest area and HP is farm harvest price for respective crops.

Climate factors are assumed to be an input factor for growth of crop in Cobb Douglas production model. Thus we can write it in the functional form as:

$$(TProd)_{sn} = f\{FC_{sn}, GAI_{sn}, AW_{sn}, Tract_{sn}, FAR_{sn}, HP_{sn}, RF_{sn}, MAXT_{sn}, MINT_{sn}\} \tag{3.6}$$

Where, MAXT and MINT are annual average maximum and minimum temperatures and RF denotes annual average rainfall, respectively. The above equation can be written in the Cobb Douglas production form as:

$$\ln(TProd)_{sn} = \beta_0 + \beta_1 \ln(FC)_{sn} + \beta_2 \ln(GAI)_{sn} + \beta_3 \ln(AW)_{sn} + \beta_4 \ln(Tract)_{sn} + \beta_5 \ln(FAR)_{sn} + \beta_6 \ln(HP)_{sn} + \beta_7 \ln(RF)_{sn} + \beta_8 \ln(MAXT)_{sn} + \mu s \tag{3.7}$$

Where, β_0 is constant coefficient; β_1, β_2, β_3, β_4, β_5, β_6, β_7 and β_8 are the coefficients for the respective variables and μs is the intercept term . Cobb Douglas Production Function's functional form is given by the above equation.

The hypothesis is given in the table below:

Table 3.1: Hypothesis - Panel Data Regressions

SN	Hypothesis	Variable	Method of Testing
1.	Higher the fertilizer consumption, higher the productivity.	FC	Linear regression with panel-corrected standard errors (PCSEs)
2.	Higher the gross area irrigated, higher the productivity	GAI	Linear regression with panel-corrected standard errors (PCSEs)
3.	Higher the agricultural workers, higher the productivity.	AW	Linear regression with panel-corrected standard errors (PCSEs)
4.	Higher the number of tractors, higher the productivity of the crop	TRACT	Linear regression with panel-corrected standard errors (PCSEs)
5.	Higher the forest area, higher the productivity of the crop	FAR	Linear regression with panel-corrected standard errors (PCSEs)
6.	Higher the farm harvest price, higher the productivity of the crop	HP	Linear regression with panel-corrected standard errors (PCSEs)

Several economists have worked using a similar approach to analyze agricultural productivity in different countries. Nastis et al. (2012) did one of such research to estimate the effect of climate change on agricultural output in Greece. Gupta et al. (2012) has also written a paper that investigates the climatic bearing on millet, sorghum and rice yield. This thesis follows the methodology and the empirical model of the first section of the paper by Kumar et al. (2013) based on the topic *'Impact of Climate Variation on Agricultural Productivity and Food Security in Rural*

India'. He emphasizes on the effect of climate change on the yield of major food grain and nonfood grain crops.

The second section of the thesis shows the relationship between agriculture and food security due to the effect of climate change on the productivity. There can be two approaches to prove that climate change is gradually resulting in food security problems resulting in poverty:

1. By taking the socio economic factors into consideration so as to prove an impact of climate change on food security that is resulting in poverty. We can make use of a similar model projected by Kumar et al. (2013)
2. Theoretically, using several references prove that variations in the climate can result in the problem of food insecurity affecting the poor sections of the society.

Many studies in the past have assessed the effect of climate change on different factors of food security- availability, accessibility and utilization, however, due to limited resources and paucity of time, the scope of this research is restricted to analyzing the impact of climate change on only one dimension of food security – food availability. This research aims at analyzing the impact of climate change on food production making an inference from the results and relating it to food security based on the present literature.

Chapter 4: Descriptive Results

Increasing agricultural productivity can improve food availability and is therefore an important step towards achieving sustainable food security. Agriculture, as we know, is strongly influenced by weather and climate. Thus, to ensure food availability, it is important to assess the impact of climate change on agricultural productivity. In order to study this effect we have used Linear Regression with Panel-Corrected Standard Errors (PCSEs) approach. The summary of the panel dataset is presented in the table below. The first table indicates the common factors that affect the productivity. The second table shows the summary pertaining to factors related to specific crops.

Table 4.1: Summary Panel-Corrected Standard Errors Approach

Variable		Mean	Std. Dev.	Min	Max	Observations
RF	Overall	1167.951	408.1097	631.7	2057.8	N=71
	Between		381.6674	785.965	1832.9	n=7
	Within		198.7115	694.0969	1580.491	T-bar=10.1429
FAR	Overall	2976.728	1764.883	1173.669	6229.899	N=71
	Between		1862.234	1173.899	5942.042	n=7
	Within		308.5784	528.1612	3264.585	T-bar=10.1429
FC	Overall	154.9225	45.48855	71.45	285.41	N=71
	Between		38.9854	107.021	2220.862	n=7
	Within		27.67419	82.49053	219.4705	T-bar=10.1429
TRACT	Overall	31244.92	20730.07	3085	95653	N=71
	Between		17953.24	9013.545	64350.4	n=7
	Within		12095.51	6047.515	64352.52	T-bar=10.1429
AW	Overall	829937	344738.4	403095	1641460	N=71
	Between		331501.7	473608.3	1422160	n=7
	Within		151031.5	422923.6	1127742	T-bar=10.1429
MAXT	Overall	27.36236	4.106162	16.4	32.3	N=69
	Between		4.179323	19.7713	30.417	n=7
	Within		1.202114	23.38236	30.58106	T-bar=9.85714
MINT	Overall	14.55145	4.133424	5.85	21.61	N=69
	Between		4.328351	7.815	10.828	n=7
	Within		0.9372149	12.44745	17.70963	T-bar=9.85714

Table 4. 2: Summary (Crop-Wise Factors) Panel-Corrected Standard Errors Approach

Variable		Mean	Std. Dev.	Min	Max	Observations
GAIW	Overall	1644.343	3289.823	0	9630.065	N=71
	Between		3438.699	0.031	9412.898	n=7
	Within		118.8525	1317.423	1868.121	T-bar=10.1429
GAIC	Overall	263.347	469.4849	0.1144	1739.55	N=71
	Between		496.5752	1.62784	1376.775	n=7
	Within		89.79598	-173.4279	626.1225	T-bar=10.1429
GAIS	Overall	591.6515	615.7764	6.980969	2105.42	N=71
	Between		653.4964	11.18518	1976.593	n=7
	Within		90.82454	304.8815	826.1815	T-bar=10.1429
GAIR	Overall	2096.46	1560.53	372.5	5012.74	N=70
	Between		1652.499	397.391	4707.074	n=7
	Within		246.3417	941.7679	3043.218	T=10
TPRODC	Overall	388.4677	148.5202	38	679	N=62
	Between		128.6085	182.1667	593.7	n=7
	Within		91.71333	215.7677	632.3677	T=8.85714
TPRODS	Overall	81321.83	15392.31	52326	114273	N=71
	Between		14435.93	58398	104680.5	n=7
	Within		7583.42	58848.47	106890.5	T-bar=10.1429
TPRODR	Overall	2473.31	553.5787	1425	3918	N=71
	Between		533.7688	1728.7	3096.3	n=7
	Within		248.7162	2018.11	3593.51	T-bar=10.1429
TPRODW	Overall	1947.787	876.5618	500	3255	N=61
	Between		923.1662	886.4	2889.2	n=6
	Within		227.6294	1474.687	2397.987	T-bar=10.1667
HPR	Overall	921.1031	316.6171	485	1596	N=71
	Between		66.03505	833.2	1010.6	n=7
	Within		310.6529	462.5031	1506.503	T-bar=10.1429
HPW	Overall	1178.039	323.531	635	2048	N=51
	Between		148.6801	1006.7	1410.9	n=5
	Within		294.9178	642.1392	1815.139	T-bar=10.2
HPC	Overall	2776.247	968.1869	1432	4974	N=50
	Between		288.1983	2293.9	2989.9	n=5
	Within		932.5144	1250.714	4760.347	T-bar=10.2
HPS	Overall	336.7619	427.9717	86	1942	N=21
	Between		237.5354	173.7	648.25	n=3
	Within		386.5272	-121.4881	1630.51	T-bar=7

Note that unlike the classical panel data models our panel size is very small. Our study considers seven states of India (n=7) over a period of 10 years (s=10) which accounts for a total of 70 observations. We have used a small dataset mainly because of the difficulty in obtaining data for different agricultural states. It was challenging to have access to the state-wise annual data for maximum and minimum temperatures due the extremely varied climatic conditions in each district of every state. Panel data estimation is a useful method when dealing with datasets where there exists heterogeneity. It also helps in examining the fixed effects in the longitudinal data. We have attempted to assess the effect of various factors on food and cash crops with the help of linear regression with panel-corrected standard errors (PCSEs) method.

Below we present the results of our analysis showing the impact of meteorological variables on productivity of each crop. The first crop that we have taken into consideration is cotton. Cotton is an important Kharif crop that caters to the needs of the expanding textile industry of India. India is a leading exporter of cotton. This crop is sensitive to climate change and requires a uniform temperature between 21 and 30 degree Celsius accompanied by rainfall within 50 to 100 cm. An estimation of the factors affecting its productivity is shown in the table below.

Table 4.3: Regression Analysis – Log Cotton

VARIABLES	Log Cotton
LGAIC	0.175***
	(0.0376)
LTRACT	-0.0172
	(0.163)
LAW	0.287*
	(0.153)
LHPC	-0.0320
	(0.221)
LFC	0.612
	(0.463)
LFAR	-0.165*
	(0.0853)
LRF	-0.00104
	(0.173)
LMINT	-0.639
	(0.734)
LMAXT	1.632
	(1.416)
Constant	-3.870
	(4.724)
Observations	44
Number of group	5
R-squared	0.689

Standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table 5 shows the regression results for cotton. An increase in maximum temperature has a positive impact on cotton productivity whereas an increase in minimum temperature negatively affects the productivity. 1% increase in maximum temperature increases the cotton productivity by 1.6% whereas a 1% increase in minimum temperature decreases the productivity by 0.6%. However, they are insignificant at 1%, 5% and 10% level of significance. The R-square value is 0.689 which explains that there is 68.9% variation in the model.

The data exploration shows that an increment in the forest area has a negative effect on the cotton yield. 1% increase in the forest area leads to a 0.165% fall in the productivity significant at 10%

level of significance. This may be attributed to the fact that cotton needs more land to grow and due to the paucity of area under cultivation of cotton, the land from the forests has to be compromised to increase the production of cotton. According to (ITC, 2011), for increasing the growth of cotton, Brazil will be dependent on the deforestation rate in future. Similar results may be true in case of India. Deforestation and destruction of forests occur in countries having a low income scale, majorly in tropics, however, high income developed nations have recovered from their forest losses and are expanding the forest area. (Kirilenko & Sedjo, 2007).

Irrigated area, on the other hand also has a significant positive effect on cotton productivity. 1% increase in the gross irrigated area will result in a 0.175% increase in the cotton yield at 1% level of significance. This proves our hypothesis that states that an increase in the irrigated area would lead to greater productivity of crops. Cotton production in India has majorly been dependent on rainfall. However, there is a huge potential for cotton to grow using irrigation techniques. It also prevents the crop from being affected from droughts. Additionally, it has been proven that growing productivity demands a greater supply of water. According to WWF, it requires more than 20,000 litres to grow 1kg of cotton. Thus, the more the irrigated area, the higher will be the area under cotton cultivation exposed to water, leading to greater productivity.

Due to the burgeoning population and the increasing pressure on agricultural land, there exists a serious shortage of food and cash crops. Cotton being one of the major commercial crops bearing the load of the expanding textile industry in India, it is crucial to increase its productivity to address the emerging needs. The results of the regressions prove that agricultural workers significantly impact the production of cotton. A 1% increase in the agricultural workers will result in 0.287% increase in the cotton yield. However, the Government of India statistics indicate that there has been a fall in the production of cotton by 43% from 2007 to 2014. This decline has been a result of farmers shifting from cotton production to production of other crops due to ease of production of other crops. Vidharbha, a region in Maharashtra has contributed to this problem and is an example of this. Cotton production dominated three-fifth portion of this region until 2006-2007. Most of the agricultural laborers cultivating cotton shifted to soybean production that now contributes 70 percent of the total production in that region. Thus, agricultural workers are regarded as a major factor in the productivity of cotton.

The second crop selected is Sugarcane. The escalating demand of sugar and ethanol in the world has made sugarcane an important source of income for the nation. It is grown in the sub- tropical and the tropical regions in India. Uttar Pradesh, Tamil Nadu, Andhra Pradesh, West Bengal, Gujarat and Karnataka have the most suitable climate for producing sugarcane. According to ICRISAT, (2009) Tamil Nadu has the highest yield of sugarcane whereas the largest area under sugarcane production is in Uttar Pradesh. Sugarcane production is sensitive to climate changes and grows well within 20-40 degree Celsius. On the other hand, rainfall between 1100 and 1500 mm is adequate for the sugarcane to give a high yield. Table (4.4) below shows the estimated impact of climate change and other production factors on sugarcane productivity.

Table 4. 4: Regression Analysis – Log Sugarcane

VARIABLES	Log Sugarcane
LGAIS	-0.0535
	(0.0495)
LTRACT	-0.0340
	(0.0702)
LAW	0.0637
	(0.135)
LHPS	0.0144
	(0.0237)
LFC	0.171
	(0.126)
LFAR	0.732***
	(0.146)
LRF	-0.130*
	(0.0673)
LMINT	-0.0404
	(0.112)
LMAXT	-0.0512
	(0.112)
Constant	5.650***
	(1.928)
Observations	21
Number of group	3
R-squared	0.933

Standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table (4.4) shows the regression results for sugarcane. It is evident that agricultural workers, harvest price, forest area and fertilizer consumption have a positive impact on the productivity of sugarcane. Whereas, rainfall, maximum and minimum temperatures, tractors and gross irrigated area have a negative effect on it. The value of R-square is 0.993 which states that there is 93.3% variation in the model.

It is interesting to find that rainfall affects the productivity of sugarcane negatively. 1% increase in the rainfall significantly decreases the yield by 0.13%. Studies have shown that Sugarcane requires a high amount of rainfall during the growth period, however, an increase in the rainfall during ripening can have serious implications on the growth of the crop. It can lead to a rise in the moisture level in the tissue giving way to vegetative growth. Moreover, it can destroy the harvest leading to a low yield (Zhao, D., & Li, Y. R., 2015). Another reason could be the seasonal variations in the rainfall which may affect the sowing and harvesting schedule of sugarcane, disturbing the production patterns leading to low productivity.

Increment in Forest area positively affects the productivity. 1% increase in forest area leads to 0.7% increment in the yield of sugarcane at a 1% significance level. This result is in accordance with our hypothesis. Forest area has an indirect impact on the productivity of crops. Afforestation and increase in the area under forests will decelerate the pace of global warming and reduce the chances of extreme climatic events successively protecting the crops from the sudden climate shocks.

Rice is the third crop chosen under our analysis. It is a Kharif crop, abundantly grown in the southern and the eastern parts of India. Since it requires a hot and a humid climate with rainfall above 100 cm, it is abundantly produced in Uttar Pradesh, Tamil Nadu, Andhra Pradesh, West Bengal, Orissa, Assam and Punjab. Cultivation of rice is highly responsive to temperature and precipitation variations and therefore we analyze the impact of climate change and other factors influencing the cultivation and yield of rice. The table (4.5) below indicates the results of our analysis.

Table 4.5: Regression Analysis – log rice

VARIABLES	Log Rice
LGAIR	0.230***
	(0.0282)
LTRACT	0.0310
	(0.0265)
LAW	0.0714
	(0.0678)
LHPR	0.0848*
	(0.0496)
LFC	-0.0646
	(0.100)
LFAR	-0.0928***
	(0.0347)
LRF	0.208***
	(0.0551)
LMINT	0.341**
	(0.169)
LMAXT	0.393
	(0.285)
Constant	1.645
	(1.205)
Observations	68
Number of group	7
R-squared	0.779

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1*

The regression results show that an increment in the minimum temperature positively affects rice productivity. 1% increase in minimum temperature increases the productivity by 0.34%. The regression coefficient for the minimum temperature is statistically significant at 5% significance level. Since rice is produced in hot and humid climate, an increase in the minimum temperature will make the climate more suitable for producing higher yields. The R-square value is 0.779 which explains that there is 77.9% variation in the model.

Annual rainfall and gross area irrigated are also important factors positively affecting the productivity of rice. An increment of 1% in both increases the productivity by 0.2% at a significance level of 1%. Rice is usually grown in areas dominated by rainfall due to the high water requirements of the crop while planting. The states that have low chances of rainfall completely rely upon irrigation techniques. According to ICRIER, sources of water such as rainfall and irrigation have a great impact on the productivity of rice. The states that are not endowed with enough rainfall sometimes produce better because of their dependence on the irrigation systems instead. Andhra Pradesh, Tamil Nadu, Karnataka are the only states that have a high yield of rice along with a significant coverage of land under rice cultivation. While, other states such as Orissa and Chhattisgarh have a low yield but large area sown of rice. The major reason for this gap in the production and productivity is the rainfall and the size of the irrigated area. Less frequent rainfall in rice producing states has an adverse effect on the rice yield.

Rice is a staple crop for people in southern and the eastern parts of the country. The soaring population has escalated the demand for this crop. Thus, there stands a need for a greater area under rice cultivation which can only be done by compromising on the forest cover. Our results show that a 1% increase in the forest area leads to a 0.0928% fall in the productivity of rice. Hence, there holds a negative relationship between rice yield and forest area.

The next crop taken into consideration for the study is wheat. It is the second most dominant crop in India grown in the temperature varying from 14 to 18 degree Celsius. Uttar Pradesh, Punjab, Haryana, Gujarat are some of the major states having high wheat yield. It is a Rabi crop requiring rainfall between 50 and 100 cm. The impact of factors related to productivity of wheat are analyzed in the section below.

Table 4. 6: Regression Analysis – Log wheat

VARIABLES	Log Wheat
LGAIW	0.171***
	(0.0417)
LTRACT	-0.142**
	(0.0624)
LAW	0.994***
	(0.0939)
LHPW	-0.163
	(0.126)
LFC	0.0131
	(0.123)
LFAR	-0.829***
	(0.0687)
LRF	0.0174
	(0.0814)
LMINT	0.226
	(0.206)
LMAXT	-0.393
	(0.262)
Constant	2.585*
	(1.441)
Observations	50
Number of group	5
R-squared	0.944

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1*

Table 4 shows the regression results for wheat. A rise in minimum temperature positively affects the productivity. However, the coefficient of minimum temperature is insignificant. Extremely high temperatures affects the productivity of wheat negatively, nonetheless, our results do not show a significant impact of the maximum temperature on the productivity of wheat. The value of R-square is 0.994 which explains that there is 94.4% variation in the model.

Any variation in Forest area affects the wheat productivity negatively, 1% increase in forest area leads to 0.8% decrease in the productivity. The agricultural workers and the gross irrigated area have a significant impact on productivity of wheat at 1% level of significance.

Number of workers positively affects the productivity, 1% increase in the number leads to 0.9% increase in the productivity. Even though India is emerging as a capitalist economy where there is a greater reliance on the use of tractors, machinery and technologically advanced implements, some poor regions still lack the access to these. These areas are dependent on labor intensive cropping and thus, with the increase in the labor, increases the productivity of wheat.

The results are in line with our hypothesis.1 % increase in the gross area irrigated results in a 0.17% increase in the wheat yield at the 1% significance level. This can be explained by the water shortage problem that Indian states face. Shortage of water is a major issue faced by the developing nations like India where a large part of cultivation is rain fed. Gradual changes in the climate are leading to precipitation variations and thus, increase in the irrigated lands and less reliance on rainfall will increase the productivity of wheat.

Tractors used is also observed to have a negative effect on productivity. According to (FAO, The challenge of tillage development in African agriculture), due to lack of trained workers, the tractors may not be used in the right agricultural zones and in the right kind of soil. This can in turn, hamper the productivity of the crop and the soil, leading to soil degradation. This may be the case in certain rural areas in India where the farmers are not educated and trained. However, further research needs to be conducted in order to find the possible reasons for the same.

Now we go on to analyze the effect of these production factors on the overall productivity of these crops in India. Table (4.7) shows the results of the regression analysis:

Table 4.7: Overall Regression – Log Yield

VARIABLES	Log Yield
LHP	-0.0544*
	(0.0290)
LFAR	-0.0658**
	(0.0306)
LGAI	-0.252***
	(0.0554)
LMINT	0.121
	(0.101)
LMAXT	-0.382*
	(0.200)
LRF	0.151***
	(0.0414)
LTRACT	0.0454
	(0.0297)
LAW	0.111***
	(0.0362)
LFC	0.173***
	(0.0540)
Constant	11.53***
	(1.200)
Observations	68
Number of group	7
R-squared	0.788

Standard errors in parentheses
**** $p<0.01$, ** $p<0.05$, * $p<0.1$*

While farm harvest price, forest area, irrigated area and maximum temperature are negatively linked to the agricultural yield, factors like minimum temperature, rainfall, number of tractors, agricultural workers and fertilizer consumption have a positive impact on agricultural productivity in India. Table (4.7) shows the effect of the considered variables on the overall yield of the country. The value of R-square is 0.778 which explains that there is 78.8% variation in the model.

A 1% increase in the maximum temperature results in the fall of the total productivity by 0.382% at the highest level of significance. Lately, India has been experiencing warmer temperatures and varied precipitation levels. The World Bank has projected a rise in the temperature in the south and the west region of India leading to an adverse effect on the productivity of crops like, rice, millet, sugarcane, cotton, turmeric and maize. These crops require high temperature at the time of sowing, however, rise in the temperature beyond a limit can cause loss in the yield of the crops. Warming of temperature may lead to the distortion of the intermolecular linkages in the crop preventing it from maturing. It also results in the reduction of groundwater levels resulting in dry areas becoming even drier. This water shortage has a negative effect on the productivity of the crops.

Most of the farming till date banks on rainfall. The interpretation of the results proves farming in India to be positively linked to monsoon.1% increment in the rainfall results in 0.151% fall in the productivity. Monsoon in India is a major factor in determining the quantity and the quality of yield. Rainfall at regular intervals maintains the soil moisture and reduces the cost of producing the crops consequently leading to a lower reliance on the irrigating systems. Even though irrigation techniques are becoming popular by the day, a huge section of small and marginal farmers in India find irrigation unaffordable. This gives rise to a negative effect of gross irrigated area on crop productivity. According to our results, 1% increase in the gross irrigated area leads to a 0.252% fall in the total agricultural yield in India. Installment of irrigation systems, creating canals, training farmers on the application involves a great amount of investment by the government eventually raising the cost of production of crops. Thus, there proves to be greater productivity in rain-fed areas than in the irrigated areas in the backward agricultural districts involved in farming and hence a more a positive relation with rainfall than irrigation.

The forest area has a negative impact on total productivity. 0.065% decline in the yield results from a 1% increase in the forest cover. This may be attributed to the fact that there is limited land available for cultivation and grazing. The more the area under forests, the less will be the land available for agricultural production. Thus, the results show that in order to increase productivity of crops more land is required for cultivation. According to (ITC, 2011), agriculture is assumed to be the major cause of reduction in the forest area.

Approximately 33% of India's growth in agricultural sector between 1970 and 1980 has been a consequence of greater use of fertilizers. Revolution in the agricultural sector of India brought about a positive change in the productivity of crops. According to the ministry of agriculture, fertilizer use has expanded from 1.1 million tonnes to 25 million tonnes from 1966 to 2014. This is also accountable to the growing needs of food crops by the burgeoning population in India. While some states like Haryana, Punjab and Andhra Pradesh require higher consumption of fertilizers because of soil type and large area under cultivation, other states like Orissa, Chhattisgarh. Madhya Pradesh and Rajasthan have a low consumption. Adequate amount of fertilizers lead to increase in the efficiency of the soil. The estimated results prove our hypothesis right. With 1% percent increase in the fertilizer consumption, there is a 0.173 % increment in the yield. Indian land suffers from soil degradation and lack of nutrients which is supported by the fertilizers. In order to boost the fertility of soil promoting higher yield, there is a greater requirement of fertilizers and organic manure.

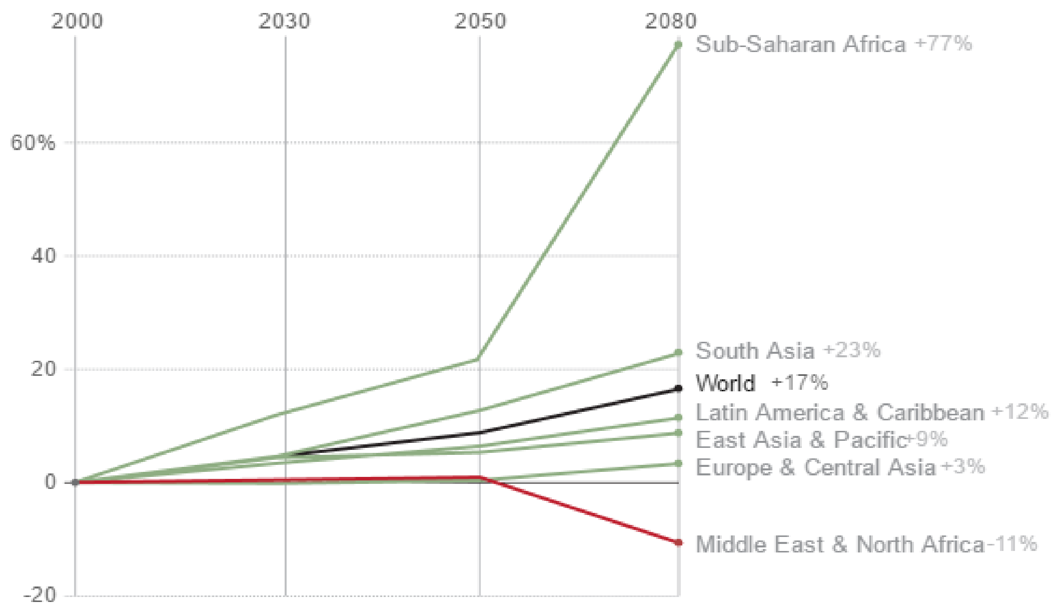
Workers have a positive impact on the productivity. An increment in the number of workers leads to a 0.111% increase in the yield. Agricultural workers in India have been proven to be more productive than the use of advanced machines and implements. However, the labor intensive farm is usually small and does not contribute much to the income of the nation. This is due to the high disparities in the farming sector in India which is divided into very rich and small farmers. Thus, there is a need to employ more workers in the primary sector of the economy to increase the production of the crops.

Lastly, it is interesting to note that an increase in the harvest price results in the fall in productivity of the crops. The fast paced urbanization and industrialization has provided advanced and varied techniques to increase the productivity. Nonetheless, more than 60 % of the landholdings in India are owned by small and marginal farmers. The poor economic status for a large section of farmers in India makes it difficult for these farmers to use high yielding varieties, expensive pesticides, fertilizers and implements. Lack of training on the usage of these new methods adds to the expenses, making the production costly and unaffordable, leading to losses for the farmers, successively lowering the production of the crops.

Chapter 5: Implications of Climate Change on Food Security

The rising magnitude of climate shocks across Indian economy has affected food productivity in numerous ways- both directly and indirectly. Significant alterations in the production cycle and the agricultural eco-system are the common direct impacts of such climate variations. On the other hand, the effect on the demand of crops, impacting the economic growth can be regarded as an indirect impact. Agricultural prices have a major indirect effect due to climatic shocks, not only in India but globally.

Figure 5.1: Projected percent change in agricultural prices overtime



Source: World Bank, Havlik et.al.

The World Bank data as shown above clearly projects a steep rise in agricultural prices globally by about 17%, with approximately 23% and almost 77% rise in agricultural prices in South Asian economies and Sub Saharan Africa, respectively. In line with these projections and increasing distortion in climatic stability, there has been an upward pressure on the agricultural prices, especially in India. With majority of the Indian population living below or at the poverty line, such rise in agricultural prices due to climatic shocks, poses a grave challenge for the Indian state to ensure food security for its masses.

Agriculture forms a major source of livelihood for around 58 percent of the rural population in India. Small and marginal farmers possess approximately 83 percent of the landholdings in the rural areas. With growing uncertainty in the food production due to changes in the climatic conditions, the poor sections of the society become the most vulnerable in the Indian economy. A study carried out by Centre for Low Carbon Futures, (2012) predicts that India will be affected by severe droughts in the years to come, leading to acute food and water shortages.

Furthermore, industrialization and the mounting reliance of manufacturing sector on agriculture have resulted in a drastic shift from food crop production towards cash crop production across the Indian economy. This continuously increasing pressure of the industrial sector on agriculture for cash crops with the simultaneous rise in negative externalities from industrialization is another major driver of food insecurity in the rural as well as urban areas. According to USDA and FAO, India will suffer from a nutritional deficiency in 2024.

All these above defined direct and indirect effects of climatic shocks coupled with the results of the regression analysis clearly establish an inverse relationship between climate change and food productivity in India. The analysis of our study indicates a negative affiliation of maximum temperature with the overall agricultural productivity of the crops taken into consideration. For a 1% increase in the maximum temperature, there is a 0.382% fall in the overall productivity. Soil transpiration and productivity are likely to be disrupted owing to the fluctuations in the rainfall and rise in the maximum temperature. Additionally, due to extreme and unsuitable weather conditions in the country there exist high chances of soil infertility leading to a decline in the quantity and quality of the crop. The study suggests that an increment in the temperature is expected to increase the risk of land degradation making it unsuitable for agricultural production. All these factors along with the inverse relationship identified by the study holds a far more significant implication for the question of 'FOOD SECURITY' for the Indian economy.

The results of our study also indicate a positive influence of rainfall on overall productivity. A 1% increase in the rainfall leads to a 0.151% increase in the yield of crops. This outcome has a positive effect on food security. An increasing rainfall will result in surplus production of food and cash crops. Since rainfall is a seasonal phenomenon, it cannot be regulated by the government. To augment the supply of water, the Indian government should focus on the development of advanced irrigation systems, in order to reduce the dependence of farmers on rainfall. The next section points out the various schemes and policies that the government has implemented to reduce the impact of climate change and low productivity on food security.

Considering the gravity of the situation, there holds an indispensable need to focus on the issue of food security, before it worsens. The government of India has been working on addressing the food security issues by providing subsidies for fertilizers, high yielding varieties, pesticides and manures and installing better irrigation systems. It has also launched, ‘The Eleventh Five Year Plan’ (2007-2012) that concentrated on reviving the production of crops through the operation of National Food Security Mission (NFSM). This programme has been extended to the ‘Twelfth Five Year Plan’ due to its success. Another scheme introduced by the government was the Rashtriya Krishi Vikas Yojana (RKVY). This programme aimed at providing incentives to the states to plan adequate policies in case of sudden natural calamities. The Government has introduced insurance plans for the crop, livestock and weather. Some of the other initiatives by the Indian government to address the problem of low agricultural productivity, food security and poverty are; the introduction of the ‘Watershed Development and Micro Irrigation Plan’, ‘Protection of Plant Varieties and Farmers’ Rights Act’, Establishment of ‘National Rain-fed Area Authority’ and the commencement of ‘ National Rural Health Mission’.

After understanding the interconnectedness between climate change, agricultural productivity and food security and looking into the government policies that have been shaped in order to address the upcoming challenges in India, we now move on to the next section that intends to provide necessary mitigation and adaptation strategies to tackle climate change and food insecurity.

5.1. Mitigation and Adaptation Strategies

Countering the various challenges faced by the Indian economy, including low productivity of the agricultural sector, health problems, poor infrastructure, endangered forests and wild life, rising sea levels, increasing pressure on the land with the growing population and lack of technology intervention of the government, public and private institutions is of utmost importance. It is for this precise reason that we would now be illustrating concisely the diverse mitigation policies outlined by the government of India in regard to climate change. To this end, the first section highlights the basic necessities provided to the poor and the improvement brought upon thereafter. The second section would be putting emphasis on the preservation of the natural biodiversity in the Indian subcontinent and finally in the third section, an analysis of policies vis-a-vis the conservation of water would be done.

According to NAPCC report, (2016), several organizations in India like NAPCC and NGOs including the National Institute of Malaria Research; Indian Institute of Tropical Meteorology (IITM), the India Meteorological Department (IMD), Director General of Health Services (DGHS), ICMR, NCDC, MOEF, NEERI, TERI, PHFI, WHO, UNICEF have been working on the mitigation and adaption techniques to reduce the magnitude of the impact of climate change on the country.

Resorting to Sustainable Agriculture Techniques that improve Agricultural Productivity:

All three key issues highlighted in this study- climate change, food security and poverty- are majorly linked to agricultural productivity. Owing to the growing population and the limited resources of the country, there is an immediate requirement to raise the productivity levels. Advanced farming techniques should be used in order to cope in a better fashion, with the climatic shocks. Improved irrigation systems should be introduced along with the cultivation of different types of crops which are not very sensitive to the climate changes. As mentioned in the IPCC Fourth Assessment Report, many researchers (Li et al., 2002; Wang et al., 2004a; Batima et al., 2005c) estimate that ‘improving the adaptive capacity by changing agricultural practices, upgrading livestock and crops by breeding and spending in latest know-hows and infrastructure’ will be of greatest significance. They equally state that these procedures would be made possible by ‘the adaptation of grassland management to the actual environmental conditions as well as the practice of reasonable rotational grazing to ensure the sustainability of grassland resources’ (p.499). Furthermore, it is deemed relevant to increase the land holding size of the farmers and to as such, expand the area under cultivation. Special emphasis should also be given to agriculturally rich states and those that are prone to natural calamities like floods and droughts by advancing the infrastructure of these states. Moreover, increasing the farmer's awareness by providing basic education in rural villages can also be a useful step contributing towards advancement of technology. Currently, National Initiative on Climate Resilient Agriculture (NICRA), an initiative the Indian council of Agricultural Research (ICAR), has been started to find out strategies to mitigate the effect of climate change on the primary sector. Agricultural policies should promote organic farming to bring about sustainable agriculture, thereby reducing the effects of agriculture on climate and ensuring higher yield and profits. According to(FAO, 2002), genetically modified crops can be planted, that have the capacity to resist natural occurrences and sudden climatic shocks curbing the pressure on the environment and in turn increasing the production of food without getting affected by climate.

Providing Basic Necessities to the Poor

According to the World Bank estimates, there has been a significant decline in the number of people below poverty line in India from 419 million people in 2004 to 273 million people in 2011. However, there is still an urgent need for tremendous advancement in terms of standard of living. Flourishing industries and low productivity in the agriculture sector has led to a large rural population migrating to urban areas in search of job opportunities. The government must ensure the smooth working of the Public Distribution System, (PDS). Food should be readily available to the poor at subsidized rates to solve the problem of food availability. More Viable plans and acts should be introduced by the government agencies aiming at reducing poverty levels by generating more jobs and increasing the minimum wage level so that each household has sufficient income to meet their basic needs.

One of the most successful schemes that were initiated by the government was the MNREGA, implemented in 2005. The act guaranteed at least 100 days of work to every household in rural areas who were willing to take up unskilled jobs. It aimed at providing financial security, motivated women to work reducing the gender gap and reduced migration from rural areas to urban areas providing rural poor better job opportunities. Several other programs such as the Jawahar Rozgar Yojana, Integrated Rural Program (IRDP) exist but unfortunately, they are not very actively followed and should as such be re-implemented (Upadhyay and Palanivel, 2011).According to IPCC Fourth Assessment Report, new contingency plans should be developed in order to spread awareness about the occurrence of natural calamities among the low skilled workers and to prepare them for mitigation and adaptation in case of emergency.

Improvement of Public Health Services

Indian climate is prone to weather changes and thus, it is sensitive to transmission of diseases. Dhara et al., (2013) and IPCC report of 2007 declare that there is an increasing risk of vector-borne diseases like diarrhea, dengue and cholera due to changes in the climate. More investment in the development of hospitals and regulation of free health check-ups for rural and urban poor should be taken into consideration. In 2013, the Government of India implemented the National Health Mission (NHM) which comprised of The National Rural Health Mission (NRHM) and the National Urban Health Mission (NUHM). Both of these aimed at addressing the needs of those who did not have an access to proper health facilities. Moreover, according to the report of Ministry of Health and family Welfare, Government of India, (2016), it would be beneficial to develop risk indicators for climate sensitive diseases such as *Chikungunya*, Dengue, Malaria, West Nile Virus, Tick-borne Encephalitis, and Lyme disease etc. (p.14)

Preserving Natural and Biodiversity

Forests are very strongly linked with the agriculture productivity. Promoting afforestation and preserving the natural habitat will not only reduce the chances of global warming by reducing pollution levels but will also provide fuel and other benefits to the rural population, thus, increasing their income and standard of living. Programs that prevent deforestation and forest fires should be initiated to improve the land use and increase sustainability of agricultural land (IPCC, Fourth Assessment Report). To this end, several Programs have been started by the Forest Development Agencies (FDA) to conserve the forests. One of their initiatives is the National Afforestation Program (NAP) which aims at forest protection and also at the improvement of the livelihood of the population living in and around the forest area.

Conserving Water Resources

Agriculture in India is hugely dependent upon groundwater for irrigation purposes. Growing population has increased the pressure on the agricultural land demanding a higher yield from the limited resources that India possesses. This in turn has led to overexploitation of non-renewable water, making it inaccessible and out of reach for small and marginal farmers. According to Singh, (2016), there is a need for 'Promotion of *in situ*/*ex situ* rainwater harvesting, conservation and application through precision irrigation techniques such as drip and sprinkler'. It is necessary to have water conservation plans and techniques especially in states that struggle with the problem of water shortage. Advanced irrigation systems and tube wells should be installed in maximum villages to avoid water scarcity. Some Indian states are highly endowed with surplus rainfall. The government of India has taken an initiative to re-direct the excessive rainfall and collect the same in an artificial groundwater storage which can be used in case of water stress. Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India have conceived a Master Plan for Artificial Recharge to Ground Water. Initiated in 2013, it aims at building 1.11 crore water recharge systems in both rural and urban areas.

Chapter 6: Conclusion

This dissertation laid the foundation by establishing a base on how agriculture developed in the world and how cultivation techniques were introduced in the epoch which marked the rise of Homo sapiens. It then continued to discuss the agricultural sector in India, followed by the developments and hardships that prevailed during colonialism. The study moved on to defining climate change and its positive and negative influences on agriculture around the world and in India. It subsequently escorted us to the question of why India is more sensitive to climatic shocks and what are the effects of these variations on agricultural productivity. Further, it establishes a link between agriculture and food security which is analyzed theoretically in this thesis. The study undertakes the following research questions:

1. What is the impact of climate change on agricultural productivity in 7 agriculturally rich states of India?

2. Does the impact of climate change on agriculture productivity differ from crop to crop?

3. What are the steps for adaptation of climate change, mitigating its effect on agriculture and food security?

A theoretical review has been presented demonstrating the relationship between climate change and agriculture. Corroborating studies were summarized, indicating the risk of rise in the temperature and the global warming levels in the world, accompanied by consequent results for the same. After this global research, the focus moved on to India, highlighting the key facts and events related to climate change and how it affected the productivity of some crops in the past. In addition to this impact of weather volatility on agriculture, a number of other consequences of changing climate have been accentuated. In the subsequent section, an attempt was made to display the interconnectedness of food security and agricultural productivity. It goes on elucidating the concept of food security in view of other researchers and organizations and describes the four aspects of food security in light of the trends and past records of Indian agriculture. The study identifies the deficiencies in the agricultural sector, suggesting some improvements to convalesce the problem of food security existing in India. Further, the interconnectedness between changing climate, agriculture and food security has been underlined, focusing on how variations in the prior is bringing about alterations in the latter. The research also articulates various factors other than agricultural productivity that engender food insecurity as a result of climate variations. Additionally, the major challenges faced by the poor population in the urban as well as rural areas have been emphasized.

This research adapted econometric analysis of secondary data gathered from various authorized sources, conducive to proving the aim of this study, mentioned above. To evaluate the repercussions of climate change on agricultural productivity, four major crops had been taken into consideration. These crops cover both cash and food crops. Crops were selected on the basis of their importance and dominance in the agricultural sector in India. This analysis was performed, keeping in mind the size of the country, on account of which seven major agriculturally rich states of India were selected. The area of research did not cover entire India owing to the extremely varied climatic conditions in each state which could have resulted in erroneous and biased results. In order to estimate the impact of climate shocks on agricultural productivity of crops, various factors influencing productivity were taken to be explanatory variables whereas yield in kilogram per hectare was considered as the dependent variable. Cobb Douglas production function was applied in the regression analysis. In addition, to avoid the risk of heteroskedasticity and multicollinearity, linear regression analysis with panel corrected standard errors has been used in the empirical model.

The empirical results of the regression analysis demonstrates the bearing of climate shocks on each crop in the first part and subsequently attempts to illustrate the effect of meteorological changes on the overall productivity of the country. The results indicate that cotton and wheat productivity are not significantly affected by climate change in the seven states mentioned above whereas sugarcane and rice are more sensitive to the variations in weather. The analysis presented a negative relationship between precipitation and productivity of wheat and showed a positive correlation between rice yield and rainfall. Rice productivity also proved to have a positive noteworthy impact of minimum temperatures. The overall production of the crops was negatively influenced by maximum temperature and had a positive effect of rainfall. Increment in the gross irrigated area positively affects cotton, wheat and rice productivity whereas it has a negative impact on sugarcane yield. Forest area was taken to be another factor influencing productivity. While it proves to have a positive influence on sugarcane, it holds a negative relationship with the productivity of cotton and rice. A strange but important result could be seen in case of mechanization. It was found that tractors have a negative effect on the productivity of wheat in India. Agricultural laborers also had a significant positive effect on cotton and wheat yield. The overall production of crops in the seven states was influenced positively by rainfall, agricultural workers and fertilizer consumption while it was negatively impacted by harvest price, forest area and irrigated area.

Hence, we can summarize the results by stating that Indian agriculture is sensitive to climate variations and changing precipitation levels. Sugarcane and rice are the most affected by meteorological changes. Further, we go on to correlate the changes in the climate with food security inferring that adverse effects on agricultural productivity of stable crops like rice has led to food insecurity in India. Policy implications and adaptations have been recommended to mitigate the impacts of climate change on agricultural productivity and food security.

Annexure

STATA Output and Commands

The STATA output with commands are presented in this section of the appendix. The STATA 12 software package was used to perform all the regressions and subsequent tests.

Since the output depicts the variables as entered in STATA, the short form for each variable is stated here.

Variables	Stata Variable Names	Actual Variable Name
Dependent Variable	TProd	Agricultural productivity (kg per hectare)
Explanatory Variable	Fa	Forest Area
Explanatory Variable	Ra	Rainfall
Explanatory Variable	mmin	Minimum Temperature
Explanatory Variable	mmax	Maximum Temperature
Explanatory Variable	fert	Fertilizer Consumption
Explanatory Variable	fap	Harvest Price
Explanatory Variable	Tt	Tractors
Explanatory Variable	Ir	Gross Irrigated Area
Explanatory Variable	Work	Agricultural Workers

Table A.1. Stata output of the summary of variables (Crop-wise)

Variable		Mean	Std. Dev.	Min	Max	Observations
states	overall	.	.	.	.	N = 0
	between		.	.	.	n = 0
	within		.	.	.	T = .
irw	overall	1644.343	3189.823	0	9630.065	N = 71
	between		3438.699	.031	9412.898	n = 7
	within		118.8525	1317.423	1868.121	T-bar = 10.1429
irc	overall	263.347	469.4849	.1144	1739.55	N = 71
	between		496.5752	1.62784	1376.775	n = 7
	within		89.79598	-173.4279	626.1225	T-bar = 10.1429
irs	overall	591.6515	615.7764	6.980969	2105.42	N = 71
	between		653.4964	11.18518	1976.593	n = 7
	within		90.82454	304.8815	826.1815	T-bar = 10.1429
fa	overall	2976.728	1764.883	1173.669	6229.899	N = 71
	between		1862.234	1173.899	5942.042	n = 7
	within		308.5784	528.1612	3264.585	T-bar = 10.1429
fert	overall	154.9225	45.48855	71.45	285.41	N = 71
	between		38.9854	107.021	220.862	n = 7
	within		27.67419	82.49053	219.4705	T-bar = 10.1429
tt	overall	31244.92	20730.07	3085	95653	N = 71
	between		17953.24	9013.545	64350.4	n = 7
	within		12095.51	6047.515	64352.52	T-bar = 10.1429
work	overall	829937	344738.4	403095	1641460	N = 71
	between		331501.7	473608.3	1422160	n = 7
	within		151031.5	422923.6	1127742	T-bar = 10.1429
c	overall	388.4677	148.5202	38	689	N = 62
	between		128.6085	182.1667	593.7	n = 7
	within		91.71333	215.7677	632.3677	T = 8.85714
s	overall	81321.83	15392.31	52326	114273	N = 71
	between		14435.93	58398	104680.5	n = 7
	within		7583.42	58848.47	106890.5	T-bar = 10.1429
r	overall	2473.31	553.5787	1425	3918	N = 71
	between		533.7688	1728.7	3096.3	n = 7
	within		248.7162	2018.11	3593.51	T-bar = 10.1429
w	overall	1947.787	876.5618	500	3255	N = 61
	between		923.1662	886.4	2889.2	n = 6
	within		227.6294	1474.687	2397.987	T-bar = 10.1667
mmax	overall	27.36236	4.106162	16.4	32.2	N = 69
	between		4.179323	19.7713	30.417	n = 7
	within		1.202114	23.38236	30.58106	T-bar = 9.85714
mmin	overall	14.55145	4.133424	5.85	21.61	N = 69
	between		4.328351	7.815	20.828	n = 7
	within		.9372149	12.44745	17.70963	T-bar = 9.85714

Table A.2. Stata output of the summary of variables

ra	overall	1167.951	408.1097	631.7	2057.8	N = 71
	between		381.6674	785.965	1832.9	n = 7
	within		198.7115	694.0969	1580.491	T-bar = 10.1429
fapr	overall	921.1031	316.6171	485	1596	N = 71
	between		66.03505	833.2	1010.6	n = 7
	within		310.6529	462.5031	1506.503	T-bar = 10.1429
fapw	overall	1178.039	323.531	635	2048	N = 51
	between		148.6801	1006.7	1410.9	n = 5
	within		294.9178	642.1392	1815.139	T-bar = 10.2
fapc	overall	2776.247	968.1869	1432	4974	N = 50
	between		288.1983	2293.9	2989.9	n = 5
	within		932.5144	1250.714	4760.347	T = 10
faps	overall	336.7619	427.9717	86	1942	N = 21
	between		237.5354	173.7	648.25	n = 3
	within		386.5272	-121.4881	1630.512	T-bar = 7
irr	overall	2096.46	1560.53	372.5	5012.74	N = 70
	between		1652.499	397.391	4707.074	n = 7
	within		246.3417	941.7679	3043.218	T = 10
group	overall	4.042254	2.031443	1	7	N = 71
	between		2.160247	1	7	n = 7
	within		0	4.042254	4.042254	T-bar = 10.1429
year	overall	2008.5	2.89302	2004	2013	N = 70
	between		0	2008.5	2008.5	n = 7
	within		2.89302	2004	2013	T = 10

Table A.3. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (COTTON)

```
. xtpcse c irc fa fert tt work ra mmin mmax fapc

Number of gaps in sample:  1

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs      =        44
Time variable:    year                          Number of groups   =         5
Panels:           correlated (unbalanced)       Obs per group:
Autocorrelation:  no autocorrelation                          min =          6
Sigma computed by casewise selection                          avg =        8.8
                                                              max =         10
Estimated covariances      =        15          R-squared          =    0.8069
Estimated autocorrelations =         0          Wald chi2(9)       =    368.34
Estimated coefficients     =        10          Prob > chi2        =    0.0000
```

c	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
irc	.2096715	.0245619	8.54	0.000	.1615311	.2578119
fa	.0063159	.0091195	0.69	0.489	-.011558	.0241898
fert	1.341387	.6989094	1.92	0.055	-.0284499	2.711225
tt	.0002822	.0012563	0.22	0.822	-.0021801	.0027445
work	.0002183	.0000641	3.41	0.001	.0000927	.0003439
ra	.0850321	.0432443	1.97	0.049	.0002747	.1697894
mmin	-15.99635	9.681706	-1.65	0.098	-34.97215	2.979446
mmax	14.81823	8.824569	1.68	0.093	-2.477603	32.11407
fapc	.0022248	.0202629	0.11	0.913	-.0374897	.0419394
_cons	-378.9113	163.1389	-2.32	0.020	-698.6577	-59.16495

Table A.4. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (SUGARCANE)

```
. xtpcse s irs fa fert tt work ra mmin mmax faps

Number of gaps in sample:  2

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs     =         21
Time variable:    year                          Number of groups  =          3
Panels:           correlated (unbalanced)       Obs per group:
Autocorrelation:  no autocorrelation                          min =          4
Sigma computed by casewise selection                          avg =          7
                                                              max =         10
Estimated covariances      =         6          R-squared         =     0.9380
Estimated autocorrelations =         0          Wald chi2(9)      =     593.31
Estimated coefficients     =        10          Prob > chi2       =     0.0000

-------------------------------------------------------------------------------
             |           Panel-corrected
           s |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+-----------------------------------------------------------------
         irs |  -4.771265    7.072562    -0.67   0.500    -18.63323    9.090703
          fa |   14.13027    7.641554     1.85   0.064    -.8469026    29.10744
        fert |   90.85444    69.24388     1.31   0.189    -44.86107    226.5699
          tt |  -.1190096    .0717016    -1.66   0.097    -.2595421    .0215229
        work |   .0074624     .019573     0.38   0.703    -.0309001    .0458248
          ra |   4.051541    6.316356     0.64   0.521     -8.32829    16.43137
        mmin |  -1429.322      1628.6    -0.88   0.380     -4621.32    1762.676
        mmax |   310.7441    647.0951     0.48   0.631     -957.539    1579.027
        faps |   5.972637    3.192995     1.87   0.061    -.2855184    12.23079
       _cons |   34671.33    24484.37     1.42   0.157    -13317.14    82659.81
-------------------------------------------------------------------------------

.
```

Table A.5. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (RICE)

```
. xtpcse r irr fa fert tt work ra mmin mmax fapr

Number of gaps in sample:  1

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs     =         68
Time variable:    year                          Number of groups  =          7
Panels:           correlated (unbalanced)       Obs per group:
Autocorrelation:  no autocorrelation                          min =          8
Sigma computed by casewise selection                          avg =  9.7142857
                                                              max =         10
Estimated covariances      =        28          R-squared         =     0.7027
Estimated autocorrelations =         0          Wald chi2(9)      =     217.04
Estimated coefficients     =        10          Prob > chi2       =     0.0000
```

r	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
irr	.2604729	.0554253	4.70	0.000	.1518414	.3691045
fa	-.0610817	.0293772	-2.08	0.038	-.1186599	-.0035035
fert	.3844295	1.958291	0.20	0.844	-3.45375	4.222609
tt	-.0013125	.002334	-0.56	0.574	-.0058871	.0032621
work	.0000815	.0002322	0.35	0.726	-.0003736	.0005366
ra	.4871401	.137069	3.55	0.000	.2184897	.7557905
mmin	88.49351	33.13746	2.67	0.008	23.54527	153.4417
mmax	18.37068	29.72744	0.62	0.537	-39.89403	76.63539
fapr	.2211898	.1679176	1.32	0.188	-.1079227	.5503022
_cons	-560.2116	620.893	-0.90	0.367	-1777.139	656.7164

Table A.6. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (WHEAT)

```
. xtpcse w irw fa fert tt work ra mmin mmax fapw

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs     =         50
Time variable:    year                          Number of groups  =          5
Panels:           correlated (balanced)         Obs per group:
Autocorrelation:  no autocorrelation                          min =         10
                                                              avg =         10
                                                              max =         10
Estimated covariances      =        15          R-squared         =     0.8987
Estimated autocorrelations =         0          Wald chi2(9)      =    1121.32
Estimated coefficients     =        10          Prob > chi2       =     0.0000
```

w	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
irw	-.000086	.0368483	-0.00	0.998	-.0723073	.0721353
fa	-.5133871	.0537058	-9.56	0.000	-.6186484	-.4081257
fert	1.163131	2.15926	0.54	0.590	-3.068941	5.395203
tt	-.0027883	.0043487	-0.64	0.521	-.0113117	.005735
work	.0022365	.0004924	4.54	0.000	.0012715	.0032015
ra	-.3244787	.2076189	-1.56	0.118	-.7314042	.0824468
mmin	-27.05977	53.10441	-0.51	0.610	-131.1425	77.02296
mmax	-47.45822	31.48895	-1.51	0.132	-109.1754	14.25899
fapw	-.4495481	.2435051	-1.85	0.065	-.9268093	.0277131
_cons	4300.075	685.0196	6.28	0.000	2957.461	5642.689

Table A.7. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (OVERALL YIELD)

```
. xtpcse yield gia gfa fert fap ra mmin mmax tt work

Number of gaps in sample:  1

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs     =         68
Time variable:    year                          Number of groups  =          7
Panels:           correlated (unbalanced)       Obs per group:
Autocorrelation:  no autocorrelation                          min =          8
Sigma computed by casewise selection                          avg =  9.7142857
                                                              max =         10
Estimated covariances      =        28          R-squared         =     0.7551
Estimated autocorrelations =         0          Wald chi2(9)      =    2038.46
Estimated coefficients     =        10          Prob > chi2       =     0.0000
```

yield	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
gia	-.8660404	.4383709	-1.98	0.048	-1.725232	-.0068492
gfa	-2.133908	.6051241	-3.53	0.000	-3.319929	-.9478865
fert	74.26588	34.56968	2.15	0.032	6.510552	142.0212
fap	-1.571827	.6936928	-2.27	0.023	-2.93144	-.2122143
ra	15.90891	3.641003	4.37	0.000	8.772679	23.04515
mmin	1162.878	561.2864	2.07	0.038	62.77697	2262.979
mmax	-639.091	655.2726	-0.98	0.329	-1923.402	645.2196
tt	.0368108	.0660359	0.56	0.577	-.0926173	.1662388
work	.0182575	.0039534	4.62	0.000	.010509	.026006
_cons	57792.54	19034.44	3.04	0.002	20485.73	95099.35

Table A.8. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (LOG OVERALL YIELD)

```
. xtpcse ly lra lfert lmmax lmmin lwork lfap lgfa lgia ltt

Number of gaps in sample:  1

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs     =         68
Time variable:    year                          Number of groups  =          7
Panels:           correlated (unbalanced)       Obs per group:
Autocorrelation:  no autocorrelation                          min =          8
Sigma computed by casewise selection                          avg =  9.7142857
                                                              max =         10
Estimated covariances      =        28          R-squared         =     0.7876
Estimated autocorrelations =         0          Wald chi2(9)      =     917.65
Estimated coefficients     =        10          Prob > chi2       =     0.0000
```

ly	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
lra	.1508655	.0413972	3.64	0.000	.0697285	.2320024
lfert	.1731927	.0540352	3.21	0.001	.0672857	.2790996
lmmax	-.3818651	.199628	-1.91	0.056	-.7731289	.0093987
lmmin	.1212646	.1011825	1.20	0.231	-.0770495	.3195787
lwork	.1112444	.0361687	3.08	0.002	.0403551	.1821337
lfap	-.0544018	.0289788	-1.88	0.060	-.1111991	.0023956
lgfa	-.0657766	.0306285	-2.15	0.032	-.1258074	-.0057457
lgia	-.2521236	.0553782	-4.55	0.000	-.3606628	-.1435844
ltt	.0453744	.0297057	1.53	0.127	-.0128477	.1035965
_cons	11.52721	1.199796	9.61	0.000	9.175648	13.87876

Table A.9. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (LOG COTTON)

```
. xtpcse lc lra lfert lmmax lmmin lwork lfapc lfa lirc ltt

Number of gaps in sample:  1

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs      =        44
Time variable:    year                          Number of groups   =         5
Panels:           correlated (unbalanced)       Obs per group:
Autocorrelation:  no autocorrelation                          min =         6
Sigma computed by casewise selection                          avg =       8.8
                                                              max =        10
Estimated covariances      =        15          R-squared          =    0.6886
Estimated autocorrelations =         0          Wald chi2(9)       =    225.54
Estimated coefficients     =        10          Prob > chi2        =    0.0000

------------------------------------------------------------------------------
             |           Panel-corrected
          lc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lra |  -.0010414   .1731895    -0.01   0.995    -.3404866    .3384038
       lfert |   .6116443   .4629917     1.32   0.186    -.2958028    1.519091
       lmmax |   1.631531    1.41591     1.15   0.249    -1.143602    4.406664
       lmmin |  -.6388947   .7337427    -0.87   0.384    -2.077004    .7992145
       lwork |   .2868578    .152584     1.88   0.060    -.0122014    .5859169
       lfapc |  -.0319734   .2207003    -0.14   0.885     -.464538    .4005912
         lfa |  -.1647326   .0853098    -1.93   0.053    -.3319368    .0024716
        lirc |   .1748081    .037558     4.65   0.000     .1011958    .2484204
         ltt |  -.0172111   .1626702    -0.11   0.916    -.3360387    .3016166
       _cons |  -3.870149   4.724447    -0.82   0.413     -13.1299    5.389596
------------------------------------------------------------------------------

.
```

Table A.10. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (LOG SUGARCANE)

```
. xtpcse ls lra lfert lmmax lmmin lwork lfaps lfa lirs ltt

Number of gaps in sample:  2

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs     =        21
Time variable:    year                          Number of groups  =         3
Panels:           correlated (unbalanced)       Obs per group:
Autocorrelation:  no autocorrelation                          min =         4
Sigma computed by casewise selection                          avg =         7
                                                              max =        10
Estimated covariances      =         6          R-squared         =    0.9328
Estimated autocorrelations =         0          Wald chi2(9)      =    306.41
Estimated coefficients     =        10          Prob > chi2       =    0.0000
```

ls	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
lra	-.1296458	.0672558	-1.93	0.054	-.2614647	.0021732
lfert	.1706253	.126082	1.35	0.176	-.0764909	.4177415
lmmax	-.0511767	.1122394	-0.46	0.648	-.2711618	.1688085
lmmin	-.0403879	.11168	-0.36	0.718	-.2592767	.178501
lwork	.0637305	.1345807	0.47	0.636	-.2000429	.3275038
lfaps	.0144288	.0237224	0.61	0.543	-.0320663	.0609239
lfa	.7320531	.1457242	5.02	0.000	.4464389	1.017667
lirs	-.0534529	.0494774	-1.08	0.280	-.1504269	.043521
ltt	-.0340091	.0702366	-0.48	0.628	-.1716703	.1036521
_cons	5.650299	1.927814	2.93	0.003	1.871853	9.428746

.

Table A.11. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (LOG RICE)

```
. xtpcse lr lra lfert lmmax lmmin lwork lfapr lfa lirr ltt

Number of gaps in sample:  1

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                        Number of obs      =        68
Time variable:    year                            Number of groups   =         7
Panels:           correlated (unbalanced)         Obs per group:
Autocorrelation:  no autocorrelation                            min =         8
Sigma computed by casewise selection                            avg =  9.7142857
                                                                max =        10
Estimated covariances      =        28            R-squared          =    0.7788
Estimated autocorrelations =         0            Wald chi2(9)       =    329.81
Estimated coefficients     =        10            Prob > chi2        =    0.0000
```

lr	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
lra	.2079439	.0551397	3.77	0.000	.099872	.3160158
lfert	-.0646184	.1001885	-0.64	0.519	-.2609842	.1317474
lmmax	.3926497	.2846483	1.38	0.168	-.1652506	.95055
lmmin	.3413419	.1687486	2.02	0.043	.0106008	.6720831
lwork	.0714439	.0678448	1.05	0.292	-.0615295	.2044172
lfapr	.0847857	.0496258	1.71	0.088	-.0124791	.1820506
lfa	-.0928204	.0347487	-2.67	0.008	-.1609266	-.0247141
lirr	.23037	.0281767	8.18	0.000	.1751447	.2855954
ltt	.0309656	.0264733	1.17	0.242	-.0209211	.0828524
_cons	1.645402	1.205367	1.37	0.172	-.7170747	4.007878

Table A.12. Stata Output for Linear Regressions, Correlated Panels Corrected Standard Errors (LOG WHEAT)

```
. xtpcse lw lra lfert lmmax lmmin lwork lfapw lfa lirw ltt

Linear regression, correlated panels corrected standard errors (PCSEs)

Group variable:   statenum                      Number of obs     =        50
Time variable:    year                          Number of groups  =         5
Panels:           correlated (balanced)         Obs per group:
Autocorrelation:  no autocorrelation                          min =        10
                                                              avg =        10
                                                              max =        10
Estimated covariances      =        15          R-squared         =    0.9436
Estimated autocorrelations =         0          Wald chi2(9)      =   1829.07
Estimated coefficients     =        10          Prob > chi2       =    0.0000
```

lw	Coef.	Panel-corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
lra	.01739	.0813805	0.21	0.831	-.1421128	.1768928
lfert	.0130563	.1231499	0.11	0.916	-.2283131	.2544257
lmmax	-.392724	.2618958	-1.50	0.134	-.9060303	.1205822
lmmin	.2263559	.2055719	1.10	0.271	-.1765576	.6292694
lwork	.9938839	.0938711	10.59	0.000	.8099	1.177868
lfapw	-.1631851	.1256422	-1.30	0.194	-.4094393	.0830691
lfa	-.8292163	.0687115	-12.07	0.000	-.9638884	-.6945443
lirw	.1710759	.0416857	4.10	0.000	.0893734	.2527784
ltt	-.1419295	.0623736	-2.28	0.023	-.2641795	-.0196795
_cons	2.585255	1.440572	1.79	0.073	-.2382155	5.408725

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Table A.13. Regression Analysis - Cotton

VARIABLES	Cotton
GAI	0.210***
	(0.0246)
FAR	0.00632
	(0.00912)
FC	1.341*
	(0.699)
TRACT	0.000282
	(0.00126)
AW	0.000218***
	(6.41e-05)
MINT	-16.00*
	(9.682)
MAXT	14.82*
	(8.825)
RF	0.0850**
	(0.0432)
HPC	0.00222
	(0.0203)
Constant	-378.9**
	(163.1)
Observations	44
Number of group	5
R-squared	0.807

Source -*Estimated by Author; and *, ** and *** indicates the 10%, 5% And 1% Significance level of regression coefficient for respective variables in the table and* Standard errors in parentheses

Table 1 shows the regression results for cotton. Any increase in the maximum temperature has a positive significant impact on the productivity of cotton. 1 unit increase in the Maximum Temperature would lead to 14.8 units increase in the cotton yield at 10 % level of significance. However, minimum temperature has a significant (at 10% level) negative impact on yield and 1 unit increase in the minimum temperature decreases the cotton productivity by 16 units. Rainfall also has a positive significant effect on the productivity at 5% level of significance Fertilizer consumption also has a significant effect on the productivity of cotton. With 1 unit increase in the consumption of fertilizers, there is a 1.34 unit increase in the yield. Other factors such as workers and gross irrigated area under cotton also have a significance at 1% level.

Table A.14.Regression Analysis – Rice

VARIABLES	Rice
GAI	0.260***
	(0.0554)
FAR	-0.0611**
	(0.0294)
FC	0.384
	(1.958)
TRACT	-0.00131
	(0.00233)
AW	8.15e-05
	(0.000232)
MINT	88.49***
	(33.14)
MAXT	18.37
	(29.73)
RF	0.487***
	(0.137)
HPR	0.221
	(0.168)
Constant	-560.2
	(620.9)
Observations	68
Number of group	7
R-squared	0.703

Source -*Estimated by Author; and *, ** and *** indicates the 10%, 5% And 1% Significance level of regression coefficient for respective variables in the table and* Standard errors in parentheses

Table 2 shows the regression results for rice. An increment in maximum and minimum temperatures positively affects rice productivity. 1unit increase in maximum temperature increases the productivity by 18 units whereas a 1unit increase in minimum temperature increases the productivity by 88.5 units. The regression coefficient for minimum temperature is statistically significant at 1% significance level whereas the coefficient of annual maximum temperature is insignificant even at 10% level. Annual rainfall is also an important factor positively affecting the productivity of rice. An increment of 1unit in annual rainfall increases the productivity by 0.5 units with a significance level of 1%. It is seen that forest area has a negative impact on the yield. With 1 unit increase in the forest area, there is a 0.0611 unit decrease in the yield of rice at 5 % significance level.

Table A.15. Regression Analysis – Wheat

VARIABLES	Wheat
GAI	-8.60e-05
	(0.0368)
FAR	-0.513***
	(0.0537)
FC	1.163
	(2.159)
TRACT	-0.00279
	(0.00435)
AW	0.00224***
	(0.000492)
MINT	-27.06
	(53.10)
MAXT	-47.46
	(31.49)
RF	-0.324
	(0.208)
HPW	-0.450*
	(0.244)
Constant	4,300***
	(685.0)
Observations	50
Number of group	5
R-squared	0.899

Source -*Estimated by Author; and *, ** and *** indicates the 10%, 5% And 1% Significance level of regression coefficient for respective variables in the table and* Standard errors in parentheses

Table 3 shows the regression results for wheat. A rise in maximum and minimum annual temperature has a negative impact on wheat productivity. However, the coefficients of both the variables are insignificant. Any variation in Forest area affects the wheat productivity negatively, 1 unit increase in forest area leads to 0.5 units decrease in the productivity. The coefficient of FAR is significant at 1%. Total fertilizer consumption is also a variable of importance positively affecting the productivity but the coefficient of FC is insignificant even at the 10% significance level.

Table A.16.Regression Analysis – Sugarcane

VARIABLES	Sugarcane
GAI	-4.771
	(7.073)
FAR	14.13*
	(7.642)
FC	90.85
	(69.24)
TRACT	-0.119*
	(0.0717)
AW	0.00746
	(0.0196)
MINT	-1,429
	(1,629)
MAXT	310.7
	(647.1)
RF	4.052
	(6.316)
HPS	5.973*
	(3.193)
Constant	34,671
	(24,484)
Observations	21
Number of group	3
R-squared	0.938

Source -*Estimated by Author; and *, ** and *** indicates the 10%, 5% And 1% Significance level of regression coefficient for respective variables in the table and* Standard errors in parentheses

Table 4 shows that any increment in the usage of tractors would result in a negative effect on the sugarcane yield. A 1 unit increase in the tractor machinery is expected to result in a 0.119 unit decrease in the sugarcane yield. The variable is highly significant at the 10% significance level. Any increment in the irrigated area would result in a positive effect on the cotton yield. A 1% increase in the area irrigated is expected to result in 0.16% increase in the yield. The variable is not significant at either the 1 or 5 or 10% level. Any increment in the farm harvest price of cotton would result in a positive effect on the cotton yield. A 1% increase in the farm harvest price is expected to result in a 0.0001% increase in the yield. The variable is not significant at either the 1 or 5 or 10% level. Rainfall is expected to have a positive impact on crop productivity. A 1% increase in rainfall is expected to have a 0.02% increase in the crop productivity. However, the variable is not significant at the 1 or 5 or 10% level. The maximum temperature has a positive impact and the minimum temperature has a negative effect on the yield of sugarcane. However, they are not significant.

Bibliography

1. Lewis, W. A. (1954). Economic development with unlimited supplies of labour. *The manchester school*, *22*(2), 139-191.
2. Johnston, B., Mellor, J., 1961. "The role of agriculture in economic development." American Economic Review 51(4): 566-593.
3. Dethier, J. J., & Effenberger, A. (2012). Agriculture and development: A brief review of the literature. *Economic Systems*, *36*(2), 175-205.
4. Matsuyama, K. (1992). Agricultural productivity, comparative advantage, and economic growth. *Journal of economic theory*, *58*(2), 317-334.
5. Martin, W., &Mitra, D. (2001). Productivity growth and convergence in agriculture versus manufacturing. *Economic Development and Cultural Change*, *49*(2), 403-422.
6. Dercon, S. (2009). Rural poverty: Old challenges in new contexts. *The World Bank Research Observer*, lkp003.
7. World Bank. (2007). *World development report 2008: Agriculture for development*. World Bank.
8. Aggarwal, P.K. (2009), "Vulnerability of Indian agriculture to climate change: current state of knowledge", paper presented at the National Workshop – Review of Implementation of Work Programme towards Indian Network of Climate Change Assessment, October14. Ministry of Environment and Forests, New Delhi, http://moef.nic.in/downloads/others/Vulnerability_PK%20 aggarwal.pdf.
9. Palut, M. P. J., &Canziani, O. F. (2007). Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change.
10. Birthal, P. S., Negi, D. S., Kumar, S., Aggarwal, S., Suresh, A., & Khan, M. T. (2014). How Sensitive is Indian Agriculture to Climate Change?. *Indian Journal of Agricultural Economics*, *69*(4).
11. Goswami, B. N., Venugopal, V., Sengupta, D., Madhusoodanan, M. S., & Xavier, P. K. (2006). Increasing trend of extreme rain events over India in a warming environment. *Science*, *314*(5804), 1442-1445.

12. Acharya, S. S. (2009). Food security and Indian Agriculture: policies, production performance and marketing environment. *Agricultural Economics Research Review*, *22*(1), 1-19.
13. Narayanan, S. (2015). Food security in India: the imperative and its challenges. *Asia & the Pacific Policy Studies*, *2*(1), 197-209.
14. The State of Food Insecurity in the World: *Addressing food insecurity in protracted crisis Food and Agriculture Organization of the United Nations*, Rome 2010.p.50
15. The state of food insecurity in the world. *Eradicating world hunger-taking stock ten years after the World Food Summit.* FAO corporate documentary repository 2006.p.14
16. Reddy, A. A. (2016). Food security indicators in India compared to similar countries. *Current Science*, *111*(4), 632-640.
17. Dand, S. A., ChakravartySujoy (2005). Food Insecurity in India: Causes and Dimensions.*Economics Area, Indian Institute of Management*, Vastrapur, Ahmedabad, 380015.
18. Upadhyay, R. P., &Palanivel, C. (2011). Challenges in Achieving Food Security in India. *Iranian Journal of Public Health*, *40*(4), 31–36.
19. Kiresur, V. R., Melinamani, V. P., Kulkarni, V. S., Bharati, P., &Yadav, V. S. (2010). Agricultural productivity, rural poverty and nutritional security: a micro evidence of inter-linkages from Karnataka State. *Agricultural Economics Research Review*, *23*, 29-40.
20. Datt, G., &Ravallion, M. (1998). Farm productivity and rural poverty in India. *The Journal of Development Studies*, *34*(4), 62-85.
21. Self, S., & Grabowski, R. (2007). Economic development and the role of agricultural technology. *Agricultural Economics*, *36*(3), 395-404.
22. Mozumdar, L. (2012). Agricultural productivity and food security in the developing world. *Bangladesh Journal of Agricultural Economics*, *35*(1-2).
23. McMichael, A. J. (2003). *Climate change and human health: risks and responses*. World Health Organization.
24. Samra JS, Singh G, Dagar JC. 2006. *Drought Management Strategies in India*. ICAR, New Delhi, India; 277.
25. Singh G. 2004. Climate change: impact on agriculture. Invited lecture delivered to postgraduate students, Khalsa College, Karnal, 24 April.

26. David B. Lobell, Adam Sibley and J. Ivan Ortiz-Monasterio, "*Extreme heat effects on wheat senescence in India*", Nature Climate Change, 2(2012): 186

27. Aggarwal, P. K. (2008). Global climate change and Indian agriculture: impacts, adaptation and mitigation. *Indian Journal of Agricultural Sciences*, *78*(11), 911.

28. Tripathi, A. (2017). Socioeconomic backwardness and vulnerability to climate change: evidence from Uttar Pradesh state in India. *Journal of Environmental Planning and Management*, *60*(2), 328-350.

29. Jha, B., &Tripathi, A. (2011). Isn't Climate Change Affecting Wheat Productivity in India?. *Indian Journal of Agricultural Economics*, *66*(3), 353.

30. Pattanayak, A., &Kumar, K. K. (2014). Weather sensitivity of rice yield: evidence from India. *Climate Change Economics*, *5*(04), 1450011.

31. Palanisami, K., Ranganathan, C. R., Senthilnathan, S., Govindraj, S., &Ajjan, S. (2009). Assessment of Vulnerability to Climate Change for the Different Districts and Agro-Climatic Zones of Tamil Nadu. *CARDS Series*, *42*, 2009.

32. Hobbs, P. R., Hettel, G. P., Singh, R. K., Singh, R. P., Harrington, L. W., Singh, V. P., & Pillai, K. G. (1992). Rice-Wheat Cropping Systems in Faizabad District of Uttar Pradesh. *India: Exploratory surveys of farmers' practices and problems and needs for further research, ICAR, NDUA&T, CIMMYT and IRRI*.

33. World Food Summit : 1996 : Rome, I., & Food and Agriculture Organization. (1997). *Report of the World Food Summit, 13 - 17 November 1996: Part one*. Rome: FAO

34. Kimani-Murage, E. W., Schofield, L., Wekesah, F., Mohamed, S., Mberu, B., Ettarh, R., ...&Ezeh, A. (2014). Vulnerability to food insecurity in urban slums: experiences from Nairobi, Kenya. *Journal of Urban Health*, *91*(6), 1098-1113.

35. Ramachandran N. 2014. *Persisting undernutrition in India. Causes, consequences and possible solutions.*

36. Ziervogel, G., Nyong, A., Osman, B., Conde, C., Cortés, S., & Downing, T. (2006). Climate variability and change: implications for household food security. *Assessment of Impacts and Adaptations to Climate Change (AIACC): Washington, DC, USA*.

37. Shinsugi, C., Matsumura, M., Karama, M., Tanaka, J., Changoma, M., & Kaneko, S. (2015). Factors associated with stunting among children according to the level of food

insecurity in the household: a cross-sectional study in a rural community of Southeastern Kenya. *BMC public health*, *15*(1), 441.

38. Khan, S. A., Kumar, S., Hussain, M. Z., &Kalra, N. (2009). Climate change, climate variability and Indian agriculture: impacts vulnerability and adaptation strategies. In *Climate Change and Crops* (pp. 19-38). Springer Berlin Heidelberg.
39. Geethalakshmi, V; Lakshmanan, A; Rajalakshmi, D; Jagannathan, R; Gummidi S; Ramaraj, AP; Bhuvaneswari, KL. Gurusamy and R. Anbhazhagan, (2011) *'Climate change impact assessment and adaptation strategies to sustain rice production in Cauvery basin of Tamil Nadu'*, Current Science 101(3): 342-347
40. Gupta, S; Sen, P; Srinivasan, S (2012) 'Impact of climate change on the Indian economy: evidence from food grain yields', Working Paper No. 218, Centre for Development Economics, Department of Economics, Delhi School of Economics, New Delhi.
41. IPCC (2001) '*The scientific basis, contribution of working group I to the third assessment report of the intergovernmental panel on climate change'*, in Houghton, JT; Ding, Y; Griggs, DJ; Noguer, M; van der Linden, PJ; Dai, X; Maskell, K; Johnson , CA (eds.) Cambridge, UK.: Cambridge University Press, p. 881
42. IPCC (2007) *'Summary for policymakers', Climate Change 2007: The Physical Science Basis'* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, in S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller (eds.), Cambridge, UK: Cambridge University Press.
43. IPCC (2014) '*Summary for Policymakers'*, In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, CB; Barros, VR; Dokken, DJ; Mach, KJ; Mastrandrea, MD; Bilir, TE; Chatterjee, M; Ebi, KL Estrada, YO; Genova, RC; Girma, B; Kissel, ES; Levy, AN; MacCracken, S; Mastrandrea, PR; White, LL (eds.)]. Cambridge University Press, Cambridge, United Kingdom, pp. 1-32
44. Kavikumar, KS; Parikh, J (1998) 'Climate change impacts on Indian agriculture: the Ricardian approach', Measuring the Impact of Climate Change on Indian Agriculture, in

Dinar, A; Mendelsohn, R; Evenson, R; Parkikh, J; Sanghi, A; Kumar, K; McKinsey, J; Lonergan, S (eds), Technical Paper No. 402, World Bank, Washington, D.C.

45. Mall, RK; Singh, R; Gupta, A; Srinivasan, G; Rathore, LS (2006) 'Impact of climate change on Indian agriculture: a review', Climatic Change 78(2-4): 445-478.
46. Rupakumar, K; Ashrit, RG (2001) 'Regional aspects of global climate change simulations: validation and assessment of climate response over Indian monsoon region to transient increase of greenhouse gases and sulfate aerosols'. Mausam 52(1): 229-244
47. Geethalakshmi, V., A. Lakshmanan, D. Rajalakshmi, R. Jagannathan, G. Sridhar, A.P. Ramara, Bhuvaneswari, K.L. Gurusamy, and R. Anbhazhagan (2011), 'Climate change impact assessment and adaptation strategies to sustain rice production in cauvery basin of Tamil Nadu', Current Science 101(03).
48. Kar, J., and M. Kar (2008), 'Environment and changing agricultural practices: evidence from Orissa, India', Indus Journal of Management and Social Sciences 2 (2):119-128.
49. Bhattacharya, S. and Mitra, A.P. (1998) Greenhouse Gas Emission in India for the Base Year 1990. Scientific Report, No.11, Centre for Global Change, National Physical Laboratory, New Delhi
50. Kaul, S., and G. Ram (2009), 'Impact of global warming on production of jowar in India (special issue: sustainable agriculture in the context of climate change)', Agricultural Situation in India 66 (5):253-256.
51. Rodhe, H. (1990). A comparison of the contribution of various gases to the greenhouse effect. *Science*, *248*(4960), 1217.
52. Cook, J. T., & Frank, D. A. (2008). Food security, poverty, and human development in the United States. *Annals of the New York Academy of Sciences*, *1136*(1), 193-209.
53. De Salvo, M., Begalli, D., &Signorello, G. (2013). Measuring the effect of climate change on agriculture: A literature review of analytical models. Journal of Development and Agricultural Economics, 5(12), 499-509.
54. Kumar, A., & Sharma, P. (2013). Impact of climate variation on agricultural productivity and food security in rural India (No. 2013-43). Economics Discussion Papers.
55. Gupta, S., Sen, P., & Srinivasan, S. (2014). Impact of climate change on the Indian economy: evidence from food grain yields. Climate Change Economics, 5(02), 1450001.

56. Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. Stata Journal, 7(3), 281.
57. Kang, Y., Khan, S., & Ma, X. (2009). Climate change impacts on crop yield, crop water productivity and food security–A review. *Progress in Natural Science*, *19*(12), 1665-1674.
58. Kirilenko, A. P., &Sedjo, R. A. (2007). Climate change impacts on forestry. *Proceedings of the National Academy of Sciences*, *104*(50), 19697-19702.
59. Zhao, D., & Li, Y. R. (2015). Climate change and sugarcane production: potential impact and mitigation strategies. *International Journal of Agronomy*, *2015*.
60. Zhai, F., T. Lin, and E. Byambadori (2009), 'A general equilibrium analysis of the impact of climate change on agriculture in the people's republic of China', *Asian Development Review* 26 (1):206-225
61. Salami, A., Z. Brixiova, H. Kandil, and A. Mafusire (2011), 'Toward food security in Africa: challenges, policies and the role of the African Development Bank', Africa Economic Brief
62. Kirilenko, A. P., &Sedjo, R. A. (2007). Climate change impacts on forestry. *Proceedings of the National Academy of Sciences*, *104*(50), 19697-19702.
63. Troy, T. J., Kipgen, C., & Pal, I. (2015). The impact of climate extremes and irrigation on US crop yields. *Environmental Research Letters*, *10*(5), 054013.
64. Jaeger, E. B., &Seneviratne, S. I. (2011). Impact of soil moisture–atmosphere coupling on European climate extremes and trends in a regional climate model. *Climate Dynamics*, *36*(9-10), 1919-1939.
65. Orlowsky, B., &Seneviratne, S. I. (2012). Global changes in extreme events: regional and seasonal dimension. *Climatic Change*, *110*(3), 669-696.
66. Vihma, T. (2014). Effects of Arctic sea ice decline on weather and climate: a review. *Surveys in Geophysics*, *35*(5), 1175-1214.
67. Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508-513.
68. Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *science*, *304*(5677), 1623-1627.

69. Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, *319*(5863), 607-610.
70. Schmidhuber, J., &Tubiello, F. N. (2007). Global food security under climate change. *Proceedings of the National Academy of Sciences*, *104*(50), 19703-19708.
71. Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508-513.
72. Shindell, D., Kuylenstierna, J. C., Vignati, E., van Dingenen, R., Amann, M., Klimont, Z., ...& Schwartz, J. (2012). Simultaneously mitigating near-term climate change and improving human health and food security. *Science*, *335*(6065), 183-189.
73. Kumar, M. D. (2003). *Food security and sustainable agriculture in India: the water management challenge* (Vol. 60). IWMI.