Adaptation strategies to combat rice-wheat systems to climate change in Semi-arid subtropical climate of South Asia

AgMIP The Agricultural Model Intercomparison and Improvement Project

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Transitioning Cereal Systems to Adapt to Climate Change

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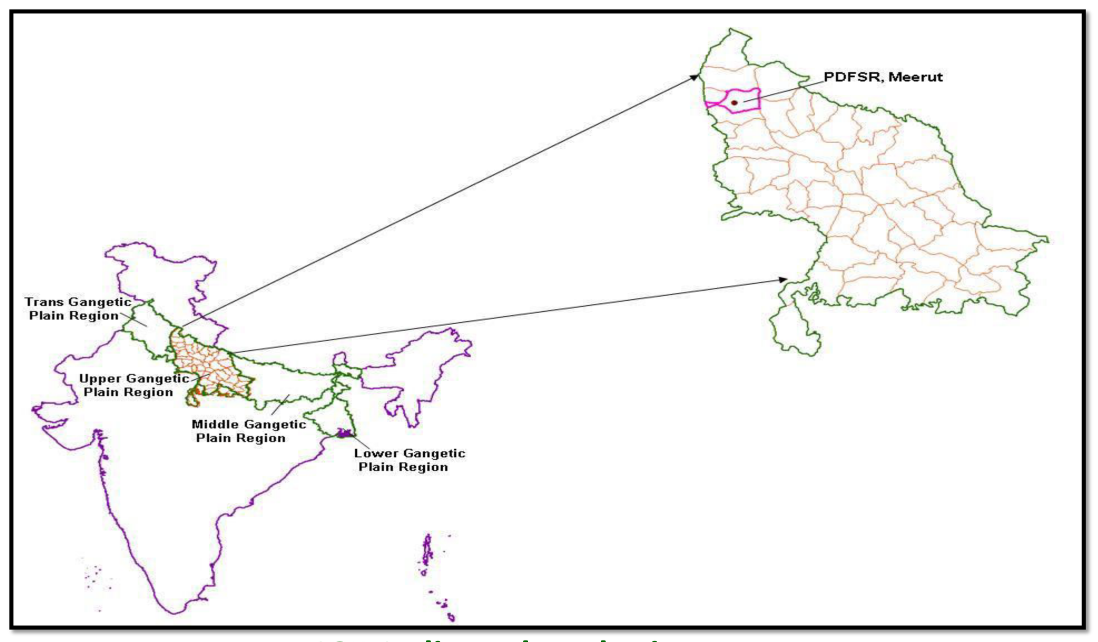
1. Introduction

- The rice (*Oryza sativa* L.) -wheat (*Trititicumaestivum* L.) cropping system is one of the largest agricultural production systems of the South Asia (SA), covering 13.5 million hectares of productive land in the Indo-Gangetic Plains (IGP) of Bangladesh, India, Nepal and Pakistan under diverse agro-climatic situations.
- It is projected that under RCP4.5, the temperature increase will be 1.1°C and 3.0°C during *Rabi* (December to February) in 2035 and 2100, respectively, and the corresponding precipitation will also increase on the order of 4% and 14%. During *Kharif* (June to August), the increase of temperature will be 0.9°C and 2.4°C in 2035 and 2100, respectively, and the corresponding precipitation will also increase on the order of 6% and 13% - IPCC(2013) AR5
- The demonstration of adaptation strategies through modeling provides meaningful support for constructive and concrete national and regional plans

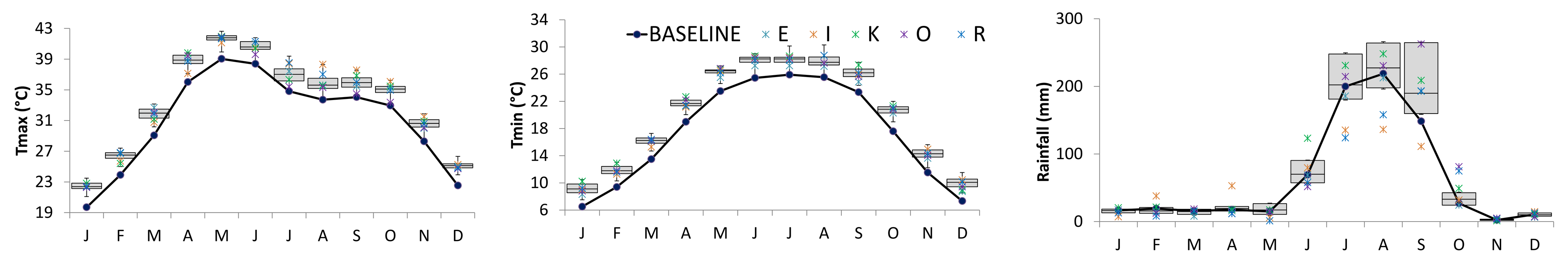
2. Characteristics of study area and data used

- **Study area :** Meerut district of Uttar Pradesh state of India in western IGP
- **Farming system:** Sugarcane-wheat, Rice –Wheat and other minor crops (maize, sorghum) and livestock.
- **Farm survey data:** 76 farms
- **Data used**
  - Rice: PR106 & Wheat: PBW343
  - Irrigation depth – 5 cm
  - Plant density, Plant spacing – as per recommendations
  - Soil parameters for 7 farms analyzed and incorporated to the nearby farms



IGP-India and study site

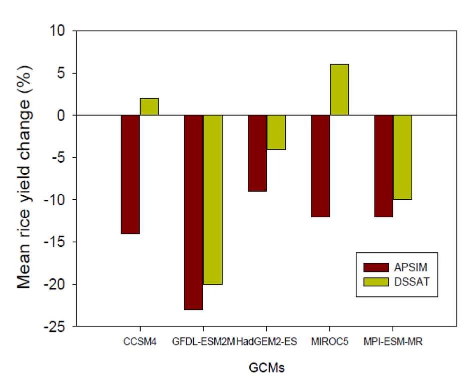
3. Climate Change Projections

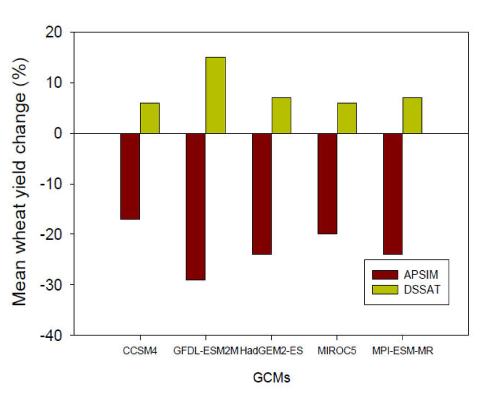


Climate Change Summary : Climate changes for 2050s compared to historical period for five targeted GCMs (RCP8.5)

Growing Season	CCSM4	GFDL-ESM2M	HadGEM2-ES	MIROC5	UKMO HadGEM2-ES
	E	I	K	O	R
Temperature change for Rice (°C)	2.4	2.9	2.2	1.7	2.7
Precipitation change for Rice (%)	3.1	-25.6	29.6	26.6	-8.4
Temperature change for Wheat (°C)	1.9	2.8	2.9	2.4	2.9
Precipitation change for Wheat (%)	-23.0	26.2	6.1	-13.9	-18.4

4. Impact of climate change on rice-wheat yield





Two crop simulation models DSSAT & APSIM were calibrated and validated for the predominant variety of the region using the experimental field data.
This study is based on the farm survey (2012) data relating to 76 rice–wheat growing farm households in Meerut district of northwest India in the IGB.
Crop management, soil characteristics and yields of rice-wheat farms, spread over the district were collected to capture the variability in management decisions followed.
The rice and wheat yields during baseline (1980-2010), survey year (2012) as well as under future scenarios (CCSM4, GFDL-ESM2M, HadGEM2-ES, MIROC5 & MPI-ESM-MR) were simulated and obtained the mean yield changes in rice and wheat.

- ✓The current agricultural production system under a climate change scenario would experience a decline in mean rice yield from 8% to 23% with APSIM. However, DSSAT simulations show both decline (4% to 19% under climate scenarios GFDL-ESM2M, HadGEM2-ES and MPI-ESM-MR) as well as increase in mean yield (2% to 5% for climate scenarios CCSM4 and MIROC5).
- ✓In the case of wheat, the mean yield changes show a similar trend. APSIM estimates show decline in mean yield of wheat (17% to 29%), while DSSAT shows an increase in mean yield (6% to 15%). Thus rice yield declines upto 23 % and wheat yield declines upto 19 % in 2050s on rice-wheat farms of middle gangetic plains of India under RCP8.5.

Adaptation packages:

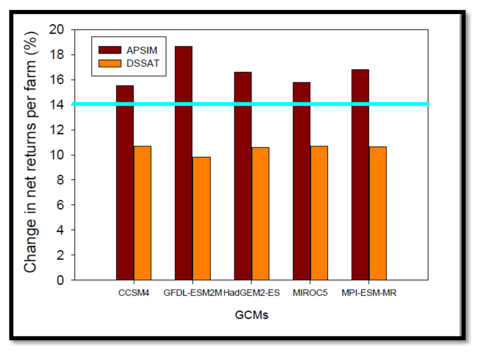
- Advancement of date of sowing—10 days from the present.
- Use of short-duration rice and wheat varieties.
- Balanced fertilizer application in both rice and wheat.
- Modification of first date of irrigation in wheat.

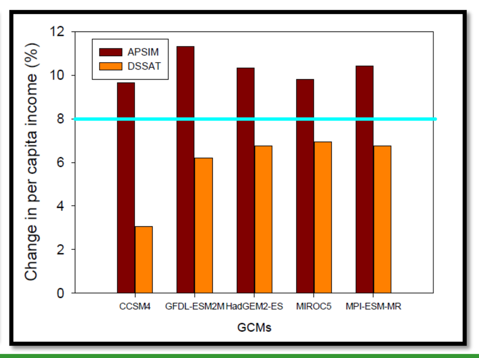
5. Benefits of adaptation strategy

- Linking of Climate-Crop-Economic model through AgMIP protocol provided the integrated assessment results.
- Based on the RAPs (Representative Agricultural Pathways) and secondary information, TOA-MD model was used for integrated assessment.

RAPs parameters used in analysis

RAPS Parameters	Direction of Change	Magnitude (%)
Variable cost of production	Increase	20
Farm size	Decrease	10
Herd size	Decrease	10
Milk yield	Decrease	10
Non-farm income	Increase	50





- The adaptation strategy demonstrated was to advance the date of sowing of wheat crop by ten days.
- This strategy was tested because terminal heat (during maturing stage) has severe adverse impact on the wheat yield.
- The model simulations for adaptation strategy show an increase in wheat yield ranging from 9 to 13% for APSIM but only 1 to 3% for DSSAT.
- The adaptation strategy is likely to result in an increase of 15.5–18.6% in mean net farm returns for APSIM but the magnitude of increase would be lower (10–11%) for DSSAT.
- The *per capita* income would increase by 10–11% and 6–7% for APSIM and DSSAT, respectively.

6. Conclusion and way forward

- All the 5 GCMs projected increase in Max. and Min. temperature with greater uncertainty in rainfall.
- Rice yield declines up to 23 % and wheat yield declines up to 19 % in 2050s on rice-wheat farms of middle Gangetic plains of India
- The single adaptation strategy of advancing of 10-days of sowing in wheat under projected climate scenario in 2050s is likely to result in an average increase of 14 % in mean net farm returns and subsequently the *per capita* income would increase by 8 %.
- More adaptation packages and a set of elaborate RAPS visualizing more realistic features of the future agricultural production systems need to be tested to formulate an effective strategy under climate change and for ensuring economic viability and livelihood security of smallholders in the region.

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