J. Appl. Environ. Biol. Sci., 4(7S)358-363, 2014

© 2014, TextRoad Publication

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Ex Ante Impact Assessment of Wheat Crop in Punjab-Pakistan

Irfan Ahmad Baig[1], Muhammad Ashfaq[2], Syed Asif Ali Naqvi[2], Ashfaq Ahmed[3], Gerrit Hoogenboom[4], John M Antle[5], Roberto Valdivia[5]

[1]Dept. of Economics and Agri. Economics, PMAS Arid Agriculture University, Rawalpindi
[2]Institute of Agri. and Resource Economics, University of Agriculture Faisalabad, Pakistan
[3]Department of Agronomy, University of Agriculture Faisalabad, Pakistan
[4]Biological System Engineering, Washington State University, USA
[5]College of Agricultural Sciences, Oregon State University, USA

Received: September 1, 2014
Accepted: November 13, 2014

ABSTRACT

The debate on climate change is now one step forward from its occurrence and adverse impacts to the plausible adaptation now and in the future. Existing data for wheat crop from rice-wheat cropping zone of Punjab were used to analyze the impacts of climate change on crop productivity and climate induced adaptation practices thereafter. In this paper Tradeoff Analysis model for Multi-Dimensional Impact Assessment (TOA-MD) was used for economic impact assessment. In case of economic impact assessment for climate change impact only (without any adaptation), results showed about 30 percent gainers, while after implication of adaptation package the percentage of adopters under two pessimistic scenarios would increase up to 66.5 and 74.5 percent while for the case of optimistic (low adaptation challenges) scenario, adaptation rate would be about 83 percent. From the investigated results it was clear that a substantial number of farmers in the study area would be economically more prosperous from adopting high yielding and more resistant wheat crop variety from RAP1 (optimistic) rather than RAP2 (pessimistic). For the optimistic low adaptation challenges scenario, the base poverty rates and other economic indicators were lower than the high adaptation challenges scenario.

KEYWORDS: Climate change, adaptation strategies, assessment, TOA-MD, RAPs, Punjab-Pakistan.

1. INTRODUCTION

Agricultural systems usually characterized with interaction of complicated bio-physical and human sub-systems having significant diversity within and across the geographic regions [1]. Agricultural scenarios are changing due to climate change since agricultural enterprises are highly dependent on weather and climatic changes that could have major effects on crop yield, food supply and socio-economic indicators of the region. Climate changes are worsening the vulnerabilities of the poor rural masses whose majority are dependent on semi-subsistence agriculture [2]. Agriculture is greatly dependent on weather thus changes in global and regional climatic patterns could have major effects on crop yield and thereafter food supply. The Intergovernmental Panel on Climate Change has already reported that average global temperatures have increased by about 0.6 °C since the industrial revolution [3], these findings were verified by [4] showing that 20th century was the warmest century while 1990s was the warmest decade of millennium.

In Pakistan temperature is rising on average 0.5 °C per decade. Due to the increasing temperature crop productivity is expected to decrease and suitable adaptation practices are required because more food is required for the future population. Accurate and timely assessments are needed to provide decision makers with the information and decision tools to reduce the hazards from exposure to erratic and unfavorable climate through effective adaptation. For the purpose, research based policies based on ex ante impact assessments are being focused now a days [5]. Present study is also first effort of its kind to analyze the socio-economic impacts of climate changes and adaptation strategies.

Wheat is the main crop in Pakistan which not only main supports for the local consumption but also provide livelihoods to rural masses. It is grown on approximately 8.69 million hectares with a total

*** Corresponding Author:** Irfan Ahmad Baig, Dept. of Economics and Agri. Economics, PMAS Arid Agriculture University, Rawalpindi. irfan.baig@uaar.edu.pk

production of 24.2 million tons [6]. It is cultivated in different agro-ecological zones of Pakistan, with each zone representing diverse edaphic, social, hydrological and climatic conditions. Assessments are needed to provide decision makers with information for developing appropriate plans to reduce the climatic change hazards. The traditional approaches have not been proved successful to provide an effective framework entirely. That's why this study uses new techniques for impact assessment and provides few insights into climate change trends in the region and its impacts on crop productivity and other socio-economic indicators.

In the paper, the impact of climate change on the socio-economic indicators like poverty, per capita income and net farm returns were quantified. Further the impacts of adaptation strategies based on the different representative agricultural pathways were tested to tackle the vulnerability of poor households and to enhance the resilience of prevailing production systems and best one was selected from them. In the first part introduction is given, at second the material and methods used are given, in the third part results and discussion of study described and at the lase section the conclusions are drawn from the results.

2. MATERIALS AND METHODS

In the study, crop yield simulations were generated using crop growth models i.e., Decision Support System for Agro-technology Transfer (DSSAT) [7]. Climate change impact was assessed by using seasonal analysis. DSSAT Models were run with base line data (1980-2010) and future climatic data (2040-2069) which were generated using global circulation models (GCMs) with 5 climate models Intercomparison projects (CMIPs) i.e. CCSM4, GFDL-ESM2M, HadGEM2-ES, MIROC5 and MPI-ESM-MR [8] and [9]. For assessment of socio-economic variability based on above discussed GCMs for this study, Tradeoff Analysis Model for Multidimensional Impact Assessment (TOA-MD) was used [10]. TOA-MD methodology allows an integrated analysis of tradeoffs between economic and climatic indicators and it involves a multi-disciplinary approach. Further, it requires the usage of bio-physical and econometric simulations [11]. To analyze the effects of climate change TOA model uses comparison of a base (S1) and an alternative system (S2). Data for the alternative system was acquired through calibration of different biophysical simulation scenarios which quantify the changes in crop yields over time [12]. Farms are supposed to select a system to maximize a function v(h) where h =1, 2 indexes the production system and all attributes associated with it. Here, v(h) is interpreted as expected net farm returns which based on an objective function that depends on the characteristics of the farms and the system being studied. This objective function induces an ordering ω over all farms. Where ω is defined as,

$$\omega = v(1) - v(2) \quad (1)$$

This is basically the opportunity cost such that for the adoption threshold a,

$\omega > a$ is for those farms using system 1 and

$\omega < a$ is for those using system 2

The opportunity cost ω is spatially distributed across the landscape according to the density $\phi(\omega)$, this is generally a function of prices and other exogenous variables, it is from the major contributors to adoption. This adoption could be incomplete due to constraints on adoption like risk aversion and lack of information etc [13]. The cumulative distribution function which is basically the proportion of farms using system 2 which can be called adoption rate of system 2, and described by [12] as,

$$r(2,a) \equiv \int_{-\infty}^{a} \phi(\omega)\mathrm{d}\omega, \quad 0 \le r(2,a) \le 1, \quad (2)$$

So the outputs from DSSAT crop model were used as the inputs for TOA-MD model. In order to quantify the impact of these changes on the socio-economic indicators of future system (i.e. System 2) was parameterized by using the regional Representative Agricultural Pathways (RAPs). In order to make them consistent with the global RAPs, global economic models outputs were used for analysis. The output of

these global economic models was available through the Agricultural Model Inter-Comparison (AgMIP)[1] project in the study area. While the different regional representative agricultural pathways (RAPs) i.e. optimistic and pessimistic [14] were developed for wheat crop in the rice-wheat cropping zone of Punjab and analyses were carried out to select the most suitable package for the study area. These RAPs were developed with the help of team of transdisciplinary scientist by following the nested approach as used by IPCC for SSP [14].

In the study farm survey of more than 155 farms from the five districts i.e. Shekhupura, Nankana Sahab, Hafizabad, Gujranwala and Sialkot of rice wheat cropping zone of Punjab was used. In the all three types of assessments poverty line was USD 1.25 per person per day whereas one USD was equal to PKR 94.68 and time period (i.e. wheat season) was equal to six months.

3.RESULTS AND DISCUSSIONS

First of all the sensitivity of current agricultural production systems to climate change was estimated by simple without adaptation analysis. In this scenario system 1 contain the base climate and base production system and system 2 was composed of change climate and base production system. Then impacts of climate change on future agricultural production system of selected zone were quantified. For this purpose system 1 was base climate and base technology and alternate system was composed of change climate and base technology. In this analysis global trends were implemented but no adaptation. And finally in the third analysis the benefits of climate change adaptations from proposed adaptation package on selected zone were computed. In this scenario system 1 was the alternate system of second type of analysis and alternate system of this analysis was composed of change climate and adapted production system with global trends.

3.1. Sensitivity of Current Agricultural Production Systems to Climate Change.

For each GCM, gains, losses and net impacts as percent of mean net returns are given in Table 1. It is clear from the analysis that observed mean yield of wheat was 18915 Kg per farm for all analysis. Mean yield reduction of wheat was from 6.2 to 19.0 percent. In case of livestock, observed mean production of milk was 1633 litres per farm for all GCMs with a mean yield reduction of about 12 percent for sensitivity to climate change analysis. Depending upon the distribution of costs and benefits across the area, TOA-MD analysis showed about 62–73 percent losers due to perturbed climate. Gains and losses as a percent of mean net farm returns were from 16.6 to 18.6 percent and -24 to -31 percent respectively. Observed net returns without climate change were Rs. 2.48 lacs. While with adverse climate change observed net returns would be from Rs. 2.04 to Rs. 2.28 lac per farm per season. Observed per-capita income without climate change would be Rs. 0.33 lac per person per season for all GCMs. While with climate change per-capita income would range between Rs. 0.28 to 0.30 lac per person per season. Without climate change poverty would be 33.2 percent for all GCMs and these ranges are consistent with the finding of [15] and [16] for the rice wheat cropping zone of Punjab. While in case of climate change it would increase and would show a range from 36 to 42 percent.

Table 1. Climate sensitivity of current agricultural production systems for the wheat crop (by using yield simulations by DSSAT) in Rice Wheat Cropping System of Punjab

Aggregated Results (for all 155 farms)	GCMs Range	
	FROM	TO
Observed mean yield wheat (Kg/Farm)	18915.2	--
Mean yield change wheat (%)	-19.0	-6.2
Observed mean yield rice (Kg/Farm)	1633.4	1633.4
Mean production change milk (%)	-12.0	-12.0
Losers (%)	61.9	73.3
Gains (% mean net returns)	16.6	18.6
Losses (% mean net returns)	-30.9	-24.3
Observed net returns without climate change (PKR/Farm/Season)	247748.0	247748.0

[1]For detail of AgMIP project and data outputs, please visit www.agmip.pk and www.agmip.org

Observed net returns with climate change (PKR/Farm/Season)	204032.6	228075.3
Observed per-capita income without climate change (PKR/Person/Season)	33037.1	33037.1
Observed per-capita income with climate change (PKR/Person/Season)	27368.6	30628.3
Observed poverty rate without climate change (%)	33.2	33.2
Observed poverty rate with climate change (%)	36.1	41.7

3.2. Impacts of Climate Change on Future Agricultural Production Systems Change

Here the gain, losses and net impacts as percent of mean net are given in Table 2. It is clear from the table that projected mean yield of wheat crop would be 26473 Kg per farm for all analyses. Projected mean yield reduction of wheat crop in future due to climate change would be from 6 to 19 percent. In case of livestock, projected mean milk production was 1878 litres per farm for all analysis and its mean yield reduction was 12 percent for all case of this analysis. Percentage losers would be lying between 49 to 67 percent. Gain and losses as a percent of mean net farm returns for would be 13 to 16 percent and -16 to -23 percent respectively. Projected net returns without climate change would be up to Rs. 5.55 lac per farm for a season for all five GCMs. Projected net returns with climate change were between Rs. 4.96 to Rs. 5.58 lac per farm. Projected per-capita income without climate change would be Rs. 0.51 lac per person per season for all GCMs. For with climate change per capita income case it would be from Rs. 0.45 to Rs. 0.51 lac per person for a season. Without climate change poverty rate would be 18.7 percent for all climate models. While in case of poverty rate would be range between 18 to 22 percent.

Table 2. Impact of climate in future without adaptation for wheat crop (by using yield simulations by DSSAT) in the Rice Wheat Cropping System of Punjab-Pakistan

Aggregated Results (for all 155 farms)	**GCMs Range**	
	FROM	TO
Projected mean yield Wheat (Kg/Farm)	26473.3	26473.3
Mean yield change Wheat (%)	-19.0	-6.2
Projected mean milk production (Litre/Farm/Annum)	1878.4	1878.4
Mean milk production change (%)	-12.0	-12.0
Losers (%)	48.7	67.3
Gains (% mean net returns)	13.4	16.2
Losses (% mean net returns)	-22.5	-15.7
Projected net returns without climate change (PKR/Farm/Season)	554526.8	554526.8
Projected net returns with climate change (PKR/Farm/Season)	496518.6	558288.3
Projected per-capita income without climate change(PKR/Person/Season)	50842.5	50842.5
Projected per-capita income with climate change(PKR/Person/Season)	45108.3	51098.3
Projected poverty rate without climate change (%)	18.7	18.7
Projected poverty rate with climate change (%)	18.3	22.0

3.3. Evaluation of Potential Adaptation Strategies Change

For each GCM percentages of adopters and other quantifications for adaptations are given in Table 3. The adaptation curves from both RAPs are depicted in the Figure 1 for each GCM. It is clear from the figure optimistic RAP is giving higher adoption rate than the pessimistic RAP.

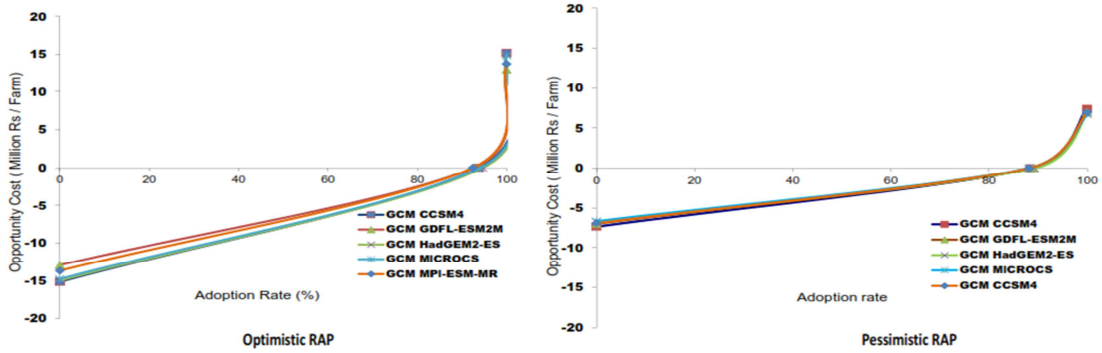

Figure 1. Adaptation curves for wheat growers for both RAPs in rice wheat cropping system of Punjab

Although the difference in case of adoption is less but in case of poverty and per capita income outcome from both RAPs were significantly different. Optimistic RAP gave the plausible and acceptable ranges for future, so it is better to optain the optimistic RAP and its adaptation package for future for other research and policy purposes. It is evident from Table that projected mean yield of wheat crop, without adaptations vary from 21584 to 24820 Kg per farm. Mean yield change for was from 60 to 73 percent. In case of livestock, projected mean milk production without adaptation was 1797 litres per farm for all analysis and its mean yield increase was 42 percent for all cases. Percentage adopters for RAP1 and RAP2 would be lying between 90–91 percent. For RAP1, projected net returns without and with adaptation would be up to Rs. 4.96–5.58 lac per farm and Rs. 8.88–9.62 lac per farm for a season, respectively. While for RAP2, projected net returns without and with adaptation would be up to Rs. 4.96–5.58 lac per farm and Rs. 8.56–9.31 lac per farm for a season, respectively. For RAP1 projected per-capita income for without and with adaptation cases would range between Rs. 0.45–0.51 lac per person and 0.8–0.87 lac per person in a season. For the case of RAP2 projected per-capita income for without and with adaptation cases would be from Rs. 0.38–0.43 lac per person and 0.65–0.71 lac per person for a season. Without adaptation poverty rate would be up to 18–22 percent for RAP1 and 22–26 percent for the case of RAP2, respectively. While for the case of with adaptation, poverty rate would vary from 14.7 to 15.6 percent for RAP1 and up to 17 to 19 percent for RAP2, respectively.

Table 3. Analyzing the benefits of climate change adaptations of wheat crop (by using yield simulations by DSSAT) for the Rice Wheat Cropping System of Punjab-Pakistan

Aggregated Results (for all 155 farms)	RAP1 Results		RAP2 Results	
	FROM	TO	FROM	TO
Projected mean yield without adaptation wheat (Kg/Farm)	21583.8	24819.5	21583.8	24819.5
Mean yield change wheat (%)	60.2	72.6	60.2	72.6
Projected mean milk production without adaptation(Litre/Farm/Annum)	1796.7	1796.7	1796.7	1796.7
Mean milk production change (%)	42.0	42.0	42.0	42.0
% adoption rate	89.7	90.8	88.0	89.3
Projected net returns without adaptation (PKR/Farm/Season)	496518	558288	496518	558288
Projected net returns with adaptation (PKR/Farm/Season)	888152	962925	856797	931545
Projected per-capita income without adaptation (PKR/Person/Season)	45108.3	51098	38273	43356
Projected per-capita income with adaptation (PKR/Person/Season)	80340	87075	65729	71440
Projected poverty rate without adaptation (%)	18.3	22.0	21.8	26.5
Projected poverty rate with adaptation (%)	14.7	15.6	17.4	18.6

4. Conclusion. It is evident from the results that climate change could have adverse impacts on the smallholder farmers in the study region. . In case of economic impact assessment it is clear from the results that 62 to 73 percent of wheat growers would be negatively impacted by the current climatic variabilities. With climate change the poverty rate would increase from 36 to 42 and net return returns would reduce upto 8 percent and per capita 17 percent then the base system. After the implementation of adaptation package upto 10 percent of households would remain vulnerable to climate change. Further results give the evidence that optimistic RAP gives the more plausible ranges of adaptation rates and other socio economic indicators than pessimistic RAP.

5. Future Research Avenues. Present study gives very good starting into the effectiveness of alternative adaptation strategies bringing in different climate change and adaptation scenarios developed through the involving trans-disciplinary approach. The future research opportunities involve the study of the farming system as a whole involving live-stock and minor crops. It could also involve multiple cropping areas especially the arid regions which largely depend on rain for sustaining the cropping patterns.

6. Acknowledgment.
This research was conducted within the framework of Agricultural Model Intercomparison and Improvement Project (AgMIP) Pakistan project funded by Global AgMIP Project (A collaborated effort of a consortium of US Universities, NASA and other international organizations funded by UKaid and USDA).

REFERENCES

1. Antle. JM and Stoorvogel. JJ, "Incorporating systems dynamics and spatial heterogeneity in integrated assessment of agricultural production systems", Environmental and Development Economics, 2006; 11: 39-58.

2. Nelson. GC, Rosegrant. MW, Koo, Robertson. J, Sulser. R, Zhu. Z, Ringler. T, Msangi. C, Palazzo. L, Batka. A, Magalhaes. M, Valmonte-Santos. M, Ewing. R and Lee. MD, "Climate change: impact on agriculture and costs of adaptation", Food Policy Report 21, International Food Policy Research Institute (IFPRI), Washington DC, USA, 2009.

3. IPCC, "Fourth Assessment Report, contribution of WG-II mitigation, adaptation, vulnerability and projections of climate change", 2007.

4. Borhan. P, Kennedy. JJ, Haris. I, Tett. SFB and Jones. PD, "Uncertainty estimates in regional and global observed temperature changes: a new data set from 1850", 2006; Journal of Geophysical Research,111D12106.doi: 10.1029/2005JD00654.

5. Thornton. PK, Kristjanson. PM and Thorne. PJ, "Measuring the potential impacts of improved food–feed crops: methods for ex ante assessment", Field Crops Research, 2003; 84, (1–2), 199–212.

6. Government of Pakistan, "Economic Survey of Pakistan 2012-13", Finance Division, Economic Advisor's Wing, Islamabad, Pakistan, 2013.

7. Jones. JW, Hoogenboom. G, Porter. CH, Boote. KJ, Batchelor. WD, Hunt. LA, Wilkens. PW, Singh. U, Gijsman. AJ and Ritchie. JT, "The DSSAT cropping system model", European Journal of Agronomy, 2003; 18: 235–265.

8. Moss. RH, Edmonds. JA, Hibbard. KA, Manning. MA, Rose. SK, van Vuuren. DP, Carter. TR, Emori. S, Kainuma. M, Kram. T, Meehl. GA, Mitchell. FJB, Nakicenovic. N, Riahi. K, Smith. SJ, Stouffer. RJ, Thomson. AM, Weyant. JP andWilbanks. T, "The next generation of scenarios for climate change research and assessment", Nature, 2010; 463: 747–756.

9. Taylor. KE, Stouffer. RJ and Meehl. GA, "A summary of the CMIP5 Experiment Design", Last accessed February 23rd, 2011 at: http://www.clivar.org/organization/wgcm/references/Taylor CMIP5.pdf, 2009.

10. Antle. JM and Valdivia. RO, "Tradeoff analysis for multi-dimensional Impact assessment Version 5.0: Users Guide", tradeoffs.oregonstate.edu, 2011; Accessed on 20 December 2013.

11. Stoorvogel. JJ, Antle. JM and Crissman. CC, "The tradeoff analysis model: integrated bio-physical and economic modelingof agricultural production systems", Agricultural Systems, 2004; 80: 43–66.

12. Antle, JM, "Parsimonious multi-dimensional impact assessment", American Journal of Agricultural Economics, 2011; 93(5): 1292-1311.

13. Suri. T, "Selection and Comparative Advantage in Technology Adoption", Econometrica, 2011; 79: 159–209.

14. O'Neill. BC, Carter. TR, Ebi. KL, Edmonds. J, Hallegatte. S, Kemp-Benedict. E, Kriegler. E, Mearns. L, Moss. R, Riahi. K, van Ruijven. B and van Vuuren. D, "Meeting Report of the Workshop on the Nature and Use of New Socioeconomic Pathways for Climate Change Research, Boulder, CO, November 2-4", 2011, 2011; Available at: http://www.isp.ucar.edu/socio-economic-pathways

15. IWMI. "Impact assessment of irrigation infrastructure development on poverty alleviation: a case study from Pakistan", Japan Bank for International Cooperation (JBICI). Paper no 31, 2007.

16. Jamal. H, "Predicting Sub-National Poverty Incidence for Pakistan. Social Policy and Development Centre (SPDC)", 2013; Available at: http://www.spdc.org.pk/pubs/rr/rr85.pdf. Last accessed at March 23, 2014.