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Analysis of Reactive Adaptations by Rice Farmers Towards Climate Change—A Case Study of Rice-Wheat Zone of Punjab, Pakistan

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The study aims to identify the actual adaptations and their extent, effect of these on technical efficiency of farmers and the barriers in effective implementation of these practices in rice region of Punjab district, Pakistan. The study aims to introduce the effective adaptation practices at regional and national level by reducing the barriers confronting the efficiency of these practices. The paper selected a survey based exploratory research approach, comprising 200 interviews with rice farmers and 3 focal group discussions with experts. The data was compiled and analysed in Microsoft Excel, SPSS, STATA and FRONTIER 4.1, by using descriptive statistics, adaptation index formulation, Stochastic Frontier Analysis (SFA), Likert Scale analysis and two sample t-test. The paper recognises increased irrigation, change of varieties and planting time and fertiliser rates and soil conservation techniques etc. which have an extent of 40 percent. These practices have positive significant impact on efficiency of farmers. 14 other practices were identified which would impart positive role towards efficiency, if implemented successfully. There were barriers in effective implementation of ongoing practices, which would be overcome with technical, social, market and institutional support. The paper suggests implications for increase in rice production, by certain policies including installation of solar tube-wells, trainings and trials regarding adaptations' implementation at village or UC level, building rice-purchase centres, easy access to formal credits, establishment of agro-information system and quality assurance measurements. This paper indicates actual effective adaptation practices in rice.

Keywords: Adaptations, Agriculture, Pakistan, Climate Change, Rice

1. INTRODUCTION

On the current global scenario, the climate is going to change, with conspicuous influences on the living beings of planet earth. The latest scientific assessment by IPCC, Intergovernmental Panel on Climate Change, approximated an average upsurge in temperature of about 2-6^{o}F and 6-37 inches rise in sea level by the year 2100 [IPCC (2007)]. Pakistan is a country which is highly dependent on agriculture sector. Though its contribution to greenhouse gas (GHG) emissions is quite negligible when compared with other countries, it adds only about 0.8 percent out of total GHG emissions, but it is one of the main victims of the antagonistic effects of changing climate [Akram and Hamid (2015)]. Pakistan is ranked 16th in list of countries most vulnerable to changing climate [Ahmad, *et al*. (2013)]. Extent of negative relationships of climate change is higher for the agricultural sector as compared to other two sectors i.e., manufacturing and services [Akram and Hamid (2015)]. Shakoor, *et al.* (2011) revealed, by employing, Ricardian model, that negative effects of temperature are higher than positive effects of rainfall on agriculture production and revenue. With the intrinsic problems in agriculture sector,

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levels of production in sub-Saharan and South Asia will be greatly affected by changing climate than in most of the other parts of World [Wassmann and Dobermann (2007)].

Pakistan needs to focus on immediate measures of adaptations mainly in agriculture sector [Amir (2011)]. Actions taken prior to changing climate are called anticipatory adaptations, whereas the adaptations in response to changing climate fall under reactive adaptations [Smith (1997); Ngaruiya (2014)]. In Pakistan the rice-wheat growing areas are located in central Punjab, followed by Sindh. The rice-wheat cropping system is the major one in Pakistan with an assessed area of 1.6 mha [Ahmad and Iram (2014)]. Rice crop stands at second number among staple food crops, and it is also exported, contributing 3.2 percent towards value addition. Its share in GDP is 0.7 percent. Export of rice produced foreign exchange of about 1.53 billion US dollars during July-March 2015-16 [Pakistan (2016)]. Studies forecasted that changing climate may have a considerable negative or positive impact on rice production, conditional to the region. Negative impact of changing climate on productivity of rice, cotton and sugarcane, for both short and long run has been proved by Siddique, *et al*. (2012). It was suggested by Matthews, *et al*. (1997) that under the climate of next century, the production of rice in Asian region may decrease by –3.8 percent. Rainfall and temperature patterns and the frequency of storm events greatly damage the production of rice [Wichelns (2016)]. Elevated temperatures can badly affect the yields of rice through two main pathways which are (1) higher night time temperatures, and (2) maximum high temperatures, the former cause adverse effects on grain quality and spikelet sterility in combination with increased humidity and the later may cause reduction in accumulation [Wassmann, *et al*. (2009)].

Many probable agricultural adaptations have been advised, expressing methods or practices that might lessen expected hostile effects. They include a varied range of scales, methods and participants [Smithers and Mohsin (1997); Francisco (2008)]. Farmers make responses to climate change according to their own experiences and indigenous knowledge through both non-agricultural as well as agricultural adaptations adopting at individual's level [Manandhar, *et al*. (2011)]. Farmers need to modify choices of crops, water and soil management and crop calendars are needed to be managed [Wichelns (2016)]. For rice crop, dry sowing in place of transplanting, transplanting date optimisation in accordance with temperature changes, escalation of heat and drought-tolerant and short-duration varieties, soil mulching, incorporation of crop residues into the soil, deep planting, soil drainage improvement, enhancement of water resources etc. have been suggested under planned adaptations [Iqbal, *et al*. (2009)]. Another report by Ahmed, *et al.* (2013) suggested deep tillage for preservation of moisture and rainwater harvesting, use of private water channels for water diversion, altering sowing time, tube-wells installation, delayed wheat sowing, smoking and watering, ridge sowing of cotton, tunnel farming, direct seeding in case of rice, use of hybrid seeds for many crops etc. At international level, extensive work on adversities of climate change and related adaptations have been done. Sowing dates' modification at high latitudes, adjustments in the time of planting, use of highly tolerant varieties having spikelet fertility to temperature, use of longer-maturing varieties and adopting better strategies might allow growth of a second crop in Asian region [Matthews, *et al*. (1997)]. Need for strategies of adaptation in rice agriculture of Indonesia, increasing investments in storage of water, diversification of crops and alert systems has been reported by Naylor, *et al*. (2006).

Farooq, *et al*. (2009) explained that water-saving production systems of rice like aerobic rice culture, GCRPS, raised beds, SRI and AWD can sharply cut down the water outflows which are unproductive and increase WUE. Advanced date of planting for rice by one month is declared as a non-cost adaptation strategy for changing climate in Kurunegala District of Sri Lanka [Dharmarathna, *et al.* (2014)].

There exist very few assessments for verifying the effectiveness as well as possible strategies' adoption rates. A dynamic and comprehensive approach is needed to overcome barriers occurring to adaptation options, including both the approach of individual farmers and efficiency of markets [Howden, *et al*. (2007)]. Therefore the current study aimed to report the extent of adaptations adopted in the area, their effectiveness through their impact on efficiency of farmers, the barriers which reduce their effectiveness, possible solutions for these barriers and support needed by the farmers is also focused, as expansion in adaptations beyond individual level should be made feasible by providing support [Manandhar, *et al*. (2011)].

2. MATERIALS AND METHODS

To analyse the adaptations in Rice-Wheat zone of Punjab, primary data was collected through questionnaires based survey and interview technique was employed to collect data from farmers. Two districts were selected for sampling i.e. Sheikhupura and Sialkot, where rice is grown as a major crop. Focus Group Discussions (FGDs) were conducted with farmers of Sheikhupura and Sialkot to identify the major adaptations practiced in the area, and barriers occurring in those practices. Data was collected from 200 farmers of both adaptive and non-adaptive categories, after pre-testing of questionnaire. Multistage random sampling technique was used to define sample in target population. First of all descriptive analysis was carried out to check the distribution of farmers as adapters and non-adapters and ranking of adaptations in the area.. Adaptation index was formulated from this information, as was employed by Yila and Resurreccion (2013) to check the extent of adaptations in the area. Stochastic Frontier Analysis (SFA) was carried out to measure the efficiencies of high-adapters and low-adapters, as SFA measures the production and cost function along with efficiencies of individual firms [Meeusen and Broeck (1977); Aigner, *et al*. (19770; Tijani (2006); Kolawole and Ojo (2007)]. Model Specification for Stochastic Production Frontier is as follow:

$$lnY_j = a + b_1ln(LAB_j) + b_2ln(Urea_j) + b_3ln(PES_j) + b4ln(IRR_j) + b4ln(PLOW_j) + b_5ln(D_{DAPj}) + b_5ln(D_{PLANKj}) + V_j - U_j$$

Where

Y_j = Output of rice in kg per acre of j^{th} farm
LAB_j = per acre number of labour hours of j^{th} farm
$Urea_j$ = amount of urea in kg per acre of j^{th} farm
PES_j = cost of pesticide per acre of j^{th} farm
IRR_j = No. of irrigations per acre
$PLOW_j$ = Number of ploughings per acre
D_{DAPj} = Dummy for DAP
D_{PLANKj} = Dummy for Planking

Model for technical inefficiency is specified as follow:

$$U_j = (c, Z_j) + w_j$$
$$U_j = c + c_1ln(Z_1) + c_2ln(Z_2) + c_3ln(Z_3) + c_4ln(Z_4) + c_5Z_5 + w_j$$

Where

lnZ_1 = Natural log of Age of the Farmer
lnZ_2 = Natural log of Experience of the Farmer
lnZ_3 = Natural log of Area under Rice Crop
lnZ_4 = Natural log of Distance from Market
Z_5 = Dummy for Access to Mass Media

To check that either there existed some difference between technical efficiency of high adapters and low adapters, a two-sample t-test was applied on technical efficiency of two groups i.e. high-adapters and low-adapters. T-test reveals that either there exist significant difference between mean of two groups or not [Schou (2002)]. A five point Likert scale analysis was used in the current study to show the perception of farmers about effectiveness of certain proposed adaptation practices. Mean scores were calculated for Likert-scale items as Likert Scale results can be summarised somewhat numerically by using method of average scoring [The University of Reading Statistical Services Centre (2001)].

3. RESULTS AND DISCUSSIONS

Distribution of adapters and non-adapters, ranking of adaptations according to their benefits and barriers against potential adaptations have been found and given in Table 1. The highest adopted practices included increase in irrigation (rank-1), change in fertiliser rate (rank-3), soil conservation techniques (rank-5), switching from crops to livestock (rank-7) and change of planting date (rank-4) and/or crop variety (rank-2).

Table 1

Distribution of Adapters and Non-Adapters and Ranking of Adaptations

Adaptation Practice	Adapters (%age)	Non-Adapters (%age)	Ranking (%age Response of Farmers)	Barriers (%age Response of Farmers)
Change of Crop Variety	26	74	Rank-2 (47%)	Non-availability of Fresh Hybrid seed (16.5%), Improper market price (6.5%)
Change in Time of Planting	27	73	Rank-4 (32%)	Improper market price (6.5%)
Plant Early Maturing Varieties	8	92	Rank-7 (16%)	–
Soil Conservation Techniques	44	56	Rank-5 (27%)	Cost Increment (39%), Weed control is difficult in Cross-Soil Farming (9%)
Change in Fertiliser Rate	49	51	Rank-3 (44%)	Cost Increment (39%), Adulteration in Fertilisers by Fertiliser Providers. No Quality Check by Government (17.5%)
Buy Insurance	6	94	Rank-6 (18%)	Cost Increment (39%)
Put Trees for Shading	6	94	Rank-8 (13%)	Less Information regarding benefits (14.5%)
Increase Irrigation	53	47	Rank-1 (87%)	Cost Increment (39%), Less Canal Water provision (17%)
Switch from Crops to Livestock	33	67	Rank-7 (16%)	Less Information regarding benefits (14.5%)
Reduce Number of Livestock	4	96	Rank-9 (10%)	–

The adaptation index presented in Table 2 was found by including only those 6 adaptation practices which were being adopted by more than 10 percent farmers. A score of 1 was assigned to the adaptation adopted by the rice growers and a score of 0 is assigned to the adaptation not adapted by the growers. Then all scores were aggregated and divided by 6 to obtain a composite index. The value of composite index was 0.4, indicating that extent of adaptations in Rice-Wheat zone of Punjab was up to 40 percent as a whole.

Table 2

Adaptation Index Showing Extent of Adaptations in Study Area

Adaptations	Description	No. of Farmers Adopting (a)	Adapters (a^)	Non-adapters (a^^)	Index
(1) Different crop varieties	Use of differing crop varieties, and hybrids, to enhance the suitability and tolerance of crop to moisture, temperature and other conditions of Climate	53	26.5	73.5	0.26
(2) Changing time of planting	Changing the time of sowing to adjust with temperature and moisture changes	54	27	73	0.27
(3) Soil conservation techniques	Development and use of resources at farm-level for management of changes in temperature, moisture and nutrient deficiencies e.g. ridge sowing, mulching, earth bunds etc.	88	44	56	0.44
(4) Change in fertiliser rate	Changing fertiliser rates to enhance the yield which is decreasing due to changing Climate	98	49	51	0.49
(5) Increase irrigation	Increased number of irrigations to offset the increased temperatures	106	53	47	0.53
(6) Switch from crop to livestock	Increased livestock rearing and reducing crop cultivation to avoid yield and profit losses	66	33	67	0.33

Composite Index

Note: n = 200; a = Frequency of Adapters; a^ = a/n 0.4

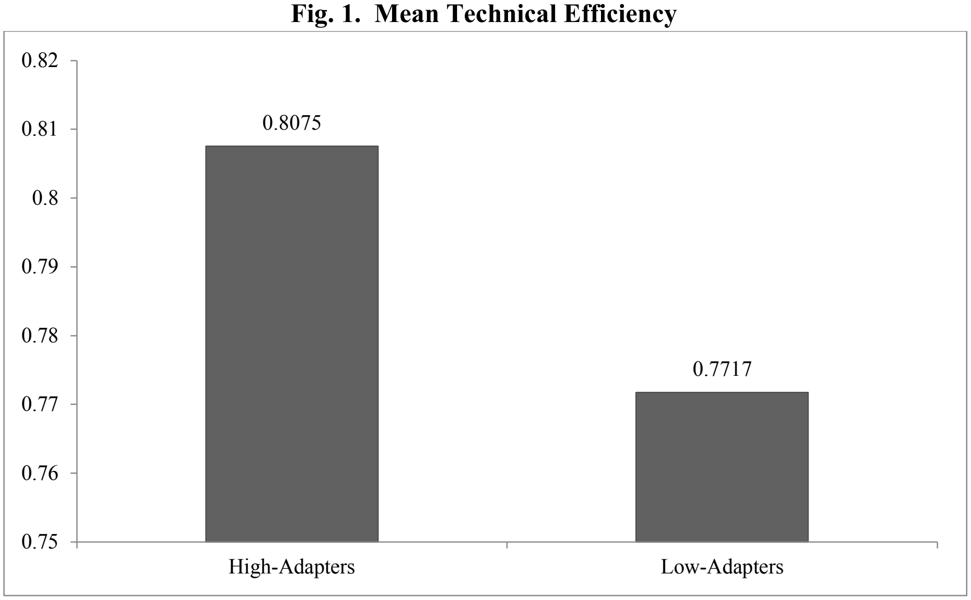
Results of SFA are given in Table 3, showing that uses of labour, urea, irrigation, ploughing and planking are positively related with rice production. While plant protection cost and DAP were negatively associated with rice production, these findings are similar to those of Abedullah, *et al.* (2007) The coefficients of inefficiency revealed that age, experience, farm size and access to mass media all are positively related with efficiency of rice farmers, while distance from market have negative relation with efficiency. The value of gamma indicated that 99 percent variation in output is due to the presence of technical inefficiency.

Table 3

MLE Coefficients of Stochastic Frontier Analysis for Rice Farmers

	Coefficient	S.E	t-value
Production Model			
Constant	2.781	0.0891	31.201
Labour (Hours)	0.007	0.011	0.647
Urea (Kg)	0.052	0.015	3.505
Plant Protection Cost (PKR)	–0.083	0.007	–11.738
Irrigation (Number)	0.381	0.036	10.598
Ploughing (Number)	0.014	0.013	1.068
Dummy for Planking	0.021	0.008	2.602
Dummy for DAP	–0.011	0.004	–2.918
Inefficiency Model			
Age (Years)	–0.007	0.013	–0.587
Experience (Years)	–0.005	0.007	–0.727
Farm Size (Acre)	–0.009	0.004	–2.085
Distance from Market (Km)	0.126	0.012	10.692
Dummy for Access to Mass Media	–0.022	0.004	–4.971
Sigma-Squared	0.001	0.0001	10.118
Gamma	0.990	0.081	12.349
Log likelihood Ratio		380.067	

Fig. 1. Mean Technical Efficiency



Technical efficiencies of high-adapters and low-adapters was found using SFA. Low-adapter group (N=49) was associated with a technical efficiency E=80.75% (Variance = 0.0025). By comparison the high-adapter group (N=151) was associated with a numerically higher technical efficiency E=77.17% (Variance = 0.00085). The value of t-test was significant at both 5 percent and 1 percent level of significance (2.854E-09 and 5.708E-09 respectively). Thus the high-adapters were associated with a larger technical efficiency than the low-adapters. The current study also tried to explore the farmers' attitude towards future implications on adaptations. For this purpose, farmers were judged by using a five-point Likert scale having 14 proposed adaptation practices which could be proved beneficial for rice crop against changing climate. Mean scoring of Likert scale revealed that farmers showed positive attitude towards some practices including cooperative farming, weather forecasting, up-to-date market information system, use of technical consultation, on-farm storage and maintenance of farm records. These practices were considered as effective tools against changing climate, if adopted at large scale. Whereas farmers gave negative response towards use of more varieties, space diversification, planning expenditures and production diversity. To resolve the barriers occurring to farmers and to promote adaptations in the area, certain kind of technical, institutional, social and market support is needed by the farmers. These suggestions are presented in Table 4.

Table 4

Suggestions Regarding Support Needed by the Rice Farmers

Suggestion	Percentage Response
(A) Technical Support by Government	
Provision of latest Agricultural Technology	34.0%
Cleaning Watercourses	20.5%
Provision of Storage Facility by the Government	18.5%
Installation of Solar Tube wells	20.0%
Provision of Fresh Hybrid Seed	16.5%
Provision of Free Electricity	25.5%
Provision of Latest Machinery	8.0%
Provision of High-yielding varieties	10.5%
Weather forecasting system at village level	14.0%
Quality Assurance of Agricultural Inputs by the Government	17.5%
(B) Institutional Support	
Monthly meetings with agriculture department	9.5%
Making finance feasible and Approachable at the end of Banks	10.0%
Establishment of Finance centers by Government at union-Council Level	5.5%
Built Rice-Purchase Centers just like Wheat Purchase Centers	22.0%
(C) Social Support	
Promote Corporate Farming	9.5%
Union-council level seminars for importance of Corporate farming and Technology Sharing	3.0%
(D) Market Support	
Ensure Optimum/Stable Price	8.0%
Exclude Middlemen	19.0%
Govt. purchase Rice directly from growers	17.5%
Provide compensation in case of natural calamities	12.5%
Up-to-date market information Provision	7.5%

4. CONCLUSION

The current study focused on identification of potential adaptation practice for rice crop through different techniques. It has been seen that major adaptations in the area included increase in irrigations, change of varieties and time of planting, change in fertiliser rates, implementation of soil conservation techniques and switching from crops to livestock. These adaptations are practiced to an extent of 40 percent in Rice-Wheat zone of Punjab. Impact of these adaptations on efficiency was proved positive and significant. So these adaptations can be proved effective if adopted on large scales. For promotion of adaptations, certain barriers have to be resolved by government, institutes and markets, including non-availability of fresh inputs, adulteration in fertiliser, cost increment, sale problems, less provision of canal water and difficulty in weed control etc. Installation of solar tube-wells, trainings and trials regarding adaptations' implementation at village or UC level, building rice-purchase centers, easy access to formal credits, establishment of agro-information system and quality assurance measurements could be proved helpful for promotion of adaptations in rice-wheat zone of Punjab.

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