Trend Analysis of Climate Change and Investigation on Its Probable Impacts on Rice Production at Satkhira, Bangladesh

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Abstract

This study aimed at statistical analysis of the recent trend of climate change and prediction of future climate change scenarios with Global Climate Models (GCMs) and most importantly investigation on the impacts of climate change on rice production. The Satkhira district was taken as the study area, which represented the coastal zone of Bangladesh. There was a statistically non-significant increasing trend of annual maximum and minimum temperature and annual total rainfall through the period of 1950-2006. The trend analysis of seasonal rainfall for the period 1981-2006 could reveal that, from the last two decades the seasonal normal rainfall pattern has been altered. Rainfall in pre-monsoon and winter season had a decreasing trend whereas it had an increasing trend during monsoon and post-monsoon seasons. Temperature variations had an observable effect on crop yield. The summer crop Aus production was decreasing significantly. The production of Boro rice, a winter crop is increasing significantly with the increase of lowest minimum temperature. The inter-annual variation in the amount of winter season rainfall was little. Boro production, therefore, was insignificantly affected by this variable. However, correlation between the production and climatic variables was not statistically significant. In case of the future climate change prediction, GFDL-TR predicted delta values ranging from 1.1 to 1.7℃ for 2050, while it varied from 1.5 to 2.3℃ for 2070. Whereas, UKTR suggested mean temperature increase was 1.5 to 2.1℃ in 2050 and 1.2 to 2.7℃ in 2070. According to HadCM2 generated delta values, temperature would increase 1.3 to 2.9℃ in 2050 and 1.7 to 4.0℃ in 2070. It could be seen that different GCMs predicted different sets of values for rainfall increase (or decrease). Among the three GCMs, GFDL-TR predicted milder changes while HadCM2 suggested severe changes and the values increased with time. In case of rainfall, GFDL-TR and UKTR both predicted a decreasing tendency in future during winter season (DJF). However, HadCM2 suggested that there would be higher precipitation (35.6% increase in 2050 and 48.9% increase in 2070) during the winter season (DJF), which will be beneficial for agriculture. Different crop responded differently under different climate change scenarios. Yield of Boro was reduced from 3.47 to 48.64% in calcareous soils, while, it was increased from 0.16 to 16.47% in noncalcareous soil conditions. In case of T. Aman, mainly increased yields (up to 49%) could be observed under rainfed conditions in future climate change scenarios. However, there was also declining trend of yields ranging from 1 to 12%. The most detrimental effects were observed in case of T. Aus. The yield decreased in all soil conditions and future climate scenarios. The per cent yield difference decreased from at least 5% up to 42%. In most cases, irrespective of crops and GCMs, climate change would have negative impact. Therefore, in the event of climate change the cropping pattern of the region may change considerably. Agriculture in Bangladesh is already under pressure both from increasing demands for food, and from problems of agricultural land and water resources depletion. The prospect of global climate change makes the issue particularly urgent.

Key words: GCMs, GFDL-TR, HadCM2, UKTR

Introduction

Climate variability and change, its impacts and vulnerabilities are growing concern worldwide. The climate of Bangladesh is changing and it is becoming more unpredictable every year. Global warming induced changes in temperature and rainfall are already evident in many parts of the world, as well as in our country (Ahmed, A.U. & M.A., 1999). Hazards like floods, droughts, cyclones and others, which are aggravated by climate change and its variability being experienced more frequently in Bangladesh than ever before. Uncertainty of rainfall and uneven temporal and spatial distribution in one hand, creating flooding and of the other hand longer dry spells evoking droughty conditions (Lai, M. et. al., 1998).

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These entire have profound impact on agriculture (McCarthy et. al., 2001). As the great majority of the people of Bangladesh are depended on agriculture for their livelihood, crop agriculture in this region is highly susceptible to variations in climate system. It is anticipated that crop production would be extremely vulnerable under climate change scenarios, and as a result, food security of the country will be at risk (Karim et al., 1996). Despite being highly vulnerable, very little efforts have so far been made to understand potential of agricultural adaptation in Bangladesh. Present development efforts aim to increase food production through the expansion of irrigation, flood protection embankments, with the support of modern agricultural technology especially HYV seeds and fertilizers to achieve national self-sufficiency in food grains. Threats from undefined climate change can terribly hinder this national target, for what reason it is of utmost significance to investigate about the trend of climate change together with model predictions and the probable impacts on the agricultural production (Karim et. al., 1994). Therefore, Bangladesh has given special emphasis on research works on location specific climate change and its impact analyses, particularly at district level for crops, livestock, and forestry.

Soil Condition

The study area consists of two Agroecological Zones (AEZ) namely; High Ganges River Floodplain (AEZ –11) and Ganges Tidal Floodplain (AEZ-13); the extent of these two AEZ is 86049 and 97867 hectares, respectively. Rainfall, evapotranspiration, thermal conditions and soil moisture availability largely determine crops and cropping practice of the coastal region.

High Ganges River Floodplain (AEZ-11)

Northern part of Satkhira consists of this agroecological zone. This region occupies an extensive area of tidal floodplain land in south-west of the country. The greater part of this region has relief. There is a general pattern of grey; slightly calcareous, heavy soils on river banks and grey to dark grey, noncalcareous, heavy silty clays in the extensive basins. Noncalcareous Grey Floodplain soil is the major components of general soil types. Acid Sulphate soil also occupies significant part of the area where it is extremely acidic during dry season. In general, most of the topsoils are acidic and subsoil is neutral to slightly alkaline. Soils of Sundarbans area are strongly alkaline. General fertility level is high with medium to high organic matter content.

Ganges Tidal Floodplain (AEZ-13)

Southern part of Satkhira consists of this agroecological zone. This region includes the western part of the Ganges River Floodplain which is predominantly highland and medium highland. Most areas have a complex relief of broad narrow ridges and inter-ridge depression, separated by areas with smooth broad ridges and basins. There is an overall pattern of olive-brown silt loams and silty clay loams on the upper parts of the floodplain ridges and dark grey, molted brown, mainly clay soils on ridge sites and in basins. Most ridge soils are calcareous throughout.

In 2000, SRDI conducted a soil survey in the coastal areas of Bangladesh. It is found that 187300 hectares salinity increased over last 3 decades. The most parts of the Satkhira soil are affected by moderate to strong levels of salinity. During the dry months of March and April, salinity problems, resulting from seawater intrusion, are more acute and lands are commonly left fallow as crop production is restricted by the presence of salts. As a consequence, lesser extent of soil suitability is hampering specifically the rice production.

Objectives

Considering the importance of agricultural sector for the economy and food requirements of Bangladesh, there is a need for reliable estimates of major crop production under varied climate change provisions and circumstances. In order to have a reliable estimate of varied climate change provisions, the first objective of this study was to analyze the recent and future trend of annual average maximum and minimum temperature and trend of annual and seasonal total rainfall. The second and prime objective was to investigate probable impacts of observed recent and predicted future climate change on rice production.

Materials and Methods

Collection of Climatic and Agricultural Data

Required data on agriculture and local climate, particularly of the study area, Satkhira, was collected from authentic organizations. Climatic data was collected from Bangladesh Meteorological Department (BMD). District level agricultural area, production and yield data were taken from Department of Agricultural Extension (DAE) and Bangladesh Agricultural Research Center (BARC). SAARC Meteorological Research Center (SMRC) and SAARC Agricultural Research Center (SAIC) acted as sources of pertinent information for climate and agriculture of Bangladesh.

Recent Trend Analysis and Future Prediction of Climate Change

In order to understand the climate variability and change throughout the period 1950-2006, the analysis work devoted to recognize the recent trend of variation of each climatic parameter (maximum and minimum temperature, total rainfall). Three climate scenarios extending from 1950 to 1980 (Climate Scenario 1), 1960 to1990 (Climate Scenario 2), 1970 to 2000(Climate Scenario 3) and the overall period of 1950-2006 (Climate Scenario 4) were developed and analyzed to understand the trend of average annual maximum and minimum temperature. The trends for the rainfall over study area for four seasons (pre-monsoon, monsoon, post- monsoon and winter) and on annual basis have been obtained for overall period 1950-2006. Trends of maximum temperature, minimum temperature, and rainfall in five-year moving average fashion were computed for each year during 1950-2005, by plotting data in MS Excel. These five-year moving averages of annual climatic data have been used to obtain the regression equations.

Investigation on Impacts on Rice Production

An effort was taken to investigate the probable linkage between the climate variability and change and trend of rice production, so that the impact on production can be revealed. For this part of analysis, the production data of three varieties of rice - Aman, Aus, and Boro as the major crops of Satkhira, was used to recognize the trend of production of these crops in response to highest maximum and lowest minimum temperature and the amount of seasonal total rainfall, for the period of 1990-2006. Then, an attempt was taken to investigate on any possible correlation between the trend of local climate change and trend of change in the rice production, to realize any types of probable impacts of local climate change on rice production during the specified period.

Future Climate Change Scenarios

In order to predict the future trend of climate change, delta values for mean temperature and precipitation with respect to 1990 (baseline) were generated for two time intervals 2050 and 2070 using three GCMs – i. GFDL-TR (Geophysical Fluid Dynamics Laboratory Transient), ii. HadCM2 (Hadley Centre during 1995 and 1996 using the Second Version of the United Kingdom Meteorology Office's Unified Model), and iii. UKTR (UK Meteorological Office/Hadley Centre Transient with respect to the base year of 1990). The generated delta values are presented in Table 1.

Simulation Studies

During the second analysis part, to study the impacts of predicted future climate change on rice crops as compared to the base year (1990), crop simulation studies were conducted. For this Decision Support System for Agrotechnology Transfer (DSSAT) 4.0 (2004) based crop simulation model was used to assess the yields/productions of three rice varieties under base year and changed climate scenarios.

The simulation studies were conducted using climatic data on rainfall, maximum and minimum temperature, and solar radiation of Satkhira and utilizing the DSSAT Crop simulation models

(CERES Rice) for base year (1990) and the previously generated climate change delta values for the years 2050 and 2070. Yields of different rice crops were generated under baseline (360 ppmv CO2, temperature and precipitation of 1990) climate and with no stress condition (no stress means that optimum levels of fertilizer and irrigation) and under the varied climate change scenarios.

For simulation runs, experiments were designed with optimum agronomic and management practices. As per requirement of the models, weather files and soil profiles were also created. Each experiment was run for the selected crops with two major types of soil of the study area, i.e., calcareous soil and noncalcareous soil, under rainfed and irrigated conditions. The treatments were operated under the base year climate and previously developed varied climate change scenarios of GFDL-2050 and 2070, HADcam-2050 and 2070 and UKTR-2050 and 2070 (MAGICC and SCENGEN, 2000). Output dataset for crop yield from each treatments and experimental conditions were compared with respect to the yield in the base year to reveal the impact of climate change on agricultural production of the crops.

Results and Discussion

Trend of Annual Maximum Temperature

During Climate Scenario 1, the five-year moving average of annual maximum temperature had an increasing trend (Fig.1) which was statistically significant. Climate Scenario 2 showed an increasing trend (Fig. 2), which was not statistically significant. In Climate Scenario 3, the annual maximum temperature had a decreasing trend, which was not statistically significant (Fig. 3).

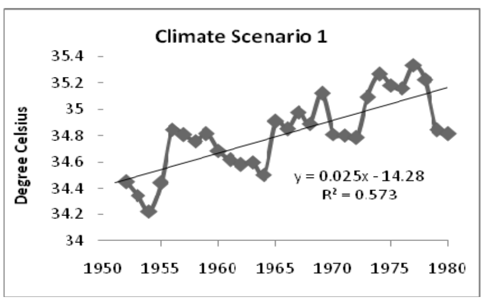

Fig. 1: 5yr moving avg. of Tmax (1950-1980)

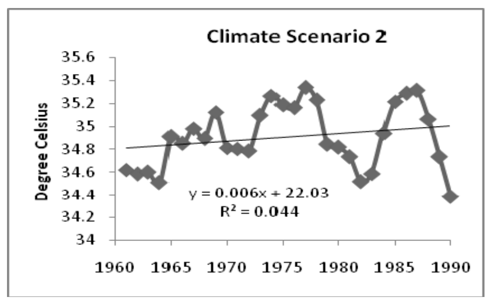

Fig. 2: 5yr moving avg. of Tmax (1960-1990)

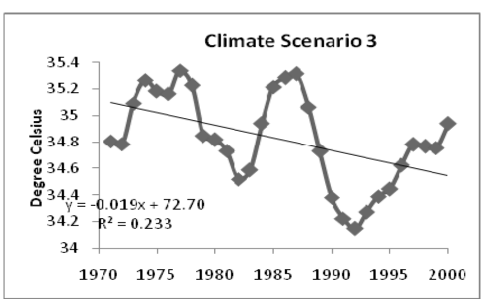

Fig. 3: 5yr moving avg. of Tmax (1970-2000)

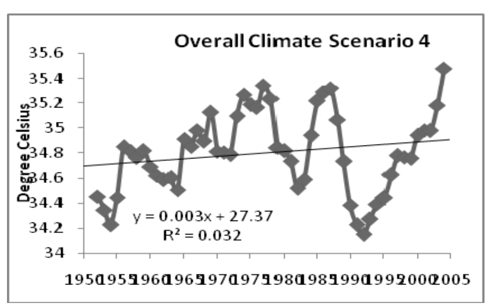

Fig. 4: 5yr moving avg. of Tmax (1950-2005)

The trend of annual maximum temperature (Fig. 4) for the Climate Scenario 4 exhibited an increasing trend, which was not statistically significant. During 1970-2000, the five-year moving average of annual maximum temperature exhibited a decreasing trend; otherwise, there was a statistically non-significant increasing trend of annual maximum temperature through the period of 1950-2006.

Trend Annual Minimum Temperature

During climate scenario 1, the annual minimum temperature had an increasing trend, which was not statistically significant (Fig. 5). The annual mean temperature during climate scenario 2 exhibited an increasing trend, which was not statistically significant (Fig. 6).

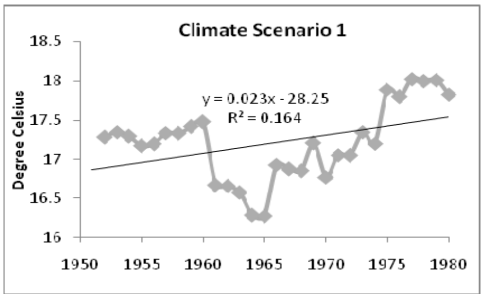

Fig. 5: 5yr moving avg. of Tmin (1950-1980)

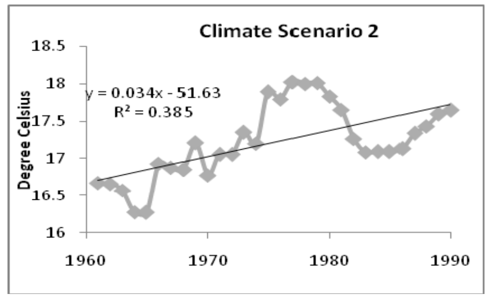

Fig. 6: 5yr moving avg. of Tmin (1960-1990)

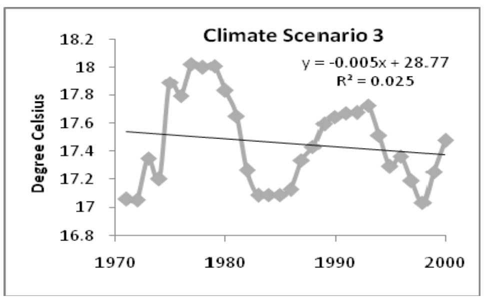

Fig. 7: 5yr moving avg of Tmin (1970-2000)

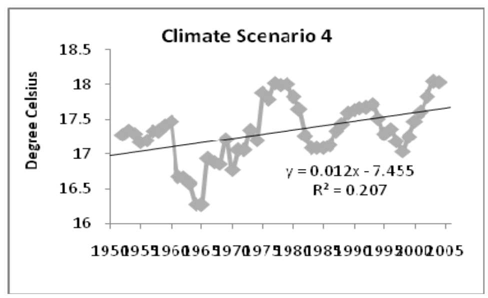

Fig. 8: 5yr moving avg of Tmin (1950-2005)

During climate scenario 3, the annual minimum temperature had a decreasing trend (Fig.7), which was not statistically significant. For the overall period of 1950-2005, Fig. 8 showed that the annual minimum temperature had an increasing trend, which was not statistically significant. Therefore, it could be revealed that though there was a decreasing trend during 1970-2000; the annual average minimum temperature had an increasing trend through the period of 1950-2006; and the trend was not statistically significant.

Rainfall Trends

<u>Trend of Annual Rainfall</u>

During the climate scenario1, the five-year moving average of the annual total rainfall had a decreasing trend, which was not statistically significant (Fig.9). While, during the climate scenario 2, and 3 the five-year moving average of the annual total rainfall had an increasing trend.

These trends were not statistically significant (Figs.10 & 11). The overall climate scenario 4, exhibited an increasing trend of total annual rainfall, which was not statistically significant. The trend analysis of annual rainfall revealed that there was an increasing trend throughout the period 1950-2006, with the exception of a decreasing trend during the period of 1950-1980. However, no trends were statistically significant.

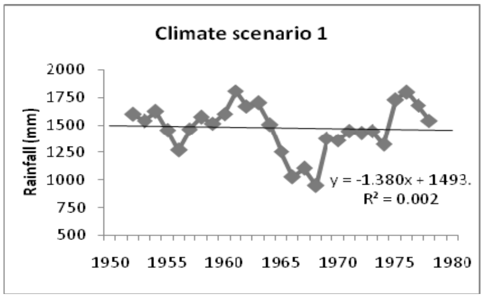

Fig. 9: 5yr moving avg of annual rainfall (1950-1980)

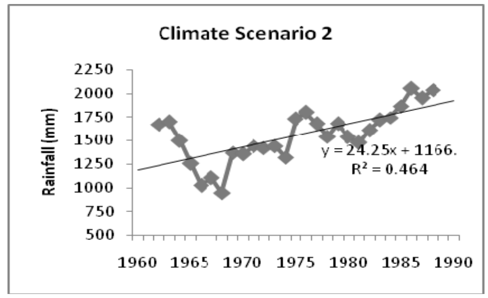

Fig. 10: 5yr moving avg of annual rainfall (1960-1990)

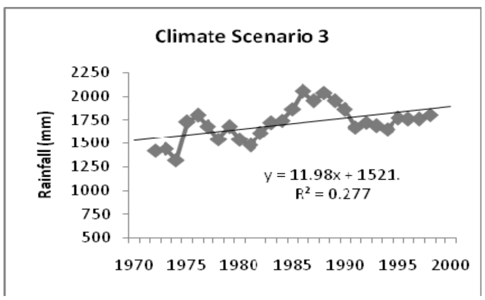

Fig. 11: 5yr moving avg of annual rainfall (1970-2000)

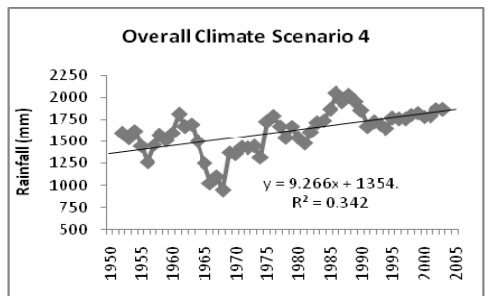

Fig. 12: 5yr moving avg of annual rainfall (1950- 2005)

Trend of Seasonal Rainfall:

The trends of seasonal rainfall over study area for the period 1981-2006 were shown in Figs. 13-16. In pre-monsoon season (Fig.13) a decreasing trend of rainfall was found, which was not statistically significant. Fig. 14 showed that during monsoon season rainfall had an increasing trend, which was not statistically significant. The rainfall in post-monsoon season exhibited an increasing trend, which was not statistically significant (Fig.15). However, in case of winter season, the rainfall had a decreasing trend (Fig.16), which was not statistically significant. The trend analysis of seasonal rainfall for the period 1981-2006 could reveal that, from the last two decades the seasonal normal rainfall pattern has been altered.

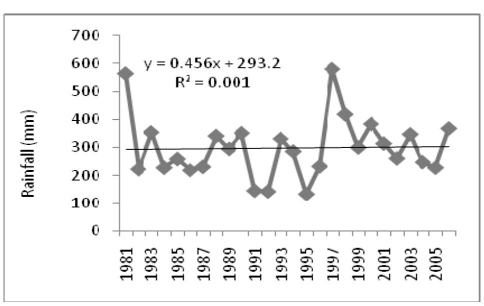

Fig. 13: Trend of pre-monsoon rainfall

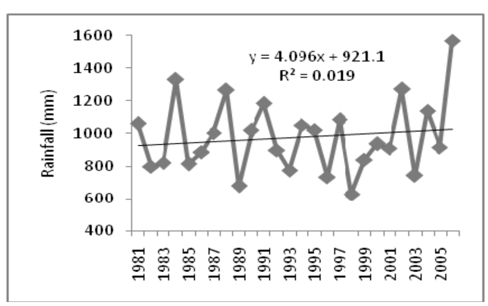

Fig. 14: Trend of monsoon rainfall

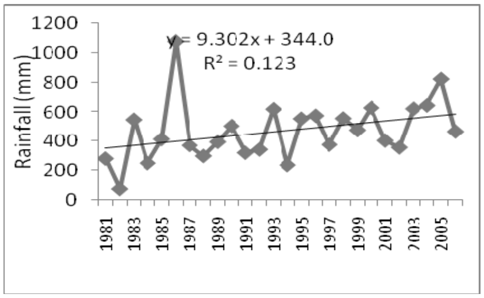

Fig. 15: Trend of post-monsoon rainfall

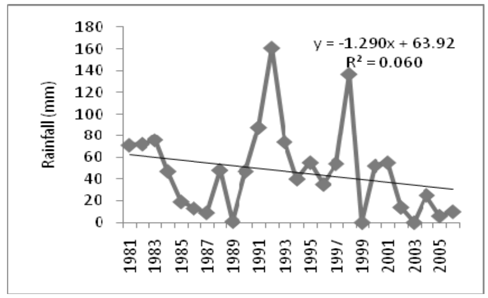

Fig. 16: Trend of winter rainfall

Rainfall in pre-monsoon and winter season had a decreasing trend whereas it had an increasing trend during monsoon and post-monsoon seasons. None of these trends were statistically significant.

Future Climate Change Scenarios

Though all three GCMs suggested an increase in temperature, the range of change in mean temperature with respect to base year was different for the three GCMs. Both GFDL-TR and UKTR predicted higher range of temperature increases during the winter season (DJF) compared to rest of the months in 2050 and 2070. Nevertheless, the highest temperature increase in winter season would be experienced in 2070 according to HadCM2 generated delta values. Whereas, suggested highest mean temperature increase was 2.9°C in 2070 during the post-monsoon season (SON). From Table 1 it could be seen that different GCMs predict different sets of values for rainfall increase (or decrease). Among the three GCMs, GFDL-TR predicted milder changes while HadCM2 suggested severe changes and the values increased with time. In case of rainfall, GFDL-TR and UKTR both predicted a decreasing tendency in future during winter season (DJF). But, HadCM2 suggested that there would be higher precipitation during the winter season (DJF), which will be beneficial for agriculture. The results of the analysis for investigating the probable impacts of recent temperature and rainfall changes on rice production are presented in the following sections.

Table 1: Delta values for mean temperature and rainfall generated by various Global Climate Models for 2050 and 2070 using MAGICC 4.1/SCENGEN 4.1

Month / Season	Global Climate Models											
	GFDL-TR				UKTR				HadCM2			
	Mean Temp (°C)		Precipitation (%)		Mean Temp (°C)		Precipitation (%)		Mean Temp (°C)		Precipitation (%)	
	2050	2070	2050	2070	2050	2070	2050	2070	2050	2070	2050	2070
Jan	1.5	2.1	-5.4	-7.4	2.1	2.5	-9.5	-13.1	2.0	2.7	29.5	40.5
Feb	1.5	2.1	0.6	0.8	2.0	2.1	4.2	5.8	1.9	2.5	40.9	56.3
Mar	1.7	2.3	4.9	6.7	1.7	2.1	15.2	20.9	1.7	2.4	11.8	16.2
Apr	1.1	1.5	15.2	21	1.5	1.8	10.2	14	1.7	2.3	-3.1	-4.2
May	1.4	2.0	6.2	8.6	1.8	2.2	2	2.8	2.0	2.7	-14	-19.2
Jun	1.4	1.9	10.2	14	1.7	2.7	17.2	23.7	2.9	4.0	-17.4	-23.9
Jul	1.2	1.7	25.3	34.8	1.7	1.7	32.3	44.4	2.1	2.9	0.8	1.1
Aug	1.3	1.8	19.6	27	1.6	1.4	25	34.4	1.3	1.7	11.8	16.3
Sep	1.2	1.7	18	24.8	1.6	1.2	19.5	26.9	1.4	1.9	3.8	5.2

Oct	1.4	1.9	5.6	7.7	1.7	2.0	8.4	11.5	1.9	2.6	-7.5	-10.4
Nov	1.2	1.7	3.1	4.3	1.6	1.9	-21.2	-29.2	2.3	3.1	-8.7	-12
Dec	1.4	2.0	0.8	1.1	1.7	1.9	-10.4	-14.3	1.9	2.6	36.3	50.0
DJF	1.5	2.1	-1.4	-1.9	2.0	2.2	-5.2	-7.2	1.9	2.6	35.6	48.9
MAM	1.4	1.9	7.6	10.4	1.7	2.1	6.8	9.3	1.8	2.5	-1.8	-2.4
JJA	1.3	1.8	18.5	25.5	1.7	1.7	24.0	33.0	1.9	2.7	-0.2	-2.2
SON	1.3	1.8	7.4	10.3	1.7	1.9	-0.3	-0.4	2.1	2.9	-8.1	-5.7
ANN	1.4	1.9	11.7	16.1	1.7	2.0	13.8	19.0	1.9	2.6	7.0	9.7

GFDL-TR = Geophysical Fluid Dynamics Laboratory Transient; HadCM2 = Hadley Centre during 1995 and 1996 using the Second Version of the United Kingdom Meteorology Office's Unified Model; UKTR = UK Met. Office/Hadley Centre Transient.

DJF = December-January-February, MAM= March-April-May, JJA= June-July-August, SON= September-October-November, ANN= Annual

<u>Correlation with Maximum Temperature</u>

The production of Boro with response to average maximum temperature during 1999-2006, exhibited a nearly strong positive correlation (Fig. 17). On the other hand, production of Aman with response to average maximum temperature during the same period was found to have a nearly strong negative correlation (Fig. 18). In case of Aus production the correlation indicated that there was no significant relation of Aus production with temperature rise (Fig. 19).

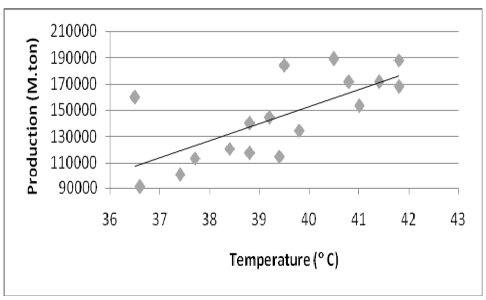

Fig 17: Annual variation of Boro production with response to highest maximum temperature during 1999-2006

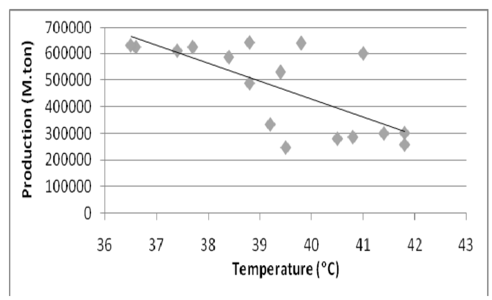

Fig. 18: Annual variation of Aman production with response to highest maximum temperature during 1999-2006

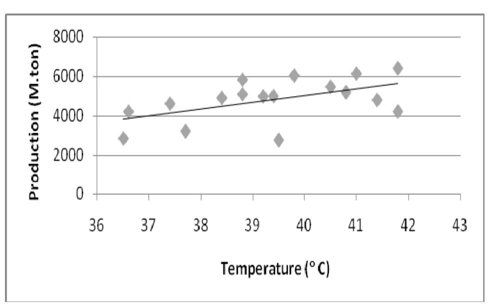

Fig. 19: Annual variation of Aus production with response to highest maximum temperature during 1999-2006

The trend of highest maximum temperature over the period 1950-2006 was increasing. The summer crop Aus production was decreasing significantly. The Aus production may decrease due to the increasing trend of highest maximum temperature. The decreasing trend of Aus production might also be related as because of flash flood due to heavy rainfall, nor'wester, Tornados and early onset of monsoon.

Correlation with minimum temperature

Temperature variations have an observable effect on crop yield. Boro rice is a winter crop. It has been found that the Boro production is increasing significantly with the increase of lowest minimum temperature. This increasing trend in the Boro production might be credited in part to the scientific cultivation techniques which are increasingly being used, the proper use of fertilizers, the use of proper harvesting methods, use of hybrid seed, following of meteorological forecasts, proper use of pesticides, proper land management and increasing awareness among the cultivators.

The production of Boro with response to average minimum temperature during 1999-2006, exhibited a non-significant positive correlation (Fig. 20). On the other hand, production of Aman with response to average minimum temperature during the same period was found to have a very weak negative correlation (Fig. 21). In case of Aus production the correlation coefficient value indicated that there was no significant relation of Aus production with temperature rise (Fig. 22).

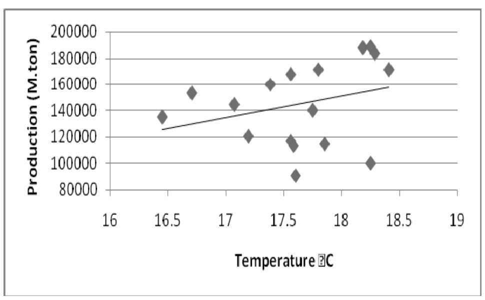

Fig 20: Annual variation of Boro production with response to minimum temperature during 1999-2006

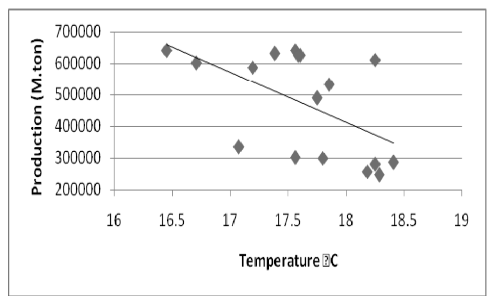

Fig 21: Annual variation of Aman production with response to minimum temperature during 1999-2006

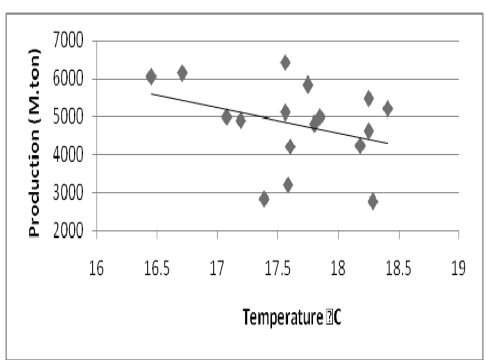

Fig 22: Annual variation of Aus production with response to minimum temperature during 1999-2006

Correlation with Rainfall

The trend of production of Boro, Aman and Aus in response to the seasonal rainfall (Fig.ure 23, 24, 25) in which period the rice varieties are grown, with the correlation coefficient values of -0.47, -0.24 and 0.19 respectively, did not show any significant correlation.

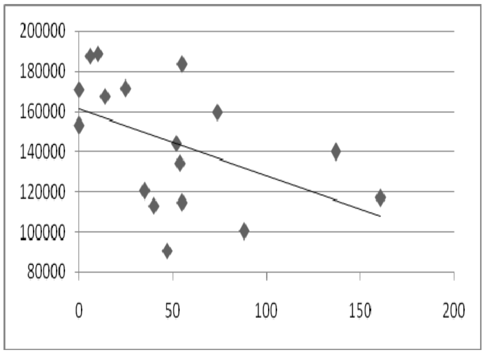

Fig. 23: Annual variation of Boro production with response to winter rainfall during 1999-2006

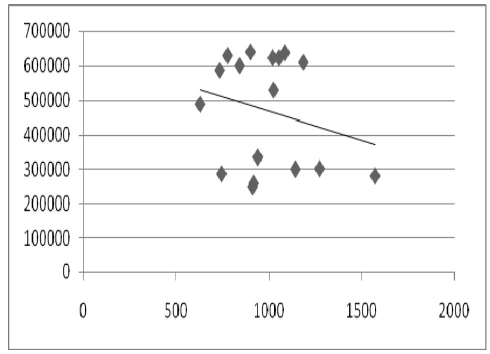

Fig. 24: Annual variation of Aman production with response to monsoon rainfall during 1999-2006

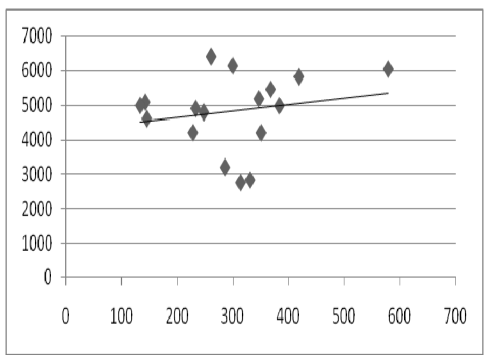

Fig. 25: Annual variation of Aus production with response to pre-monsoon rainfall during 1999-2006

The inter-annual variation in the amount of winter season (December to February) rainfall was little. Boro production, therefore, was insignificantly affected by this variable. However, Boro production is increasing prominently. This might be due to supplementary irrigation and other related factors.

Impacts of Future Climate Change on Rice Production

Results in Table 2 showed that different crops responded differently under different climate change scenarios. In most cases, irrespective of crops and GCMs, climate change will have negative impact.

Table 2: Per cent Change in Crop Yield under various Climate Change Scenarios, with Calcareous (CALC) and Noncalcareous (NCALC) soil under Irrigated (IR) and Rainfed (RF) conditions.

Climate Change Scenarios	Soil Type	Boro Rice	T. Aus Rice	T. Aman Rice
		Percent Yield difference with respect to baseline scenario		
BASE IR	CALC	0	0	0
GFDL 50 IR	CALC	-4.68	-7.82828	-12.6879
GFDL 70 IR	CALC	-3.47	3.202072	-2.70893
HADC 50 IR	CALC	-10.63	-38.0691	-22.3083
HADC 70 IR	CALC	-4.01	-41.915	-16.9169
UKTR 50 IR	CALC	-11.52	-41.01686	-23.044
UKTR 70 IR	CALC	-5.71	-9.73847	-16.6778
BASE RF	CALC	0	0	0
GFDL 50 RF	CALC	-11.26	-8.17839	-6.39736
GFDL 70 RF	CALC	-21.76	5.900652	41.7223
HADC 50 RF	CALC	-13.03	-36.3249	36.33947
HADC 70 RF	CALC	-48.64	-25.8301	49.73995
UKTR 50 RF	CALC	-26.45	-23.0802	13.56486
UKTR 70 RF	CALC	-22.06	-12.7754	43.95648
BASE IR	NCALC	0	0	0
GFDL 50 IR	NCALC	11.04	-7.82828	-12.8
GFDL 70 IR	NCALC	16.48	3.202072	-2.79588
HADC 50 IR	NCALC	10.59	-38.0719	-22.0363
HADC 70 IR	NCALC	13.84	-42.4022	-16.8937
UKTR 50 IR	NCALC	9.17	-18.202	-23.0056
UKTR 70 IR	NCALC	13.22	-9.73847	-16.7766
BASE RF	NCALC	0	0	0
GFDL 50 RF	NCALC	13.25	-5.24689	1.059372
GFDL 70 RF	NCALC	10.80	1.589738	13.30415
HADC 50 RF	NCALC	0.76	-30.914	-1.8392
HADC 70 RF	NCALC	11.62	-22.4611	3.285216
UKTR 50 RF	NCALC	3.18	-20.2807	-9.20427
UKTR 70 RF	NCALC	1.83	-12.2906	1.105787

Note: Base = (360 ppmv CO2, temperature and precipitation of 1990), GFDL50 and GFDL70 = Geophysical Fluid Dynamics Laboratory Transient model for year 2050 and 2070 respectively; HadC50 and HadC70 = Hadley Centre model for 2050 and 2070, UKTR50 and UKTR70 = UK Met.Office/Hadley Centre Transient model for year 2050 and 2070 respectively.

The magnitude of the impact varied with crops and GCMs. Crop suffers even greater loss due to increase in temperature and reduction in the amount of rainfall, especially during the winter and pre-kharif seasons.

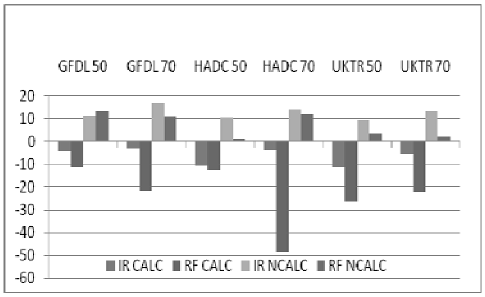

Fig. 26: Per cent yield difference of Boro under different soil conditions and varied climate change scenarios with respect to base year scenario

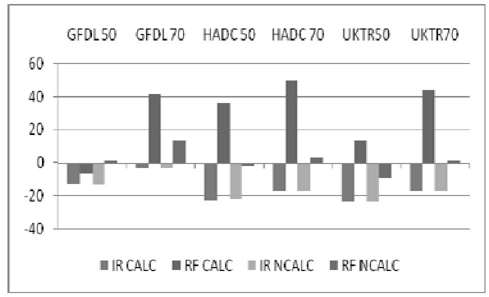

Fig. 27: Per cent yield difference of T. Aman under different soil conditions and varied climate change scenarios with respect to base year scenario

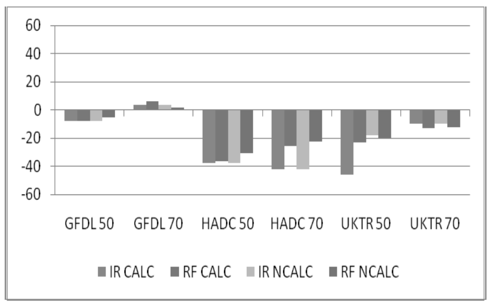

Fig. 28: Per cent yield difference of T. Aus under different soil conditions and varied climate change scenarios with respect to base year scenario

From the Fig. 26, it could be seen that per cent yield difference of Boro under different soil conditions and varied climate change scenarios with respect to base year scenario varied significantly. Yield of Boro was reduced from 3.47 to 48.64% in calcareous soils, while, it was increased from 0.76 to 16.48% in noncalcareous soil conditions. This could be due to the reason that the noncalcareous soils have generally more fertility compared to that of calcareous soils. In case of T. Aman, mainly increased yields (up to 49%) could be observed under future climate change scenarios.

This phenomenon occurred probably because; according to model prediction the amount of monsoon rainfall would increase significantly, which supported the production. However, there was also declining trend of yields ranging from 1 to 12% (Fig. 27). The most detrimental effects were observed in case of T. Aus. The yield decreased in all soil conditions and future climate scenarios. The per cent yield difference with respect to base year scenario decreased from at least 5% up to 42%. From the predicted yield difference of crops under dissimilar climate change scenarios it was evident that yield of rice of the three varieties - Boro, T. Aus and T. Aman would decrease. Therefore, in the event of climate change the cropping pattern of the region may change considerably.

Conclusions

Effects of the climate changes would vary because of the differences in the variety and local differences in growing seasons, crop management etc. Higher levels of temperature and precipitation would aggravate declining condition of the soils. It would certainly have adverse impacts on food-grain production. The rice varieties now in use might not be able to tolerate temperature rise and sustain current level of yield. Moreover, the standing crop failure due to prolonged submergence, flood and salinity intrusion have to be tackled by devising anticipatory adaptation techniques. As predicted by the crop simulation models, yield of most of the crops would be negatively impacted by rise in temperature and erratic rainfall, flooding, droughts, salinity, etc. This will definitely, have depressing effect on the access to food and food security. Depending on the local agro-climatic environment as well as the magnitude of the changes alleviation strategies has to be developed. To tackle the water scarcity problem, effort should be made to develop crop cultivars with high water use efficiency. As the incidences of floods and droughts are likely to increase in frequency, effort should be made to develop crop cultivars tolerant to these hazards. On the other hand, agronomic manipulations such as shifting the planting dates, using short duration crop cultivars could be other options. Use of raised beds and irrigated through drip irrigation systems permit proper leaching of salts from the root zone. This system of crop cultivation produce high economic benefit compared to traditional methods. In the coastal tidal floodplains during kharif season normally nothing can be grown due to high standing water only in some cases farmers take chances of planting aman rice. To minimize the risk maize could be grown under wet-bed no tillage method. Improvement in the crop-based weather and flood forecasting systems, etc. are some of the adaptation measures that would also be urgently required. Early warning system should be strengthened to inform the farmers about their roles in an adverse weather condition. Integrated wetland farming, improved fish farming, mangrove and inland plantation, development of appropriate agroecosystem–based crop production technologies, manipulation of crop production practices, and adoption of available appropriate crop production technologies would definitely improve the livelihood of the study area and of the coastal region as a whole. Future production must be achieved with less land and less water with no harm done to the natural environment. This challenge is indeed enormous and only the application of the most appropriate strategies will lead to success.

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