Chapter V

Introduction

In this chapter we will discuss firstly the Agro Climatic Zones, followed by cropping patterns and further the long term climate change impacts on the agricultural productivity of Assam. The study thoroughly examines the impact of climate change on four major crops of Assam viz. rice, wheat, pulses, oil seeds and also adds district wise study about the impact of climate change on rice separately.

5.1: Features of Agro Climatic Zones in Assam:

Based on the rainfall patterns, terrain and soil characteristics, Assam is divided into six Agro Climatic Zones which comprises 27 districts as shown in the following table no. 5.1.

Table 5.1: Features of Agro Climatic Zones in Assam

Zones	Districts	Area in Sq. Km[1]	Cropping Intensity (in %)[2]	Normal Rainfall (in mm), 2008-10[3]	(Temperature (Max. and Min in Degree Celsius), 2008-10[4]	Soil Type[5]
(i)Barak Valley Zone	Cachar, Hailakandi and Karimganj	6962	131.5	3100	39^0 C – 11^0 C	Old reverine alluvial, old mountain alluvium, Non-laterised red soil, Laterised red soil and Peat soil
(ii)Central Brahmaputra Valley Zone	Nagaon and Morigaon	5561	146.5	1807	38^0 C –10^0 C	Most recent immature soil (Entisol) and Old mature soil (Alfisols)
(iii)Lower Brahmaput	Kokrajhar, Bongaigao	20148	148.4	2450	31^0 C- 10^0 C	New alluvium soil and old alluvium

ra Valley Zone	n, Barpeta ,Goalpara, Dhubri, Nalbari, Kamrup Metro, Kampur Rural, Chirang and Baksa					soil
(iv)North Bank Plain Zone	Lakhimpur, Sonitpur, Darrang, Dhemaji and Udalguri	14421	152.5	2350	37^0 C – 8^0 C	Old alluvial soil (Alfisols), Old alluvial soil (Inceptisols) and New alluvial soil (Entisols)
(V) Upper Brahmaputra Valley Zone	Dibrugarh, Sibsagar, Jorhat, Golaghat and Tinsukia	16,192	129.7	1800	37^0 C – 11^0 C	Most recent alluvium, Mature ultisol, Sandy loam, Silty loam and loamy sand
vi)Hill Zone	Karbi Anglong and NC hilis	15322	149.1	1125	37^0 C – 9^0 C	Red loamy soil and old alluvial soil

Sources: 1& 2 – Statistical Handbook of Assam, 2009 & Economic Survey Assam, 2009-10, 3 & 4 - Regional Meteorological Centre, Guwahati, 5 – National Agriculture Research Project, 2008-09

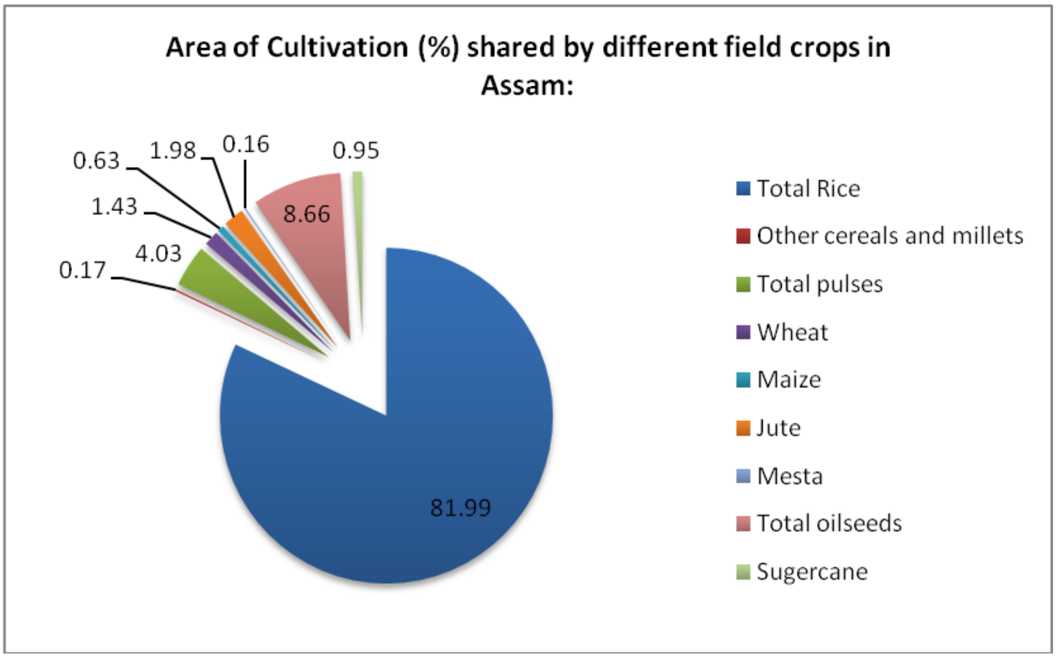
Accordingly the climate of Barak Valley Zone is characterised by annual normal rainfall of 3100 mm, the temperature ranges maximum 39^0 C during July-August and minimum 11^0 C during December-January. The Barak Valley Zone comprises of various types of soil such as old reverine alluvial, old mountain alluvium, non-laterised red soil, laterised red soil and peat soil. The major crops cultivated in this region are rice and pulses. The Central Brahmaputra Valley consists of only two districts of Assam i.e. Nagaon and Morigaon. The climatic condition is characterised by annual normal rainfall of 1807 mm and the temperature ranges from maximum 38^0 C during summer season to the minimum of 10^0C during the winter season. Types of soils found in this valley are; most recent immature soil (entisol) and old mature soil (alfisols); and major grown crops are rice, jute and pulses. As seen in the above table, the Brahmaputra Valley includes maximum number of districts and has annual normal rainfall of 2450 mm and the temperature ranges maximum 31^0 C in summer hot days and minimum 10^0C during the winter cold days. The types of the soil found in this region are; new alluvium soil and old alluvium soil, and the major grown crops are rice, oil seeds, pulses and jute. The climatic condition of North Bank Plain Zone is reported with the annual normal rainfall of 2350 mm and the temperature ranges from maximum 37^0 C in summer season to the minimum of 8^0 C during the winter season. The soil characteristic in this zone varies from old alluvial soil (alfisols), old alluvial soil (inceptisols) and new alluvial soil (entisols). Interestingly, the soil quality in this zone is very much suitable for growing rice, other cereals and pulses. The Upper Brahmaputra Valley Zone consists of four districts of Assam. The climatic condition is characterised by annual normal rainfall of 1800 mm and the temperature ranges from maximum 37^0 C in summer season to minimum of 11^0C during the winter season. The types of soils found in this valley are; most recent alluvium, mature ultisol, sandy loam, silty loam and loamy sand; and the major grown crops are rice, oil seeds and pulses. The only hill zone of Assam comprises the district of Karbi Anlong and North Cachar Hills, which has an annual normal rainfall of 1125 mm and the temperature ranges maximum 37^0 C in summer hot days to minimum of 9^0 C during the winter cold days. The types of soils found in this valley are basically red loamy soil and old alluvial soil. The major crops are rice irrespective of topography whereas maize is the second most important crop.

5.2: Area of Cultivation Shared (%) by Different Field Crops in Assam

The following figure no. 5a shows the area of cultivation (%) shared by different field crops in the 10 undivided districts of Assam during the year 2010-2011. The reason behind the selection of the 10 districts has been due to the fact that these concerned districts during 1970s were not divided into the present 27 districts and most importantly our study started from that time period covering the entire state of Assam.

The figure 5a shows the percentage of cultivated area shared by different field crops in the entire state during the year 2010-2011. It has been observed from the figure that rice is the major crop in Assam, cultivated in an area of around 82 percent out of the total field crop cultivated area, followed by oil seeds (which includes sesamum, rape, mustard, linseed, castor) with only 8.7 percent and pulses (which includes black gram, arahar, peas, gram, green gram, lentil and other pulses) with only 4.03 percent. Less than 2 percent of the area is used to cultivate jute (1.98%) and wheat (1.43%). While other crops like sugarcane, maize, mesta and other cereals and millets each of them share less than 1 percent of the total field crop cultivated area.

Figure 5a: Area of Cultivation shared (%) by different field crops in Assam (2010-11)



Source: Agriculture Department, Khanapara

5.3: Annual Compound Growth Rate of Area, Production and Productivity of the Principal Crops in Assam:

To understand the status of major crops, we have calculated the compound growth rate of area, production and yield/ productivity of four major crops (rice, wheat, pulses and oilseeds) of Assam during the two time periods i.e. 1970-71 and 2010-11. From the following table no. 5.2 it has been observed that in terms of area, the highest growth rate is found in wheat having 124 percent, followed by oil seeds with 82.3 percent. Less than 50 percent growth rate has been observed in pulses, food grains and rice over the years. Again, the growth rate of production has been found highest in wheat with 368.3 percent, followed by oil seeds with 154.4 percent, food grains with 153.7 percent, rice with 153.3 percent and lastly the growth rate of pulses is 120.0 percent in the state. Further, in case of the growth rate of yield of major crops, wheat is highly grown with 102.2 percent, followed by rice with 80.3 percent, food grains with 78.4 percent, pulses with 46.6 percent and lastly the growth rate of oil seeds is 38.4 percent over the years. From the above analysis, it is found that the growth rate of area, production and yield/ productivity has been highest in case of wheat. While the lowest growth rate of area is found in rice, lowest growth rate of production is found in pulses and lowest yield/ productivity growth rate is found in oil seeds. Interestingly, second highest growth rate of yield/ productivity has been found in rice.

Table 5.2: Annual Compound Growth Rate of Area, Production and Productivity of Assam:

(Area in '000 Hectare, Production in '000 MT and Productivity in Kg per Hectare)

Crops/Year		1970-71	2010-11	CGR* (%)
Total Rice	Area	2366.5	2570.3	8.6
	Production	1987.0	5032.6	153.3
	Productivity	1022.0	1957.9	91.6
Wheat	Area	20.0	44.8	124.0
	Production	12.0	56.2	368.3
	Productivity	583.0	1254.5	115.2
Total Pulses	Area	85.0	126.0	48.2
	Production	32.0	70.4	120.0
	Productivity	379.0	558.7	47.4
Total Food Grains	Area	2096.0	2766.5	32.0
	Production	2040.0	5175.9	153.7
	Productivity	988.0	1870.9	89.4
Total Oil Seeds	Area	149.0	271.6	82.3
	Production	62.0	157.7	154.4
	Productivity	416.0	580.6	39.6

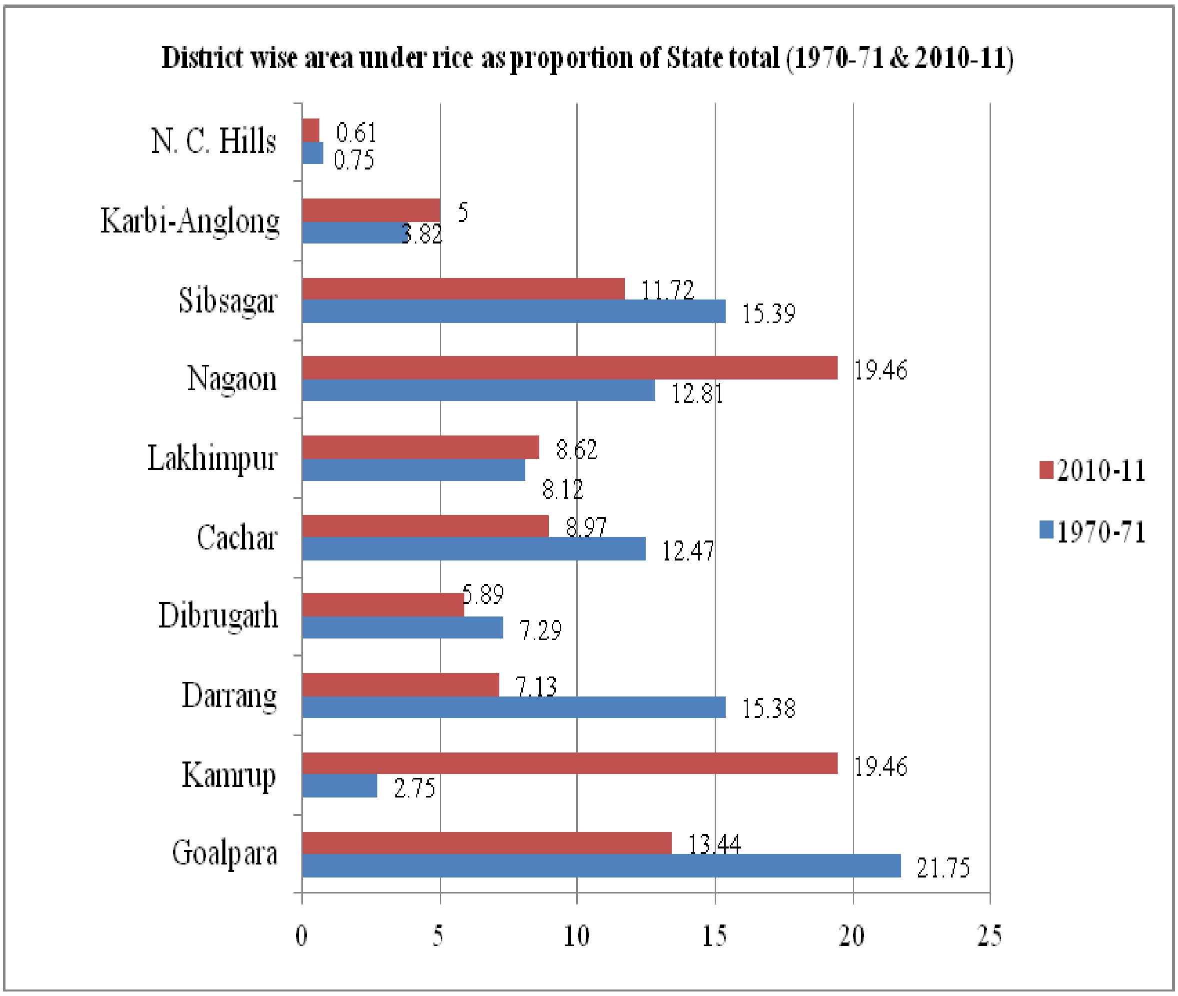
Source: Agriculture Department, Khanapara, *Compound Growth Rate

5.4: District Wise Area and Production under Rice as Proportion of State Total (1970-71 & 2010-11)

From the earlier figure no. 5a it has been found that amongst all the cultivated field crops, rice is the most important major crop of Assam comprising more than 80 percent of the total field crops cultivated area. Therefore, in order to find out the district wise proportion of area and production under rice of the state in total, the following analysis has been made.

The following figure 5b shows the area share of rice cultivation in different districts to the state total during two time periods i.e.1970-71 and 2010-11. From the figure it has been observed that in some districts viz. Goalpara, Darrang, Dibrugarh, Cachar, Sibsagar and N. C. hills the proportion of rice cultivation area has decreased over the years. On the other hand, proportion of area has notably increased in some districts like Kamrup, Lakhimpur, Nagaon and Karbi Anglong.

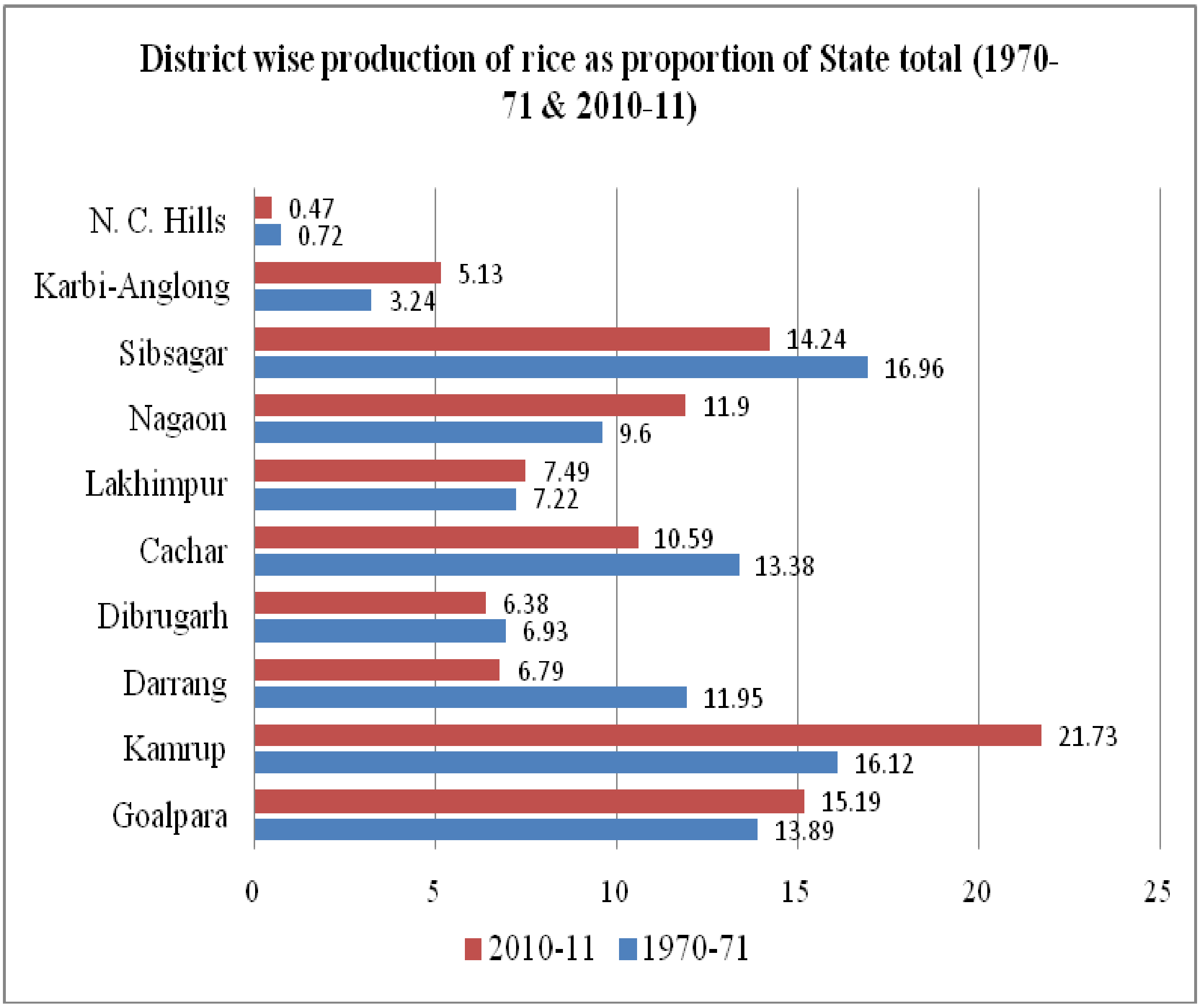
Figure 5b: District wise area under rice as proportion of State total (1970-71 & 2010-11)



Source: Agriculture Department, Khanapara

Again the following figure 5c shows the rice production share in percentage (%) by different districts to the state total during the two time periods 1970-71 and 2010-11. It has been clearly observed from the figure that the share of rice production decreased in the five districts of Assam i.e. Darrang, Dibrugarh, Cachar, Sibsagar and N. C. hills during the time period of 2010-11 as compared to 1970-71. Whereas, the districts like Goalpara, Kamrup, Lakhimpur, Nagaon and Karbi Anglong the share of district wise rice production to form the state total has been increased.

Figure 5c: District wise production of rice as proportion of State total (1970-71 & 2010-11)



Source: Agriculture Department, Khanapara

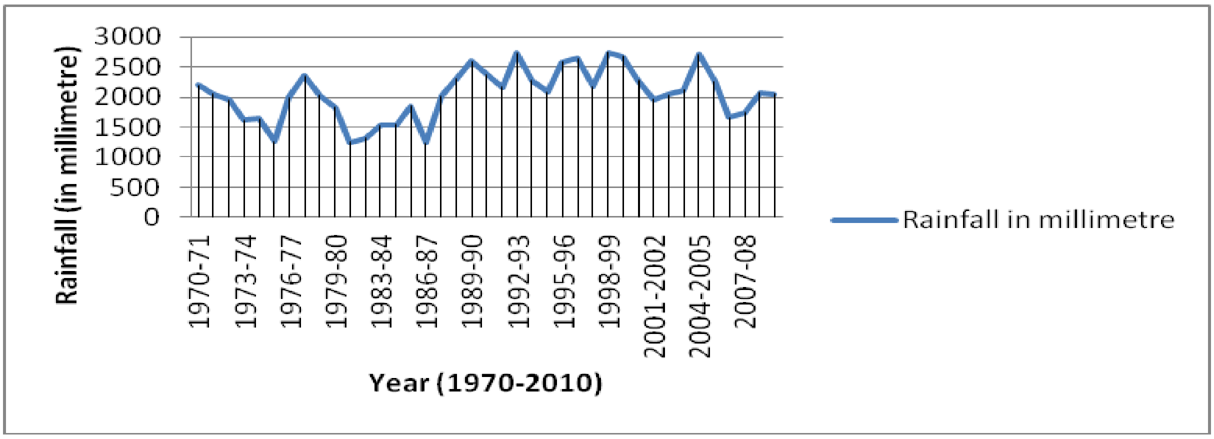
The reason behind decrease in the share of rice cultivation area and production from the different districts to the state total might be because of the crop diversification taking place in the state. Also, due to the introduction and preferences given to some central and state government schemes such as National Horticulture Mission, National Food Security Mission, Rastriya Krishi Vikash Yojana etc. which focus only on horticulture, floriculture, Pulses etc. might be behind the decreasing trends in the share of rice cultivation area and production by different districts of Assam over the years.

5.5: Annual Total Rainfall and Temperature Variations in Assam (1970-2010)

It has been already mentioned in the above discussion that Assam is divided into six Agro Climatic Zones, having different climatic conditions in every zone. Assam receives plenty of rainfall during the monsoon, but excessive rainfall causes flood problem in most of the districts like Cachar, Darrang, Goalpara, Jorhat, Kamrup, Lakhimpur, Nagaon and Sibsagar. The figure 5d shows the annual total rainfall variations in the state. It has been observed from the figure that the variations based on yearly total rainfall are very high in the state. During the period of 1989-90 to 2004-05 high fluctuations in the total annual rainfall has been observed in the state, causing frequent incidences of floods leading to huge loss in cropped areas. Whereas, during the two periods i.e. 1970-71 and 2007-08 the state received almost equal amount of total annual rainfall. We observed that while low rainfall causes drought like situation in the state, high rainfall i.e. more than normal causes flood in the state. Also it has been found in many studies done earlier that the rainfall is expected to increase in future in the higher latitudes during the climate change situations and this rainfall fluctuation can directly affect the agricultural sector.

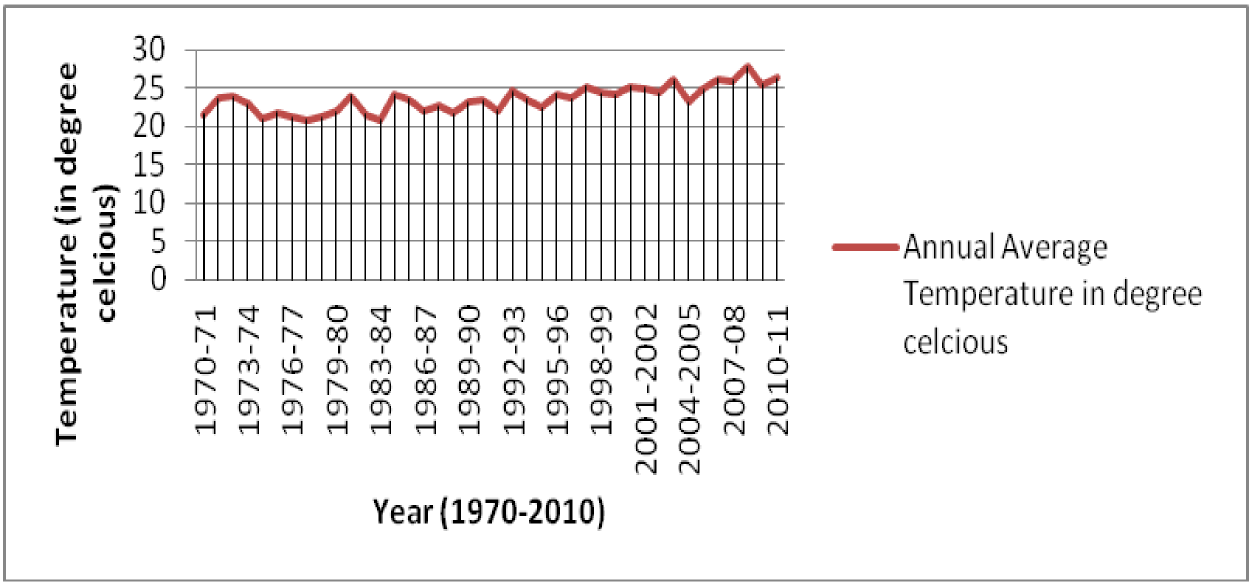
The figure 5d shows the annual mean temperature variations of the state. From the figure we can clearly observe that the mean annual temperature variation shows an increasing trend over the years in the state. These temperature fluctuations can result in extreme climate change situations which can directly effect the agriculture sector of the state.

Figure 5d: Annual Total Rainfall Variation in Assam (1970-2010)



Source: Regional Meteorological Centre, Guwahati & Statistical Hand Book of Assam

Figure 5e: Annual Mean Temperature Variations in Assam (1970-2010)



Source: Regional Meteorological Centre, Guwahati & Statistical Handbook of Assam

To show the rainfall and temperature variations more clearly in the state the following standard deviation analysis has been done.

Table 5.3: Standard Deviation of Annual Total Rainfall and Annual Mean Temperature (1970-2010)

Variables	Observation (years)	Mean	Std. Dev.	Min	Max
All Assam					
Total Annual Rainfall	40	2290.86	347.71	1700.20	3125.20
Annual Mean Temperature	40	23.05	0.35	22.25	23.90
Cachar					
Total Annual Rainfall	40	2952.77	525.32	1333.90	3602.80
Annual Mean Temperature	40	23.99	0.41	23.20	24.80
Darrang					
Total Annual Rainfall	40	2483.01	728.35	415.00	3485.50
Annual Mean Temperature	40	23.27	0.38	22.50	24.10
Dibrugarh					
Total Annual Rainfall	40	2117.99	420.57	819.30	2649.40
Annual Mean Temperature	40	23.56	0.38	22.73	24.38

Goalpara					
Total Annual Rainfall	40	2509.33	434.55	1082.00	3299.59
Annual Mean Temperature	40	24.10	0.47	23.04	24.95
Kamrup					
Total Annual Rainfall	40	2904.76	948.75	1114.00	4396.40
Annual Mean Temperature	40	22.38	0.46	21.39	23.25
Karbi Anglong					
Total Annual Rainfall	40	2409.34	1065.63	310.40	3735.70
Annual Mean Temperature	40	21.97	0.41	21.20	22.80
Lakhimpur					
Total Annual Rainfall	40	2268.16	582.23	779.00	3287.00
Annual Mean Temperature	40	24.49	0.39	23.66	25.34
Nagaon					
Total Annual Rainfall	40	2801.58	1000.47	451.00	4117.27
Annual Mean Temperature	40	20.99	0.41	20.18	21.83
N. C. Hills					
Total Annual Rainfall	40	2675.66	1159.68	325.20	4002.20
Annual Mean Temperature	40	23.13	0.39	22.40	23.90
Sibsagar					
Total Annual Rainfall	40	2065.28	419.67	654.10	2618.60
Annual Mean Temperature	40	22.91	0.38	22.10	23.70

In the above table no. 5.3, it has been observed that in N. C. Hills more variation in rainfall has taken place, followed by Karbi Anglong, Nagaon, Kamrup and Darrang and less variations is observed in the districts of Sibsagar, Dibrugarh, Goalpara, Cachar and Lakhimpur. In case of temperature, more variation have been observed in the districts of Goalpara, Kamrup, Nagaon, Karbi Anglong and Cachar, whereas low variation has been observed in case of Sibsagar, Dibrugarh, Darrang, N. C. Hills and Lakhimpur.

Therefore we can say that more variations in rainfall and temperature can result in more extreme weather situations in the state, which can directly effect the livelihoods through agriculture sector in the state.

5.6: Impact of Climate Change on Agricultural Productivity in Assam (1970-2010)

In order to fulfil following objective and hypothesis the following analysis has been done. The objectives and hypotheses of the study are mentioned below.

Objective: 1

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

Hypothesis: 1

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

In the above analysis as done in table no 5.3, it is clearly found that rainfall and temperature variations are taking place in the study area and it is a threat to the agriculture sector in the state. In order to examine the impact of climate change on agricultural productivity in Assam, we have conducted log linear regression analysis by taking all the explanatory variables along with the dependent variables i.e. productivity of the four major crops i.e. rice, wheat, pulses and oil seeds separately as shown below. The regression model for the 1st objective and 1st hypothesis is formed as a production function of the Cobb-Douglas type in a log linear form. The formed equation is:

$$\ln Y_{t,a} = \ln \beta_1 + \beta_2 \ln R_{1t} + \beta_3 \ln T_t + \beta_4 \ln F_t + \beta_5 \ln IR_t + \beta_6 \ln HYV_t + U_t \quad \text{-----(1)}$$

Here, $Y_{t,a}$= Agricultural productivity in the state,

R_t = Annual total rainfall in the state,

T_t = Annual mean temperature in the state,

F_t = Proportion of fertilizer consumption in agriculture production,

IR_t =Proportion of area covered by irrigation facility in agriculture production,

HYV_t = Proportion of area covered by HYV seeds in agricultural production,

U_t = Standard error term

Here $\beta_1, \beta_2, \ldots\ldots, \beta_8$ are the parameters of the equation. Where t refers to time period from 1970 to 2010.

Table 5.4: Regression Analysis for Impact of Climate Change on Agricultural Productivity of Assam (1970-2010)

Variables	Co-efficient	Std. Error	Beta value	P value
Constant	97.76	0.07	18.22	0.00
Total Annual Rainfall	-0.50	0.03	-15.74	0.00
Mean Annual Temperature	-0.28	0.11	-14.78	0.00
Fertilizer Consumption	0.34	0.14	45.77	0.00
Irrigation Area	0.83	0.04	28.02	0.00
HYV Area	0.13	0.18	14.10	0.01

Here R^2 =0 .91, Pro > F = 0.000 and N = 40

The result of the regression analysis is presented in equation form as seen below:

$\ln Y_{t,a}=(97.76)In + (-0.50)\ln R_t + (-0.28)\ln T_t + (0.34)\ln F_t + (0.83)\ln IR_t + (0.13)\ln HYV_t + U_t$ ------------(1)

In the equation (1), left hand side shows the dependent variable and the right hand side shows the independent variables of the study. These estimated results reveal the relationship between the dependent and independent variables of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.91 which implies that the regression line is almost perfectly fit with all the variables of the study. Here, N represents the number of observation years of the study i.e. 40 years (1970-2010). Here t value stands for the ratio of the co-efficient to the standard error of the dependent variable of the study.

From the above table it is revealed that the long term climate change factor i.e. annual total rainfall and annual mean temperature results has negative impact in annual agricultural productivity in the state. If the temperature increases by (log) 1^0C then annual agriculture productivity decreases by log of 28 kg per hectare, on the other hand if the annual total rainfall increases by (log) 1 mm, then annual agricultural productivity decreases by log of 50 kg per hectare over the period of time while keeping other controlled variables of the study constant.

Other independent variables of the study i.e. fertilizer consumption, area covered by HYV seeds and area under irrigation facility has positive impact on dependent variable of the model. Increase in fertiliser consumption by (log) 1 hectare causes increase in annual agricultural productivity by log of 34 kg per hectare and if the area under HYV seeds increases by (log) 1 hectare, then agricultural productivity increases by log of 13 kg per hectare. Further, from the analysis it is clearly revealed that if area under irrigation increases by (log) 1 unit then annual agricultural productivity also increases by log of 83 kg per hectare, which is a very key input for agricultural production. Hence, we can say that during the drought situation irrigation facility can solve the water problem for growing the agricultural crops.

5.7: Impact of Climate Change on Rice Productivity in Assam (1970-2010)

In this section, the climate change impact on rice productivity has been discussed. The following regression equation has been formed to show the results of the analysis.

$lnY_{t,r} = In\ \beta_1 + \beta_2 ln\ R_t + \beta_3 ln\ T_t + \beta_4 lnF_t + \beta_5 ln\ IR_t + \beta_6 ln\ HYV_t + U_t$ ----(2)

Here

Y_{t},r= Annual rice productivity in kg per hectare in the state,

R_t = Annual total rainfall in the state,

T_t = Annual mean temperature in the state,

F_t = Proportion of fertilizer consumption for rice cultivation.

IR_t =Proportion of area under irrigation facility for rice cultivation.

HYV_t = Proportion of area under HYV seeds for rice cultivation.

Here β_1, β_2,……, β_6 are the parameters term of the equation, where t for time period from 1970 to 2010.

Table 5.5: Regression Analysis of Impact of Climate Change on Annual Rice Productivity of Assam (1970-2010)

Variables	Co-efficient	Std. error	t value	p value
Constant	6.10	3.19	48.66	0.00
Total Annual Rainfall	-0.68	0.06	-13.46	0.00
Mean Annual Temperature	-0.42	1.02	-9.67	0.00
Fertilizer Consumption	-0.73	0.00	-6.62	0.00
Irrigation Area	0.22	0.07	6.74	0.00
HYV Area	1.77	0.07	28.43	0.00

R- Squared = 0.81, Prob > F = 0.000 and N=40

From calculated values, we have formed the log-linear regression equation as follows:

Y_t,r=(6.10)In + (-0.68)ln R_t+ (-0.42)ln T_t+ (-0.73)lnF_t+ (0.22)ln IR_t+ (1.77)ln HYV_t+ U_t --------- (2)

In the equation (2), the left hand side shows the dependent variable i.e. annual rice productivity of Assam and the right hand side shows the independent variables of the study. From the estimation result, it is revealed that all the independent variables have both negative and positive impacts on the dependent variable of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.81 which implies that the regression line is almost perfectly fit with all the variables of the study. Where, N represents the number of the observation years of the study i.e. 40 years (1970-2010). Here t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are found 0.00 which implies that the results of the analysis are statistically significant.

The above regression analysis result shows that the area covered by HYV seeds and area covered by irrigation facility has significant positive impact in annual rice productivity in Assam but the long term climate change factors i.e. annual total rainfall, annual mean temperature and fertiliser consumption has significant negative impact on the dependent variable. With the help of above log linear regression analysis we can say that (log) 1^0C increases in annual mean temperature in the state would result in decrease of rice productivity by log of 42 kg per hectare withholding the other explanatory variables of the analysis constant.

On the other hand (log) 1 millimetre increase in the amount of annual total rainfall would also result in loss of rice productivity by log of 68 kg per hectare. Interestingly increase consumption of fertilizer also has negative impact in annual total rice productivity in Assam. Again, it has been observed that (log) 1 hectare increase in area under irrigation facility for rice cultivation would result increase in annual rice productivity of the state by log of 22 kg per hectare while keeping other independent variables of the study constant. The other independent variable of the above regression analysis i.e. area under HYV seeds if increased by (log) 1 hectare, then rice productivity also increases by log of 177 kg per hectare withholding other variables of the study constant. In Assam basically rice cultivation is rain-fed, so the farmers are solely dependent on rainfall during the rice cultivation/ sowing season. Generally rice needs sufficient amount of rainfall and favourable temperature i.e. mean annual temperature of 24^0 C with range of 22^0 C to 32^0 C and rainfall between 150 to 300 mm (millimetre) throughout the growing period. From the above result we can say that the climate change factor has significant negative impact in rice productivity in Assam. Again, an excessive use of fertilizer also has negative effect on the rice productivity in the state, so the farmers should have some basic knowledge about the required amount of fertilizer usage on particular crops.

5.8: Impact of Climate Change on Wheat Productivity in Assam (1970-2010)

It is reflected from the above discussions that the compound growth rate of area, production and yield/ productivity of wheat has been found highest in Assam over the period of time, therefore to see the long term impact of climate change on wheat productivity the following analysis has been done.

To find out the result of the study, the following log linear regression equation has been formed………

$$\ln Y_{t,w} = \ln \beta_1 + \beta_2 \ln R_t + \beta_3 \ln T_t + \beta_4 \ln F_t + \beta_5 \ln IR_t + \beta_6 \ln HYV_t + u_t \text{ -----(3)}$$

Here, $Y_{t,w}$ = Annual wheat productivity in kg per hectare in the state,

R_t = Annual total rainfall in the state,

T_t = Annual mean temperature in the state,

F_t =Proportion of fertilizer consumption for wheat cultivation,

IR_t =Proportion of area under irrigation facility for wheat cultivation,

HYV_t = Proportion of area under HYV seeds,

U_t = error term of the study,

Here $\beta_1, \beta_2, \ldots, \beta_6$ are the parameters of the analysis, where t stands for time period from 1970 to 2010.

Table 5.6: Regression Analysis for Climate Change Impact on Annual Wheat Productivity of Assam (1970-2010)

Variables	Co- efficient	Std. Error	t value	p value
Constant	7.68	11.26	32.67	0.00
Total Annual Rainfall	0.01	0.24	12.14	0.00
Mean Annual Temperature	0.002	0.00	5.62	0.00
Fertilizer Consumption	0.00	0.00	2.17	0.01
Irrigation Area	0.001	0.04	4.58	0.00
HYV Area	0.00	0.00	2.66	0.00

Here R^2 =0 .76, Prob > F = 0.0034, N = 40

$\ln Y_{t,w} = (7.68)\ \text{In} + (0.01) \ln R_t + (0.002) \ln T_t + (0.00) \ln F_t + (0.001) \ln IR_t + (0.00) \ln HYV_t + u_t$ -----(3)

The above regression equation represents the relationship between the dependent and independent variables of the study. Here, Prob >F = 0.0034 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.76 which implies that the regression line is almost perfectly fit with all the variables of the study. Here, N represents the number of the observation years of the study i.e. 40 years (1970-2010). Here t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are 0.00 and 0.01 which implies that the result of the analysis is statistically significant.

From the above log linear regression analysis it has been found that, when the total annual rainfall increases by log of 1 millimetre, then the wheat productivity of the state also increases by log of 1 kg per hectare while holding other independent variables of the study constant.

Again if the temperature increases by (log) 1^0C, then the annual wheat productivity increases by log of 0.2 kg per hectare withholding other variables of the study constant. The other controlled variable of the study i.e. area covered by irrigation facility if increases by (log) 1 hectare then the productivity of wheat increases by log 0.1 kg per hectare. Increase in fertiliser consumption and area under HYV seeds do not have any impact in the wheat productivity of the state.

From the above analysis, we can say that climate change factor i.e. rainfall and temperature has positive impact on wheat productivity of Assam but of lesser magnitude. Also excessive rainfall during the wheat growing period is not favourable for good amount of wheat production. Since only 1.4 percent of total field cropped cultivated area has been covered by wheat cultivation in Assam during 2010-11, which is a very negligible percentage, but interestingly the compound growth rate of area and production is found to be highest among all other principal crops over the period of time. Wheat is a rabi crop and it requires an average temperature of 10^o C to 30^0 C and rainfall of 500 millimetres to 1000 millimetres during the growing season. But most importantly during the harvesting period the temperature should be at least 30^0C with no rainfall, or else the crop will be damaged, leading to production loss. Since it has been found in various studies done earlier that winter rainfall is declining day-by-day resulting in very dry and moisture less climate, thus in order to get plenty of wheat production especially in winter season, irrigation facility is immediately required in Assam. The suitable soils for wheat cultivation are alluvial soil, sandy loamy or drained black soil. Importantly, these types of soils are available in the entire Agro Climatic Zone so wheat cultivation can be an option during the climate change situation in Assam.

5.9: Impact of Climate Change on Pulses Productivity in Assam (1970-2010)

Pulses are the second most cultivated food grain crops in Assam. With the recent introduction of National Food Security Mission, there have been various efforts taken by the government to increase the pulses production in India including Assam. Here, we have made an attempt to find out the long term climate change impact on pulses productivity in the state. To analyse the result of the study, the following log linear equation has been formed….

$\ln Y_{t,}p = In\ \beta_1 + \beta_2 \ln R_t + \beta_3 \ln T_t + \beta_4 \ln F_t + \beta_5 \ln IR_t + \beta_6 \ln HYV_{t+}\ \beta_7 \ln F_t + \beta_8 \ln IR_t + U_t$ -----(4)

Here, $Y_{t,p}$ = Annual pulses productivity in kg per hectare in Assam,

R_t = Annual total rainfall in the state,

T_t = Annual mean temperature in the state,

F_t =Proportion of fertilizer consumption for pulses cultivation in the state,

IR_t = Proportion of area under irrigation facility for pulses cultivation in the state,

HYV_t =Proportion of area under HYV seeds in the state,

U_t = standard error term of the study

Here β_1, $\beta_{2,\ldots\ldots}$, β_6 are the parameters term ,where t stands for time period from 1970 to 2010 for all the variables.

Table 5.7: Regression Analysis for Impact of Climate Change on Annual Pulses Productivity of Assam (1970-2010)

Variables	Co-efficient	Error term	t value	p value
Constant	4.36	51.30	16.26	0.00
Total Annual Rainfall	-0.04	0.22	-3.38	0.00
Mean Annual Temperature	-0.03	3.27	-1.80	0.00
Fertilizer Consumption	0.00	1.17	0.27	0.66
Irrigation Area	0.02	0.00	0.38	0.38
HYV Area	0.01	0.57	14.58	0.02

Here R^2 =0.61, Prob > F = 0.000 and N=40

For the above calculated values we have formed the log linear regression equation which is presented as follows.

Y_{t},p= (4.36) In+ (-0.04)ln R_t+(-0.03)ln T_t+ (0.00)lnF_t+ (0.02)ln IR_t+ (0.01)ln HYV_{t+} U_t-----(4)

The above regression line shows the relationship between the dependent and independent variables of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.61 which implies that the regression line is almost perfectly fit with all the variables of the study. Here, N represents the number of the observation years of the study i.e. 40 years (1970-2010). The ‘t’ value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are 0.00 and 0.02 which implies that the results of the analysis is statistically significant, but the value of $p = 0.66$ for the area under HYV seeds and $p = 0.38$ for fertilizer consumption implies the result of the analysis for these variables are statistically insignificant.

From the above analysis it has been revealed that, if the annual rainfall of the state increases by (log) 1 millimetre, then the pulses productivity of the state decreases by log of 4 kg per hectare and again if the annual average temperature increases by (log) 1^0C, then the annual pulses productivity falls by log of 3 kg per hectare while keeping other explanatory variables of the study constant. On the other hand, if the area covered by irrigation facility increases by (log)1 hectare then this would result in increase of annual pulses productivity by log of 1 kg per hectare state while keeping other explanatory variables of the study constant. Again the other independent variables of the study i.e. area covered by HYV seeds and fertiliser consumption does not have any statistically significant impact on the annual pulses productivity in the state.

Pulses are leguminous plants with high nitrate content and help restore soil fertility. This is the reason why pulses are often grown in the course of crop rotation. Pulses like arhar, urad, mung are grown in kharif season, while masur (lentil), grams and peas are grown during the rabi season in Assam.

The climatic requirements for pulses cultivation are favourable only when the temperature is moderate to warm i.e. between 10^0C to 25^0C and the rainfall should vary from 500 to 750 millimetres during the growing season. This crop requires dry and light type of soil, which is abundantly available in Assam. The rainfall during the kharif season is sufficient for pulses cultivation in the state. But in present situation the increasing temperature and total annual rainfall has negative impact on the pulses productivity. It has been found that if the temperature and rainfall increases above the required amount for growing pulses in the state than this would have a negative impact on the productivity. But to improve the situation, the state government can give importance to pulses production during the kharif season, which helps balance the nutrition and fertility of the soil and also helpful for the farmer to adapt during the climate change situations. Importantly long term climate change affects the soil quality which will have negative impacts on the crop productivity in the state.

5.10: Impact of Climate Change on Oil Seeds Productivity in Assam (1970-2010)

Oil Seeds are also known as the principal crops of Assam, and to observe the long term impact of climate change on oil seeds productivity, we have formed the following log linear regression equation and drown the results as follows.

$\ln Y_{t,o} = \ln \beta_1 + \beta_2 \ln R_t + \beta_3 \ln T_t + \beta_4 \ln F_t + \beta_5 \ln IR_t + \beta_6 \ln HYV_t + U_t$ ----(5)

Here:

$Y_{t,o}$= Annual oil seeds productivity in kg per hectare in Assam,

R_t = Annual total rainfall in millimetre in the state,

T_t =Annual mean temperature in degree celcious in the state,

F_t = Proportion of fertilizer consumption in kg per hectare tonnes for oilseeds cultivation in state,

IR_t = Proportion of area under irrigation facility in hectare for oil seeds cultivation in the state,

HYV_t = Proportion of area under HYV seeds in hectare in the state,

U_t =Standard error term of the study

Here $\beta_1, \beta_2, \ldots\ldots, \beta_6$ are the parameters term, where t stands for time period from 1970 to 2010 for all the variables.

Table: 5.8: Regression Analysis for Impact of Climate Change on Annual Oil Seeds Productivity of Assam (1970-2010)

Variables	Co-efficient	Std. error	t value	p value
Constant	7.58	22.17	13.28	0.00
Total Annual Rainfall	-0.03	0.00	-8.80	0.00
Mean Annual Temperature	0.01	0.21	5.39	0.00
Fertilizer Consumption	0.00	0.00	8.16	0.00
Irrigation Area	0.00	0.16	0.38	0.51
HYV Area	0.00	0.45	0.27	0.73

R^2 = 0.58, Pro > F = 0.00 and N= 40

For the above analysis the following log linear regression equation is drown.

$\ln Y_{t.}o$= (7.58)In+ (-.03)ln R_t+(0.01)ln T_t+ (0.00)lnF_t+ (0.00)ln IR_t+ (0.00)lnHYV + U_t----(5)

The above regression equation shows the relationship between the dependent and independent variables of the study. Here, Prob >F = 0.00 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.58 which implies that the regression line is almost perfectly fit with all the variables of the study. Here, N represents the number of the observation years of the study i.e. 40 years (1970-2010). Whereas, t value shows the ratio of the co-efficient to the standard error of the dependent variable in the study. The p values of the analysis are 0.00 which implies that the result of the analysis is statistically significant, but the values of p = 0.73 and p = 0.51 for the area covered by HYV and irrigation facility respectively are statistically insignificant in the analysis.

From the analysis it is revealed that, when the total annual rainfall increases by (log) 1 mm then the annual oil seeds productivity of the state decreases by log of 3 kg per hectare withholding other controlled variables of the study constant. Again if the temperature increased by (log) 1^0 C, then the annual oil seeds productivity increases by log of 1 kg per hectare while keeping other independent variables of the study constant. The fertilizer consumption does not have any impact on the annual oil seeds productivity in the state. The other independent variables of the study i.e. area covered by irrigation and HYV seeds are statistically insignificant in the analysis. The oil seeds are mostly grown in dry season therefore this crop requires very less amount of rainfall and warm temperature. Oil seeds are very sensitive in nature to excessive rainfall, so if the rainfall increases during the oil seeds growing season than there are heavy chances of crop damage. So from the analysis we can say that excess rainfall has negative impact on the productivity of oil seeds but increase in temperature has positive impact on it. Oil seeds are also grown in rabi and kharif seasons all over the state. The major types of oil seeds cultivated in Assam are sesamum, rapeseed, mustard, linseed, castor etc.

From the above analysis it has been found that climate changes have remarkable impact on the agriculture productivity in the state including all the principal crops i.e. rice, wheat, pulses and oilseeds which have been shown separately in the above discussion. On the basis of that we reject the null hypothesis i.e. the climate change has no impact on the agriculture productivity in Assam.

5.11: District Wise Annual Compound Growth Rate of Area, Production and Yield of Principle Crops in Assam (2010 over 1970)

To understand the district wise status of major crops, we have calculated the annual compound growth rate of area, production and yield/ productivity of four major crops (rice, wheat, pulses and oilseeds) and total food grain crops in Assam during the two time periods i.e. from 1970-71 and 2010-11.

Table 5.9: District wise Annual Compound Growth Rate of Area, Production and Yield of Principle Crops in Assam (2010 over 1970):

Crops	Components	Goalpara	Kamrup	Lakhimpur	Nagaon	Sibsagar	Darrang	Cachar	Dibrugarh	KB	NC Hills
Total Rice	Area	18.47	14.68	72.32	37.11	23.55	45.60	16.65	24.13	147.82	30.68
	Production	198.36	221.24	149.35	195.29	99.99	192.43	88.77	119.22	281.92	57.03
	Productivity	151.85	180.12	44.70	115.37	61.88	100.84	61.83	76.60	54.11	20.17
Wheat	Area	25.08	-28.50	-30.00	111.95	36.78	5.35	-3.57	-56.25	502.00	-31.67
	Production	36.73	-14.55	-32.98	65.91	-16.11	15.75	16.55	-47.86	656.00	-15.00
	Productivity	9.32	19.52	-4.25	-21.72	-38.67	9.88	20.87	19.18	25.58	24.39
Total Pulses	Area	77.13	-0.95	151.00	-13.05	263.89	28.29	347.25	52.09	229.02	184.00
	Production	151.02	96.00	272.72	6.44	304.25	89.61	620.19	241.39	337.90	229.59

	Productivity	41.72	97.87	48.49	22.40	11.09	47.80	61.02	124.46	33.09	16.05
Total Food Grains	Area	21.40	11.82	78.01	25.53	27.73	43.89	19.21	23.80	159.36	38.53
	Production	187.50	203.77	148.45	187.52	101.27	175.84	89.83	117.44	288.72	62.17
	Productivity	136.82	171.65	39.57	129.04	57.58	91.71	59.24	75.64	49.87	17.07
Total Oil Seeds	Area	141.37	37.01	348.34	-0.60	46.79	36.52	150.98	43.61	421.76	388.08
	Production	215.53	67.36	556.06	5.89	14.62	68.36	18.71	94.76	300.65	146.54
	Productivity	30.72	22.15	46.33	6.53	-21.91	23.32	-52.70	35.62	-23.21	-49.49

Source: Department of Agriculture, Khanapara

From table no. 5.9, it has been observed that in Goalpara the growth rate of rice productivity is highest at 151.85 percent, followed by food grains with 136.82 percent. Less than 50 percent yield growth rate has been observed in pulses, oilseeds and wheat over the years. Again, the growth rate of yield in Kamrup has been found highest in rice with 180 percent, followed by food grains with around 170 percent and pulses with around 98 percent. The lowest productivity growth rate has been observed in oilseeds (22.15 %) and wheat (19.52 %) in Kamrup district of Assam. In Lakhimpur district, growth rate of yield has been observed highest in pulses with around 49 percent, followed by oilseeds with 46 percent, rice with 44.7 percent, and food grains with around 40 percent and lastly the negative growth rate has been observed in pulses with -4.25 percent over the years. In Nagaon district, it has been observed that the growth rate of productivity is highest in food grains (129.04 %), followed by rice (115.3 %) and pulses (22.4 %) and lowest growth rate is observed in oilseeds (6.53 %). In Nagaon the negative growth rate of productivity has been observed in wheat with -21.72 percent. Again in Sibsagar district, the growth rate of productivity is highest in rice (61.88%), followed by food grains (57.58 %) and lowest in pulses (22.40). The negative yield growth rate has been observed in wheat and oilseeds with -38.67 and -21.91 percent respectively in Sibsagar district. In Darrang, the highest productivity growth rate has been observed in rice (100.84%), followed by food grains (91.7 %), pulses (47.8 %), oilseeds (23.32 %) and lowest productivity growth rate has been found in wheat (9.88 %). Again in Cachar district, the highest productivity growth rate has been observed in rice with 61.83 percent, followed by pulses with 61.02 percent, food grains with 59.24 percent, wheat with 20.87 percent, while negative growth rate has been observed in oilseeds (-52.70 %). The growth rate of yield in Dibrugarh has been found highest in pulses with 124.46 percent, followed by rice with around 78 percent, food grains with around 76 percent. The lowest productivity growth rate has been observed in oilseeds (35.62 %) and wheat (19.18 %) in Dibrugarh District of Assam. In the hilly district of Karbi Anglong, the highest productivity growth rate has been observed in rice (54.11 %), followed by food grains (49.87 %), pulses (33.09 %), wheat (2.58 %) and negative productivity growth rate has been found in oil seeds (-23.21 %). Further in N. C. Hills district of Assam the highest productivity growth rate has been observed in wheat with 24.39 percent, followed by rice with 20.17 percent, food grains with 17.07 percent, pulses with 16.05 percent and negative growth rate has been observed in oilseeds (-49.49 %).

5.12: Impact of Climate Change on District Wise Annual Rice Productivity in Assam (1970-2010)

From the above analysis it is clear that rice is the major crop and climate change has a significant impact on rice productivity in Assam. 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 done the following analysis for the ten districts of Assam separately. The districts are as they existed in 1970, i.e. Goalpara, Darrang, Cachar, Kamrup, Dibrugarh, Lakhimpur, Tinsukia, Nagaon, Karbi Anglong and North Cachar hills (Dima Hasao).

In order to find out the impact of climate change on annual rice productivity in all the above mentioned ten districts we have formed the log linear equation of Cob-Douglas production function type as given below:

$\ln Y_{it} = \ln \beta_1 + \beta_2 \ln R_{it} + \beta_3 \ln T_{it} + \beta_4 \ln F_{it} + \beta_5 \ln IR_{it} + \beta_6 \ln HYV_{it+} + U_{it}$ ------(6)

Here, Y_{it} = Average rice productivity in kg per hectare in all the districts,

R_{it} = Annual total rainfall in millimetre in all the districts,

T_{it} = Annual mean temperature in degree celcious in all the districts,

F_{it} = Proportion of fertilizer consumption for rice cultivation in all the districts,

IR_{it} = Proportion of area under irrigation facility for rice cultivation in all the districts,

HYV_{it} =Proportion of area under HYV seeds in all the districts,

U_{it} = standard error term of the study,

Here, $\beta_1, \beta_2, \ldots\ldots, \beta_6$ are the parameters , where t stands for time period from 1970 to 2010 for all the variables and i stands for all the ten districts which are considered in the study,

5.12.1. Impact of Climate Change on Annual Rice Productivity in Goalpara (1970-2010)

In order to find out the long term impact of climate change on the rice productivity in Assam the following analysis has been done.

Table 5.10: Regression Analysis for Impact of Climate Change on Annual Rice Productivity of Goalpara (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.21	0.17	-1.20	0.05
Temperature	-0.58	1.47	-0.39	0.05
Fertilizer	0.07	0.03	2.18	0.05
HYV seeds	-0.03	0.02	-1.63	0.12
Irrigation	-0.01	0.01	-0.97	0.35
Constant	10.59	4.88	2.17	0.05

(R^2) = 0.81, Prob. > F= 0 .000, N = 40

The above table shows the impact of climate change on rice productivity in Goalpara and to find out the impact we have formed the following log linear regression equation:

$\ln Y_{it}$ = (10.59)In + (-0.21)ln R_{it}+(-0.58)ln T_{it}+ (0.07)lnF_{it}+ (0.03)ln HYV_{it} + (-0.01)ln IR_{it}+ U_{it}------(6.1)

In the above equation (6.1), left hand side explains the dependent variable of the study i.e. annual rice productivity and the right hand side represents the independent or controlled variables of the study. From the observation it is clear that the independent variables have both positive and negative impact on dependent variable. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.81 which implies that the regression line is almost perfectly fit with all the variables of the study. Here, N represents the number of the observation years of the study i.e. 40 years (1970-2010) and t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analyses are 0.05 implies that the result of the analysis is statistically significant.

The above analysis shows that the increasing temperature and rainfall has a negative impact on the rice productivity in Goalpara district. If the annual mean temperature of the district increases by (log) 1^0C then this would result decrease in rice productivity by log of 58 kg per hectare withholding other independent variables constant. Again, if the annual total rainfall increases by (log) 1 millimetre then there is a possibility of decrease in the annual rice productivity by log of 21 kg per hectare in the district while keeping other controlled variables of the study constant. In the above analysis, it has been revealed that the increasing amount of fertiliser consumption leads to positive impact on rice productivity in the district. The other independent variables of the study like area covered by irrigation facility and HYV seeds are statistically insignificant in the analysis. Increasing temperature results in drying the roots of rice crop during its growing period which leads to insufficient amount of production. Again increasing amount of rainfall causes floods, so it has been observed from the analysis that the long term climate change has negative impact on the annual rice productivity in the district.

5.12.2: Impact of Climate Change on Annual Rice Productivity in Kamrup (1970-2010)

It is revealed in the earlier table no. 5.9 that annual compound growth rate of rice productivity has been highest in Kamrup among all the other principle crops during the year 2010 over 1970's. In this study we mostly focussed on the productivity of rice, in order to find out the long term impacts of climate change on rice productivity and the following analysis has been made.

Table 5.11: Regression Analysis for Impact of Climate Change on Annual Rice Productivity of Kamrup (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.25	0.13	-1.89	0.01
Temperature	1.72	1.35	1.27	0.05
Fertilizer	0.15	0.06	2.44	0.03
HYV seeds	0.18	0.13	1.40	0.01
Irrigation	0.05	0.06	0.99	0.00
Constant	0.03	5.25	0.01	0.00

(R^2) = .62, Prob. > F= .000, N = 40

The table no. 5.11, shows the relationship between impact of climate change on rice productivity in Kamrup and to fulfil this purpose we have formed the following log linear regression equation:

$\ln Y_{it}$ = (0.03)In + (-0.25)ln R_t + (1.72)ln T_{it}+ (0.15)lnF_{it}+ (0.05)ln IR_{it}+ (0.18) ln HYV_{it} + U_{it}

------ (6.2)

In the above regression equation (6.2), left hand side shows the dependent variable of the study i.e. annual rice productivity and the right hand side shows the independent variables or controlled variables of the study. From the observation it is clear that all the independent variables have both positive and negative impact on the dependent variable i.e. annual rice productivity in Kamrup district of Assam. Here, Prob >F = 0.0000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.62 which implies that the regression line is perfectly fit with all the variables of the study. Here, N represents the number of the observation years of the study i.e. 40 years (1970-2010). Here t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are 0.00, 0.01, 0.03 and 0.05 implies that the result of the analysis is statistically significant and associated with all the independent or controlled variables of the study.

In case of Kamrup district (log) 1 millimetre increase in annual rainfall leads to decrease in the rice productivity by log of 25 kg per hectare while keeping all the other controlled variables constant. Similarly, if annual mean temperature increases by (log) 1^0C then it would results in increase of rice productivity by log of 172 kg per hectare withholding the other controlled variables of the analysis constant. Again the other independent variable of the study i.e. increase in fertiliser consumption also leads to increase in the rice productivity at a statistically significant level. On the other hand, if the area covered by HYV seeds increases by (log) 1 hectare then annual rice productivity increases by log of 18 kg per hectare. Irrigation facility plays a very important role in rice production, as it has been proved from the observation that if the area under irrigation facility increases by (log) 1 hectare then the annual rice productivity of the district also increases by log of 5 kg per hectare over the years while keeping other controlled variables of the study constant.

5.12.3: Impact of Climate Change on Annual Rice Productivity of Darrang (1970-2010)

In Darrang district among the principle crops, rice is the major grown crops. Therefore to see the long term impact of climate change on the rice productivity the following analysis has been done.

Table 5.12: Regression Analysis for Climate Change Impact on Annual Rice Productivity of Darrang (1970-2010):

Variables	Co-efficient	Std. Error	t Value	P value
Rainfall	-0.04	0.14	-0.29	0.00
Temperature	-0.74	0.65	-1.15	0.00
Fertilizer	0.10	0.06	1.52	0.00
HYV seeds	-0.32	0.08	-3.99	0.00
Irrigation	0.12	0.13	0.98	0.00
Constant	11.31	2.96	3.82	0.00

R^2 = 71, Prob. > F= .000, N = 40

To see the relationship between long term impacts of climate change on rice productivity in Darrang district the following log linear regression equation has been formed.

$\ln Y_{it}$ = (11.31)In + -0.01)ln R_{it}+(-0.74)ln T_{it}+ (0.10)lnF_{it}+ (-0.12)ln IR_{it}+ (0.32)ln HYV_{it} + U_{it} ------(6.3)

In the above equation 6.3, the left hand side represents the dependent variable of the study i.e. annual rice productivity in Darrang and the right hand side represents the independent variables of the study. The climate change factor includes two variables i.e. mean annual temperature and the annual total rainfall. From the observation it has been revealed that all the independent variables have significant positive and negative impact on dependent variable of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.71 which implies that the regression line is perfectly fit with all the variables of the study. Here, N represents the number of observation years of the study i.e. 40 years (1970-2010). Here t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are 0.00 which implies that the result of the analysis is statistically significant.

In case of Darrang district, the study reveales that both climate change factors i.e. rainfall and temperature has significant negative impact on the annual rice productivity. Mere (log) 1 millimetre increase in annual total rainfall leads to decrease in annual rice productivity by log of 4 kg per hectare and (log) 1^0C increase in the annual average temperature results to decrease in annual rice productivity by log of 74 kg per hectare withholding other controlled variables of the study constant. The fertiliser consumption and area covered by irrigation facility leads to increase in rice productivity in the state, but the increase in area cover by HYV seeds has negative impact in rice productivity within the district. Also (log) 1 kg per hectare increase in fertilizer consumption for rice cultivation leads to increase in annual rice productivity by log of 10 kg per hectare and (log) 1 hectare increase in area covered by irrigation facility leads to increase in annual rice productivity by log of 12 kg per hectare while keeping other controlled variables of the study constant. But interestingly if area under HYV seeds increases then it leads to decreases in annual rice productivity by log of 32 kg per hectare while keeping other controlled variables of the study constant. It has been observed from the above analysis that long term climate change impact has negative effects on the annual rice productivity in the district.

5.12.4: Impact of Climate Change on Annual Rice Productivity in Dibrugarh (1970-2010)

The table below shows the long term impact of climate change on the rice productivity in Dibrugarh district of Assam.

Table 5.13: Regression Analysis for Impact Climate Change on Annual Rice Productivity of Dibrugarh (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.18	0.12	-1.42	0.05
Temperature	-0.30	0.60	-0.50	0.01
Fertilizer	0.02	0.04	0.48	0.01
HYV seeds	-0.17	0.11	-1.53	0.01
Irrigation	-0.01	0.03	-0.39	0.00
Cons	11.46	2.80	4.09	0.00

R^2 = 0.73, Prob. > F=0.000, N = 40

The above table clearly shows the relationship between impacts of climate change on rice productivity in Dibrugarh district. We have formed the following log linear regression equation to show the relation more clearly:

$\ln Y_{it} = (11.46)\text{In} + (-0.18)\ln R_{it}+(-0.30)\ln T_{it}+ (0.02)\ln F_{it}+ (-0.01)\ln IR_{it}+ (-0.17)\ln HYV_{it} + U_{it}$ ----- (6.4)

In the above equation (6.4), left hand side of the regression shows dependent variable of the study i.e. annual rice productivity in Dibrugarh district and right hand side shows the independent or controlled variables of the study. From the estimation, it is clear that all the independent variables have significant i.e. both positive and negative impact on the dependent variable of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.73 which implies that the regression line is perfectly fit with all the variables of the study. Here, N represents the number of the observation years in the study i.e. 40 years (1970-2010). Here t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are 0.00, 0.01 and 0.05 which implies that the result of the analysis is statistically significant.

From the above analysis, it has been revealed that (log) 1 millimetre increase in annual total rainfall leads to decrease in rice productivity by log of 18 kg per hectare withholding other explanatory variables of the study constant. Again, if annual mean temperature increases by (log) 1^0C then annual rice productivity decreases by log of 30 kg per hectare over the years while keeping other independent variables of the study constant. The explanatory variable i.e. increase in fertilizer consumption has positive impact in rice productivity while the other two explanatory variables of the study i.e. area under HYV seeds and irrigation have significant negative impact in annual rice productivity in the district. It is revealed from the analysis that (log) 1 hectare increase in area covered by HYV seed leads to decrease in rice productivity by log of 17 kg per hectare over the years withholding other controlled variables of the study constant. Further, (log) 1 hectare increase in area under irrigation facility results in the decline of annual rice productivity by log of 1 kg per hectare over the years while keeping other independent variables of the study constant.

5.12.5: Impact of Climate Change on Annual Rice Productivity in Cachar (1970-2010)

The following analysis has been made to find out the long term impact of climate change on the rice productivity in Cachar district of Assam.

Table 5.14: Regression Analysis for Impact of Climate Change on Annual Rice Productivity of Cachar (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.12	0.24	-0.50	0.01
Temperature	1.85	1.78	1.04	0.03
Fertilizer	-0.01	0.11	-0.12	0.01
HYV seeds	0.01	0.29	0.04	0.01
Irrigation	-0.02	0.03	-0.69	0.50
Cons	2.65	6.48	0.41	0.01

R^2 =0 .89 Prob. > F= 0.000, N = 40

To show the impact of climate change on rice productivity in Cachar, we have formed the following log linear regression equation:

Y_{it} = (2.65)In + (-0.12)ln R_{it}+(1.85)ln T_{it}+ (-0.01)lnF_{it}+ (-0.02)ln IR_{it}+ (0.01)ln HYV_{it} +U_{it} ------(6.5)

The regression equation in the left hand side represents the dependent variable of the study i.e. annual rice productivity in Cachar district and the right hand side represents the independent or controlled variables of the study. The climate change factors include two variables in the study i.e. annual mean temperature and annual total rainfall in the district. From the result, it is found that annual total rainfall and fertiliser consumption has negative impact on the dependable variable of the study, but the other controlled variables like annual mean temperature and area under HYV seeds has positive impact on the dependent variable of the study. The above regression equation shows the relationship between the dependent and independent variables of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.89 which implies that the regression line is perfectly fit with all the variables of the study. Here, N represents the number of the observation years of the study i.e. 40 years (1970-2010). In the analysis t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the estimation are 0.01 and 0.03 which implies that the result of the analysis is statistically significant.

In case of Cachar district, the above log linear regression analysis shows that (log) 1 millimetre increase in rainfall leads to decrease in annual rice productivity by log of 12 kg per hectare over the years withholding other controlled variables of the study constant. From the observation, it has been revealed that (log) 1^0C increase in annual mean temperature results to a very significant increase in annual rice productivity i.e. log of 185 kg per hectare over the years while keeping other independent variables of the study constant. Increases in consumption of fertilizer leads to decrease in annual rice productivity in the district while keeping other controlled variables of the study constant. Again (log) 1 hectare increase in area under HYV seeds leads to increase in annual average rice productivity by log of 1 kg per hectare, but area covered by irrigation facility has statistically insignificant impact on the annual rice productivity in the state.

5.12.6: Impact of Climate Change in Annual Rice Productivity in Lakhimpur (1970-2010)

In the Lakhimpur district, it is observed in the earlier table no.5.9 that annual compound growth rate of rice production is approximately 150 percent during 2010 over the year 1970, but the yield growth rate is only 44.70 percent. Therefore to see the long term impact of climate change in rice productivity in Lakhimpur district the following analysis has been done.

Table 5.15: Regression Analysis for Climate Change Impact on Annual Rice Productivity of Lakhimpur (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.53	0.15	-3.53	0.00
Temperature	-5.56	4.04	-1.38	0.00
Fertilizer	0.13	0.19	0.71	0.05
HYV seeds	-0.48	0.35	-1.36	0.00
Irrigation	0.01	0.02	0.59	0.01
Constant	32.90	14.65	2.25	0.04

R^2 = 0.78, Prob. > F= 0 .000, N = 40

With the help of above table no. 5.15, we have tried to show the relationship between long term climate change impacts in annual rice productivity in Lakhimpur. Further the following log linear regression equation has been formed to show the relationship more clearly.

lnY_{it} = (32.90)In + (-0.53)ln R_{it}+(-5.56)ln T_{it}+ (0.13)lnF_{it}+ (0.01)ln IR_{it}+ (-0.48)ln HYV_{it} + U_{it} ------- (6.6)

In the above equation (6.6), left hand side shows the dependent variable of the study i.e. annual average rice productivity in Lakhimpur district while the right hand side shows the independent or controlled variables of the study. We have considered rainfall and temperature as climate change factors for the entire study. The estimation result shows that all the independent variables have significant i.e. both positive and negative impact on dependent variable of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.78 which implies that the regression line is perfectly fit with all the variables of the study. Here, N represents the number of observation years during the study i.e. 40 years (1970-2010). In the analysis t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are 0.00, 0.01, 0.04 and 0.05 implies that the result of the analysis is statistically significant.

In Lakhimpur district of Assam, the analysis result shows that both the climate change factors i.e. rainfall and temperature has significant negative impact on the annual rice productivity. It has been found that (log) 1 millimetre increase in annual rainfall would result in the decrease of annual rice productivity by log of 53 kg per hectare over the years while keeping other controlled variables of the study constant. Again, (log) 1 degree celcious increase in annual mean temperature would results in heavy amount of decrease in annual rice productivity i.e. by log of 556 kg per hectare over the years while keeping all the independent variables of the study constant. Increase in fertilizer consumption shows positive impact in annual rice productivity, as we can say that if the fertiliser usage increases by (log) 1 kg per hectare for rice cultivation than the annual rice productivity would increases by log of 13 kg per hectare over the years in the district. On the other hand if the area under HYV seeds increases by (log) 1 hectare than the annual rice productivity of the state decreases by log of 48 kg per hectare over the year while keeping other independent variables of the study constant. Further, area covered by irrigation facility has very negligible but positive impact in annual rice productivity in the district over the period of time.

5.12.7: Impact of Climate Change on Annual Rice Productivity in Nagaon (1970-2010)

Similarly in Nagaon, it has been observed from the earlier table no. 5.9 that the annual compound growth rate of rice production was approximately 195 percent during 2010 over the year 1970, but the yield growth rate was only 115 percent. Therefore to see the long term impact of climate change in rice productivity the following analysis has been done.

Table 5.16: Regression Analysis for Impact of Climate Change on Annual Rice Productivity of Nagaon (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.05	0.05	-0.87	0.04
Temperature	0.98	1.04	0.94	0.04
Fertilizer	0.07	0.05	1.29	0.02
HYV seeds	0.32	0.14	2.22	0.04
Irrigation	0.11	0.06	1.96	0.07
Constant	0.72	2.64	0.27	0.08

R^2 = 0.69, Prob. > F= 0.000, N = 40

To estimate the climate change impacts on rice productivity in Nagaon district of Assam, we have formed the following log linear regression equation.

$\ln Y_{it}$ = (0.72)In + (-0.05)ln R_{it}+(0.98)ln T_{it}+ (0.07)lnF_{it}+ (0.11)ln IR_{it}+ (0.32)ln HYV_{it} + U_{it}------(6.7)

In the above equation (6.7), the left hand side shows the dependent variable of the study i.e. annual rice productivity for Nagaon district whereas the right hand side shows the independent or controlled variables of the study. Here, we have considered temperature and rainfall as climate change factors. The estimation result shows that apart from rainfall all the other independent variables have significant positive impact on the dependent variable of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.69 which implies that the regression line is almost perfectly fit with all the variables of the study. Here, N represents the number of the observation years for the study i.e. 40 years (1970-2010). In the analysis t value shows the ratio of the co-efficient to the standard error of the dependent variable. The p values of the estimation are 0.02, 0.04, 0.07 and 0.08 which represents the results of the analysis is statistically significant.

In the Nagaon district of Assam, the above analysis shows that rainfall has significant negative impact and temperature has significant positive impact in annual rice productivity. From the above log linear regression analysis, it has been observed that (log) 1^0C increases in annual mean temperature would result in increase of rice productivity by log of 98 kg per hectare over the period of time withholding other controlled variables of the study constant. On the other hand (log) 1 millimetre increase in annual rainfall would result to decrease in annual rice productivity by log of 5 kg per hectare in the district over the period of time while keeping other dependent variables of the study constant. Again, if consumption of fertiliser increases than annual rice productivity also increases. The other independent variables of the above regression analysis i.e. area covered by irrigation and HYV seeds if increases by (log) 1 hectare then annual rice productivity increases by log of 11 and 32 kg per hectare respectively over the period of time withholding other independent variables of the study constant.

5.12.8: Impact of Climate Change on Annual Rice Productivity in Sibsagar (1970-2010)

It has been revealed from table no. 5.9 that the annual compound growth rate of rice productivity is highest in Sibsagar among all the principle crops in 2010 over the year 1970. Therefore, to find out the long term climate change impact in annual rice productivity, the following analysis has been made.

Table 5.17: Regression Analysis for Impact of Climate Change on Annual Rice Productivity of Sibsagar (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.07	0.14	-0.54	0.06
Temperature	0.40	0.43	0.92	0.04
Fertilizer	-0.23	0.11	-2.02	0.06
HYV seeds	-0.16	0.08	-1.93	0.07
Irrigation	-0.06	0.03	-2.38	0.03
Constant	10.81	1.64	6.60	0.00

R^2 = 0.71, Prob. > F=0.000, N = 40

With the help of above table no. 5.17, in order to clearly illustrate the relationship between climate change impacts in annual rice productivity in Sibsagar district of Assam, we have formed the following log linear regression equation.

$\ln Y_{it}$ = (10.81)In +(-0.07)ln R_{it}+(0.40)ln T_{it}+ (-0.23)lnF_{it}+ (-0.06)ln IR_{it}+ (-0.16)ln HYV_{it} + U_{it} ------(6.8)

In the above regression equation (6.8), the left hand side represents the dependent variable of the study i.e. annual rice productivity in Sibsagar district and the right hand side represents the independent or controlled variables of the study. The estimation result shows that apart from annual mean temperature, the remaining controlled variables have significant negative impact on the dependent variable of the study. Here, Prob >F = 0.000 implies the p-value associated with the above F-statistic. In the interpretation the calculated R^2 is 0.71 which implies that the regression line is almost perfectly fit with all the variables of the study. Here, N represents the number of the observation years of the study i.e. 40 years (1970-2010). In the analysis t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study. The p values of the analysis are 0.00, 0.03, 0.04, 0.6 and 0.07 which represents that the estimated result of the analysis is statistically significant.

In the Sibsagar district of Assam, the above analysis shows that the climate factors of the study i.e. rainfall has significant negative impact on dependent variable of the study whereas temperature has significant positive impact in annual rice productivity. From the analysis it has been observed that (log) 1 millimetre increase in annual total rainfall leads to decrease in annual rice productivity by log of 7 kg per hectare over the years in the district withholding other controlled variables of the study constant. Again, if annual mean temperature in the district increases by (log) 1^0C then annual rice productivity increases by log of 40 kg per hectare while keeping other controlled variables of the study constant. Interestingly, fertilizer consumption, area covered by irrigation and HYV seeds also has negative impact in annual rice productivity in the district. If the fertiliser consumption increases by (log) 1 kg per hectare, then annual rice productivity also decreases by log of 23 kg per hectare while keeping other independent variables of the study constant. On the other hand, if the area covered by irrigation facility and HYV seeds increases by (log) 1 hectare then annual rice productivity also decreases by log of 6 kg and 16 kg per hectare respectively in the district while keeping other controlled variables of the study constant.

5.12.9: Impact of Climate Change on Annual Rice Productivity in Karbi Anglong (1970-2010)

Karbi Anglong is the hilly district of Assam, where rice is the principle crop. To see the long term impact of climate change in productivity of rice the following analysis has been done.

Table 5.18: Regression Analysis for Impact of Climate Change on Annual Rice Productivity of Karbi Anglong (1970-2010):

Variables	Co-efficient	Std. Error	t Value	p value
Rainfall	-0.04	0.05	-0.78	0.44
Temperature	-0.36	0.01	-6.46	0.13
Fertilizer	-0.01	0.02	-0.54	0.60
HYV seeds	0.14	0.06	2.31	0.03
Irrigation	0.23	0.18	1.27	0.22
Constant	3.90	2.61	1.49	0.02

R^2 = 0.51, Prob. > F= 0.000, N = 40

To show the long term climate change impact in rice productivity in Karbi Anglong district of Assam, we have formed the following log linear regression equation.

$\ln Y_{it} = (3.90)\text{In} + (-0.04)\ln R_{it}+(-0.36)\ln T_{it}+ (-0.01)\ln F_{it}+ (0.23)\ln IR_{it}+ (0.14)\ln HYV_{it+} U_{it}$

------(6.9)

In the above equation (6.9), the left hand side of the regression equation represents the dependent variable of the study i.e. annual rice productivity in Karbi Anglong district and the right hand side shows the independent variables of the study. In the above interpretation the calculated R^2 is 0.51 which implies that the regression line is almost perfectly fit with all the variables of the study. 'N' represents the time period of the study i.e. 40 years (1970-2010) and t value shows the ratio of the co-efficient to the standard error of the dependent variable of the study.

From the above log linear regression analysis, it has been found that the area covered by HYV seeds is only statistically significant variable in the analysis. Also if the area is increased under HYV seeds by (log) 1 hectare then this will result increase in annual rice productivity by log of 14 kg per hectare over the period of time while keeping the other controlled variables of the study constant. From the observation it has been revealed that the other independent variables of the study are statistically insignificant.

5.12.10: Impact of Climate Change on Annual Rice Productivity in N. C. Hills (Dima Hasao)

N. C. Hills is the second hilly districts of Assam similar to Karbi Anglong, where it has been found in the earlier table no. 5.9 that the annual compound growth rate of rice is 20.17 percent during 2010 over the year 1970. Therefore to see the long term impact of climate change in rice productivity the following analysis has been done.

Table 5.19: Regression Analysis for Impact of Climate Change on Annual Average Rice Productivity of N. C. Hills (Dima Hasao):

Variables	Co-Efficient	Std. Error	t Value	p Value
Rainfall	0.02	0.04	0.65	0.53
Temperature	0.72	0.41	1.74	0.10
Fertilizer	-0.07	0.03	-2.42	0.03
HYV seeds	0.15	0.08	1.76	0.10
Irrigation	0.04	0.05	0.88	0.39
Constant	3.55	1.76	2.02	0.06

R^2 = 0.59, Prob. > F= 0.049, N = 40

With the help of above table no. 5.19, we have tried to show the relationship between climate change impacts in rice productivity in N.C.Hills district of Assam. To make the relationship more clear the following log linear regression equation has been formed.

Y_{it} = (3.55)In + (0.72)ln R_{1it}+(.02)ln T_{2it}+ (-0.07)lnF_{3it}+ (0.04)ln IR_{4it}+ (0.15)ln HYV_{5it+} U_{it} ------ (6.10)

In the above equation (6.10), the left hand side of the regression equation represents the dependent variable of the study i.e. annual rice productivity in Dima Hasao and the right hand side shows the independent or controlled variables of the study. In the interpretation the calculated R^2 is 0.59 which implies that the regression line is almost perfectly fit with all the variables of the study. 'N' represents the time period of the study i.e. 40 years (1970-2010) and t value shows the ratio of the co-efficient to the standard error of the dependent variable.

From the above analysis it has been observed that only one climate change factor i.e. annual mean temperature has statistically significant impact in annual rice productivity in the district. The result also shows that the other climate change factor i.e. annual total rainfall is statistically insignificant in the analysis. It is found that if the temperature increases by (log) 1^0C it leads to increase in annual rice productivity by log of 72 kg per hectare over the period of time while keeping other independent variables of the study constant. Again if fertiliser usage increases by 1 kg per hectare than annual rice productivity of the district decreases by log of 7 kg per hectare while keeping other controlled variables of the study constant. If the area covered by HYV seeds increases by 1 hectare, then annual rice productivity also increases by log of 15 kg per hectare. In the district, it has been observed that area covered by irrigation facility has statistically insignificant impact in rice productivity.

On the basis of the above analysis, it has been found that there is a strong relationship between the agricultural productivity and long term climate change factor i.e. annual total rainfall and annual mean temperature, thus the impact is seen as adverse and also positive in a very significant level. Therefore we have fulfilled our 1st objective i.e. to study the relationship among climatic change (CC) and agricultural productivity in Assam over the years. Hence we have rejected our 1st null hypothesis i.e. the climate change has no impact on the productivity of agriculture in Assam.

5.13: Objective 2: To study the major crops of the state which are affected by climate change (CC)

In this section, we analyse the long term climate change impact on the different principle crops in the state of Assam. Accordingly the table no.5.20 has been constructed. The first column shows the four different crops of the study i.e. rice, wheat, pulses and oilseeds, second column of the table shows the regression co-efficient of annual total rainfall for the four major crops and the third column shows the regression co-efficient of annual mean temperature for the major crops It has been found from the result tables that wheat is the most climate change resistant crop in the state. Whereas oil seeds are found to be sensitive crops especially during the heavy rainfall season as its productivity increases as the temperature rises. On the other hand, pulses are negatively affected by the long term impact of climate change factors i.e. annual total rainfall and annual mean temperature. Further, rice has been found the most climate change sensitive crop and it is extensively affected by the long term increase in annual total rainfall and annual mean temperature in the state.

Table 5.20: Co-efficient Results for the Principal Crop Productivity of Assam

Variables	Total Annual Rainfall	Mean Annual Temperature
Rice	-0.68*	-0.42*
Wheat	0.01*	0.00*
Pulses	-0.04*	-0.03*
Oilseeds	-0.03*	0.01*

* 1 & 5 percent level of significance

It has been found from the below table no. 5.21 that the area shared by principle crops against the state gross cropped area shows a declining trend over the years. In terms of rice, if compared to 1980-82, it shows that the share of state gross cropped area has decreased by 5.67 percent over the year 2007-09. In case of other principal crops like wheat, pulses and oil seeds the area shared against the GCA has been declining remarkably over the period of time. Therefore we can say that the cropping pattern of the state has also been changing from the principle crops to the other commercial and horticulture crops. So in the climate change scenario, agricultural sector of Assam might be in less risk, because the state is already taking steps to cope up with the long term climate change impacts by crop diversification from principal crops to other commercial and horticulture crops.

5.21: Area Share (%) by Principal Crops to the State GCA:

Year	Rice	Wheat	Pulses	Oilseeds	Others	GCA
1980-82	65.17	2.85	3.39	7.18	21.40	100.00
1983-85	64.07	3.09	3.69	8.78	20.37	100.00
1986-88	62.93	2.93	3.60	9.48	21.05	100.00
1989-91	66.21	2.21	3.00	8.53	20.04	100.00
1992-94	60.66	1.86	2.70	7.81	26.98	100.00
1995-97	63.51	2.17	3.16	8.44	22.73	100.00
1998-00	63.90	1.95	3.20	8.47	22.48	100.00
2001-03	63.93	1.77	3.19	8.25	22.86	100.00
2004-06	60.63	1.51	2.91	7.01	27.94	100.00
2007-2009	61.47	1.39	2.97	6.87	27.30	100.00
Compound Growth Rate (1980-2009)	-5.67	-51.25	-12.53	-4.39	27.56	0

Source: Krishi Bhavan, Khanapara, ^Gross Cropped Area, Others include sugarcane, jute, mesta, fruits, vegetables etc.

5.14: $H_{0,2}$: The impact of climate change affects all the crops uniformly;

To test the 2nd hypothesis of the study the following ANOVA test has been conducted. The ANOVA result has been depicted in the following table.

Table 5.22: The ANOVA Results of Log Linear Regression Co-efficient of Different Crops in Assam is as follows:

Variables	Count	Sum	Average	Variance
Rice	2	-1.103	-0.552	0.035
Wheat	2	0.008	0.004	0.000
Pulses	2	-0.063	-0.032	0.000
Oilseeds	2	-0.021	-0.011	0.000

Variables	Total Annual Rainfall	Mean Annual Temperature
Count	4	4
Sum	-0.739	-0.44
Average	-0.185	-0.11
Variance	0.111	0.043

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	0.437	3	0.146	18.246	0.020	9.277
Columns	0.011	1	0.011	1.400	0.322	10.128
Error	0.024	3	0.008			
Total	0.472	7				

From the above ANOVA test, it has been observed that the long term impact of climate change (as represented here by rainfall and temperature) is more severe on rice productivity than the other crops at a significant level of 5 percent. Therefore we can say that climate change effects different crop differently. This is because it is observed from the analysis that the F value of the row variance is $F_{calculated} > F_{critical}$, therefore we are rejecting the null hypotheses of our study i. e. impact of climate change affects all the crops uniformly in the state.

5.15: District Wise Comparison of Long Term Impact of Climate Change on Rice

The state wise comparison regarding the impact of climate change on rice productivity has been depicted in the below table no. 5.23. From the table it is clearly revealed that the climate change factors i.e. rainfall and temperature has negative impact in the overall annual rice productivity in some districts of Lakhimpur, Goalpara, Dibrugarh and Darrang. The highest effected districts are Lakhimpur, followed by Goalpara, Dibrugarh and Darrang. This can be proved from the table no. 5.24 shown in the next page, that the average crop area damaged by floods is highest in Lakhimpur. Other districts like Goalpara, Lakhimpur and Darang are also flood prone; therefore we can say that increasing amount of rainfall may cause more incidences of floods resulting in crops damage.

Table 5.23: Co-efficient Results for the District wise Rice Productivity of Assam

Districts	Rainfall	Temperature	Fertilizer	HYV seeds	Irrigation
Lakhimpur	-0.530*	-5.560*	0.130*	-0.480*	0.010*
Kamrup	-0.250*	1.720*	0.150*	0.180*	0.050*
Goalpara	-0.210*	-0.580*	0.070*	-0.030***	-0.010***
Nagaon	-0.050*	0.980*	0.070*	0.320*	0.110**
Sibsagar	-0.073**	0.396*	-0.225**	-0.164**	-0.062*
Darrang	-0.040*	-0.740*	0.100*	-0.320*	0.120*
Cachar	-0.120*	1.850*	-0.010*	0.010*	-0.020**
Dibrugarh	-0.180*	-0.300*	0.020*	-0.170*	-0.010*
Karbi Anglong	-0.037***	-0.360***	-0.012***	0.141*	0.228***
N. C. Hills	0.024***	0.722**	-0.068*	0.147**	0.045***
Mean	-0.147*	-0.187*	0.022*	-0.036*	0.046*
Variance	0.026*	4.410*	0.012*	0.061*	0.007*

* 1 & 5 percent level of significance, ** 10 percent level of significance and *** statistically insignificance

It has also been observed from the above table no. 5.23 that only increasing amount of rainfall have negative impact in the annual rice productivity in the districts of Kamrup, Cachar, Sibsagar and Nagaon, whereas increasing temperature shows positive impact in the annual rice productivity in these districts. Further, in the two hilly districts i.e. N. C. Hills and Karbi Anglong, the climate change factors are statistically insignificant in the study.

If we looked into the impact on productivity of other controlled variable i.e. area covered by HYV seeds, it has been found to have negative impact on the annual productivity of rice in the districts of Lakhimpur, Goalpara, Sibsagar, Darrang and Dibrugarh. Interestingly apart from Sibsagar, the districts of Lakhimpur, Goalpara, Darrang and Dibrugarh districts also have negative effects on rice productivity due to both the climate change factors i.e. annual total rainfall and annual mean temperature. So, we can say that HYV seeds are less resistance to the climate change scenario in Assam and therefore farmers can adopt traditional varieties of rice in order to cope up with the long term climate change risks in the state.

It is also found that increasing usage of fertilisers have negative effects in annual rice productivity in the districts of Sibsagar and Cachar, whereas in the other districts i.e. Lakhimpur, Kamrup, Goalpara, Nagaon, Darrang and Dibrugarh shows that the increasing amount of fertiliser consumption per year have positive and statistically significant impact in annual rice productivity. Also the area covered by irrigation facility have negative impacts in annual rice productivity in the districts of Sibsagar and Dibrugarh, while irrigation plays an important, positive and significant role in the districts of Lakhimpur, Kamrup, Nagaon and Darrang.

In the earlier table 5.23, the highest negative mean value has been found in terms of rainfall, followed by temperature and HYV seeds and positive mean has been found in terms of fertiliser and irrigation. Therefore we can say that the long term climate change factors i.e. annual total rainfall and temperature has been effecting negatively in the rice productivity of the state. Again, if we look into the variance of rainfall, temperature, irrigation facility, HYV seeds and fertiliser usage, p-value associated with the test for equality of variance is 0.00 therefore we assumed that the variances are not equal in the analysis.

Table 5.24: Average Crop Area Damages by Flood During 1991-2010 (In Hectare)

Sl. No.	District	Average Area (1991-2010)
1	Lakhimpur	57882.25
2	Kamrup	51082.37
3	Goalpara	46562.99
4	Nagaon	41977.27
5	Sibsagar	26581.86

6	Darrang	24913.17
7	Cachar	17465.74
8	Dibrugarh	10343.49
9	Karbi Anglong	2182.45
10	N.C. Hills	484.15

Source: Irrigation Department, Assam

Conclusion

In terms of annual total rainfall there has been more variations taking place in the districts of N. C. Hills, Karbi Anglong, Nagaon, Kamrup and Darang and in terms of annual mean temperature more variation is taking place in the district of Goalpara, Kamrup, Nagaon, Karbi Anglong and Cachar during 1970-2010. Therefore, we can say that long term climate change is taking place in Assam. From the above analysis it is also found that the long term climate change has impose more negative impact on the crop productivity in the state, where, the long term climate change has very negligible positive impact on the wheat productivity in the state. In terms of district wise long term climate change impact on rice productivity the districts are effected more. Also the average area effected by flood during (1991-2010) are mostly in Lakhimpur, Goalpara, Dibrugarh and Darrang, therefore we can say that long term climate change influence leads to more frequent flood occurrences in the districts which results in heavy amount of crop loss leading to state's food security problems in the long run.