Chapter I

Introduction

Climate change refers to the changes beyond average atmospheric conditions, which are caused by both natural and human activities. The most important aspect of this change is that the earth's average temperature is gradually raising because of the increasing concentration of greenhouse gases (GHGs) emission in the atmosphere. The research on global warming challenges lots of uncertainties. In the trail of this research, the best predictions that were made about temperature rise were on the basis of greenhouse gas emissions, which is probabilistic in nature. These uncertainties are due to the lack of adequate scientific knowledge or insufficient accuracy in predictions, which may be expected to improve over time. With respect to agriculture, we shall first highlight the three important aspects in order to exhibit the relationship between climate change and agriculture. Firstly, climate change has a direct effect on the biological aspects of plant growth. Secondly, the impact of climate change on agriculture is considered due to the interaction between direct biological effects on the one hand, and biosphere and geosphere effects such as soil conditions, seed–water–fertiliser–pesticide technologies, plant entomology etc. on the other hand. Thirdly, we have to consider the impact of climate change on society and economy as well, dealing with the challenges posed by global warming on existing social and economic conditions, particularly in rural areas. Climate change is expected to have different type of effects in between agro-ecological regions, farming systems and different social classes and groups. More importantly temperature is the most significant variable of climate change. Where, one of the major effects of increase in temperature results the speed up of the crop growth period especially during the grain-filling stage causing lower yields. Occurrence of climate change results flood, drought and more extreme weather conditions, which can directly affect the crop yield. These effects can create food security problem in the upcoming days. Some evidences of climate change witnessed recently in India were, unexpected floods in Uttarakhand in 2013 and Jammu Kashmir in 2014, which caused havoc, took hundreds of lives and millions rupees of economic losses. Again in 2014, due to heavy rainfall across northeastern region of India many parts of Assam and Meghalaya suffered severe floods affecting several villages in Goalpara, Dhubri, Dhemaji, Lakhimpur, Jorhat, Morigaon and Kamrup districts during the monsoon season. The flood incidences were never new in Assam, but these incidences are occurring more frequently in present situation and these are major natural disasters of this era which has resulted in heavy life loss, economic loss and crop loss.

The scientific consensus has grown about the effects of climate change on human life and its significance is very likely to occur in the 21st century (Christensen et al, 2007). Climate change effects the elements of life for the people around the world and these effects are seen on access to water, food production, health and environment. Hundreds of millions of people around the world might suffer from hunger, water shortage and coastal flooding as the world warms leading to worse situations in climate change scenario (Stern, 2007). Climate change can have both direct and indirect negative impacts, on the general wellbeing of the people who depend highly on the natural resources especially agriculture and forest for their daily livelihoods. With regards to agriculture the general consensus suggests that change in temperature and precipitation will result in land and water regimes change, which will subsequently disturb the agricultural productivity (World Bank, 2003).

Climate change is one of the most burning global issues of the recent times. Melting of polar ice-caps, hole in the ozone layer, extinction of various species from the face of the earth, rise in global temperature, breeding of various deadly diseases related to climate change etc. are reported extensively worldwide. Studies suggest that if this trend continues for the next 60 to 70 years, our planet earth will no longer be a liveable place. High level delegations from different nations have in the present times realized these facts and have started to show their concerns by holding frequent talks and discussions to check the changing climate so as to take necessary preventive measures. The Copenhagen Summit held in 2009 also witnessed such initiatives like to create global awareness and to act jointly in order to suppress the emission of harmful gases and bring stability in the fast deteriorating climate. But, of course the outcome has not been very encouraging.

Sadly, the negative impacts of climate change are evident all around us. The winters are shorter and summers are longer these days, the average annual rainfall over the last few years has drastically reduced and the average global temperature has risen, leading to a high imbalance in the lives of flora and fauna.

Moreover, climate change has drastically affected our economy, which depends highly on agriculture. Climate and agriculture are inextricably linked because the later in most of the developing and under-developed countries still depends fundamentally on the weather conditions. The changing weather patterns have already started showing negative impacts on agriculture in many parts of the world including India. Notably, India has experienced a catastrophe in this regard in the recent years. Due to late arrival of monsoon and scanty rainfall, crops are destroyed every year resulting in hundreds of farmers committing suicide, out of loss and frustration, especially in the states of Andhra Pradesh, Chhattisgarh, Gujarat Maharashtra, Karnataka, Kerala and Tamil Nadu. As reported by Forbes and the Center for Human Rights and Global Justice (CHRGJ) at New York University in 2011, over the period of past 15 years, the scourge of suicides have claimed lives of an estimated 250,000 farmers and the death count is still climbing in India. According to Smita Narula, director of the CHRGJ, reported that on an average one farmer in India commits suicide every 30 minutes. She is also the co-author of the book namely Every Thirty Minutes: Farmer Suicides, Human Rights, and the Agrarian Crisis in India (Forbes, 2011). The study concluded, "The frequency of farmer suicides in India continues unabated and India has neither taken sufficient steps to address the underlying causes, nor sufficiently regulated the activities of multinationals who increasingly exercise tremendous control over multiple aspects of India's cotton and other cash crop sectors. In addition, the Indian government is approving field trials of other Genetically Modified (GM) crop varieties. The Indian government must put in place a stronger regulatory framework before more varieties are approved in order to ensure that farmers' rights are protected. It is neither inevitable, nor lawful, that the conditions that have led to this wave of suicides should continue. The Indian government should act now to implement the recommendations outlined above in order to put an end to this unnecessary tragedy." (CHRGJ, 2013)

Earlier in the year 2009, due to very low rainfall across the country during the monsoon season the agricultural output had been badly affected, resulting in the government of India to import grains in order to feed the entire population for the year 2010. Agricultural success decides the fate of a country's population in getting required amount of food grains and also employment to a certain extent and climate is the key to its success. So, there is a great need to deeply analyze the relationship between these two entities, i.e. agriculture and climate. As mentioned earlier, climate change has already had some adverse impacts on agricultural productivity and Assam being a major agricultural state is also under the scanner of this uncontrolled and deteriorating phase. In the state of Assam, agricultural sector is a major contributor to its economy, livelihood and employment. Almost 75 percent of population is directly or indirectly depended on agriculture. During the last few years, the state has experienced a gloomy situation in weather conditions leading directly to lower agricultural productivity.

1.1: Necessity of the Study

The state of Assam lies in the northeastern part of India and has essentially a tropical climate. At the same time, it being within the monsoon belt of south and southeast Asia, the region is under the tropical monsoon climate. But its location and topography, encircled on three sides by high mountain ranges and the presence of a precipitous plateau (Meghalaya) athwart the course of the incoming southwest monsoon wines, have rendered its climate somewhat different from that of the other parts of India. This peculiarity in climatic condition results in a unique crop patterns which is suitable for various agriculture based industry like tea, rubber etc. Besides, various seasonal crops are grown on massive scale including cereals, oilseeds, pulses and horticulture crops such as rice, wheat, maize, mustard, castor lentil, arhar, gram, peas banana, orange, pineapple etc. which are the main crops that supports the major population of this region. The agricultural sector contributed 20 percent of the Assam's total GDP during 2010-11. It is to be noted that the trend of growth of GDP in 2010-11 over 2009-10 was only 7 percent in the state. The net sown area in the state of Assam is 2.734 million hectares, which is approximately 35 percent of the geographical area of Assam, but the irrigation facility of the state is one of the major hindrances in agricultural growth. The statistical handbook shows that only 8.34 percent of area was available for irrigation out of the total area under crops cultivation in the state during 2010-2011. These facilities have been provided through various major/medium and minor irrigation schemes like Accelerated Irrigation Benefit programme (AIBP), Pahumara Irrigation Project, Modernisation of Jamuna Irrigation Project, Modernisation of Sukla Irrigation Project, Command Area Development and Water Management (CADWM) etc. These schemes were funded by national and state government as well as other nongovernmental organisations (Economic Survey, 2010). This implies that this high percentage of population of the state is solely dependent on climate for their livelihood.

The climate of Assam is characterized by its extreme humidity. Its most distinguishing feature is the abundant rainfall between March and May at a time when precipitation in upper India is at its minimum. Climatically the weather of Assam may be divided into the cold season and the rainy season. The cold season starts from October and remains till February and the rest of the year is rainy season. The southwest monsoon begins from middle of June and the temperature varies between 8^oC - 38^oC. Extreme rainfall in the rainy season causes floods in the state, which results in the heavy loss of crops, economy, transportation, health, and livelihoods. But in the recent year the state also faces drought like situation due to lack of rainfall and the increasing global temperature, which mostly affect the agriculture of the state. The Indian Network for Climate Change Assessment, 2010 (INCCA) report already revealed that in the Northeastern region the mean annual rainfall is projected to vary from a minimum of 940±149 mm to a maximum of 1330±174 mm. The increase in the year 2030's, with respect to the 1970's is in the order of 0.3 percent to 3 percent. In terms of temperature the INCCA report revealed that the minimum temperature is likely to raise by 1^0C to 2.5^0C and maximum temperature may rise by 1^0C to 3.5^0C (INCCA, 2010). This type of situation has threatened the food security in the state.

The rainy season in Assam begins from the month of June with the arrival of southwest monsoon and continues till September. The rainfall diminishes after September. October to February is usually the driest month of the whole year; again March to June is a pre-monsoon season, which is a transitional season between the dry cool winter, and warm rainy monsoon season. The state also experiences scanty rainfall in this period. Rice, being the staple food in Assam is cultivated in three cropping season, and this crops requires surplus water throughout its growing period, so, small alteration in the amount of rainfall accounts for drastic reduction in productivity.

Several districts in Assam suffered drought-like conditions for two years consecutively in 2005 and 2006, similar such situation in the future has been forecasted by the IPCC report of 2007 (IPCC, 2007). In the intense drought-like conditions that prevailed in as many as 15 districts of Assam during the monsoon months of 2006 owing mainly to below-normal (nearly 40%) rainfall in the region, more than 75 percent of the 26 million people associated with agriculture suffered crop failure and other peripheral effects. Normally, such fluctuations are considered as a result of inter-annual variability in the monsoons, but climate change increases the variability of the southwest monsoon beyond normal. According to Indian Meteorological Department (IMD) records, the amount of rainfall received by the northeast region in the 2006 monsoon season was the scantiest in 25 years since 1982.

Out of the eight northeastern states, Assam seems to have suffered the most from the deficit of rainfall and high temperatures that prevailed in 2006. Transplanting and sowing of rice were severely hampered. Only between 1991 and 2000, normal or above-normal rainfall was witnessed in the region. Conventionally, it becomes difficult to complete agricultural operations with heavy and continuous showers. Intense heat further aggravates the situation. In the absence of an organised water source and an irrigation management plan, the region could face complete or partial crop loss.

Rice is the predominant crop in this region, covering about 82 percent of cultivated area. The total area affected by agricultural drought during the southwest monsoon period constituted an average of 40 percent of the geographical area and 39 percent of the area under rice in the northeastern region. Drought conditions that prevailed in almost all fish farming areas also adversely affected the rearing of fish. (Malaviya, 2010)

Climate plays dice with the people of Assam. If, it is in their favor they prosper and if not famine occurs. The latter is more likely, as the climate change is becoming rampant day by day. A deep understanding of this climate and agriculture relationship will be helpful in creating awareness among the illiterate and poor farmers and help them search and adopt some alternative strategies so that the people are not left at the mercy of natural rainfall. Therefore here we propose to consider the impact of global climate change in agricultural production of Assam.

1.2: Objectives:

The main objectives of the study are as below:

i) To study the relationship among climatic change (CC) and agricultural productivity in Assam over the years.

ii) To study the major crops of the state which are affected most by climate change (CC).

iii) To find some remedies to compensate the effects of climate change (CC) on agricultural productivity.

1.3: Hypotheses:

The following hypothesis will be tested for the study,

1) H_o: The climate change has no impact on the productivity of agriculture in Assam.

2) H_o: The impact of climate change affects all the crops uniformly.

1.4: Methodology:

The required data used in the study were collected from the secondary sources. These sources were Directorate of Economics and Statistics, Krishi Bhawan, Regional Meteorological Centre, Government Press, various publications of journals, periodicals, Statistical Handbook of Assam and Economic Survey of Assam. The sample size of the data has been taken from 1970-71 to 2010-2011. The study is based on Assam with focus on the undivided ten districts separately. The ten districts considered for the study are Goalpara, Kamrup, Nagaon, Darrang, Dibrugarh, Lakhimpur, Sibsagar, Karbi-Anglong, N. C. Hills and Cachar. The reason behind taking only the ten districts of Assam was because during the 1970's i.e. in the beginning of this study period, Assam had only undivided ten districts. The undivided Goalpara in present times comprises of five districts i.e. Kokrajhar, Dhubri, Goalpara, Chirang and Bongaigaon. Whereas, undivided Kamrup comprises of Nalbari, Barpeta, Rural Kamrup, Metro Kamrup and Baksha. Again undivided Nagaon has been divided into Nagaon and Morigaon, similarly undivided Dibrugarh has been divided into Dibrugarh and Tinsukia districts of Assam. While, undivided Jorhat has been formed into three districts viz. Jorhat, Golaghat and Sibsagar and undivided Cachar district comprises of three districts i.e. Cachar, Karimganj, Hailakandi. Further undivided Lakhimpur formed into two districts namely Dhemaji and Lakhimpur. Only two hilly districts of Assam were not divided i.e. N.C. Hills and Karbi Anglong districts and till date remain same. Besides, the North Cachar Hills is presently known as Dima Hasao.

1.5: Econometric Tools and Technique:

To have the clear picture of annual total rainfall and annual mean temperature variations over the time period of 40 years i.e. 1970-2010 for district wise and state as a whole we have conducted standard deviation in the study. Again to check the status of principal crops (rice, wheat, pulses and oilseeds) productivity in the state we have calculate compound growth rate of district wise and state as a whole. Further to make the study more clear, some diagrams and charts have been included in the study.

For fulfilling the objectives of the study we have used Cob-Douglas production function technique in the log linear form where the climate is an input for agricultural productivity along with the other independent as well as controlled variables of the study. The interpretation was made for the fulfillment of the 1st objective, 2nd objective,1st hypothesis and 2nd hypothesis of the study. Here we have formed 5 different log linear analyses to find out the climate change impact on major crops in Assam. Again to have an indebt study of our 1^{st} objective i.e. to study the relationship among climate change and agricultural productivity and its related hypothesis i.e. the climate change has no impact on the productivity of agriculture in Assam, we have formed 10 separate log linear regression equation to see the impact of climate change on rice productivity in the ten districts separately and based on the results the analysis has been done.

To interpret the result of the study we have formed log linear regression equation for the analysis. Here we have used the Cob-Douglas type production function in the log linear form. The equation for the study is as follows:

$$\text{In}Y^i{}_{jt} = \ln \beta_1 + \beta_2 \ln R^i_{jt} + \beta_3 \ln T^i_{jt} + \beta_4 \ln F^i_{jt} + \beta_5 \ln IR^i_{jt} + \beta_6 \ln HYV^i_{jt} + U^i_t \text{ -----(1)}$$

Here, $Y^i{}_{jt}$ = Annual Productivity of ith commodity in kg per hectare for jth state/districts.

R^i_{jt} = Annual total rainfall in millimetre for the jth state/districts,

T^i_{jt} = Annual mean temperature in degree celcious for the jth state/districts,

F^i_{jt} = Proportion of fertiliser consumption for ith commodity production of jth state/districts

IR^i_{jt} = Proportion of area under irrigation for ith commodity production of jth state/districts

HYV^i_{jt} =Proportion of area under HYV seeds for ith commodity production of jth state/districts,

U^i_t = Standard error term

Here β_1, $\beta_{2 \ldots\ldots\ldots} \beta_8$ are the parameters of the equation, where ‘t’ stands for time period from 1970 to 2010, ‘i’ stands for the all agriculture commodity i.e. rice, wheat, oil seeds, pulses for state as a whole and annual rice productivity for the ten separate districts viz. Goalpara, Darrang, Cachar, Kamrup, Dibrugarh, Lakhimpur, Tinsukia, Nagaon, Karbi-Anglong and North Cachar hills (Dima Hasao) and again ‘j’ stands for the state as a whole and the other ten districts mentioned above.

The dependent and independent variables for the study are stated as follows:

1) In the first regression analysis, for the fulfillment of the 1^{st} objective as well as the 1^{st} hypothesis, we considered annual agricultural productivity of the state as the dependent

variable. The independent variables for the study are as follows; annual total rainfall, annual average temperature, proportion of area under irrigation, proportion of area under high yielding varieties seeds (HYV) and proportion of fertilizer consumption for all the agricultural crops. Here we have considered annual total rainfall and annual mean temperature as the long term climate change factor.

2) The 2^{nd}, 3^{rd}, 4^{th} and 5^{th} regression analysis have been applied for the fulfillment of the 1^{st} objective as well as the 1^{st} hypothesis. Here, we considered annual productivity of rice, wheat, pulses and oil seeds separately for the state as the dependent variable. The independent variables for the study are as follows; annual total rainfall, annual average temperature, proportion of area under irrigation facility, proportion of area high yielding varieties seeds (HYV) and proportion of fertilizer consumption in the state. Here we have considered annual total rainfall and annual mean temperature as the long term climate change factor.

3) 6^{th} to 15^{th} regression analysis has been applied for having district level break-up of the 1st objective of the study. Here we have considered average annual rice productivity of the ten districts separately as the dependent variable. The ten districts are Goalpara, Darrang, Cachar, Kamrup, Dibrugarh, Lakhimpur, Tinsukia, Nagaon, Karbi Anglong and North Cachar hills (Dima Hasao). The independent variables are district wise annual total rainfall, annual average temperature, proportion of area under irrigation facilities, proportion of area under high yielding varieties seeds (HYV) and proportion of fertilizer consumption. Here we have considered rainfall and temperature as the long term climate change factors, which are the independent or controlled variables of the study.

4) To fulfill the 2^{nd} objective of the study, we have taken the regression co-efficient of the climate factors i.e. annual total rainfall and annual mean temperature for all the major crops i.e. rice, wheat, pulses and oilseed to form a two-way ANOVA table and have compared the result to see the extent of climate effect on various crops.

6) The suggestions and policy implication part has fulfilled the 3^{rd} objective of the study.