Climate Change and Its Impact on Agricultural Productivity: A Case Study of Assam

Abstract

(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. 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 and Kashmir in 2014, which caused havoc, took hundreds of lives and million rupees of economic loss. Again in 2014, due to heavy rainfall across north-eastern 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 loss of lives as well as economic and crop loss. Most importantly, we, the human beings need food for survival but sadly our agriculture sector is mostly threatened by the long term impact of global climate change. Therefore, a major and immediate emphasis should be given to the global food security problem in order to cope up with the long term global climate change.

Research Gap:

From the literature reviewed in this study it has been found that there are several studies that have been conducted nationally and internationally regarding impacts of climate change on agriculture, but no specific study has been found on impact of climate change on agriculture sector in Assam. In the state agriculture plays a very important role in the Gross Domestic Product (GDP) and engages major proportion for employment in state. Here climate plays a very significant role, therefore, there is an urgent need to focus and enhance the understanding of long term climate change impact on agriculture sector in

Assam. This study has tried to focus on the long term (1970-2010) climate change regarding temperature and rainfall variations in Assam and its districts as well.

(II)

Statement of the Problem:

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.

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 in northeast region during 2006 monsoon was the scantiest in 25 years since 1982.

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 north-eastern 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 nature. Therefore here we have made an analysis of the impact of global climate change on agricultural production of Assam.

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.

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.

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. The 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.

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 calculated compound growth rate of district wise and state as a whole. Further, to make the study reflective 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 of 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 1st 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.

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:

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

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, β_2.....β_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 1st objective as well as the 1st hypothesis, we have 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 factors.

2) The 2nd, 3rd, 4th and 5th regression analysis have been applied for the fulfillment of the 1st objective as well as the 1st 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 factors.

3) 6th to 15th 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 2nd objectives 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 oil seeds 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 3rd objective of the study.

(III)

Major findings:

The effects of long term climate change have been witnessed in the agriculture sector of Assam. To cope up with these impacts of climate change on agriculture, society and livelihoods of the people in the state, there is an urgent need for better policies and their implementation by the government. The long term time series data shows that climate change has both direct and indirect negative impacts on the agriculture sector in the state. In the state, overall agricultural productivity is very much important for the well being of rural household and their livelihoods. The growth of agricultural productivity decides the well being of the rural households and their status in the society, where obviously the food security perception also comes in the way. Therefore, if immediate and appropriate measures are not taken by the government on climate change then the state will suffer more in the future.

This study analyses the inter-relationship between long term climate change effects and agriculture productivity with regard to major crops such as rice, wheat, pulses and oilseeds productivity respectively in the state of Assam during the period of 1970-71 to 2010-11. Further, this study also tries to establish a link between long term climate change effects and rice productivity in the ten undivided districts of Assam separately from 1970-71 to 2010-11. This study traces the adverse impact of long term climate change on the agricultural sector in the state.

Impact of Climate Change on Annual Agricultural Productivity in Assam:

The following findings has been revealed from the log linear regression analysis over the 40 years data; where the dependent variable is annual agricultural productivity and independent variables are annual total rainfall, annual mean temperature, proportion of fertiliser consumption, proportion of area under irrigation and HYV seeds. The findings are summarised below:

i) The results of the analysis reveal that the long term impact of climate change has very significant negative impact on the annual agricultural productivity of Assam. Whereas, the other independent variables of the model show significant positive linkages with the agricultural productivity of the state.

ii) It is also found from the analysis that both the increasing temperature and increasing amount of rainfall in the state have a negative influence on the annual agricultural productivity over the period of time. So we can say that the long term climate change factors have strong negative influences on the productivity.

iii) Other independent variables of the study i.e. fertilizer consumption, area under HYV seeds and irrigation facility when improved then agriculture productivity also shows increasing trend, therefore we can say that if each factor increases then the annual agricultural productivity also increases in the state. So, these controlled variables have strong positive influence on the agriculture productivity of the state.

Impact of Climate Change on Annual Rice Productivity in Assam:

Here we have tried to find out the long term climate change impacts on rice productivity in Assam. With the help of econometric tools the following findings have been reached relating to the long term climate change impacts on the rice productivity in Assam.

i) The increasing annual total rainfall and annual mean temperature were found to have negative impact on rice productivity in the state. If the annual total rainfall and annual mean temperature increase in the state then this would result into decrease in the annual rice productivity in a significant way.

ii) Fertiliser consumption also has a negative impact on the annual rice productivity in the state. Excessive use of fertiliser in rice cultivation does not result into increase in the yield rate.

iii) In the analysis, area under HYV and irrigation facility has significant positive impact on the rice productivity. It has been found from the analysis that if the area under HYV seeds and irrigation facility increased then there would be a very strong positive influence on the rice productivity of the state.

So we can say that the long term impact of climate change pulls down the yield rate of rice in the state, however it can be mitigated partially by the improvement in area under HYV seeds and irrigation facility in the state.

Impact of Climate Change on Annual Wheat Productivity in Assam:

During the wheat growing period plenty of rainfall is required, but as the harvesting season approaches the requirement for rain falls but the temperature required is above 30^0C. It has been found that even a small amount of rainfall during the wheat harvesting season results in crop damage. The long term climate change impacts on wheat are presented below:

i) There are marginal positive impacts of long term climate change factors i.e. annual total rainfall and annual mean temperature on the wheat productivity.

ii) Also other variables such as fertiliser consumption, area under irrigation and HYV seeds have varied positive impacts on the wheat productivity in the state.

Impact of Climate Change on Annual Pulses Productivity in Assam:

In Assam pulses includes arahar, black gram, gram, green gram, lentil and pea. It requires moderate warm type of climate and are grown in both rabi as well as kharif seasons. Pulses cultivation helps to restore the soil nutrients, thus it is harvested mostly during the crop rotation time. After analysis of the long term climate change impacts using regression model on annual pulses productivity in Assam, the following findings have been revealed:

i) Long term climate change factors i.e. annual total rainfall and annual mean temperature have negative impacts on annual pulses productivity in the state. Thus, increase in annual total rainfall and annual mean temperature respectively would result in decline of pulses productivity in the long run.

ii) Increase in area under HYV seeds has a very negligible positive impact on annual pulses productivity in the state.

iii) Further, fertiliser consumption and area under irrigation facility have statistical insignificant impact on pulses productivity in the state. Therefore, we can conclude that impact of fertiliser consumption and irrigation on yield rate of pulses in the state remains indeterminate in this study.

Impact of Climate Change on Annual Oilseeds Productivity in Assam:

Oilseeds crop are very sensitive and are basically grown in the dry season. In Assam, oilseeds are grown in kharif season as these crops are dry resistant. The oilseeds of the state include sesamum, rape, mustard, linseed and castor. Increase in temperature during the kharif season creates positive impact on the productivity of the oilseeds, but increase in rainfall creates a negative impact on the oilseeds productivity. The findings based on log linear regression analysis regarding the impacts of climate change on annual oilseeds productivity have been described below.

i) Climate change factors such as temperature and rainfall have significant both positive as well negative impacts on the annual oilseeds productivity in Assam.

ii) From the analysis we can say that if the annual total rainfall increases then this would result to decrease in the annual oilseeds productivity in long run, but if annual mean temperature increases in the state then this would positively influence the oilseeds productivity.

iii) Further increase in fertiliser consumption, area under HYV seeds and irrigation do not have any impact on the oilseeds productivity. Therefore, we can conclude that apart from temperature none other factors help in increasing the oilseeds productivity in the state.

Impact of Climate Change on District Wise Annual Rice Productivity in Assam:

The following findings are the result of climate change in the undivided ten districts of Assam as revealed from the log linear regression analysis:

i) The climate change factors i.e. annual total rainfall and annual mean temperature have significant negative impact on the rice productivity in Lakhimpur, Goalpara, Dibrugarh and Darrang districts of Assam.

ii) The major effected districts due to long term climate change are Lakhimpur, Goalpara, Dibrugarh and Darrang.

iii) Interestingly, in case of annual rice productivity, increase in annual total rainfall is found to have negative impact in the districts of Kamrup, Cachar, Sibsagar and Nagaon, whereas these districts experience positive impacts as the temperature increases. Further, in the two hilly districts i.e. N. C. Hills and Karbi Anglong, the climate change factors are statistically insignificant in the study.

iv) Increase in area under HYV seeds is found to have negative impact on rice productivity in the districts of Lakhimpur, Goalpara, Sibsagar, Darrang and Dibrugarh. While, apart from Sibsagar the other districts i.e. Lakhimpur, Goalpara, Darrang and Dibrugarh have experienced negative impacts on rice productivity due to both the climate change factors i.e. annual total rainfall and annual mean temperature.

v) It has also been found that increase in the usage of fertilisers have negative effects in rice productivity in the districts of Sibsagar and Cachar, whereas the other districts i.e. Lakhimpur, Kamrup, Goalpara, Nagaon, Darrang and Dibrugarh displayed positive impact.

vi) Further, area under irrigation facility have been found to have negative impact on rice productivity in Sibsagar and Dibrugarh districts, while irrigation plays an important, positive and significant role in Lakhimpur, Kamrup, Nagaon and Darrang districts of Assam.

Here, after analysing the long term climate change impacts on all the ten districts, we can conclude that Lakhimpur is the worst effected while Nagaon is the least effected districts in Assam. Moreover, in the two hilly districts of Assam i.e. Karbi Anglong and N C Hills the climate change effects on rice productivity is statistically insignificant.

Comparison of Climate Change Effects on Principal Crops:

If we compare the impact of long term climate change on different crops in the state, the following results are obtained:

1) From the ANOVA test, it has been observed that the calculated 'F' value has found more than the tabulated 'F' value. On the basis of that we can say different crops are affected differently by long term climate change factors i.e. annual total rainfall and annual mean temperature in the state.

3) It has been found from the observation that rice is most effected crop due to the long term climate change factors i.e. annual total rainfall and annual mean temperature in the state, while wheat is least positively affected by long term climate change factors.

(IV)

Suggestions and Policy Prescriptions:

This section of the study will fulfil the 3rd objective of our study that is to recommend some remedies to compensate the effects of climate change (CC) in agricultural productivity.

From the above analysis we can draw certain conclusions regarding long term climate change impacts. Most importantly climate change does not uniformly effect all the crops and rice is the most effected crop of the state. In order to improve the present situation, we have put forward some suggestions drawn from the study in the following lines. They are,

1) Change in planting time for different crops grown can help reduce the climate change impacts on the productivity of various crops in the state.

2) Wheat is the least effected crop due to climate change and is not grown widely in Assam. Thus, if wheat is grown instead of rice in certain major climate vulnerable rice cultivated areas then it will be significantly beneficial for the poor farmer as well as for the state.

3) In most of the districts of Assam, HYV seeds are found to have negative effects on the rice productivity; therefore farmers can go for traditional varieties of rice cultivation which have more resilience capacity during the long term climate change situation.

4) The area under irrigation facility also has negative impacts on rice productivity in the flood prone districts of Goalpara, Sibsagar, Cachar and Dibrugarh. In these districts the government should give importance to irrigation only during dry seasons so that the crops can be benefited resulting in increased yield.

5) Excessive usage of fertiliser has negative impacts on rice productivity, so there must be some training programmes in order to aware the farmers regarding proper amount and types of fertiliser to be used so as to improve rice productivity.

6) Since it is found in the study that the irrigation facility of the state is very poor therefore it requires immediate attention and improvement, especially during the winter or dry season as irrigation is very beneficial for increasing the agricultural productivity of the state.

7) Rain water harvesting (ponds, micro-water harvesting structure) is a very economical and short term arrangement to solve the water scarcity problem especially during the drought situation or dry seasons in the state. Thus, if the government takes this initiative it will be beneficial for strengthening food security during the climate change situation in the state.

8) Government as well as NGOs should train the farmers of the state to cope up with the long term impacts of climate change on agriculture sector.

9) It is high time that the government and NGOs have to realise and take initiatives for agricultural crop insurance market in the state. This will indeed be immensely beneficial for the farmers economic and livelihood security especially will help them cope-up with the extreme climate change situations such as flood and draught.

10) The government should realise the need of the hour and invest more on the research and development (R&D) relating to climate change education, its impacts, effects etc. to better understand the climate change issues and its impact on agriculture, livelihood and society in the state**.**

11) Creating markets for water and environmental services can be helpful for the farmers of the state. It can be facilitated by individual farmers, government, NGOs, local farmer unions, co-operatives etc. either at the village farm level or at the state level.

12) There is also an urgent need for the disaster management department of the state to act in favour of farmers. Also, the government can involve reputed national and international private organisations which are experts in this field.

13) Government should promote some initiatives towards risk-sharing, including social safety nets and weather insurance for the farmers of the state.

14) Although great progress has been made in predicting weather, still, annual crops often fail. Networks, that are responsible for informing weather related crisis for making well-timed decisions about how to

minimize the negative impacts of weather-induced food shortages do not provide these valuable information in order to timely deliver and work towards humanitarian aid before the crisis occurs. Since the 1980s, the number of these food emergencies has tripled as a result of this lack of preparedness.

15) Government should also take initiative for increasing soil-water retention which could be able to help in the time of drought occurrence and also sequestering carbon below ground. These efforts in the long run will help to increase crop productivity and retain soil carbon.

16) Crops and weather calendar can be issued by the agriculture and agronomy department of the state, which will be very helpful for the farmers in dealing with climate change related weather risks.

According to FAO (2008), to adapt to climate change impacts farmers need to broaden their crop genetic base and use new cultivation techniques with crops varieties. They need to adopt sustainable agronomic practices such as shift in sowing or planting periods, use of proper crop, efficient management of irrigation and reduced vulnerability of soil based agricultural production systems through the management of soil fertility, reduced tillage practices and management of the cycle of soil organic carbon more efficiently in grasslands and cropping systems.

Agriculture is important for food security as it produces the food for people to eat and (perhaps even more important) it provides the primary source of livelihood for 36 percent of the world‘s total workforce (FAO 2008) and for the 75 percent of the total population of Assam. Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and also, essentially, lower output variability in the face of climate risk as well as other risks of an agro-ecological and socio-economic nature. In order to stabilize output and income, production systems must become more resilient, i.e. more capable of performing well in the face of disruptive events like climate change situation. More productive and resilient agriculture requires transformations in the management of natural resources (e.g. land, water, soil nutrients and genetic resources) and higher efficiency in the use of these resources and inputs for production. Transitioning to such systems could also generate significant mitigation benefits by increasing carbon sinks, as well as reducing emissions per unit of agricultural products.

Recommendations for Future Research:

A more integrated approach to the impacts of climate change on food production, water availability and water quality is needed. Specifically:

1) Natural and social sciences need to work together to attain workable solutions in order to adapt to climate variability and change. The Inter-governmental Panel for Climate Change (IPCC) is a good

attempt to achieve this synthesis posterior, but it needs to occur also at the earlier stages in the research process.

2) Fully integrated crop-climate modelling is currently in its infancy but offers huge potential. Its further development and extension to include the water cycle should be a priority for research.

3) It is vital that studies quantify the uncertainty due to physical, biological and socio-economic processes in order to provide firmly based and useful information on agricultural climate change impacts.

4) More studies on the effects of rising levels of CO2 and its negative effects on ozone and their impacts on crops under field conditions are needed. These should be carried out in countries where crop vulnerability is potentially high and should cover a range of the major food crops.

5) The importance of developing adaptation options for agriculture that do not exacerbate climate and other environmental changes is crucial.

6) Defining critical temperatures and their timings within the growing cycle, across all major crops is crucial for providing more confident assessments of future global food production. High-temperature events are likely to be one of the major impacts of climate change and hence probabilities of their occurrence must be included in future assessments.

7) Crops need to be developed that are more resistant to extreme weather and growing conditions in terms of both yield and quality. This requires consideration of the complete biological system, which includes pests, diseases, toxins, protein content, etc.

8) Improved understanding of how local weather patterns will change with global warming should be a major area of research. Different crops will have different weather sensitivities and that is needed to be taken into account when considering the impacts of these changes. This information can help in the development of drought resistant varieties of staple annual crops such as wheat.

Conclusion:

From the analysis we can come to the conclusion that rice is the major field crop which is grown in the state. Climate plays a very important role in the agricultural sector of the region. There are two important factors of climate i.e. rainfall and temperature which negatively with some mere exceptions affect the agricultural sector of the state. We also observed that these climatic factors remain fluctuating over the years; though the annual total rainfall and average annual temperature show an increasing trend over the years. Apart from oilseeds, this increasing total annual rainfall and annual mean temperature exert negative impacts on rice and pulses productivity in the state. Whereas, increasing rainfall has positive

impact on wheat productivity and in terms of oilseeds productivity increasing rainfall effects negatively and increasing temperature effects positively.

Climate change can directly threaten the food security of the state and it would result in the loss of agro-biodiversity conservation as well as dependence of farmers on agriculture for survival and livelihood. So, there is an urgent need to understand the problem of climate change impacts on agriculture as well as livelihood of the masses in this region and stringent policies should be introduced to overcome of such problems.

Date: Jyoti Upadhyay