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CURRENT AGRICULTURAL PRODUCTION SYSTEM OF PUNJAB IS VULNERABLE TO CLIMATE CHANGE: IMPACT ASSESSMENT

Syed Asif Ali Naqvi, Muhammad Ashfaq, Sultan Ali Adil and Ashfaq Ahmed***

ABSTRACT

Climate change impacts assessment of current agricultural production system of Punjab was studied at (Five Districts were taken i.e. Shekhupura, Nankana Sahab, Hafizabad, Gujranwala and Sialkot, Punjab, Pakistan) during the year 2014. An extensive farm survey of 155 farmers was designed. From this study rice- wheat cropping zone comprising Sheikhupura, Nankana Sahab, Hafizaabad, Gujranwala, districts was selected. Yield simulations with two crop models, i.e. Decision Support System for Agro Technology Transfer (DSSAT) and Agricultural Production Systems Simulator (APSIM), were used in a socio-economic impact assessment. Five selected General Circulation Models (GCM) were used for crop modelling, and yield simulations were analysed for both crop models and each GCM. The Trade off Analysis Model for a Multidimensional Impact Assessment (TOA-MD) version 6 was used for the analysis. Climate change and adaptation impacts on poverty, net farm returns and per capita income were calculated for different scenarios. The results revealed that the number of losers in all forms of study area ranged from 73 to 85 percent. Losers are categorized as the farmers who would be economically worse off under a changed climate. Without climate change, observed poverty rate would be 24.4 percent and in case of climate change, the predicted poverty rates would range from 28 to 32 percent. Results urged the need for adaptation strategies to reduce the exposed vulnerabilities of farming systems for viable future.

KEYWORDS: TOA-MD; assessment; climate change; poverty; per capita income, Pakistan.

INTRODUCTION

Climate change is a global phenomenon, and no country is immune to it. (24). It is an important challenge being faced by the world today. Climate

***Institute of Agriculture and Resource Economics, University of Agriculture, Faisalabad,**
****Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.**

change is a result of global warming, which is caused by increasing greenhouse gases (GHG). According to the Inter-governmental Panel on Climate Change, GHG levels are expected to increase from 550 ppm to 700 ppm in the middle of the current century if no policy to abate these emissions is adopted (5). In this scenario, the temperature could rise from 3^{o} to 6^{o} C. The main cause of climate change is economic development and industrialization that has a rapid increase in the concentration of GHG (26). Rising global temperatures will cause changes in weather patterns, a rise in sea levels, and increased frequency and intensity of extreme weather events. These effects will be felt globally and will disproportionately affect people in regions that are more severely exposed to climate change. Global temperatures have increased at a rate of 0.6 °C per decade since industrialization. In the current millennium, temperatures are expected to increase upto 5.8ºC (12).

Despite their differences, all regions of the world would face climate change in future. The eventual climate effect will depend upon the regional conditions. Regions facing warmer conditions in spring and summer will face yield reductions. In case of South Asia, the temperature is expected to increase upto 4ºC by 2050. The Asian subcontinent is also facing the brunt of climate change and could face water resource and grain production impacts. There is an urgent need to cope with climate change, as it is disturbing the overall welfare of countries. This remedial action is also important because all four dimensions of food security (food availability, food accessibility, food utilization and food systems stability) are vulnerable to climate change (2).

Pakistan, like other South Asian countries, will be adversely affected by climate change and temperatures will increase upto 3ºC by 2040 (3). Pakistan in general and the Indus Delta in particular, may experience a 4ºC rise in temperature by the end of this century (19). The intensity of abnormal meteorological events, such as heavy rainfall and drought, is expected to increase in Pakistan.

Agricultural sector is susceptible to weather conditions and climate (22). In Pakistan, the agricultural sector contributes 21 percent to GDP, and this sector is also responsible for employing 43.7 percent of the working population in the country. Its share in the country's exports is 18 percent (4). Given the vital importance of the agricultural sector to Pakistan's economy and to the livelihoods of people, its vulnerability to climate change cannot be ignored. Climate change generally affects agriculture through changes in temperature and precipitation. As is evident from past research, precipitation has increased by an average of 40 percent in the Southeast and by 20 percent in Northern Pakistan. These changes are negatively impacting current and future economic performance.

Climate change is causing irreversible damages to Pakistan due to its tremendous social, environmental, and economic impacts (8). The land area of Pakistan is characterized by arid and semi-arid regions (approximately 60 % of the area receives less than 250 mm of rainfall per year and 24 per cent receives 250-500 mm). Pakistan has continuously witnessed history's worst disasters since 2001. The global climate risk index of 2014 ranked Pakistan as the 12th most vulnerable country in the world. In a country like Pakistan, the effect of such extreme events elevates the level of CO_2 concentrations, ultimately decreasing the productivity of crops in different cropping systems in the country (16). This decline in crop yields will exert pressure on food grain supplies and make it hard to cope with growing food demands due to high population growth. The decline in agricultural resources is another limiting factor that is aggravating the situation.

The vulnerability of Pakistan to climate change is also worsening the poverty of marginal farmers in the country (20). There is also a growing threat to food security and to the country’s economy, and there is evidence that these problems may intensify in coming years (7). Environmental degradation is causing an annual loss of 5.2 billion USD to the national economy. The problem is so huge that half of the country’s population is at risk due to climate change (17).

Quantification is necessary for decision makers to be able to develop suitable and timely plans to reduce the impacts of climate change. Although earlier studies (13,23) have been carried out at global and regional scales to evaluate the impact of climate change, yet there is a substantial research lag about socio- economic issues in the study area. The purpose of this study was to analyze the impact of climate change for the rice-wheat cropping system of Punjab, Pakistan that is the bread basket of this province. Impact of climate change on the poverty, mean net farm returns and per capita income in rice-wheat cropping system of Punjab were assessed.

METERIALS AND METHODS

The study was conducted at (Five Districts were taken i.e. Shekhupura, Nankana Sahab, Hafizabad, Gujranwala and Sialkot, Punjab, Pakistan) during the year 2014. For this study rice-wheat cropping zone in Punjab was selected. In addition to rice and wheat crops, the minor crops, i.e., fodders (sorghum, lucerne, jwar, maize and bajra), and livestock were also considered in an economic impact assessment of climate change. This zone is the bread basket of Punjab province. There are more than one million farm families in this cropping zone, cultivating a total land area of 1.1 million hectares (6).

A mixture of primary and secondary data were used for the analysis. Primary data were collected using an extensive farm survey of 155 farmers. Because the farming population is heterogeneous in nature, a stratified random sampling technique was used for sample selection. First of all, five districts were randomly selected from rice-wheat cropping zone, i.e., Sheikhupura, Nankana Sahab, Hafizabad, Gujranwala and Sialkot. After that, at least 30 farms were selected from each district (stratum).

Five selected General Circulation Models (GCM) were used for crop modelling, and yield simulations were analysed for both crop models and each GCM. Past and future time periods evaluated in the simulations were 1981-2010 and 2039-2069 (1, 11, 20). The past time period was considered the prevailing system in the study area, and future time period was considered to be the proxy for a modified system. Time averaged crops yield means for both time periods were used in the analysis. Regional Representative Agricultural Pathways (RAPs) were used for projections of milk production and the yields of minor crops (sorghum, lucerne, jwar, maize and bajra). An integrated economic impact assessment of climate change and proposed adaptations were carried using the Tradeoff Analysis Model for Multidimensional Impact Assessment (TOA-MD) Version 6 (10).

Tradeoff Analysis for Multidimensional Impact Assessment (TOA-MD) Model

Different models are used to assess the impact of environmental changes. There is a growing demand for assessments of economic, environmental, and social impacts of new food related technologies. The TOA-MD model is a novel approach for assessing economic, environmental, and social impacts in a wide array of agricultural systems that incorporate crops, livestock, and aquaculture. This model is a unique simulation tool for multi-dimensional impact assessments. It uses a statistical description of a heterogeneous farm population. This model simulates the adoption and impacts of new technologies or changes in environmental conditions (9, 10), The model is appropriate for assessments, as it employs a generic model structure that can be parameterized with existing data.

The TOA-MD model relies on data from a variety of sources, including farm surveys, experimental, simulated data and expert judgment. A key feature of this model is that it takes into account the fact that farmers systematically select themselves for adoption or non-adoption groups. This model has been successfully used for the analysis of technology adoption and payments for environmental services (10, 18) and can also be used for climate change applications. In this approach, farmers are assumed to be economically rational (i.e., they make decisions based on maximizing the expected value) and are presented with a simple binary choice. Either they can continue to operate in production system 1, or they can switch to an alternative system 2. It is necessary to distinguish between two factors (technology and climate) affecting the expected value of a production system and the climate. Therefore, in a climate change analysis, a production system is defined as a particular technology used in a particular climate regime. These two factors, technology and climate, together determine the productivity of the system. Therefore, under a climate change analysis, a farmer facing expected product and input prices *p* at site *s,* using a production system *h* (defined as a combination of technology and climate), earns net farm returns v_t during each period equal to:

$$v_t = v_t\,(p, s, h) \;\ldots\ldots\ldots..(1)$$

To simplify the presentation in Equation 1, the expected prices are assumed constant over time and the returns function is indexed by time to represent a possible transition in productivity (14). Over T time periods, system *h* provides a discounted net return,

$$V\,(p, s, h) = \sum_{t=1}^{T} \delta_t\, v_t\,(p, s, h) \;\ldots\ldots\ldots\; (2)$$

In Equation 2, δ_t is the relevant discount factor. Farmers choose to remain in System 1 or switch to System 2, based on the opportunity cost (gain or loss from switching) and it can be shown as:

TOA-MD model parameters for the systems for each farm in the survey data in future period, were calculated as Rosenzweig et al. (21) methodology and followed by Ahmad et al. (1) and Subash *et al.* (25)

Hypotheses formulation

Test statistics is given in the Equation 6,

$$Z = \frac{(\bar{X}1 - \bar{X}2) - (\mu 1 - \mu 2)}{\sqrt{\frac{S1^2}{n1} + \frac{S1^2}{n2}}} \quad \ldots\ldots\ldots\ldots (6)$$

Following was the main hypothesis,

H_o: Mean revenue of current system (R_{S1}) = Mean revenue of future system (R_{S2})

H_1: Mean revenue of current system (R_{S1}) > Mean revenue of future system (R_{S2})

RESULTS AND DISCUSSION

The total sampled farm area for each district was 176.5 hectare on average. The results (Table 1) indicated that percentage gains and losses in DSSAT ranged from 10.9 to 12.7 percent and 22 to 28.3 percent, respectively. For the case of APSIM, percentage gains and losses ranged from 12.1 to 12.6 and from 23.2 to 25.3 percent, respectively. For each GCM, gains, losses, and net impacts as a percentage of the mean net returns are given in Figure. The observed net returns without climate change were Rs. 0.61 million per farm for both crop model simulations. Under climate change, the mean net returns varied from Rs. 0.48 to 0.54 million per farm in DSSAT, and from Rs. 0.51 to 0.52 million per farm in APSIM (Table 1)The observed per capita income, without climate change, was approximately Rs. 78.6 thousand per person for a year. With climate change, per capita income would reduce and vary between Rs. 62.85 and 69.72 per person per year in DSSAT, and Rs. 65.52 and 67.54 thousand per person per annum in APSIM, respectively. Without climate change poverty rate would be 24.4 percent. Under climate change projected poverty rates would increase ranging from 28.5 to 32.5 percent in DSSAT and from 30.4 to 31.8 percent in APSIM, respectively.

For all the selected farms in the Rice-Wheat cropping system of Punjab, number of losers ranged from 73.1 to 85.4 percent in DSSAT and from 76.6 to 80 percent in APSIM, due to climate change (Table 1). These findings were consistent with the findings of Baig *et al.* (11). It is expected that current agricultural production system of study area is vulnerable to climate change. That is why in future. The productivities would go down. Most of the farmers would be worse off economically under the perturbed climate. Overall vulnerability can be measured by the proportion of farmers made worse off relative to some threshold like poverty line.

Table 1. Impact assessment results for aggregated farms of the study area for all 5 GCMs and both crop models.

Socio economic Indicator	DSSAT		APSIM	
	From	To	From	To
Observed net returns without climate change (m.Rs./farm/year)	0.614	0.614	0.614	0.614
Predicted net returns with climate change (m.Rs./farm/year)	0.476	0.537	0.507	0.523
Observed per-capita income without climate change (000.Rs./person/year)	78.6	78.6	78.6	78.6
Predicted per-capita income with climate change (000.Rs./person/year)	62.85	69.72	65.52	67.54
Observed poverty rate without climate change (%)	24.1	24.4	24.4	24.4
Predicted poverty rate with climate change (%)	28.5	32.5	30.4	31.8
Losers (%)	73.1	85.4	76.6	80.0
Gains (% mean net returns)	10.9	12.7	12.1	12.6
Losses (% mean net returns)	22.0	28.3	23.2	25.3

Hypotheses testing showed; null hypotheses were rejected at 5 % level of significance (Table 2), depicting the prevailing farming conditions were vulnerable to climate change overtime. Null hypotheses were rejected at 5% levels of significance which depict the vulnerability of current agricultural production system to climate change (Table 2). In case of poverty, similar findings were observed by Jamal (15) for the same cropping system. The Results urged the need for adaptation strategies to reduce the vulnerabilities of farming systems for viable future.

Table 2. Hypotheses testing for checking vulnerabilities of current agricultural production system to climate.

Stratum	Test statistics	Critical value	Decision (Reject Ho if $Z_{cal} \geq Z_\alpha$)
Shekhupura	24.1	1.645	Reject H_0
Nankana Sahib	25.3	1.645	Reject H_0
Hafizabad	22.5	1.645	Reject H_0
Gujranwala	32.3	1.645	Reject H_0
Sialkot	24.4	1.645	Reject H_0
Overall Study Area	54.9	1.645	Reject H_0

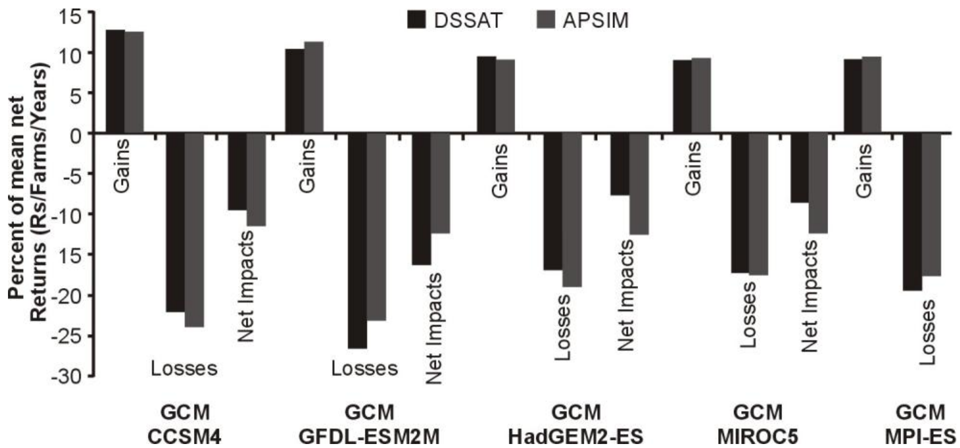

Fig. 1. Distribution of grains and losses (percentage) for all farms of study area in current agricultural production system.

CONCLUSION

The study concluded that there is a need to identify crops and regions that are more sensitive to climate variabilities and relocate them to more suitable areas. Suitable adaptations package for the selected agricultural zone is mandatory. Policies should be developed that ensure protective investments by farmers. Consequently, farmers will have the courage to adopt new technologies, i.e., the cultivation of new aerobic varieties. To achieve high productivity to meet the needs of growing population, it will be necessary to increase the sowing densities of the crops in the region.

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CONTRIBUTION OF AUTHORS:

Syed Asif Ali Naqvi	**:**	**Main author and responsible for the economic analysis and write-up**
Muhammad Ashfaq	**:**	**Interpreted results and provided introduction part of the study**
Sultan Ali Adil	**:**	**Made review of the document and added some other omitted variable for the sensitivity analysis**
Ashfaq Ahmed	**:**	**Provided the bio-physical model simulation of the yields for the analysis**