Journal of AgriSearch **2**(1): 40-43
Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)

Studies on Maize Potential in Bihar under Climate Change Scenario: Impact and Adaptation

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ARTICLE INFO

Received on : 26.11.2014
Accepted on : 23.01.2015
Published online : 10.03.2015

ABSTRACT

Agriculture sector depends on climate and climatic resources leading to the special stress upon the need to study impacts of climate change on agricultural production at local, regional, national as well as on global scales. Decision Support Systems or Crop Models provide a way, where the relative effects of these variables on crop growth and yield can be studied. Elevated CO_2 and changes in temperature, besides affecting the crop affects the environment which in turn may have either beneficial or damaging effect on agricultural production. For this study three stations were selected, representing different zones (Pusa, zone I; Madhepura, zone II and Patna, zone III). Simulated yield of kharif maize decreased from baseline for all the future time periods and stations. Advanced sowing combined with irrigation and higher dose of nitrogen may be helpful to compensate the reduction in future time periods. Simulated yield of winter maize showed an increase from baseline and maximum increase (9, 16 and 30% respectively for 2020, 2050 and 2080) was observed in Pusa. Adaptation options, such as intensification of winter maize cultivation in locations of low wheat productivity and better agronomic management needs to be looked into for food security in this region.

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Keywords: Bihar, Climate Change, Impact, Maize, Simulation.

INTRODUCTION

High carbon dioxide and other green house gases in the atmosphere tend to warm up the atmosphere, besides affecting other meteorological variables. Agriculture sector depends on climate and climatic resources leading to the special consideration for this sector among researchers stressing the need to study impacts on agricultural production at local, regional, national as well as on global scales. Decision Support Systems (DSS) or Crop Models provide a way, where the relative effects of these variables on crop growth and yield can be studied in particular combinations on regional basis. Early simulation studies on impacts of climate change gave prime importance to the expected increase in carbon dioxide levels only, while off late researchers have suggested, from their studies, that agricultural production gets affected not only by CO_2 alone, but also by weather variables (Curry *et al*., 1990; and Curtis and Wang, 1998). Most crops grown under enriched carbon dioxide environment showed increased growth and yield (Allen *et al*., 1997 and Parry *et al*., 2004). Enhanced CO_2 effects the growth and physiology of crops, enhancing photosynthesis as well as water use efficiency (De Costa *et al*., 2003; Ewert, 2004; Triggs *et al*., 2004; Tubiello and Ewert, 2002 and Widodo *et al*., 2003). Elevated CO_2 besides affecting the crop affects the environment which in turn may have either beneficial or damaging effect on agricultural production. Changes in temperature play a crucial role in determining crop productivity (Fiscus *et al*., 1997). Small changes in growing season temperature over the years appear to be key aspect of weather affecting yearly wheat yield fluctuations (Mall and Singh, 2000). Increase in minimum temperature is reported in different agro ecological zones of Bihar (Haris *et al*., 2010; Chhabra and Haris, 2014) Yield of cereals has been reported to decrease for different future scenarios (Haris *et al*., 2013; Parry *et al*.,2004; Peng *et al*., 2004; Rao and Sinha, 1994 and Sinha and Swaminathan, 1991). Decline in potential yield of wheat is linked to increase in minimum temperature in the Indo-Gangetic plains of India (Aggarwal and Sinha, 1993 and Haris *et al*., 2013).

Bihar (middle Gangetic plains of India, with dry sub-humid climatic conditions) is a low productivity region in eastern India with high potential for better agricultural production with suitable agronomic interventions. Maize cultivation in Bihar is done throughout the year owing to its adaptability to a range of temperature. Kharif Maize occupies an area of 2.34 lakh ha and winter maize 2.37 lakh ha with production of 4.7 and 9.2 lakh tonnes respectively. Modeling study reported here provides useful information about the impact of climate change over locations representing different agro-

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ecological zones of Bihar, India. The study clearly indicates losses in the yield of kharif maize with subsequent rise in temperature. Enhanced CO_2 was also unable to counter balance the decline in yield. However, the percentage decline varies among stations selected. The increase in yield of winter maize indicated suitability of the region for its cultivation. Weather conditions under future scenarios being favourable to winter maize, may result in gradual replacement of wheat by winter maize crop in the regions non-suitable to wheat cultivation in Bihar. Adaptation options, such as intensification of maize cultivation in locations of low wheat productivity and adopting new agronomic interventions needs to be looked into for sustainability of food security in this region.

Timely assessment of climate change effects on maize might help to adopt suitable farming techniques to maximize agricultural production in this low productivity, high potential region. The study, deals with the impact assessment of climate change on the maize (winter and kharif) crops for Bihar, India. The study will provide insights for agricultural decision makers about possible changes in the cropping pattern and adaptation options for future.

MATERIALS AND METHODS

Study area

State of Bihar lies in vast areas falling in alluvial plains of India. The state is situated between 24^0 to 27^0 N, 83^0 to 88^0E with a height of 52.73 m above mean sea level, having a total geographical area of 9.36 million hectares with cultivable land of 0.58 lakh hectares and a normal rainfall of 1176.4 mm (Anonymous, 2005). It is divided into three agro-ecological zones namely zone I (North West alluvial plains), II (North East alluvial plains), and III (South Bihar alluvial plains). For this study three stations were selected, representing different zones (Pusa, zone I; Madhepura, zone II and Patna, zone III).

Experimental data

Daily data for air temperature and rainfall from three representative centres were collected for the period 1961-1990. Meteorological, crop and soil data were used for the simulation studies. Intergovernmental Panel on Climate Change (IPCC,2007) describes future scenarios for the period 2010-2039, 2040-2069 and 2070-2099 referred to as 2020's, 2050's and 2080's respectively. The GCM used in this study is the output of UK Hadley Centre for Climate Prediction and Research model ver. 3 (HadCM3) for the A2 scenario. The 30 year averaged monthly changes of IPCC was incorporated into individual years according to the equations 1 and 2. The outputs of minimum, maximum temperature and rainfall were used to generate future scenarios.

Expected changes in Temperature = Baseline temperature + Expected change in temperature obtained from HadCM3 outputs [Eq.1]

Expected changes in Precipitation= Baseline daily rainfall x (1+ % change in rainfall) [Eq.2]

Crop Model Used

The generic crop model InfoCrop v. beta developed at IARI, Pusa (Aggarwal *et al.*, 2004), was used. Infocrop is a decision support system (DSS), designed to simulate the effects of weather, soil, agronomic management (including planting, nitrogen, residues and irrigation) and major pests on crop growth and yield. The model is designed to use a minimum set of soil (soil type, pH, organic matter, bulk density etc.), weather, genetic and management information (sowing date, sowing depth, transplanting date, irrigation, fertilizer, etc.). It integrates on a daily basis and therefore requires daily weather data (maximum temperature, minimum temperature, rainfall, solar radiation, vapour pressure and wind speed). The model calculates the crop development phases and morphological development as a function of temperature, day length and genetic characteristics

Calibration, validation, and simulation for selected locations

The model had been calibrated and validated by comparing the simulated yield with the observed yield for variety Ganga11. The model was run for the baseline and future scenarios based on the practices used for validation purposes. Figure 1 depicts the overall methodology in the form of flow diagram.

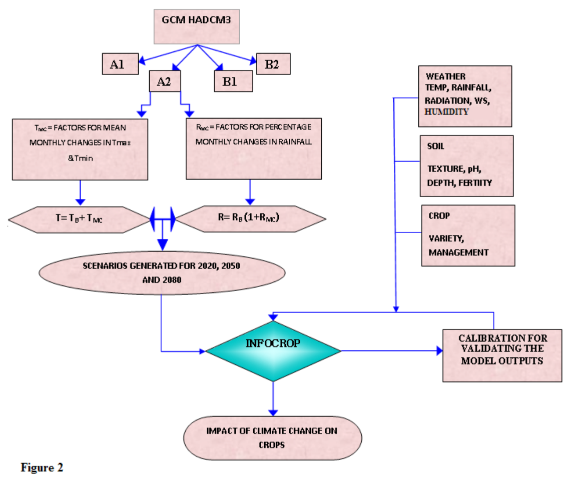

Fig. 1: Flow diagram depicting methodology

RESULTS AND DISCUSSION

Impacts of climate change on kharif and winter maize

Impact of climate change on kharif and winter maize were simulated using factors for HADCM3 A2 scenario and concomitant CO_2 increase.

Kharif Maize

Simulated yield of kharif maize decreased from baseline for all the future time periods and stations. For Pusa, a yield decline of almost 4, 9 and 11% is predicted for 2020, 2050 and 2080 periods respectively. At Madhepura, predicted decline in yield from the baseline is by 3% during 2020; 7 and 9% for 2050 and 2080 respectively. Patna showed least decline ranges from 1 % in 2020 to 6% for 2050 and 2080s (Fig. 2).

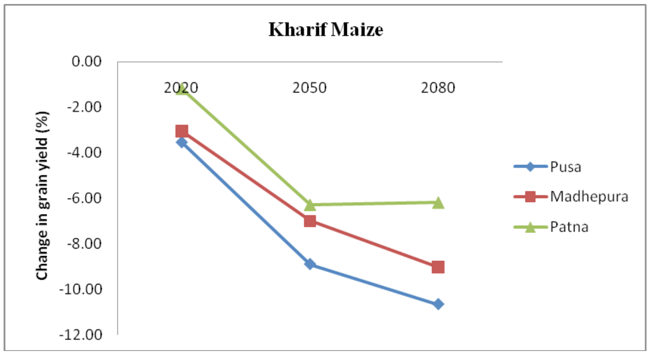

Fig. 2: Predicted changes in grain yield of kharif maize in future time periods

Winter Maize

Simulated yield of winter maize showed an increase from the baseline yield. The predicted increase is 9, 16 and 30% during 2020, 2050 and 2080 respectively at Pusa. At Madhepura, maize yield is predicted to increase from 10 to 24%, whereas at Patna yield increase is predicted to be 8 to 28% from 2020 to 2080 time periods. Maximum increase in yield is observed at Pusa for all the three time periods (Fig 3).

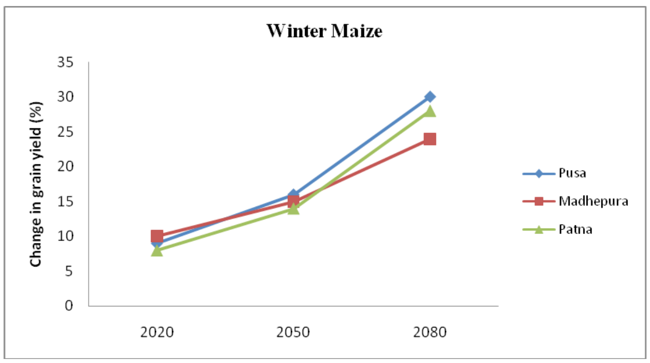

Fig. 3: Predicted changes in grain yield of winter maize in future time periods

Adaptation Measures

Kharif maize is predicted to decline in future time periods with the current management practices and inputs. Therefore to averse the effect of increasing temperature and CO_2, practices like advanced sowing, one irrigation in otherwise rainfed crop and increased fertilizer dose may somehow overcome the declining yield. It is evident from the table 1, that with 7 days advanced sowing reduction of yield is predicted to decline at Pusa during 2020 and 2050, during 2020, 2050 and 2080 for Madhepura and only during 2080 at Patna from the baseline yield. However, Pusa and Madhepura may be benefitted if advanced sowing is combined with one irrigation during all of the future time periods. At Patna, only in 2080 crop may show the reduction in its decline with different combinations of adaptation strategies.

Table 1: Changes in yield (%) from baseline yield through adaptation strategies

Time periods	Impact	7days advanced sowing	7days advanced sowing + one irrigation	7days advanced sowing + one irrigation +150 kg N
Pusa				
2020	-3.54	-4.47	0.75	2.05
2050	-8.90	-4.90	-4.13	-2.49
2080	-10.66	-12.50	-5.58	-4.35
Madhepura				
2020	-3.04	-1.25	0.21	0.21
2050	-7.00	0.02	0.98	-0.94
2080	-9.04	-2.83	-2.83	-0.20
Patna				
2020	-1.20	-4.99	-4.62	-4.21
2050	-6.28	-10.32	-9.54	-9.74
2080	-6.18	-5.94	-2.15	-2.55

CONCLUSION

Though results showed spatial and temporal variations in maize performance, the increase in winter maize yield and decline in kharif maize yield are the general features observed for future scenarios in this study.

ACKNOWLEDGEMENT

The authors wish to express gratitude to ICAR for facilitating this research work at ICAR-Research Complex for Eastern Region, Patna, Bihar.

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Correct Citation

Haris AA and Chhabra V. 2015. Studies on Maize Potential in Bihar under Climate Change Scenario: Impact and Adaptation. *Journal of AgriSearch* **2**(1): 40-43