MAUSAM, **62**, 2 (April 2011), 171-178

551.583 : 63

Impact of climate change on agriculture in eastern Uttar Pradesh and Bihar states (India)

ARVIND KUMAR, PADMAKAR TRIPATHI*, K. K. SINGH** and A. N. MISHRA*

Crop Research Station, NDUAT, Bahraich - 271 801, India

**Deptt. of Agrometeorology, N.D. University of Agril. & Tech., Faizabad - 224 229 (U.P.), India*

***India Meteorological Department, New Delhi, India*

(*Received 18 January 2010, Modified 17 September 2010*)

e mail : arvindmausam@gmail.com

सार – फसलों की पैदावार मौसमी परिघटनाओं से काफी प्रभावित होती हैं इसलिए जलवायु में किसी भी प्रकार के परिवर्तन से फसल की उपज एवं उत्पादकता बहुत अधिक प्रभावित होगी। ऋतुगत आधार पर फसल की उपज के पूर्वानुमान के लिए एन.वाई.डी. विशलेषण के उपयोग से यह पता चला है कि अधिकतम तापमान से वर्ष 2020 तक पूर्वी उत्तर प्रदेश में चावल की पैदावार में प्रति हैक्टेयर 1.0 से 1.1 प्रतिशत तक की कमी हो सकती है। इसी प्रकार न्यूनतम तापमान से पूर्वी उत्तर प्रदेश में चावल की पैदावार में प्रति हैक्टेयर 1.5 से 1.9 प्रतिशत तक की कमी हो सकती है। वर्षा के भावी परिदृश्य से ऐसा पता चलता है कि दक्षिण–पश्चिम मानसून वर्षा चावल की पैदावार को नियंत्रित करने वाली मुख्य कारक होगी। बिहार राज्य में गेहूँ के उत्पादन में अधिकतम तापमान की भूमिका पूर्वी उत्तर प्रदेश की तुलना में अधिक महत्वपूर्ण है। मॉडल का पूर्वानुमान है कि अधिकतम तापमान में वृद्धि के कारण वर्ष 2080 के अंत तक बिहार राज्य में गेहूँ की पैदावार में 5–6 प्रतिशत की कमी हो सकती है जबकि यह कमी पूर्वी उत्तर प्रदेश में 1.5 – 2 प्रतिशत तक की हो सकती है।

ABSTRACT. Production of crops is greatly influenced by weather phenomena and therefore any change in climate will have major effects on crop yield and productivity. Using NYD analysis for prediction of crop yield on seasonal basis, it has been observed that maximum temperature may cause the reduction in yield of rice in Eastern Uttar Pradesh by 1.0 to 1.1% per ha by 2020. Similarly, minimum temperature may decrease the yield of rice by 1.5 to 1.9% per ha in Eastern Uttar Pradesh. From future scenario of rainfall it was observed that south-west monsoonal rainfall would be the major factor for controlling the yield of rice. The role of maximum temperature for wheat production in Bihar state is more significant as compared to Eastern Uttar Pradesh. The model predicts that wheat yield may decrease by 5-6% in Bihar state due to increase in maximum temperature by the end of 2080 whereas this decrement in Eastern Uttar Pradesh may be 1.5-2.0%.

Key words – Climate change, Agriculture, Global warming, Rainfall and rice.

1. Introduction

Climate change is frequently considered a major conservation threat to the country. The Earth's climate has already warmed by 0.5° C over the past century and recent studies show that it is possible to detect the effects of a changing climate on ecological systems. Changes in climate in recent decades are apparent all over the globe at all levels of ecological organization, population structure and functioning of ecosystems.

Importance of climate change as a current threat to species emphasizes the need of conservation and reintroduction efforts. The temperature, humidity, air movement, solar radiation and rainfall are major climatic parameters affecting the nutritional plan of animals through production level of crops and pastures. In recent decade climate induced natural disasters like drought, cyclone, erratic and uneven distribution of rainfall have become a major problem in enhancing agricultural production in India. The IPCC predicts that the mean summer monsoon rainfall in India may decrease by 0.5 mm/day (IPCC, 2001). The magnitude of projected changes in temperature, rainfall and carbon dioxide in future for different parts of the world, including India, as simulated by various General Circulation Models have been compiled by the IPCC (Watson *et al*., 1998). According to this, by 2010 CO_2 level might increase to

397-416 ppm from the current level of approximately 368 ppm. This is further likely to increase to 605-755 ppm by 2070. There is considerable uncertainty in the projected magnitude of change in rainfall and temperature for India (Table 1). Relatively, the increase in temperature is projected to be less in kharif season than in the rabi. The rabi rainfall, however shows larger uncertainty. Kharif rainfall is likely to increase by as much as 10%. The study area-averaged annual mean warming by 2020 is now projected to be between 1.0 and 1.4° C and between 2.23 to 2.87° C by the year 2050. It is again confirmed that kharif rainfall would increase and rabi rainfall may decrease in some areas (Aggarwal *et al*., 2001).

2. Data and methodology

A study of climate change on Indian Agriculture has been done under the network project of ICAR entitled "Impact, adaptation and vulnerability of Indian Agriculture to climate change". The weather data like maximum temperature, minimum temperature, relative humidity, wind direction, total evaporation and bright sunshine hours for last 30 years (1976-2005) of different stations of Eastern India (Eastern Uttar Pradesh and Bihar states), as shown in Table 2, were collected from India Meteorological Department, Pune. The area, production and productivity data of major crops of the selected stations (Table 2) and other weather parameters mentioned above were also collected from the Departments of revenue, statistical and Directorate of Agriculture of the concerned State. Normalized Yield Difference (NYD) analysis of future crop yield scenario on the seasonal basis was predicted by using HadCM3 model; variability of quantum of rainfall has been analyzed using statistical model, which has five parameter averages *viz*.; air temperature (°C), relative humidity (%), wind direction (degree), total evaporation (mm) and bright sun shine duration (hrs).

3. Results and discussion

3.1. *Crops and weather*

Using NYD analysis for prediction of crop yield on seasonal basis, it has been observed that changes in maximum temperature may cause the reduction in yield of rice in Eastern Uttar Pradesh to the tune of 1.0 to 1.1% per hectare by 2020 (Fig. 1). Similarly, minimum temperature change may decrease the yield of rice by 1.5 to 1.9% per hectare in Eastern Uttar Pradesh (Fig. 2). From future scenario of rainfall, it was observed that south-west monsoonal rainfall will remain a major factor in controlling the rice yields (Fig. 3). The role of maximum temperature for wheat production in the state of Bihar is more significant as compared to Eastern Uttar Pradesh.

TABLE 1

Expected changes in weather parameters in south Asia by 2010 and 2070 A.D. due to global warming

Parameter	Rabi		Kharif	
	2010	2070	2010	2070
Temperature increase (°C)	0.3 to 0.7	0.1 to 0.3	0.1 to 0.3	0.4 to 2.0
CO_2 (ppm)	397 to 416	605 to 755	397 to 416	605 to 755
Rainfall change in south west monsoon region (%)	0	-10 to +10	0	0 to +10

(*Source* : Watson *et al*., 1998)

TABLE 2

Districts for which data were collected

S. No.	Eastern Uttar Pradesh	Bihar
1.	Ambedkar Nagar	Patna
2.	Azamgarh	Samastipur
3.	Barabanki	Gaya
4.	Bahraich	Buxur
5.	Ballia	Bhagalpur
6.	Balrampur	Katihar
7.	Basti	Madhubani
8.	Chandauli	Muzaffarpur
9.	Deoria	Rohtas
10.	Faizabad	Purnia
11.	Gonda	Darbhang
12.	Ghazipur	Siwan
13.	Gorakhpur	Nalanda
14.	Jaunpur	Madhepura
15.	Mau	Kishanganj
16.	Maharajganj	Sheohar
17.	Mirzapur	Vaishali
18.	Sant Kabir Nagar	Sitamarhi
19.	Siddharthanagar	West Champaran
20.	Sonebhadra	Begusarai
21.	Sultanpur	Gopalganj
22.	Shravasti	Bhojpur
23.	Varanasi	Bhabhua

*T*max (Seasonal) Scenario and NYD of rice crop in E.U.P. | *T*max (Seasonal) Scenario and NYD of rice crop in Bihar

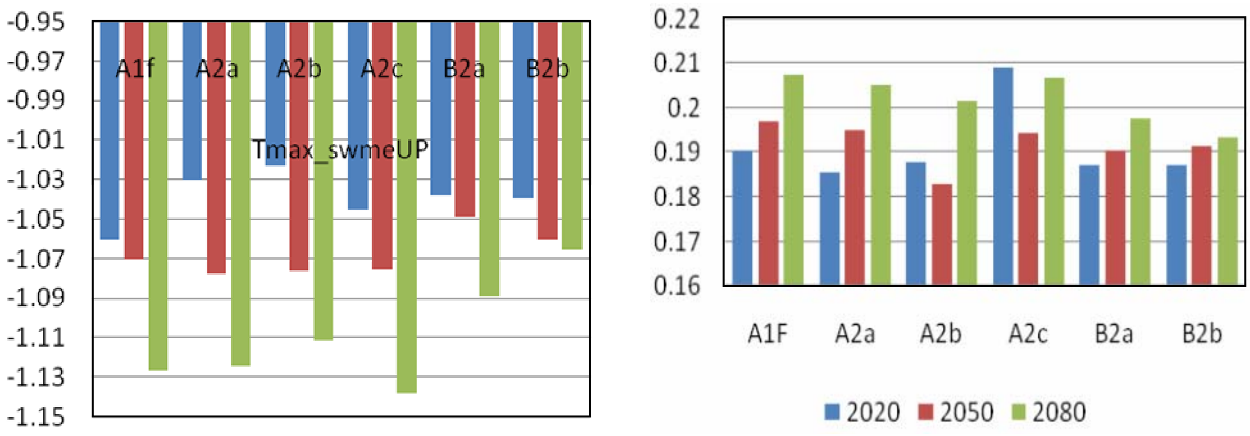

Fig. 1

*T*min (Seasonal) Scenario and NYD of rice crop in E.U.P. | *T*min (Seasonal) Scenario and NYD of rice crop in Bihar

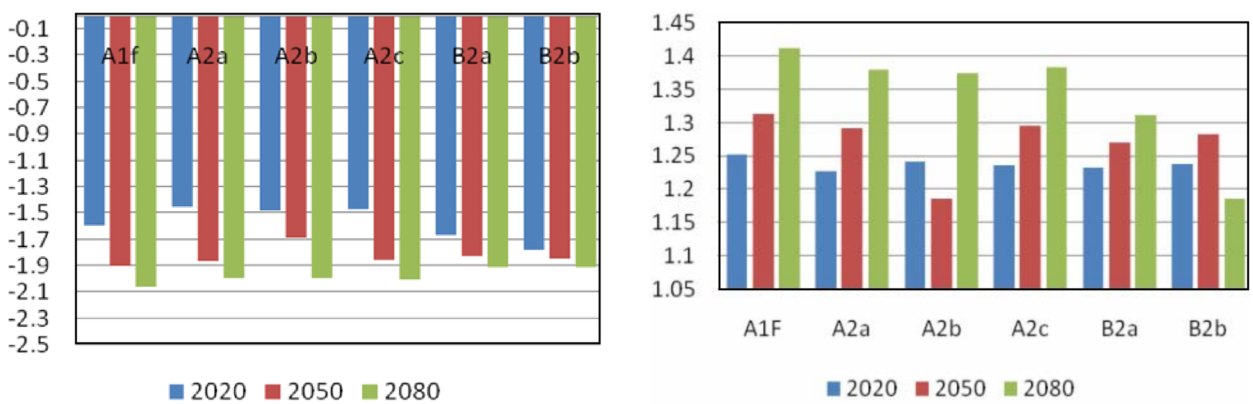

Fig. 2

Rainfall Scenario and NYD of rice crop in E.U.P. | Rainfall Scenario and NYD of rice crop in Bihar

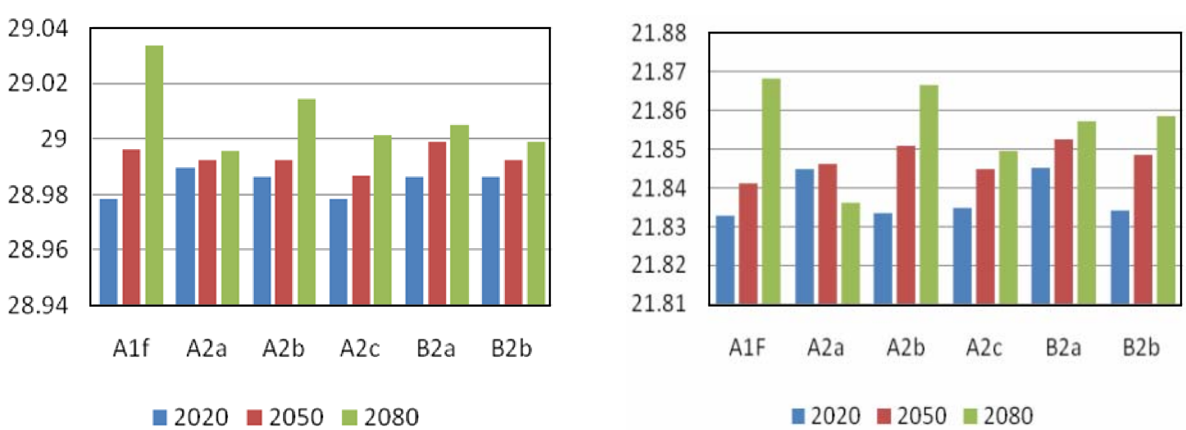

Fig. 3

Figs. (1-3). Prediction of Normalized Yield difference (NYD) in eastern India of rice crop

*T*max (Seasonal) Scenario and NYD of wheat crop in E.U.P. *T*max (Seasonal) Scenario and NYD of wheat crop in Bihar

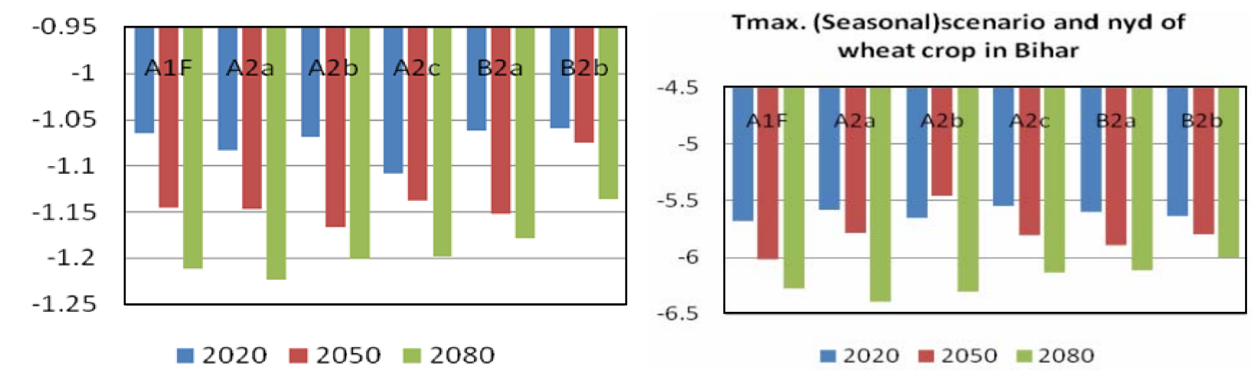

Fig. 4

*T*min (Seasonal) Scenario and NYD of wheat crop in E.U.P. *T*min (Seasonal) Scenario and NYD of wheat crop in Bihar

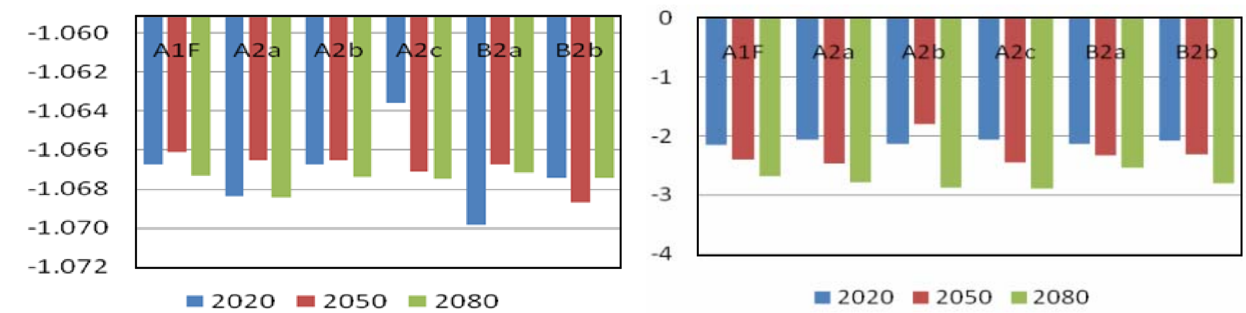

Fig. 5

Rainfall (Seasonal) Scenario and NYD of wheat crop in E.U.P. Rainfall (Seasonal) Scenario and NYD of wheat crop in Bihar

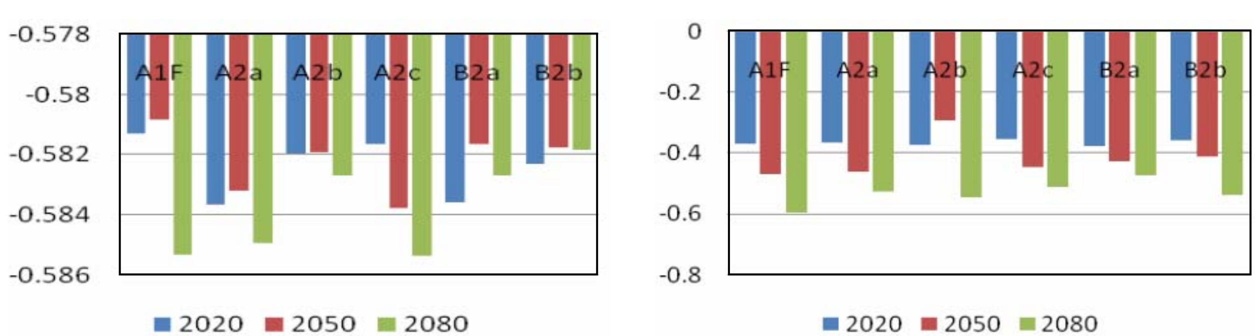

Fig. 6

Figs. (4-6). Prediction of Normalized Yield difference (NYD) in eastern India of Wheat crop

- In the Fig. 1 to Fig. 6, *X*-axis represents different seasons (A1F, A2a, etc.) and *Y*-axis, the value in %
- A1F stands for annual average of the entire year
- A2a stands for Pre monsoon season of particular year
- A2b stands for monsoon season of particular year
- A2c stands for post monsoon season of particular year
- B2a stands for winter season of particular year
- B2b stands for summer season of particular year

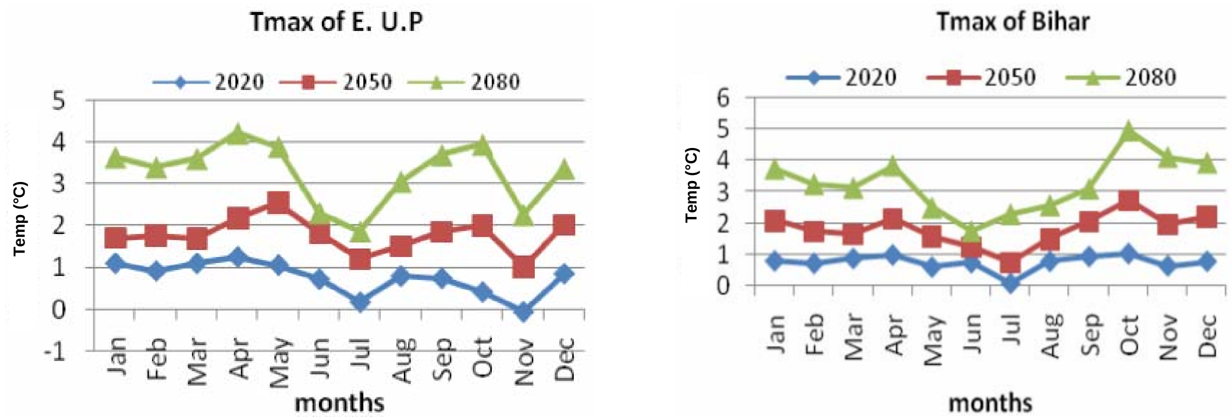

Fig. 7

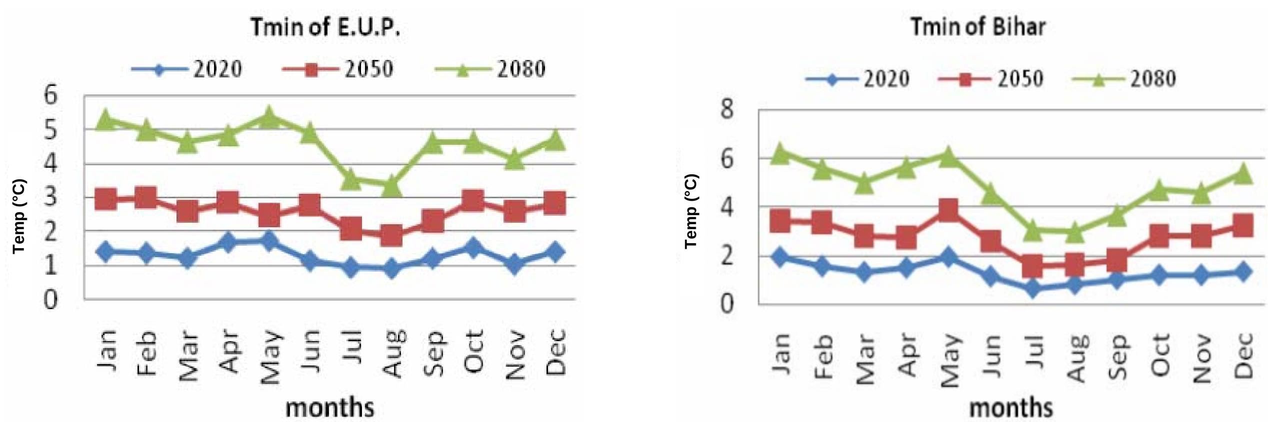

Fig. 8

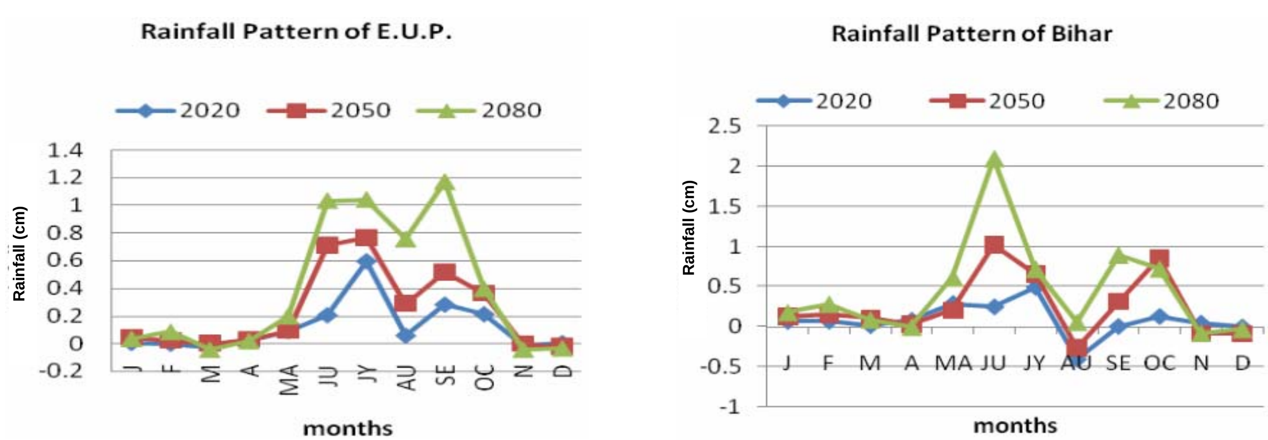

Fig. 9

Figs. (7-9). Future prediction of *T*max./ *T*min. and rainfall for eastern U.P. and Bihar

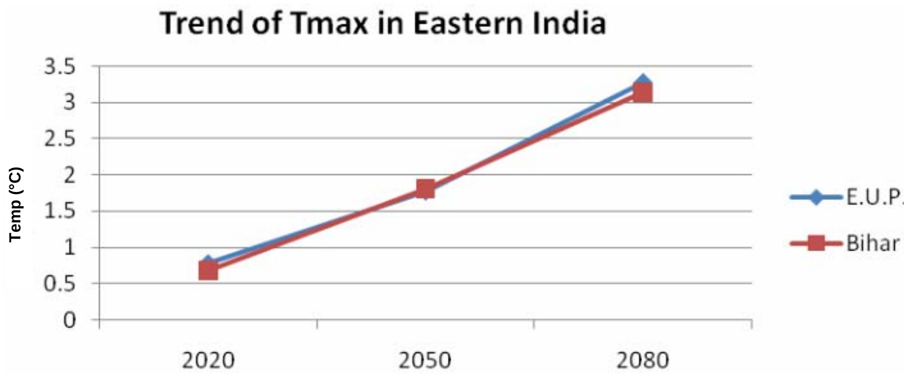

Fig. 10

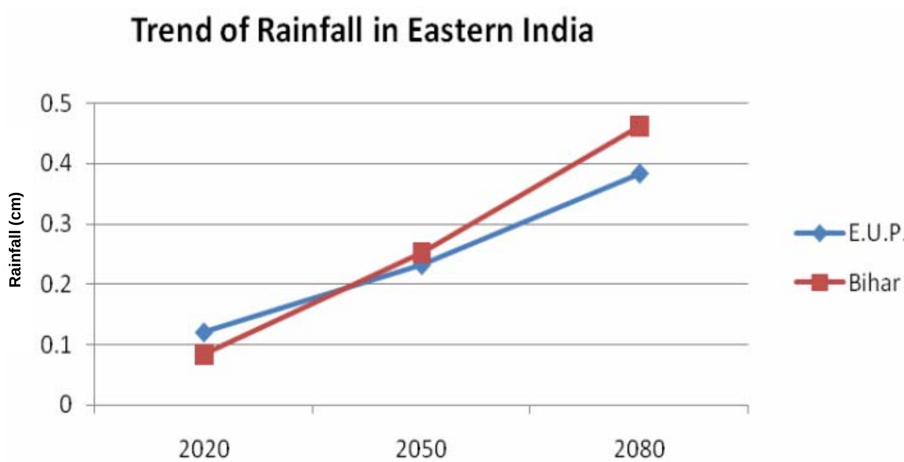

Fig. 11

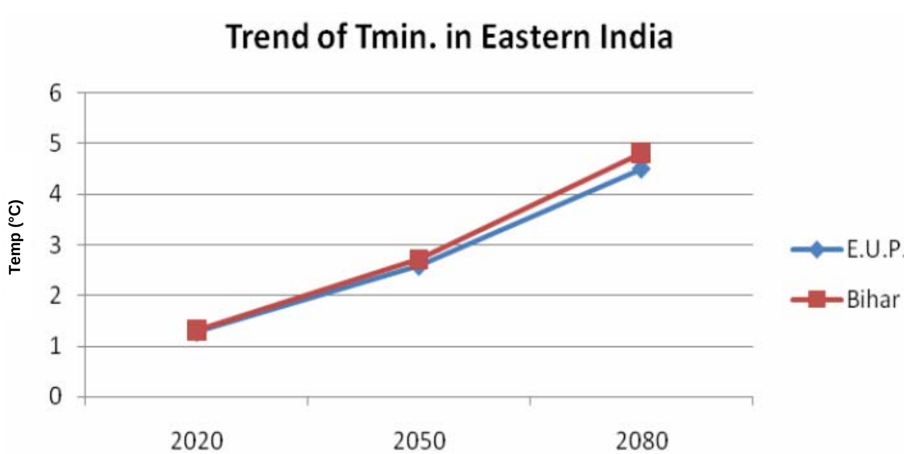

Fig. 12

Figs. (10-12). Trend scenario of weather in eastern India

The model predicts that wheat yield may decrease by 5 to 6% in Bihar state due to changes in maximum temperature alone by the end of the year 2080 whereas this decrement in Eastern Uttar Pradesh is expected to be between 1.5-2.0% (Fig. 4). Similar results were also found by Aggarwal and Sinha, 1993. Similarly the effect of minimum temperature on estimated yield is more in Bihar (2 to 3%) as compared to Eastern Uttar Pradesh (1-2%) with respect to average yield (Fig. 5). Future scenario of rainfall in rabi season in both eastern U.P. and Bihar will not affect significantly yield of wheat crops as compared to temperature (Fig. 6.). In general, the rate of increase of maximum temperature in Eastern India is computed to be higher during the period 2050 to 2080 (2-4° C) as compared to the period 2020 to 2050 (1-2° C) (Fig. 10). Fig. 11 depicts that Bihar would receive lower rainfall compared to eastern U.P. during the decade 2020 while the trend is reversed during the period 2050 to 2080. Similar projections were obtained for variation in minimum temperature too with greater magnitude in both Eastern Uttar Pradesh and Bihar ranging between 3-5° C in later part of this century as compared to early part (2-3° C) (Fig. 12). In Eastern Uttar Pradesh, the months of December and January are projected to be hotter as compared to November, contrary to the normal trend (Figs. 7, 8). Future scenario of rainfall over Eastern Uttar Pradesh reveals that rainfall would increase during south west monsoon period during 2020 to 2080 but month of August may face sharp decline in rainfall in all scenarios (Fig. 9). Similarly, August may receive lower temperature (both maximum and minimum in all months of the year). The two peaks of rainfall during kharif season were estimated in Eastern Uttar Pradesh, primarily peak during July and secondary peak in September month. A drastic decrease of rainfall, *i.e.*, intermittent drought during August was also estimated. Also significant reduction in terminal drought is expected because of secondary peak of rainfall during September. In Bihar, a stronger primary peak of rainfall was estimated in June as compared to July/August and a secondary peak in October. Trend analysis of temperature (maximum/minimum) of Eastern India shows an increasing trend in both Eastern Uttar Pradesh and Bihar states whereas a slight increase in minimum temperature in Bihar over Eastern Uttar Pradesh was estimated during 2080 only. Frequency of terminal drought in Eastern India is 70% (1970-2003), but the recent trend of drought shows the frequency of increasing early and intermittent drought occurrence. Terminal drought could decrease the yield of rice in Eastern Uttar Pradesh with a margin of 44% as compared to early stage drought, *i.e.*, 23% (Kumar *et al.*, 2006).

3.2. *Climatic, Bio-physical production potential and constraints*

Rice and wheat are the prominent cereal crops of Uttar Pradesh. During 2005-06, the state produced 235.7 lakh metric tonnes of wheat from an area of 91.85 lakh hectare with productivity level of 2.57 tonnes/ha whereas the crop coverage of rice during 2006 was 59.25 lakh hectare with a total production of 150.6 lakh metric tonnes at average productivity level of 2.3 tonnes per hectare. (Agricultural Production in Uttar Pradesh, 2005-06). There is wide disparity in productivity levels of rice and wheat in Eastern India due to following constraints;

(*i*) Out of total rice cropped area more than 90% is rainfed. Due to erratic rainfall and uneven distribution, the frequency of floods in Bihar and drought in Eastern Uttar Pradesh are considerably increasing affecting the crop productivity to a great extent. Rice farming in eastern India is therefore most vulnerable and risk prone due to complex ecological situations marked by frequent flood and drought (Aggarwal and Mall, 2002).

(*ii*) Abiotic stress is one of the major constraints in wheat crop production. High temperature during reproductive stage of wheat crop is one parameter identified as a production constraint (Fangmeier *et al*. 1999).

(*iii*) There is yield gap between attainable and farm level yields across the ecologies in Eastern India which ranged from 10 to 60 % in rainfed and flood prone regions.

4. Conclusion

Variability of quantum of monsoon rainfall has made a significant impact on agricultural production. Future yield prediction scenarios through segregation model of Normalized Yield Deviation (NYD) using HadDCM3 model of Eastern India have been made and found that by the end of 2080 the rice yield may increase to the tune of 25% per hectare when rainfall is considered to be major factor. In case of yield of wheat changes in maximum temperature is considered to be a major factor in Eastern India.

References

Aggarwal, P. K., Nagarajan, S. and Udai Kumar, 2001, "Climate Change and Indian Agriculture: Current Status of Understanding and Future Perspectives", Report submitted to the Indian Council of Agricultural Research, New Delhi, India (Unpublished).

Aggarwal, P. K. and Sinha, S. K., 1993, "Effect of probable increase in Carbon dioxide and temperature on productivity of Wheat in India", *Journal Agric Meteorol*., **48,** 811-814.

Aggarwal, P. K. and Mall, R.K., 2002, "Climate Change and rice yields in diverse agro environment of India. II: Effect of uncertainties in scenarios and crop models on impact assessment", *Climate Change*, **52**, 331-343.

Agricultural Production in U.P., 2005-06, Annual Report published by Directorate of Agriculture, Govt. of U.P., 3-5.

Fangmeier, A., De Temmerman, L., Kemp, K., Burke, J., Mitchell, R., Oijenvan, M. and Weigel, H. J., 1999, "Effects on nutrients and grain quality in spring wheat crops grown under elevated CO_2 concentration and stress condition in European, multiple site experiment ESPACE-wheat", *European J. Agronomy*, **10**, 215-229.

IPCC, 2001, "Climate Change 2001, "Impact, adaptation and vulnerability. Inter-Governmental Panel on Climate Change, Report of the working group II, Cambridge, UK, p967.

Kumar, Arvind, Tripathi, P. and Singh, A. K., 2006, "Effect of dry spell on growth, development and yield of rice (Oryza sativa)", *Indian J. Agric Sci*., **76,** 1, 47-49.

Watson, R. T., Zinyowera, M. C. and Moss, R. H. (Eds.), 1998, "The regional impacts of Climate Change", An assessment of vulnerability. IPCC II Report, Cambridge University Press, p517.