Impact of Farm Households' Adaptation on Agricultural Productivity: Evidence from Different Agro-ecologies of Pakistan

Iqbal, Muhammad and Ahmad, Munir and Mustafa, Ghulam

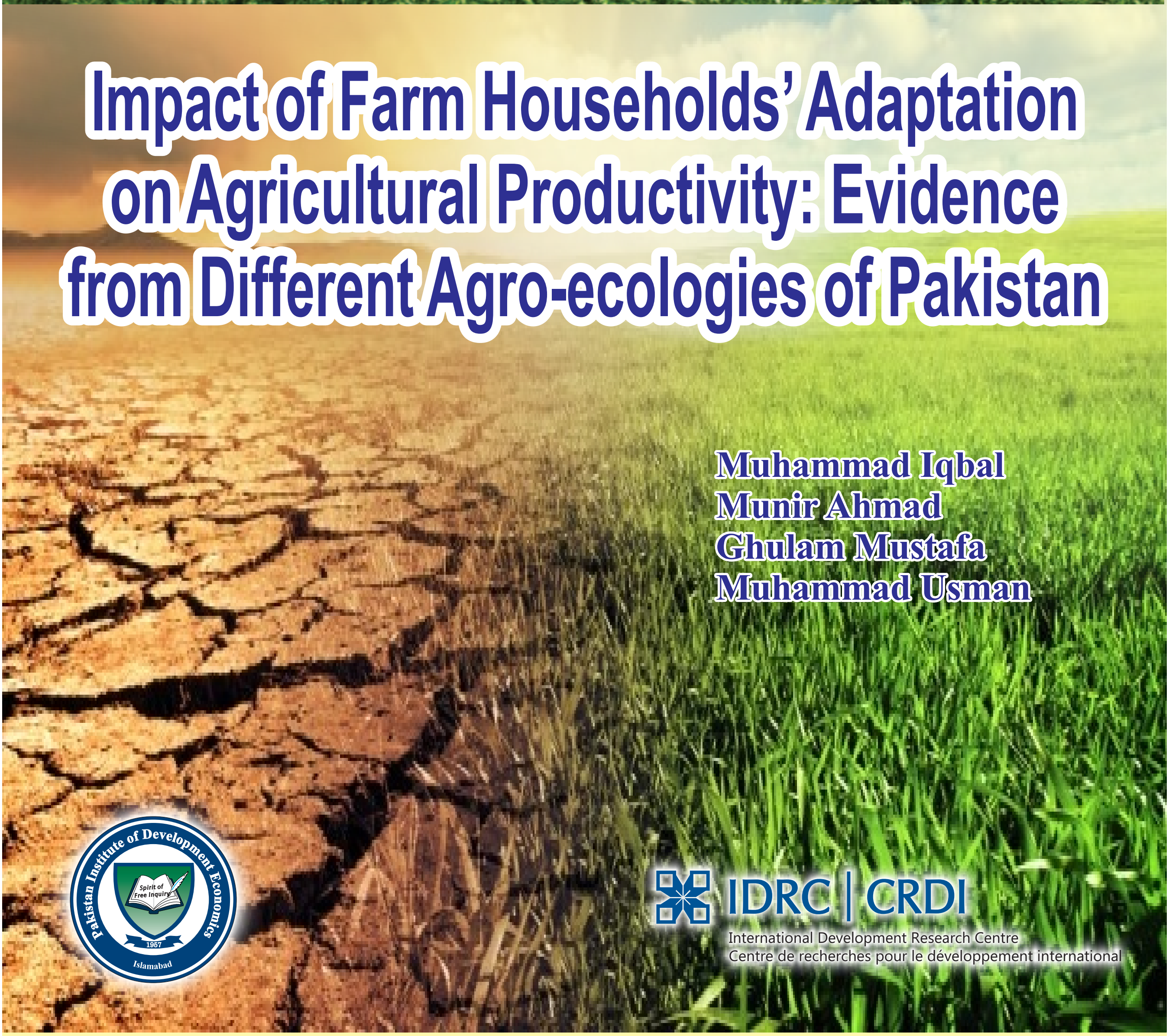
PIDE

2015

Climate Change Working Paper Series
No. 5

Impact of Farm Households' Adaptation on Agricultural Productivity: Evidence from Different Agro-ecologies of Pakistan

Muhammad Iqbal
Munir Ahmad
Ghulam Mustafa
Muhammad Usman



Pakistan Institute of Development Economics
Spirit of Free Inquiry
1957
Islamabad

IDRC | CRDI
International Development Research Centre
Centre de recherches pour le développement international

Climate Change Working Papers
No. 5

Impact of Farm Households' Adaptation on Agricultural Productivity: Evidence from Different Agro-ecologies of Pakistan

Muhammad Iqbal
Pakistan Institute of Development Economics, Islamabad

Munir Ahmad
Pakistan Institute of Development Economics, Islamabad

Ghulam Mustafa
Pakistan Institute of Development Economics, Islamabad

and

Muhammad Usman
Pakistan Institute of Development Economics, Islamabad

PAKISTAN INSTITUTE OF DEVELOPMENT ECONOMICS
ISLAMABAD
2015

Pakistan Institute of Development Economics
Islamabad, Pakistan

E-mail:
Website: http://www.pide.org.pk
Fax: +92-51-9248065

CONTENTS

List of Tables

ABSTRACT

This study has utilised the Climate Change Impact Survey (CCIS, 2013) data and applied Treatment Effect Model (Heckman type) to analyse the impact of identified adaptation strategies if implemented in isolation or as portfolio (package of two or more) strategies on net revenue earned from wheat production in Pakistan. The implementation of adaptation strategies including varietal change, delayed sowing, and input intensification effect net revenues positively and significantly if adopted separately or as a part of portfolio strategies. Interestingly, the portfolio adaptation strategies missing delayed sowing resulted in either insignificant results or in reduced net revenues from wheat production. The evidence is found temperature (Nov-Dec.) and precipitation (March-April) norms and deviations of Jan-Feb. temperature from norm of the period are important determinants of net revenue. The results are supportive that fertility of land, farmer's tenancy status, size of holding, non-farm income, and access to certain extension source are important determinants in the selection of various adaptation strategies. The study suggests revisiting the recommendations regarding wheat sowing dates by agricultural research institutions.

Keywords: Agriculture, Wheat Yield, Climate Change, Adaptation, Growth Stages, Pakistan, and Treatment Effect Model

I. INTRODUCTION

Climate change and its impacts on various sectors of the economy including agriculture, human health, infrastructure, and biodiversity are well debated issues in the current scientific literature. There is documented evidence available that increase in temperature has affected crop yields adversely in various regions of the world [IPCC (2007); Deresa, *et al*. (2008), Ahmad, *et al*. (2014a); Ahmad, *et al*. (2014b)]. The studies have reported that changes in climatic factors have significant effects on food security of rural households especially in developing countries where adaptive capacity of the communities to such changes is very poor [Downing (1992); Benson and Clay (1998); Chipanshi, *et al*. (2003); Deressa (2007); Rosenzweig, *et al*. (2007); Yesuf, *et al*. (2008)].

South Asia is one of the most vulnerable regions in the world because it contains disaster and drought prone areas. The vulnerability extent of this region can be visualised by taking into account that highly poor (80 percent) and undernourished people of the world (45 percent) live here and climate change projections alarmingly have suggested that temperature in this region would increase by 3-4 ^{0}C by the end of 21st century and there would be occurrence of extreme events [UNEP (2003); Spijkers (2011)].

Pakistan is situated among the most volatile countries in South Asia where majority of people overwhelmingly dependent on Agriculture. The agriculture sector is playing a vital role in the economic growth and development of Pakistan as it is contributing about 21 percent to GDP and is providing employment to 45 percent of the total labour force [Pakistan (2013-14)]. It is reported that temperature increase in Pakistan will be higher than the increase in global average [TFCC (2010)]. Studies support the evidence that increase in temperature adversely affects crops yield including food crops [Sivakumar and Stefanski (2011), Ahmad, *et al.* (2014), Iqbal, *et al.* (2009)]. It is inevitable to cope with these negative effects of threatening climate changes through enhancing adaptive capacity to climate changes.

The research conducted on the issue suggests that implementation of various adaptation measure can reduce the damages of changes in climatic variables [McCarthy (2001); Vergara (2005); Deressa (2007); Howden, *et al.* (2007); Adger (2010); Reidsma, *et al.* (2010); Di Falco, *et al.* (2011); Di Falco and Veronesi (2013); Di Falco, *et al.* (2014)]. These studies analysed the monetary or yield impact of climate change and suggested adaptation measures. However, little research has been undertaken to explore the extent of adaptation to climate

---

Authors' Note: This paper was also presented at a seminar held on August 31, 2015 at the National Agricultural Research Centre, Islamabad. The seminar was jointly organised by the Pakistan Institute of Development Economics and Pakistan Agricultural Research Council, Islamabad. We are thankful to seminar participants for their valuable comments.

change by Pakistani farmers and the impact of these adaptations on crop yield or farm revenues.

The main objective of this study is to explore the relationship between different climatic factors different and performance of wheat. The study will also analyse the impact of adaptation to climate change on net revenues earned from wheat production. The more specific objectives are listed below:

Objectives of the Study

The specific objectives of the study are to:

- identify various adaptation strategies to climate change adopted by the farmers;
- analyse the impact of adaptations to climate change on wheat productivity; and
- suggest recommendation

Organisation of Study

The report has been organised in four sections. Introduction is followed by Section-II dealing with the data and methodology used in this study. The Section-III presents results and discusses findings of the study. The final section concludes and suggests policy recommendations.

II. DATA AND METHODOLOGY

The study is based on the *Climate Change Impact Survey* (CCIS, 2013) data collected from 3430 households from 16 randomly selected districts representing various cropping systems[1] of Pakistan. The universe and selection procedure of the district, village, and household level samples has been described in detail in Ahmad, *et al*. (2015). This study uses data regarding 3018 wheat growers who were interviewed during the survey CCIS, 2013. The adaptation strategies adopted by the wheat growers in response to climate change are categorised into four categories namely varietal change (S-1), delayed sowing (S-2), input intensification (S-3), and soil and water conservation (S-4). In total, 15 mutually exclusive combinations of adaptation strategies are possible when implemented in isolation or adopted in portfolios that combine two or more strategies. Various possible adaptation strategies (isolated or in portfolios) are described in the Table 1.

---

[1] Punjab: (1) Rice-Wheat; (2) Cotton-Wheat; (3) Mixed; (4) Barani & Partial Barani
Sindh: (1) Rice-Wheat; (2) Cotton-Wheat; (3) Mixed
KP: (1) Wheat-Mix; (2) Maize-Wheat; (3) Partial Barani

Table 1

Various Regimes of Adaptation Strategies Adopted by the Wheat Growers

Regime of Strategy	Description
Varietal Change (S-1)	S-1=1 if the farmer only changed wheat varieties in response to climate change as an adaptation strategy, and 0 otherwise
Delayed Sowing (S-2)	S-2=1 if the farmer only delayed sowing of crop in response to climate change i.e. planted crop on 15th November or later as an adaptation strategy, and 0 other wise
Input Intensification (S-3)	S-3=1 if the farmer only increased application of material inputs (like seed rate, fertiliser, and pesticides etc.) in response to climate change as an adaptation strategy, and 0 otherwise
Soil and Water Conservation (S-4)	S-4=1 if the farmer only adopted soil and/or water conservation measures (precision levelling, changed tillage practices, manure/green manure, and bed planting) in response to climate change as an adaptation strategy, and 0 otherwise
Varietal Change and Delayed Sowing (S-12)	S-12=1 if the farmer adopted S-1 as well as S-2 in response to climate change as adaptation strategy, and 0 otherwise
Varietal Change and Input Intensification (S-13)	S-13=1 if the farmer adopted S-1 as well as S-3 in response to climate change as an adaptation strategy, and 0 otherwise
Varietal Change and Soil & Water Conservation (S-14)	S-14=1 if the farmer adopted S-1 as well as S4 in response to climate change as an adaptation strategy, and 0 otherwise
Delayed Sowing and Input Intensification(S-23)	S-23=1 if the farmer adopted S-2 as well as S3 in response to climate change as an adaptation strategy, and 0 otherwise
Delayed Sowing and Soil & Water Conservation(S-24)	S-24=1 if the farmer adopted S-2 as well as S4 in response to climate change as an adaptation strategy, and 0 otherwise
Input Intensification and Soil & Water Conservation (S-34)	S-34=1 if the farm household adopted S-3 as well as S4 in response to climate change as an adaptation strategy, and 0 otherwise
Varietal Change, Delayed Sowing, and Input Intensification (S-123)	S-1234=1 if the farm household adopted S-1, S-2 as well as S3 in response to climate change as an adaptation strategy, and 0 otherwise
Varietal Change, Delayed Sowing, and Soil & Water Conservation (S-124)	S-124=1 if the farm household adopted S-1, S-2 as well as S4 in response to climate change as an adaptation strategy, and 0 otherwise
Delayed Sowing, Input Intensification, and Soil & Water Conservation (S-234)	S-234=1 if the farm household adopted S-2, S-3 as well as S4 in response to climate change as an adaptation strategy, and 0 otherwise
Varietal Change, Delayed Sowing, Input Intensification, and Soil & Water Conservation(S-1234)	S-1234=1 if the farm household adopted S-1, S-2, S3 as well as S4 in response to climate change as an adaptation strategy, and 0 otherwise

Theoretical Framework

Farmers' decision to adapt and selection of strategy to be adopted is voluntary, and is based on individual self-selection. Farm households that adopted a particular strategy are not a random sample of the original population, they may have systematically different characteristics from farm households that did not adapt or adopted a different strategy. Unobservable characteristics of farmers and their farm may affect both the adaptation strategy decision and net revenues, resulting in inconsistent estimates of the effect of adaptation on net revenues. For example, if only the most skilled or motivated farmers choose to adapt or choose the most profitable strategy then self-selection bias can affect the estimates. In addition, this simple approach assumes that the observable variables have the same marginal effects on net revenues independently of the type of strategy considered. This assumption imposes a model restriction, which may yield to biased estimates.

The development of sample selection model by Heckman (1976,1979), Heckman and Smith and Huang (1995) for modelling the effects of selection biases and later work of other researchers induced formulation of a number of "Heckit" models [name as suggested by Greene and Hensher (2003)] leading to direct application of sample selection model to treatment effect models in observational studies. The choice of the model depends on whether the outcome equation variables are observed under each treatment regime (treatment is a dummy variable which takes value equal to one or zero) or not. The data used in this study are collected from farmers who adapted to climate change as well as from those who did not adapt. Following [Green (2003)] we applied Heckman type Treatment Effect Model to estimate the impact of adaptation to climate change on net revenue per acre as this model deals treatment effect score and selection simultaneously. The model is expressed in the following two equations.

Outcome or Regression Equation:

$$R_i = X_i\beta + S_i\delta + \varepsilon_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where "*i*" represents the *i*th farm household, *R* is dependent variable (net revenue per acre) in the outcome equation, *X* is vector of explanatory variables (including variable representing education and age of the household head, wheat acreage, farm location, tenancy status, soil fertility status, farm location, and climatic factors etc.), β is the column vector of parameters and *S* is a binary variable coming directly from selection equation (Equation 2) which is known as treatment effect score in outcome equation. The coefficient δ gives counterfactual analysis or significant differences of treated and non-treated households, and ε is the error term. The *S* takes value of 1 in the outcome equation if its value in the treatment equation exceeds a threshold level (say$S_i^* > 0$) and zero otherwise.

Selection equation

$$S_i^* = Z_i\gamma + U_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

With $S_i = \begin{cases} 1 & if \quad S_i^* > 0 \\ 0 & Otherwise \end{cases}$

and Prob. $(S_i = 1 \mid z_i) = \varphi(z_i\gamma)$ and Prob. $(S_i = 0 \mid z_i) = 1 - \varphi(z_i\gamma)$

In selection equation *Z* is a vector of explanatory variables that effect likelihood to adapt (like age and education of household head, non-farm income, farm size, tenancy status dummies, fertility status of farm land dummies, and extension sources dummies etc.) and γ is a vector of coefficients and U_i is a random disturbance. Where, ε_i and U_i are bivariate normal with mean zero and covariance matrix $\begin{bmatrix} \sigma_\varepsilon & \rho \\ \rho & 1 \end{bmatrix}$

Given sample selection and that *S* is an endogenous variable, the problem is to use the observed variables to estimate the regression coefficient β, while controlling for selection bias induced by non-ignorable treatment assignment. The model is estimated using *treatreg* command in SATA 12 software.

The net revenue per acre is used as a dependent variable in the outcome equation and is defined as the difference of total revenues (wheat price x wheat yield) and variable costs per acre involved in production of wheat (seed, labour, fertiliser, rental cost of tractor and other machines, and pesticides/weedicides etc.). The explanatory variables used in the outcome equation(s) include farm and farmer related characteristics and climatic factors (temperature and precipitation) and a binary variable S representing relevant adaptation strategy given in Table-1. The explanatory variables used in the outcome and treatment equations are listed and described in Table 2.

Table 2

List of Explanatory Variables

Variables	Description
Farmer & Farm Characteristics	
Education	Education of household decision maker (completed school years)
Age	Age of household decision maker in (years)
farm_exp	Farming experience of the household decision maker (year)
owner_farmer	Dummy=1 if farmer owns operated farm land, 0 otherwise
owner_cum_tenant	Dummy=1 if farmer owns only a part of operated land, 0 otherwise
Tenant	Dummy=1 if farmer does not own the operated farm land, 0 otherwise (used as reference)
poor fertility	Percent area of operational holding having poor soil fertility
average_fertility	Percent area of operational holding having average soil fertility
good_fertility	Percent area of operational holding having good soil fertility
Farm Location Dummies	
cotton_wheat_zone	Dummy variable equal to 1 if farm is located in cotton wheat zone and zero otherwise
rice_wheat_zone	Dummy variable equal to 1 if farm is located in rice wheat zone and zero otherwise
mixed_zone	Dummy variable equal to 1 if farm is located in mixed cropping zone and zero otherwise
barani_&_partial_barani	Dummy variable takes value equal to 1 if farm is located in Barani or Partial Barani zone and zero otherwise (used as reference)
Climatic Factors	
Nov_Dec_t_5 years	Average of mean temperatures of Nov & Dec in last 5 years (^{0}C)
Jan_Feb_t_5 years	Average of mean temperatures of Jan & Feb in last 5 years (^{0}C)
Mar_Aprl_t_5years	Average of mean temperatures of March & April in last 5 years (^{0}C)
Nov_Dec_p_5years	Average of precipitation of Nov & Dec in last 5 years (mm)
Jan_Feb_p_5years	Average of precipitation of Jan & Feb in last 5 years (mm)
Mar_Aprl_p_5years	Average of precipitation of March & April in last 5 years (mm)

Continued—

Table 2—(*Continued*)

Nov_Dec_t_5years_deviation	Deviation of Nov & Dec temperature from average of last five years
Jan_Feb_t_5years_deviation	Deviation of Jan & Feb temperature from average of last five years
Mar_Aprl_t_5years_deviation	Deviation of March & April temperature from average of last five years
Nov_Dec_p_5years_deviation	Deviation of Nov & Dec precipitation from average of last five years
Jan_Feb_p_5years_deviation	Deviation of Jan & Feb precipitation from average of last five years
Mar_Aprl_p_5years_deviation	Deviation of March & April precipitation from average of last five years
squared_t_Nov_Dec_5years	Square of average temperature of Nov. & Dec. in last 5 years
squared_t_Jan_Feb_5years	Square of average temperature of Jan & Feb in last 5 years
squared_t_Mar_Aprl_5years	Square of average temperature of March & April in last 5 years
squared_p_Nov_Dec_5years	Square of average precipitation of Nov & Dec in last 5 years
squared_p_Jan_Feb_5years	Square of average precipitation of Jan & Feb in last 5 years
squared_p_Mar_Aprl_5years	Square of average precipitation of March & April in last 5 years
tnd_pnd_5years	Interaction term (5 year Avg. of Nov & Dec temperature) * (5 years Avg. of Nov & Dec precipitation)
tjf_pjf_5years	Interaction term (5 years Avg. of Jan & Feb temperature) * (5 year Avg. of Jan & Feb precipitation)
tma_pma_5years	Interaction term (5 years Avg. of March & April temperature) * (5 year Avg. of March & April precipitation)
S-i	i^{th} Adaptation Strategy (S-i) as defined above
operational_area	Size of the farm operated by the farm (acres)—[(area owned) – (area rented or shared out) + (area rented in or shared in)]
wheat_area	Area under wheat crop at a farm (acres)
Loan	Dummy equals 1 if the farm household availed formal credit, and zero otherwise
ext_only_gov	Dummy =1 if extension department is the only source of technical information available to the farm household and zero otherwise
ext_only_media	Dummy =1 if electronic/print media is the only source of technical information available to the farm household and zero otherwise
ext_other	Dummy =1 if the source of technical information available to the farm household is other than above mentioned sources and zero otherwise
non_farm_income_dummy	Dummy=1 if the farm household has income from non-farm activities and zero otherwise

III. ESTIMATION AND DISCUSSION OF RESULTS

The Treatment Effect Model is estimated to explore the impact of adaptation to climate change on net revenues per acre generated by Pakistani farmers through wheat production. The dependent variable in the outcome equation is net revenue gained from wheat production while the explanatory variables include age and education of household head, wheat acreage, cropping systems dummies, tenancy status dummies, soil fertility, and norms of climatic variables (five years' averages) as well as deviations of current year's weather conditions (temperature and precipitation) from respective norms for periods (months) covering various phenological stages of wheat–germination/tillering stage (November-December), vegetative growth/flowering stage (January-

February), and grain formation/maturing stage (March-April). The squared terms of climatic factors (temperature and precipitation) as well as interaction terms are also included among the explanatory variables in order to check for the non-linearity of relationship between net revenue and climatic factors and to account for joint effect of the climatic factors. The treatment variable is a binary variable representing that whether a particular strategy out of possible total of 15 mutually exclusive adaptation strategies was adopted by the farming household or not. The explanatory variables used in the treatment equation included wheat area, operational area, education, tenancy status, access to extension sources, and non-farm income. Regression equations for all the possible (15) adaptation strategies are estimated using the two step Treatment Effect Model.

Out of these fifteen combinations, only six combinations (S-1, S-2, S-3, S-12, S-124, and S-134) are found to have significant impact. Hence, these six strategies have been used to describe the results and to find the impact of adaptation of respective strategies on net revenue of wheat growers. For the convenience of the reader, direction (positive or negative) of the impact and significance of the coefficients of relevant variables are presented by using "+" or "-" symbol in the following table whereas the detailed results have been reported in Appendixes 1a, 1b, 2a, and 2b.

The results from Treatment Effect Model suggest that all the six estimated models are fitted good as indicated by Wald chi-square statistics which are highly significant in all equations (see Appendix-1b and Appendix-2b). Evidence is suggestive that adaptation strategies namely varietal change (S-1), delayed sowing (S-2), and input intensification (S-3) have a significant positive impact on net revenues when adopted in isolation (Table-3 and Appendixes 1a through 2b). Interestingly, these strategies when implanted as part of a portfolio combining all the three adaptation strategies (S-123) resulted in an insignificant impact on net revenues. The adaptation strategies S-1 and S-2 when implemented jointly as a part of the adaptation package (S-12) though results in a significant positive impact but generates lower net revenues as compared to that if either of the adaptations is implemented in isolation. Similarly, soil and water conservation (S-4) do not impact net revenues significantly when adopted in isolation, however, when implemented as a part of a portfolio adaptation strategy (S-124), yielded the highest returns in terms of increased net revenue. The same adaptation (S-4) when implemented in combination with S-1 and S-3 i.e. implementation of portfolio adaptation strategy (S134) resulted in significant negative effect on net revenues of the wheat growers who adopted them. We found that delayed sowing has positive impact when it is implemented in isolation or implemented as part of the package adaptation (as in S-12 and S-124). The net productivity gains from portfolio adaptation strategies were found conditional on delayed sowing. Interestingly, research and extension are continuing to recommend completion of wheat sowing by 20th November.

Table 3

The Direction and Significance of Various Variables Included in Out-come Equations

Dependent Variable: Net Revenue (PKR/acre)

	Strategies					
Independent Variables	S-1	S-2	S-3	S-12	S-124	S-134
Education (schooling years)	+	+	+	+	++	++
Age (years)						
Wheat Area (acres)						
Cotton-wheat Zone (dummy)	+++	+++	+++	+++	+++	+++
Rice-wheat Zone (dummy)	+++	+++	+++	+++	+++	+++
Mixed-Zone (dummy)	+++	+++	+++	+++	+++	+++
Owner Farmer (dummy)	- - -	- - -	- - -	- -	- - -	- - -
Owner-cum-tenant (dummy)						
Fertile Land (proportion of holding)	+++	++	+++	++	+++	++
Average Land (proportion of holding)						
Nov-Dec Temperature (5 years mean of Avg.)	-	-	-	-	-	-
Jan- Feb Temperature (5 year means of Avg.)		+	+			
Mar- Apr Temperature (5 year means of Avg.)						
Nov-Dec Precipitation (5 year means of Avg.)						
Jan-Feb Precipitation (5 year means of Avg.)						
Mar -Apr Precipitation (5 year means of Avg.)	++	++	++	++	++	++
Nov-Dec Temperature Deviation (from 5 years mean)						
Jan-Feb Temperature Deviation (from 5 years mean)	- -	- -	- -	- -	- -	- -
Mar. Apr. Temperature Deviation (from 5 years mean)						
Nov-Dec Precipitation Deviation (from 5 years mean)						
Jan. Feb Precipitation Deviation (from 5 years mean)						
Mar-Apr Precipitation Deviation (from 5 years mean)	+++	+++	+++	+++	+++	+++
Squared Temperature Nov-Dec (5 years mean)	++	++	++	++	++	++
Squared Temperature Jan-Feb (5 years mean)		-	-			
Squared Temperature Mar- Apr (5 years mean)				-	-	-
Squared Precipitation Nov- Dec (5 years mean)	++	++	++	++	++	++
Squared Precipitation Jan- Feb (5 years mean)						
Squared Precipitation Mar- Apr (5 years mean)	- - -	- - -	- - -	- - -	- - -	- - -
Nov-Dec Temp * Nov Dec Precipitation	- -	- -	- -	- -	- -	- -
Jan-Feb Temp* Jan-Feb Precipitation						
Mar-Apr Temp * Mar -Apr Precipitation	++	++	++	++	++	++
Strategy	+	+	++	+	++	-
Additional Net Revenue/Acre (000 Rs.)	13.1	17.1	17.6	12.2	22.1	-10.8
Treatment equation	**S-1**	**S-2**	**S-3**	**S-12**	**S-124**	**S-134**
operational area (acres)					++	- -
wheat area (acres)					-	+++
good fertility (proportion of holding)		++	- -	+++		
farming experience (years)				- -		
education (Years)			- -			
loan (dummy)	++					
tenant (dummy)				+++		++
owner-cum-tenant (dummy)	- -	-			+	
extension government (dummy)					+	-
extension media (dummy)	+	+	+++			
extension other (dummy)	+++		+++	++		- - -
non-farm income (dummy)	+++	- -	+			

Note: +++, ++, + denote positive impact significant at 1 percent, 5 percent, and 10 percent respectively; - - -, - -, - denote negative impact significant at 1 percent, 5 percent, and 10 percent respectively; and blank cells indicate insignificant effect

Among the other explanatory variables in the outcome equations; education of the household head, farm location (Zone dummy), soil fertility as well as norms of January-February temperature and March-April precipitation have significant positive impact on net revenues. The norm of temperature during November-December (germination/tillering stage) and deviation of temperature from the norm during January-February (vegetative growth/flowering) are found to be affecting the net revenues negatively and significantly. The results are suggestive that the climatic variables have non-linear impact on net revenues. The norms of climatic variables (temperature and precipitation) during March-April have significant positive joint impact on net revenues. The owner farmers were found generating lower net revenues as compared to pure tenant operators. The farms in cropping systems other than Barani and Partial-Barani cropping system are generating higher net returns from production of wheat.

Empirical results suggest that wheat area and operational areas are found significantly affecting the likelihood of implementing portfolio adaptation strategies. Those farmers who have higher wheat acreage are more likely to implement portfolio adaptation strategy (S-134) whereas farmers cultivating larger operational area are more likely to adopt adaptation strategy S-124 and less likely to implement S-134. Further, those farmers who have good fertile land are more likely to adopt delayed sowing as isolated adaptation strategy as well as in portfolio adaptation strategy comprising of varietal change and delayed sowing. However, farmers having higher proportion of fertile soils of operational farms are less likely to implement input intensification. Education and farming experience turned out to be less important determinants of adaptation as in most of the strategies these were found either statistically insignificant (mostly) or having negative impact (education in S-3 and farming experience in S-12). The access to loan is found significantly and positively affecting the probability to implement isolated adaptation strategy of varietal change (S-1).

Tenancy status is also found significantly affecting the likelihood of implementing portfolio adaptation strategies. Results show that tenants are more likely to adapt as compared to owner farmers whereas owner-cum-tenants are less likely to adapt the climate change. The government extension is found playing significant role in adoption of portfolio adaptation strategies while the electronic media and other sources are important determinants of adaptation of isolated adaptation strategies and media extensions are positively affecting the likelihood to adapt climate changes. Non-farm income is also found significantly affecting the likelihood to adapt climate changes (especially the isolated adaptations) however direction of the effect varies across these strategies.

IV. SUMMARY AND CONCLUSION

This research is based on Climate Change Impact Survey [CCIS (2013)] data regarding 3432 crop growers from 16 districts of Pakistan which represents major cropping systems of the country. The study identified four types of adaptation strategies adopted by the farmers and employed Treatment Effect Model (Heckman type) to analyse the impact of adaptations on net revenue per acre realised by the wheat growers. The results indicate that adaptation strategies namely varietal change, delayed sowing, and input intensification effect net revenues positively and significantly when adopted separately or implemented in combination with other strategies. The adoption of soil and water conservation strategy as an isolated option has insignificant effect on net revenues whereas it has significant positive results when used in portfolio adaptation along with varietal change and delayed sowing. Interestingly, when delayed sowing was missed in portfolio adaptation strategies it resulted in either insignificant results or in reduced net revenues from wheat production. Further, the evidence is found that norms of November-December temperature, March-April precipitation, and temperature deviations from the norm during January-February are important determinants of net revenue. The temperature (Nov-Dec) and its deviation (Jan-Feb) both have adverse impact on net revenues whereas the norm of precipitation in March-April affects net revenues positively and significantly. The results are also suggestive that relationship between long run norm of November-December temperature and net returns is non-linear. The results of selection equations support that fertility of land, farmer’s tenancy status, size of holding, non-farm income, and access to certain extension source are important determinants of selection of various adaptation strategies. The study suggests revisiting of recommendations regarding wheat sowing dates by agricultural research institutions. The encouragement of crop and livestock insurance especially in rain-fed regions as an adaptation strategy may prove a useful exercise.

APPENDIX-1a:

Outcome Equations (Strategies 1-3)
Dependent Variable: Net Revenue per Acre

	Strategy-1		Strategy-2		Strategy-3	
Variables	Coefficients	P>[Z]	Coefficients	P>[Z]	Coefficients	P>[Z]
Education	78.493	0.059	71.177	0.083	76.700	0.068
Age	6.352	0.661	8.474	0.557	7.782	0.590
wheat_area	-23.004	0.179	-24.457	0.151	-15.130	0.395
cotton_wheat_zone	3907.886	0.000	3811.198	0.000	3807.710	0.000
rice_wheat_zone	3280.778	0.000	3154.233	0.000	3204.656	0.000
mixed_zone	3886.479	0.000	3770.536	0.000	3792.446	0.000
owner_farmer	-1577.598	0.003	-1461.537	0.005	-1525.035	0.004
owner_cum_tenant	24.542	0.963	-16.038	0.975	-157.841	0.759
good_fertility	20.775	0.010	19.529	0.017	24.872	0.002
average_fertility	4.345	0.584	4.145	0.602	4.655	0.554
nov_dec_t_5year	-5090.299	0.070	-4877.449	0.083	-5085.375	0.069
jan_feb_t_5year	7276.341	0.120	7564.300	0.107	7567.773	0.105
mar_aprl_t_5year	3389.347	0.258	3458.174	0.249	3411.818	0.252
nov_dec_p_5year	-65.456	0.830	-72.185	0.813	-53.164	0.862
jan_feb_p_5year	211.560	0.672	255.749	0.610	254.849	0.609
mar_aprl_p_5year	2168.987	0.021	2050.731	0.030	2042.081	0.029
nov_dec_t_5year_deviation	179.320	0.770	232.867	0.704	179.298	0.771
jan_feb_t_5year_deviation	-2737.522	0.018	-2802.567	0.015	-2835.428	0.014
mar_aprl_t_5year_deviation	-476.337	0.712	-443.874	0.732	-305.864	0.813
nov_dec_p_5year_deviation	-336.684	0.159	-326.300	0.173	-317.277	0.184
jan_feb_p_5year_deviation	-124.888	0.345	-120.421	0.364	-111.313	0.397
mar_aprl_p_5year_deviation	2861.951	0.002	2749.317	0.003	2815.010	0.002
squared_t_nov_dec_5year	168.619	0.037	166.069	0.040	170.134	0.034
squared_t_jan_feb_5year	-214.589	0.123	-230.089	0.099	-224.553	0.105
squared_t_mar_aprl_5year	-84.147	0.117	-85.373	0.112	-85.266	0.111
squared_p_nov_dec_5year	3.943	0.027	4.029	0.024	4.038	0.023
squared_p_jan_feb_5year	2.056	0.357	1.949	0.384	2.175	0.328
squared_p_mar_aprl_5year	-3.384	0.001	-3.328	0.001	-3.330	0.001
tnd_pnd_5year	-40.614	0.052	-39.458	0.059	-40.387	0.053
tjf_pjf_5year	-33.722	0.290	-37.177	0.244	-36.758	0.246
tma_pma_5year	29.443	0.017	29.573	0.017	31.809	0.010
only1	13133.480	0.073	17171.830	0.106	17595.560	0.054
_cons	-29534.690	0.412	-33555.960	0.352	-32094.060	0.368

Strategies:

S-1 Varietal Change S-2 Delayed Sowing S-3 Input Intensification
S-4 Soil & Water Conservation S-12 1 plus 2 S-124 1 plus 2 plus 4
S-134 1 plus 3 plus 4

APPENDIX-2b

Treatment Equations (Strategies in Combinations)

	Streategy-12			Streategy-124			Streategy-134	
Variables	Coefficients	P>[Z]	Variables	Coefficients	P>[Z]	Variables	Coefficients	P>[Z]
wheat_area	-0.010	0.315	wheat_area	-0.018	0.080	wheat_area	0.014	0.006
operational_area	0.007	0.123	operational_area	0.008	0.036	operational_area	-0.008	0.039
farm_exp	-0.009	0.038	farm_exp	-0.002	0.706	farm_exp	0.001	0.739
good_fertility	0.005	0.000	good_fertility	-0.002	0.185	good_fertility	-0.001	0.303
Education	-0.008	0.528	Education	-0.013	0.246	Education	0.007	0.214
Loan	0.070	0.393	Loan	-0.005	0.949	Loan	0.000	0.995
tenant_farmer	0.402	0.001	tenant_farmer	-0.097	0.488	tenant_farmer	0.136	0.048
owner_cum_tenant	-0.013	0.934	owner_cum_tenant	0.227	0.067	owner_cum_tenant	-0.111	0.131
ext_only_gov	-0.044	0.780	ext_only_gov	0.260	0.059	ext_only_gov	-0.135	0.066
ext_only_media	-0.002	0.989	ext_only_media	0.092	0.517	ext_only_media	-0.003	0.960
ext_other	0.309	0.024	ext_other	0.105	0.473	ext_other	-0.185	0.013
non_farn_income_dummy	-0.024	0.819	non_farn_income_dummy	0.087	0.393	non_farn_income_dummy	-0.037	0.488
_cons	-2.240	0.000	_cons	-1.947	0.000	_cons	-0.758	0.000
Lambda	-5281.987	0.099	Lambda	-9406.550	0.030	Lambda	6734.237	0.079
Rho	-0.533		Rho	-0.911		Rho	0.622	
Sigma	9911.900		Sigma	10330.784		Sigma	10826.094	
Wald Chi-square	182.22	0.000	Wald Chi-square	167.59	0.000	Wald Chi-square	168.78	0.000

Strategies:

S-1	Varietal Change	S-2	Delayed Sowing	S-3	Input Intensification
S-4	Soil & Water Conservation	S-12	1 plus 2	S-124	1 plus 2 plus 4
S-134	1 plus 3 plus 4				

APPENDIX-2a:

Outcome Equations (Strategies in Combinations)
Dependent Variable: Net Revenue per Acre

	Streategy-12		Streategy-124		Streategy-134	
Variables	Coefficients	P>[Z]	Coefficients	P>[Z]	Coefficients	P>[Z]
Education	76.791	0.066	90.041	0.041	91.598	0.051
Age	12.914	0.386	10.275	0.495	9.490	0.537
wheat_area	-21.912	0.203	-18.210	0.313	-5.583	0.797
cotton_wheat_zone	3806.378	0.000	3781.131	0.000	3733.370	0.000
rice_wheat_zone	3192.211	0.000	3257.911	0.000	3315.068	0.000
mixed_zone	3799.487	0.000	3790.943	0.000	3780.761	0.000
owner_farmer	-1096.598	0.056	-1600.370	0.004	-1904.923	0.002
owner_cum_tenant	-226.143	0.658	-593.109	0.287	-645.117	0.286
good_fertility	18.155	0.031	23.643	0.004	20.156	0.016
average_fertility	4.710	0.557	4.288	0.588	4.968	0.532
nov_dec_t_5year	-5060.318	0.074	-5042.099	0.076	-5233.550	0.064
jan_feb_t_5year	7425.961	0.117	7385.354	0.120	6804.929	0.151
mar_aprl_t_5year	3562.473	0.239	3624.812	0.233	3675.684	0.223
nov_dec_p_5year	-41.116	0.894	-0.401	0.999	-0.415	0.999
jan_feb_p_5year	201.048	0.690	194.947	0.698	119.083	0.813
mar_aprl_p_5year	2115.720	0.026	2088.419	0.028	2191.221	0.020
nov_dec_t_5year_deviation	189.673	0.758	192.572	0.755	202.416	0.743
jan_feb_t_5year_deviation	-2733.361	0.019	-2708.896	0.020	-2691.560	0.020
mar_aprl_t_5year_deviation	-507.448	0.696	-434.539	0.740	-465.336	0.719
nov_dec_p_5year_deviation	-333.945	0.166	-307.149	0.205	-334.504	0.164
jan_feb_p_5year_deviation	-130.314	0.329	-128.959	0.333	-114.678	0.387
mar_aprl_p_5year_deviation	2789.090	0.003	2775.251	0.003	2862.173	0.002
squared_t_nov_dec_5year	169.303	0.038	170.147	0.037	173.680	0.033
squared_t_jan_feb_5year	-219.011	0.119	-217.349	0.123	-198.148	0.159
squared_t_mar_aprl_5year	-89.373	0.099	-91.009	0.095	-90.454	0.094
squared_p_nov_dec_5year	3.943	0.028	3.972	0.027	3.775	0.035
squared_p_jan_feb_5year	2.089	0.354	2.179	0.333	2.421	0.278
squared_p_mar_aprl_5year	-3.474	0.001	-3.541	0.001	-3.538	0.001
tnd_pnd_5year	-42.745	0.042	-44.191	0.036	-45.589	0.030
tjf_pjf_5year	-34.969	0.276	-35.009	0.276	-28.227	0.379
tma_pma_5year	29.381	0.018	30.025	0.016	29.315	0.018
only1	12217.260	0.096	22148.890	0.031	-10799.910	0.104
_cons	-32209.950	0.375	-32814.400	0.367	-25308.980	0.485

Strategies:

S-1 Varietal Change   S-2 Delayed Sowing   S-3 Input Intensification
S-4 Soil & Water Conservation   S-12 1 plus 2   S-124 1 plus 2 plus 4
S-134 1 plus 3 plus 4

APPENDIX-1b:

Treatment Equations (Strategies 1-3)

Variables	Streategy-1 Coefficients	Streategy-1 P>[Z]	Variables	Streategy-2 Coefficients	Streategy-2 P>[Z]	Variables	Streategy-3 Coefficients	Streategy-3 P>[Z]
wheat_area	0.003	0.402	operational_area	0.003	0.441	wheat_area	-0.027	0.047
good_fertility	0.001	0.241	good_fertility	0.003	0.015	good_fertility	-0.003	0.025
Education	-0.016	0.157	Education	-0.001	0.955	Education	-0.006	0.579
Loan	0.177	0.027	Loan	0.041	0.669	Loan	0.077	0.343
tenant_farmer	-0.137	0.287	tenant_farmer	0.103	0.475	tenant_farmer	-0.012	0.921
owner_cum_tenant	-0.435	0.016	owner_cum_tenant	-0.411	0.064	owner_cum_tenant	-0.029	0.842
ext_only_gov	0.145	0.382	ext_only_gov	-0.153	0.461	ext_only_gov	0.187	0.260
ext_only_media	0.269	0.072	ext_only_media	0.305	0.057	ext_only_media	0.401	0.006
ext_other	0.495	0.001	ext_other	0.196	0.258	ext_other	0.449	0.003
non_farn_income_dummy	0.274	0.009	non_farn_income_dummy	-0.305	0.017	non_farn_income_dummy	0.190	0.065
_cons	-2.596	0.000	_cons	-2.372	0.000	_cons	-2.215	0.000
Lambda	-4959.675	0.117	Lambda	-5942.724	0.165	Lambda	-7149.768	0.069
Rho	-0.502		Rho	-0.602		Rho	-0.711	
Sigma	9872.418		Sigma	9871.070		Sigma	10059.274	
Wald Chi-square	173.5	0.000	Wald Chi-square	171.92	0.000	Wald Chi-square	174.66	0.000

Strategies:

S-1 Varietal Change S-2 Delayed Sowing S-3 Input Intensification S-4 Soil & Water Conservation S-12 1 plus 2
S-124 1 plus 2 plus 4 S-134 1 plus 3 plus 4

REFERENCES

Adger, W. N. (2010) Social Capital, Collective Action, and Adaptation to Climate Change. In *Der Klimawandel* (pp. 327-345). VS Verlag für Sozialwissenschaften.

Ahmad, M., G. Mustafa, and M. Iqbal (2015) Impact of Farm Households' Adaptations to Climate Change on Food Security: Evidence from Different Agro-ecologies of Pakistan. (Final Draft Report of PIDE-IDRC Project).

Ahmad, M., H. Siftain, and M. Iqbal (2014a) Impact of Climate Change on Wheat Productivity in Pakistan: A District Level Analysis. Pakistan Institute of Development Economics, Islamabad. (Climate Change Working Paper Series No. 1).

Ahmad, M., M. Nawaz, M. Iqbal, and S. A. Javed (2014b) Analysing the Impact of Climate Change on Rice Productivity in Pakistan. Pakistan Institute of Development Economics, Islamabad. (Climate Change Working Paper Series No. 2).

Benson, C. and E. Clay (1998) The Impact of Drought on Sub-Saharan African Economies. Washington DC World Bank. (World Bank Technical Paper No. 401).

Chipanshi, A. C., R. Chanda, and O. Totolo (2003) Vulnerability Assessment of the Maize and Sorghum Crops to Climate Change in Botswana. *Climatic Change* 61:3, 339–360.

Deressa (2007) Measuring the Economic Impact of Climate Change on Ethiopian Agriculture: Ricardian Approach. Washington D.C., World Bank. (World Bank Policy Paper Number 4342).

Deressa, T., R. Hassen, T. Alemu, M. Yesuf, and C. Ringler (2008) Analysing the Determinants of Farmers' Choice of Adaptation Measures and Perceptions of Climate Change in the Nile Basin of Ethiopia. International Food Policy Research Institute (IFPRI), Washington, DC: IFPRI. (Discussion Paper No. 00798).

Di Falco, S., F. Adinolfi, M. Bozzola, and F. Capitanio (2014) Crop Insurance as a Strategy for Adapting to Climate Change. *Journal of Agricultural Economics* 65:2, 485–504.

Di Falco, S., M. Veronesi, and M. Yesuf (2011) Does Adaptation to Climate Change Provide Food Security? A Micro-perspective from Ethiopia. *American Journal of Agricultural Economics* 93:3, 829–846.

Di Falco, S. and M. Veronesi (2013) How can African Agriculture Adapt to Climate Change? A Counterfactual Analysis from Ethiopia. *Land Economics* 89:4, 743–766.

Downing, T. (1992) Climate Change and Vulnerable Places: Global Food Security and Country Studies in Zimbabwe, Kenya, Senegal and Chile. Environmental Change Unit, University of Oxford. (Research Report No. 1).

Pakistan, Government of (2014) *Pakistan Economic Survey 2013-14*. Islamabad: Economic Advisor's Wing, Finance Division.

Greene, W. H. and D. A. Hensher (2003) A Latent Class Model for Discrete Choice Analysis: Contrasts with Mixed Logit. *Transportation Research Part B: Methodological* 37:8, 681–698.

Heckman, J. J. (1979) Sample Selection Bias as a Specification Error. *Econometrica: Journal of the Econometric Society*, 153–161.

Heckman, J. J. (1976) The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for such Models. *Annals of Economic and Social Measurement* 5:4, 475–492. NBER.

Howden, S. M., J. F. Soussana, F. N. Tubiello, N. Chhetri, M. Dunlop, and H. Meinke (2007) Adapting Agriculture to Climate Change. *Proceedings of the National Academy of Sciences* 104:50, 19691–19696.

Intergovernmental Panel on Climate Change (IPCC) (2007) Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom.

Iqbal, M., G. M. Arif, and M. Arshad Khan (2009) Climate-change Aspersions on Food Security of Pakistan. *Science Vision* 15:1.

McCarthy, J. J. (Ed.) (2001) *Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Reidsma, P., F. Ewert, A. O. Lansink, and R. Leemans (2010) Adaptation to Climate Change and Climate Variability in European Agriculture: the Importance of Farm Level Responses. *European Journal of Agronomy* 32:1, 91–102.

Rosenzweig, C. and F. N. Tubiello (2007) Adaptation and Mitigation Strategies in Agriculture: An Analysis of Potential Synergies. *Mitigation and Adaptation Strategies for Global Change* 12:5, 855–873.

Sivakumar, M. V. and R. Stefanski (2011) Climate Change in South Asia. In *Climate Change and Food Security in South Asia* (pp. 13-30). Springer Netherlands.

Smith, V. K. and J. C. Huang (1995) Can Markets Value Air Quality? A Meta-analysis of Hedonic Property Value Models. *Journal of Political Economy*, 209–227.

Spijkers, M. A. (2011) Implications of Climate Change on Agriculture and Food Security in South Asia. In *Climate Change and Food Security in South Asia* (pp. 217-227). Springer Netherlands.

Vergara, W. (2005) Adapting to Climate Change. Latin America and Caribbean Region Sustainable Development Working Paper, 25.

Yesuf, M., S. Di Falco, T. Deressa, C. Ringler, and G. Kohlin (2008) *The Impact of Climate Change and Adaptation on Food Production in Low-income Countries: Evidence from the Nile Basin, Ethiopia*. International Food Policy Research Institute.

This series of papers is an outcome of a joint research project of PIDE and IDRC. Transnational financing of developmental projects by donor agencies has emerged to be a notable phenomenon around the globe. Amongst others, International Development and Research Centre (IDRC) Canada remains one of the leading agencies providing funds for multifaceted developmental projects being implemented in developing countries. The project **"*Climate Change Agriculture and Food Security in Pakistan: Adaptation Options and Strategies*"** is one such an endeavor of PIDE and IDRC. Broadly speaking, the project aims at exploring responses of crop yields to changing climate and analyzing the adaptation efforts undertaken by farmers. The issue of climate change bears a special importance for Pakistan's economy being heavily dependent on agriculture sector both in terms of its contribution to GDP and employment. This project involves two strands of empirical undertakings: i) studies based on districts-level panel; and ii) studies based on Rapid Rural Appraisal (RRA) and household level survey data. The outcomes of the studies based on panel and cross-sectional data are being reported in working paper series of the project whereas findings of RRA have been published as a policy brief. However, for information of readers, the salient upshots of RRA are summarized in the following.

The evidence from RRA is suggestive that the farming communities in various regions of Pakistan widely perceive that climate is changing and is adapting accordingly through undertaking a wide range of adaptation strategies. Some of the adaptations in rainfed areas include use of deep tillage for rainwater harvesting and preserving moisture, building of small check dams, shifting away from shallow rooted to deep rooted crops, and delayed sowing of wheat and mustard by 15-30 days etc. While adaptations in irrigated agriculture include, in major, increased installation of tube-wells, increased area under low-delta/low-input requiring crops like canola and mustard as alternative to wheat in water scarce areas and substitution of other crop (guar seed and cotton crops being replaced with mungbean in low intensity zone), delayed wheat sowing by 15-21 days, and sowing of cotton on ridges to manage water scarcity etc.

Surprisingly, however, notwithstanding the changing climate, the research institutions and extension department still keep recommending completion of wheat sowing by 20th of November irrespective of regional climate variations. The sowing of rice nursery before 20th of May is prohibited according to the Punjab Agricultural Pest Ordinance, 1959 in order to control multiplication of harmful pests on early sown rice nurseries. Further, canal closure schedules do not match with the adaptation needs of farmers confronting climate changes (especially wheat in Punjab and rice in Sindh. The farmers have an urgent need of support from agricultural research and extension as well as other government departments to enhance their adaptive capacities.

Climate Change Working Paper Series No. 5

Pakistan Institute of Development Economics
Spirit of Free Inquiry
1957
Islamabad

IDRC | CRDI
International Development Research Centre
Centre de recherches pour le développement international