Integrated Economic Assessment of Climate Change Impacts in Indo-Gangetic Basin

Harbir Singh[1], Nataraja Subash[1], Gokul Paudel[2], B. Gangwar[1]
Guillermo Baigorria[3], Roberto Valdivia[4]

AgMIP The Agricultural Model Intercomparison and Improvement Project

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1. Introduction

The Indo-Gangetic Basin (IGB) is characterised by cereal-based farming systems with livestock being an integral part of the farm economy. The system productivity (rice-wheat) is either stagnating or declining. Sustaining rice-wheat productivity has become a major challenge in recent years due to various socio-economic and institutional constraints. Moreover, climate change impacts are very much visible in this region with greater variability of monsoon and an increase in the occurrence of extreme weather events (heat waves; intense precipitation) with adverse impacts on the farmers' livelihoods (Thornton et al., 2009; Thornton & Herrero, 2014). There is huge gap in understanding the complex interactions of crop-livestock enterprises under climate change and its impact on the farm economy. This study uses an integrated climate-crop-economic modelling framework (using AgMIP protocols) for an integrated economic assessment of climate change and adaptation strategy in at two locations in Upper-Gangetic plains (UGP) and Trans-Gangetic plains (TGP) region of IGB. The study sites are shown in figure 1.

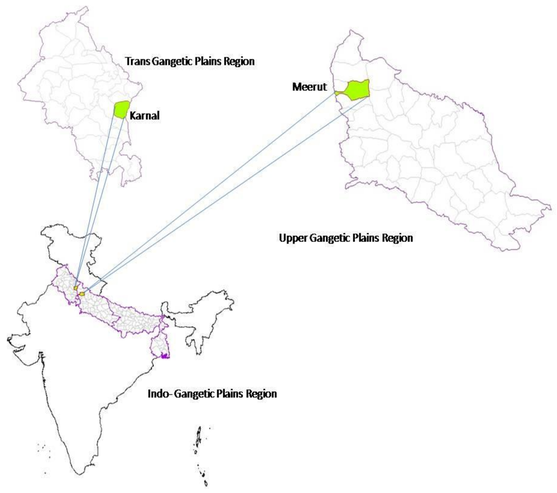

Fig. 1: Map of Indo-Gangetic Basin (India)

2. Material and Methods

Study area: Two agro-climatic zones (UGP & TGP) and one district from each zone, UGP (Meerut) and TGP (Karnal).
Farming system: Cereal-based (see, figure 2). The average farm size and family size is 0.45 ha & 3.9 ha and 6.3, and 7.6, respectively in Meerut & Karnal.
Data: Survey data of 76 farms (Meerut) and randomly selected 100 farms from CSISA project (Karnal) were used for climate and crop modeling (APSIM & DSSAT). The present rice and wheat yields on sample farms is 2365 & 3743 kg/ha (Meerut) and 4427 & 4393 kg/ha (Karnal), respectively.
Representative agricultural pathways (RAPS): The RAPS scenario used for TOA-MD analysis is as follows:

Ground water depletion	↘	Mechanization	↗
Farm size	↘	Inputs price	↗
Labor availability	↘	Inputs subsidy	↘
Family size	→	MSP	↗
Livestock holding	→	Technology	↗
Off farm income	↗		

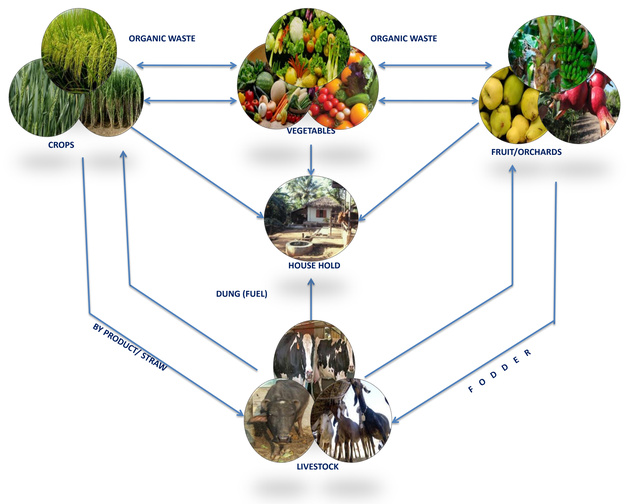

Figure 2: A typical farming system in the study area

3. Sensitivity of Current Agricultural Production Systems to Climate Change

- For UGP (Meerut), mean yield of rice declines by 8–23 percent with APSIM. However, DSSAT simulations shows both decline (4–19% under climate scenario C2, C3 & C5) as well as increase in mean yield (2–5% for climate scenario C1 &4)
- In case of wheat, mean yield changes shows similar trend. While APSIM estimates shows decline in mean yield of wheat (17-29%), DSSAT shows increase in mean yield (6-15 percent).
- The percentage gains in mean net farm return, accordingly, are higher under DSSAT (14-15%) as compared to APSIM (11-12%) in all five climate scenario (CCSM4, GFDL-ESM2M, HadGEM2-ES, MIROC5 and MPI-ESM-MR), denoted by C1, C2, C3, C4, and C5, for the current production system (Fig. 3 & 4).
- Overall, mean net farm returns (MNFR) would decline by 12–16% percent (APSIM) and 4–8 percent (DSSAT) for the two crop models under five climate scenarios.
- The per capita income (PCI) would decline by approximately 7.5 – 10 percent (APSIM) and 2.4 –5 percent (DSSAT), respectively.

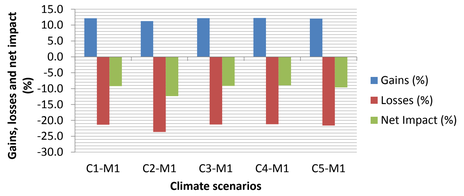

Fig. 3: Current production system and climate change (APSIM)

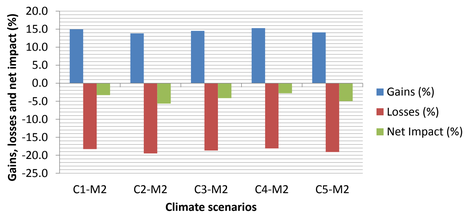

Fig. 4: Current production system and climate change (DSSAT)

4. Impacts of Climate Change on Future Agricultural Production Systems

- Rice yield is projected to decline by 9–23 percent with APSIM but DSSAT estimates provide a mix picture showing 4–20 percent decline in yield (climate scenario (GFDL-ESM2M, HadGEM2-ES & MPI-ESM-MR) and 2–6 percent increase in rice yield under two climate scenario (CCSM4 & MIROC5) in UGP (Meerut).
- Mean yield of wheat is projected to decline by 17–29 percent with APSIM but DSSAT shows an increase of 6–15 percent.
- The losses in mean net farm return (23.4 -25.4 %) would be more than gains (18.5 -21.3 %) under APSIM, but DSSAT shows that gains in mean net farm return (23.8 -28.6%) are little higher than losses (21-22 %). Corresponding figures for TGP (Karnal) shows net gains under all the five climate scenarios.
- Mean net farm return is likely to decline by about 3–9 percent (APSIM) whereas, DSSAT shows a little increase in mean net farm returns (2–8%). PCI would decline by 2–6 percent (APSIM) but shows little increase (1–5 %) under DSSAT (Fig. 5&6).
- Though there is only small difference in poverty reduction (1-3 %) without and with climate change, still a large proportion of the population (39–64%) is vulnerable to climate change.

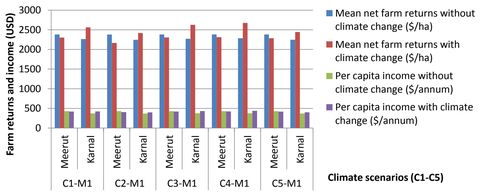

Fig. 5: Climate change impact on future agricultural production systems (APSIM)

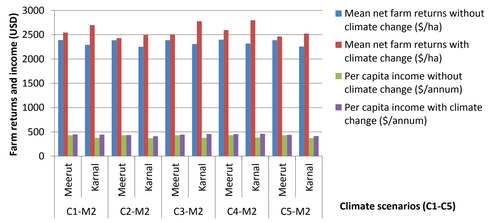

Fig. 6: Climate change impact on future agricultural production systems (DSSAT)

5. Benefits of Climate Change Adaptations

- RAPS development process outlined the following adaptation package to deal with climate change –advancement of date of sowing of wheat (10 days), use of short-duration rice and wheat varieties, balanced fertilizer application in both rice and wheat and modification of first date of irrigation in wheat.
- The adaptation strategy would result in an increase of 15.5–18.6 percent in mean net farm returns (APSIM) but the magnitude of increase would be lower (10–11%) for DSSAT.
- Increase in per capita income would vary from 6–11% (for APSIM & DSSAT) at Meerut (UGP), and 30-50% at Karnal (TGP).
- The poverty rate would decline by 3–6 percent for the population as a whole.
- The adoption rates for the adaptation strategy at Meerut ranges from 59–64 percent (APSIM) but less than 50 percent (46–49%) for DSSAT. Adoption rates are higher (61-81%) for Karnal site.
- Overall, the adaptation strategy results in an increase in mean net farm returns for the population as a whole. However, 36–41 percent population still remains vulnerable to climate change.
- The model estimates for Karnal site are substantially higher in comparison to Meerut site (Fig.7 & 8).

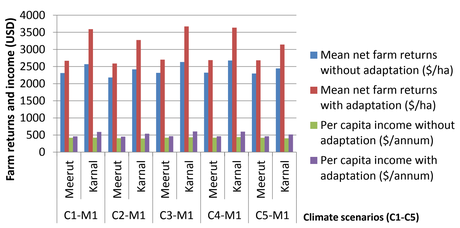

Fig. 7: Benefits of adaptation under climate change (APSIM)

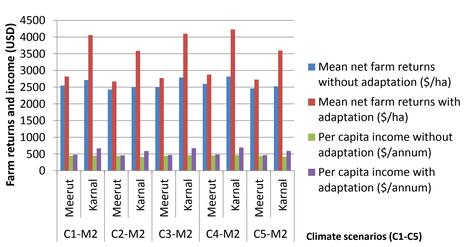

Fig. 8: Benefits of adaptation under climate change (DSSAT)

6. Conclusions and Recommendations

- The current agricultural production system is sensitive to climate changes and would experience a decline in yields, mean net farm returns, per capita income resulting in an increase in population poverty rate at both the study sites in UGP (Meerut) and TGP (Karnal). Though population poverty rate increases only marginally (1 –3%) under current climate scenario, it has wider implications because of a large proportion of adversely affected farms (53–79% losers at Meerut, and 49–65% at Karnal site).
- Under future climate scenario, the losses in mean net farm return (23.4 –25.4 %) would be more than gains (18.5–21.3 %) under APSIM, but DSSAT shows little gains in mean net farm return (3–6%) at Meerut.
- Mean net farm return is likely to decline by about 3–9 percent (APSIM) whereas, DSSAT shows a little increase in mean net farm returns (2–8%). PCI declines by 2–6% (APSIM) but shows little increase (1–5 %) under DSSAT. However, the Karnal site shows positive impacts of climate change on mean net farm returns and per capita income across all the five scenarios.
- The adaptation strategy at Meerut results in an increase of 15.5–18.6 percent (APSIM) & 10–11% (DSSAT) in mean net farm returns. Accordingly, the per capita income would increase by 10–11% and 6–7% for APSIM and DSSAT, respectively. Farm returns at Karnal site would increase by 30–50 percent.
- At Meerut, the adaptation strategy was tested for one crop (wheat) only and the adoption rates varies from 42–62%, whereas, at Karnal site 61–81% farm population adopts the adaptation strategy.
- Therefore, there is need for integrating different adaptation packages and a set of more comprehensive RAPS to get more realistic Integrated Economic Assessment of climate change impact for the region.

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2 CIMMYT

3 University of Nebraska Lincoln

4 OSU Oregon State University

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Corresponding Author: Dr. Harbir Singh, ICAR-Project Directorate for Farming Systems Research, Modipuram, Meerut-250 110, Uttar Pradesh, India (hs.pdfsr@yahoo.com)