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CLIMATE CHANGE, FARMERS' ADAPTATION CAPACITY AND CROPS PRODUCTION: A DISAGGREGATED MICRO-LEVEL STUDY FROM SOUTHERN PUNJAB, PAKISTAN

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ABSTRACT

The present study aims at providing insights, based on disaggregated micro-level surveyed data, about the climate resilient crop production strategies available for small, medium and big landholder farmers by investigating a number of micro-level factors – ranging from socio-economic to demographic – that assess the farmers' capability for the adaptation of climate change strategies. This research study gradually maintains three contemplation in the analysis: primarily; the study focuses on the nexus between climate change and crops production, Secondly; study estimates the impact of climate change adaptation strategies on crops production, Thirdly, the novelty of the study lies in putting forward the economic, social and demographic factors which envisages that how the farmers can enhance their capacity to become more effective in adapting the strategies. Our conclusive findings suggest that, for the farmers producing crops at small scale, the farmers' health and medical treatment, education level, gender, marital status, land ownership, and access to market are the significant factors augment farmers' adaption capacity to climate change, while for the farmers producing crops at a significantly lagers scale, their experience does matter. The study would be helpful in suggesting prudent policy on agriculture crops production that on which grounds the different farmers, who have some different level of crop production and farm size, can be provided opportunities to limit the devastating effects of climate change in Pakistan.

1. INTRODUCTION

Adequate supply of food and its production is essential for human survival. Procedure of food production entails resources either natural or artificial e.g., labor, capital and entrepreneurship largely influenced by human (Olayide and Heady, 1982; Oyekale, Bolaji and Olowa, 2009)]. Natural resources, on the other hand, are comprised of all materials endowed by the nature i.e., land, water, sunshine, air and temperature. Amongst natural resources, climate is a key factor influences food production (Oyekale et al., 2009). Recent estimates showed that, by the year 2080, food demand would be increased by around 300%, whereas agricultural output in developing countries is expected to decline by 20 percent due to climate change, while output in industrial countries is expected to decrease by 6 percent [Food and Agriculture Organization (FAO, 2017)]. Therefore, climate transformation is considered responsible for limiting economic expansion in developing countries, especially those largely depending on agriculture, comprise a considerable share of agriculture sector in their GDP composition (Rosegrant et al. 2008).

Important factors responsible for global warming, climate change and for exhaustion of ozone layer are the anthropogenic factors, the recent studies have observed. Such factors are caused from urbanization, population explosion, deforestation, industrialization and the release of greenhouse gases (Buba, 2004: Odjugo, 2007). Intensification of these factors formed a greenhouse effect that has changed ultimately the precipitation level, and global temperature patterns, effecting crop production badly as a consequence (IPCC, 2007). Adaptation strategies against such rampant climate changes, yet low in practice in developing countries, are indispensable to encounter the growing nourishment demand of today (Rosegrant et al. 2008). Changing designs of cultivation practices, mechanization process and land use has transpired the fact climate variation needs some urgent measures to address it. But in Pakistan, farmers have a low capacity to adapt against climate changes. After providing a brief introduction in Section 1, a comprehensive review is given in Section 2. Data and methodology is given in Section 3. Profile of climate change adaptation strategies, farmers' socio-economic status, and crop production in Pakistan, is presented in section 4. Results and their interpretations are made in section 5, while the Section 6 concludes.

2. LITERATURE REVIEW

The recent literature has earned a lot of entice, making a healthy endeavor to represent the relationship of climate change and agriculture sector productivity. Increasing amount of carbon emissions, the foremost contributor to the greenhouse effect, seems to be provoking this problem. Rampant evidences found diffident factors that affect climate and global agriculture production. Studies observed that hunger people ratio increase from 40 million to 300 million due to direct result of carbon dioxide (Reilly, 1995). Climate shocks effect on one country varies from global world. Intensification to uncertainty like temperature variability with adverse expectation has changed production level in tropical and northern areas (Gupta, 2005). Variations in frequency, duration and intensity of extreme events refer to increase in temperature, precipitation and rise in sea level caused to damage agriculture production, water resources and health. It is also asserted that the developed countries remained less affected as compare to developing countries Paavola and Adger, 2006; Mendelsohnset et al., 2006; Kumar, 2007; Parynaka, 2009; Verge` et al., 2007. Lioubimtseva and Henebry (2009) analyzed the influence of climate change and adaptation on agriculture of central Asia and adaptation. Vulnerability to extreme shocks created a link between society and environment. Study also found that central Asian countries face more vulnerability due to its geographical location. Vulnerability and adaptation to extreme events explained as a multidimensional task [Raman et al. (2011); Gornallet al. (2010)].

In case of Pakistan, Hussain and Mudasser (2007), and Ashley et al. (2009) traced the impact of climate change on wheat production in mountain areas of Pakistan through econometric analysis. Study examined the impact of climate shocks Swat and Chitral district and found an increase in temperature effect on growing degree stages and growing degree season length. Rise in temperature from 1.50c to 30c has adversely effected on wheat crop and caused by 7 to 24% decline agriculture production. It also quantified increase in precipitation from 5 to 15 % in growing season also harmfully influence on wheat production. Other studies, for Pakistan, focused on climate change and its economic impact on agriculture is analyzed by Janhua et al. (2013) explored (Asif et al., 2013); Ahmad and Schmitz (2011), accessed Pakistan is facing climate sensitive's effect, such as a rise in temperature and reduction in rain fall pattern adversely affected crops in addition to the cause of disappearing glaciers. Findings also shown food shortfall and lower agriculture production is caused by non-supporting weather conditions. Studies also highlighted the negative influence of climate variability on crop production i.e., wheat and rice production that has adversely effected from climate change in Pakistan. The brief review of the prior studies expressed an understanding of weaknesses and strengths of the previous international and national research work related to climate change, adaptation and agriculture yield. It exposed the facts that bad climate outcomes like the negative effect of the different types of climate changes has different mechanization to leave impact on agriculture productivity—which require accordingly different adaptation techniques to cope with that climatic issues, closely related with farmers' socio-economic, political and demographic factors.

3. DATA, MODELS AND METHODOLOGY

The main purpose of the study is to determine the impact of climate change, adaptation strategies, and the socio-economic status of the farmers on average crop production. For this sake, this section provides data sources, sampling techniques, theoretical and the empirical model sued in the study.

3.1 Data

The present study uses primary resources of the data. Data are taken from a field survey of selected districts (Multan, Bahawalpur, and D.G. Khan Districts) of South Punjab, Pakistan, detailed in Table 1. Sample is chosen from each Tehsil of different districts of Southern Punjab, Pakistan. The study has collected data from 1000 males and females farmers of age group (15 – 65) years.

3.2 Empirical methodology

The present study uses is based on primary data, where the dependent variable is dichotomous as well as a continuous variable. Therefore, following Hafeez and Ahmad (2007); Fredous and Altomous (1985), this study uses Logit model and Multinomial Logit model for the estimations.

3.2.1 Binomial logit model

A binomial logistic regression, also referred as logistic regression, predicts the possibility that an indicator lies into one of two groups of a dichotomous dependent variable depend on one or more explanatory variables that might be continuous or categorical (discrete).

Let, $z= \alpha_1+ \alpha_2 y2+\alpha_3 y3+\alpha_4 y4+\text{--------}+\alpha_n yn+\mu i$ ……..(1)

Where,

$$z = \sum yi\alpha_j + \mu i \text{……..……(2)}$$

Where, $z_i = \sum yi\alpha i + \mu i > 0 \quad if\ z_i = 1$
$z_i = \sum yi\alpha i + \mu i < 0 \quad if\ z_i = 0$

3.3 Multinomial logit model

Multinomial logistic regression calculates approximate relationship between a set of estimators and a multi-category dependent variable. Suppose that K is the total categories of the variable, indexed by the subscript k. The equation of the model can be written down in an expression of the logit:

$$ln\left(\frac{\pi_k}{\pi_k}\right) = \delta_k + \beta_k y \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

The k-subscript on both sides of the equation the intercept, δ_k, and slope, βk, specify that there are a slope and an intercept for the assessment of every group to the reference group.

The estimated probabilities can be calculated from the model constraint for the precise value of y. For the standard logistic regression, we applied the logistic adaption to obtain the probability through the LCDF (logistic cumulative distribution function) for a simple logistic regression with one estimator:

$$\pi = \frac{1}{1+e^{\delta+\beta y}+} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

A particular value of y and the model approximate of δ and β and using the exponential function, the valuation of the predicted probability can be calculated for the specific value of y. To estimate this model researcher use the multinomial logit model and probability for this model is given below

$$Prob\ (Y_{i\,=}\ j) = \frac{e^{\beta_j x_i}}{1+\sum_{k-1}^{j} e^{\beta_k^1 x_i}}$$

$$Prob\ (Y_{=}0) = \frac{1}{1+\sum_{k-1}^{j} e^{\beta_k^1 x_i}} \quad ; \quad for\ \ j= 1,2,3 \text{ and } 4\ldots.$$

By using model, we now can estimate average production of different crops in the agriculture sector affected by climate change, and socio-economic status of farmers.

3.4 Definition and description of variables

The study uses a number of variables, categorical as well as continuous, for our analysis, described in the following table in detail, along with their abbreviations.

Table 1. Definition and Description of Variables

Variables/ (Short Notation)	Categories	Description
AVERAGE PRODUCTION(AVPRO)	<800kg	=1 if production < 800 kg otherwise 0
	8001-1200kg	=2 if production level is between 8001kg to 1200kg
	1201-1600mn	=1 if production level is between 1201 kg to 1600kg
	1601-2000kg	=3 if production level is between 1601kg to 2000kg
	>20000kg	=4 if production level is greater than 2000kg
INCOME(INCOME)		Total monthly income of an individual
EDUCATION(EDUCT)		Education in completed years
AGE(AGE)		Total age in years
HOUSEHOLD SIZE(HSIZE)		Total No. of persons in a household
NO. OF FARMING (NFARM)		A total number of persons involved in farming activities in a household.
VISIT TO FIELD(VFIELD)		Total visits to the field in a cropping season.
FARM SIZE(FSIZE)	<10	=1 if holding the size of a farm is <10 acres otherwise 0
	20-30	=1 if holding the size of a farm is 10-20 acres otherwise 0
	21-30	=1 if holding the size of a farm is 21-30 acres otherwise 0
	31-40	=1 if holding the size of a farm is 31-40acres otherwise 0
	>40	=1 if holding the size of a farm is >40acres otherwise 0
MARITAL STATUS(MSTAT)	Unmarried Married	Married=1 if a person is married otherwise 0

GENDER(GEND)	Female Male	=1 if individual is male otherwise 0
OWNERSHIP STATUS(OWNSTS)	Self-owned Tenant	=1if Land is self –owned otherwise 0
CREDIT FACILITY (CRDTF)	Availed Not availed	=1 if credit facility is present otherwise 0
INSURANCE (INSUR)	Availed Not availed	=1 if insurance facility is present otherwise 0
HEALTH CARE (HCARE)	Availed Not availed	=1 if health care facility is present otherwise 0
MEDICAL CURE (MCURE)	Public	=1 if medical care facility is provided by the public sector Otherwise 0
	Private	=2 if medical care facility is provided by the public sector Otherwise 0
	Self- modern	=3 if medical care facility is provided by the public sector Otherwise 0
	Self-traditional	=4 if medical care facility is provided by the public sector Otherwise 0
CLIMATE CHANGE AWARENESS(CCAWR)	Aware Not aware	=1 if an individual has climate change awareness otherwise 0
CLIMATE CHANGE DUE TO TEMPERATURE(CCTEMP)	High temperature Low temperature	=1 if climate change is due to high temperature otherwise 0
CLIMATE CHANGE DUE TO RAIN (CCRAIN)	Increase rainfall Decrease rainfall Delayed rainfall	=1 if climate change is due to increase rainfall otherwise 0 =2 if climate change is due to decrease rainfall otherwise 0 =3 if climate change is due to delayed rainfall otherwise 0
CLIMATE CHANGE DUE TO CO2(CCCO2)	Yes No	=1 if climate change is due to co2 otherwise 0
HUMIDITY(HUMDT)	Less High No role	=2 if climate change is due to less humidity otherwise 0 =2 if climate change is due to high humidity otherwise 0 =3 if no climate change is due to humidity otherwise 0
MULTI CROPPING(MULTCRO)	Utilized Not Utilized	=1 if multi-cropping is an adaptation strategy otherwise 0
FRAGMENTATION(FRAGM)	Utilized Not Utilized	=1 if fragmentation is adaptation strategy otherwise 0
MULTIPLANTING(MULTPLN)	Utilized Not Utilized	=1 if multi-planting is adaptation strategy otherwise 0
CROP DIVERSIFICATION(CRODIVR)	Utilized Not Utilized	=1 if crop diversification is an adaptation strategy otherwise 0
FERTILIZER APPLICATION(FERTAPP)	Utilized Not Utilized	=1 if an individual is applying fertilizer otherwise 0
ORGANIC CROPPING(ORGCRO)	Utilized Not Utilized	=1 if organic crop is an adaptation strategy otherwise 0
TREE PLANTING(TREEPL)	Utilized Not Utilized	=1 if tree planting is an adaptation strategy otherwise 0
COVERING CROPS(COVCRO)	Utilized Not Utilized	=1 if multi-cropping is an adaptation strategy otherwise 0
MARKET ACCESS (MKTACC)	Availability Not availability	=1 if an individual has market access otherwise 0

Source: Authors' illustration

3.5 The Models

After the specification of econometric models, this section presents operational model. Our study formulates a number of models, which analyze the impact of climate change on crop production with different perspective.

i) Climate Change and Crop Production

To analyze the impact of climate change on average crop production, following the study of Wratt et al. (2006), this study takes production function depending on labor and capital along with other climate change indicators. The econometric equation of the model is given as follows:

$$AVPROi = \alpha_0 + \alpha_1 INCOME + \alpha_2 NFARM + \alpha_3 FERTAPP + \alpha_4 CRDTF + \alpha_5 FSIZE + \alpha_6 CCTEMP + \alpha_7 CCRAIN \alpha_8 CCCO2 + \alpha_9 HUMDT + \alpha_{10} CCAWR + \varepsilon t$$

ii) Climate Adaptation and Crop Production

Following Challinor et al. (2007), to examine the impact of adaptation strategies on crop production, following model is constructed:

$$AVPROi = \beta_0 + \beta_1 INCOME + \beta_2 VFIELD + \beta_3 NFARM + \beta_4 CRDTF + \beta_5 FSIZE + \beta_6 MULTCRO + \beta_7 FRAGM + \beta_8 MULTPLN + \beta_9 CRODIVR + \beta_{10} ORGCRO + \beta_{11} TREEPL + \beta_{12} COVCRO + \epsilon$$

By using Principal Component Analysis (PCA), the study also constructed an 'Index for climate change adaptation strategies' to see the compact impact of the adaptation on crop production. The use of the constructed index will show the combined influence of all the variables/dimensions of the adaptation strategies.

$$AVPROi = \gamma_o + \gamma_1 INCOME + \gamma_2 VFIELD + \gamma_3 NFARM + \gamma_4 CRDTF + \gamma_5 FSIZE + \gamma_6 ADPINDX + \mu$$

iii) Farmers' Socio-Economic Status and Crop Production

The model is formulated to see the influence of socio-economic status on average crop production. The inclusion of socio-economic variables into the crop production models will help us understand that how crop production is influenced by the socioeconomic status of the farmers.

$$AVPROi = \delta_0 + \delta_1 NFARM + \delta_2 EDUCT + \delta_3 INCOME + \delta_4 AGE + \delta_5 FSIZE + \delta_6 GEND + \delta_7 MSTAT + \delta_8 OWNSTS + \delta_9 INSUR + \delta_{10} HCARE + \delta_{11} MCURE + \sigma$$

iv) Contemporaneous Effect of Climate Change and Adaptation on Crop Production

This model is formulated to examine the combined impact of climate change and adaptation strategies on crop production. This combine effect will help understand the extent to which adaptation strategies can make the farmers enable to cope with climate change. The specification of the model is given as under:

$$AVPROi = \delta_0 + \delta_1 INCOME + \delta_1 NFARM + \delta_2 CRDTF + \delta_3 FSIZE + \delta_4 CCTEMP + \delta_5 CCRAIN + \delta_6 CCCO2 + \delta_7 HUMDT + \delta_8 MULTCRO + \delta_9 FRAGM + \delta_{10} MULTPLN + \delta_{11} CRODIVR + \delta_{12} FERTAPP + \delta_{13} ORGCRO + \delta_{14} TREEPL + \delta_{15} COVCRO + \varphi$$

v) Contemporaneous Effect of Adaptation and Farmers' Socio-Economic Status on Crop Production

In order to examine that how the adaptation capacity can be affected by the socio-economic status of the farmers, this study also take socio-economic variables along with the adaption in the crop production equation. The specification of the model is given as:

$$AVPROi = \omega_o + \omega_1 NFARM + \omega_2 EDUCT + \omega_3 INCOME + \omega_4 AGE + \omega_5 FSIZE + \omega_6 CRDTF + \omega_7 GEND + \omega_8 MSTAT + \omega_9 OWNSTS + \omega_{10} INSUR + \omega_{12} HCARE + \omega_{13} MCURE + \omega_{14} CCAWR + \omega_{15} MULTCRO + \omega_{16} FRAGM + \omega_{17} MULTPLN + \omega_{18} CRODIVR + \omega_{19} ORGCRO + \omega_{20} TREEPL + \omega_{21} COVCRO + \tau$$

vi) Contemporaneous Effect of Adaptation, Farmers' Socio-Economic Status and Climate Change on Crop Production

The last model of our study will see comprehensively the impact of our all core variables, i.e., climate change, farmers' socio-economic status and adaptation strategies, on crop production. This comprehensive model will estimate that how much the adverse effect of climate change is reduced if socio-economic factors help enhance the adaption capacity of the farmers.

$$AVPROi = \theta_o + \theta_o INCOME + \theta_o EDUCT + \theta_o AGE + \theta_o HSIZE + \theta_o NFARM + \theta_o VFIELD + \theta_o FSIZE + \theta_o MSTAT + \theta_o GEND + \theta_o OWNSTS + \theta_o CREDF + \theta_o INSUR + \theta_o HCARE + \theta_o MCURE + \theta_o CCAWR + \theta_o CCTEMP + \theta_o CCRAIN + \theta_o CCCO2 + \theta_o HUMDT + \theta_o MULTCRO + \theta_o FRAGM + \theta_o MULTPLN + \theta_o CRODIVR + \theta_o FERTAPP + \theta_o ORGCRO + \theta_o TREEPL + \theta_o COVCRO + \theta_o MKTACC + \rho$$

4. CROPS, CLIMATE CHANGE AND ITS ADAPTATION, FARMER'S SOCIO-ECONOMIC STATUS: AN ELEMENTARY DATA ANALYSIS

4.1 Descriptive Analysis

Present section comprehensively represents the data, collected through the field survey from three districts of South Punjab (Pakistan), namely Multan, Bahawalpur, and D.G Khan District, from 100 respondents, aged between is between 16-65 years. Details of all the variables concerning farmer's socio-economic status, climate change, and adaptation strategies are illustrated separately. The respondent's average age is 42 years as presented in Table 2.

Table 2. Descriptive Statistics

Variables	Minimum value	Maximum value	Mean	Std. Deviation
AGE	17.00	65.00	42	11.48
EDU	.00	20.00	11	6.26
HSIZE	1.00	10.00	4	1.73
TMINC	4000.00	120000.00	39694	20852.27
NFARM	1.00	8.00	3	1.41474
VFIELD	1.00	90.00	33	19.80
FRTAPP	1.00	3.00	1.15	.369

Source: Authors' calculations

Educational status, is observed, that showed much variation in the educational status of the respondents. Maximum education is Ph.D., while there are illiterate individuals as well. The average education of respondents is 11 years of education. The household is maximum 10 members and 1 is minimum size of the household. The household is involved in farming has 4 members on average with a deviation of 1.73. Income level of the respondents demonstrates many variations as the data describe that from each level of income, the individuals are involved with the crop production. The range of income starts from a minimum of 4000 rupees and the maximum income is 120000 rupees per month. A household with an average income of 39694 rupees per month is involved with farming and the average monthly income has a deviation of 20852. Visits to the field in a cropping season are at least 1 and maximum visits to the field are 90 recorded during the field survey that depends upon the nature of the crops. The average number of visits to the field is 33 in a cropping season with the standard deviation 19.80. Fertilizer applications to crop in a carping season are used for one time at its minimum while the maximum number of fertilizer applications is 3 during a carping season. On average fertilizer is applied for 1 to 2 (1.15) times in cropping season with the standard deviation of 0.369.

5. RESULTS AND DISCUSSIONS

This section presents the estimates of crops production and climate change, adoption and farmers' socio-economic factors. Estimates are based on primary data collected, using Logit (Multi-nominal) Regression. The average crop production is taken as the dependent variable, which have different five categories. These categories can be elaborated as, average production (AVPRO) less than 800 kg, AVPRO (801-1200) kg, AVPRO (1201-1600) kg, AVPRO (1601-2000) kg and AVPRO more than 2000 kg, also taken as base category.

5.1 Estimates of Climate Change and Crop Production

The results, illustrated in Table 3, showed that climate change has a strong impact on the crop production, while the equation is controlled with control variables land, labor, and capital proxied with the farm size, and the number of individuals involved in farming activities, and credit facilities, respectively.

Table 3. Estimates of Climate Change and Crop Production[1]

Variables	AP < 800kg	AP(801-1200kg)	AP(201-1600kg)	AP(1601-2000kg)
Intercept	11.278[.000][2]	11.944 [.000]	14.914[.996]	68.951 [.976]
INCOME	.00001[.017]	.00009[.000]	.000012[.008]	.00003[.127]
NFARM	-.575[.005]	-.551[.005]	-.585[.004]	-.797[.005]
FERTAPP	1.445[.134]	1.674[.074]	1.391[.153]	1.699[.142]
CREDF	-3.381[.000]	-3.407[.000]	-3.366[.000]	-2.737[.004]
[FSIZE=1]	2.849[.023]	.369[.770]	.308[.808]	-39.082[.000]
[FSIZE=2]	10.548[.918]	6.989[.946]	7.179[.944]	-33.633[.749]
[FSIZE=3]	-2.084[.028]	-.596[.520]	-2.139[.022]	-41.552[.000]
[FSIZE=4]	.568[.000]	.705[.000]	3.179[.000]	-39.255[.000]
[CCTEMP=1]	.923[.416]	.488[.662]	-2.474[.999]	-19.319[.993]
[CCTEMP=2]	2.796[.000]	2.354[.000]	-.614[.999]	-17.964[.994]
[CCRAIN=1]	-.278[.852]	-.114[.937]	-.056[.970]	.130[.942]
[CCRAIN=2]	-2.229[.017]	-2.111[.020]	-2.205[.018]	-1.481[.205]
[CCCO2=1]	-2.680[.001]	-2.675[.001]	-2.731[.001]	-2.931[.003]
[HUMDT=1]	.543[.630]	.240[.828]	.395[.727]	.494[.712]
[HUMDT=2]	-1.832[.049]	-2.004[.027]	-1.902[.040]	-2.004[.076]
[CCAWR=1]	-1.448[.059]	-1.414[.058]	-1.579[.040]	-1.528[.099]

Source: Authors' calculations using SPSS.

The number of household in farming increase by 1 log of the odd ratio for average production less than 800 kg decreased by .575 kg relative to the reference category (AVPRO> 2000 kg) and concluded that regression coefficient for a number of the household has been found to be statistically significant for the AVPRO<800 kg. This research observed that fertilizer applied on the cultivated land increased by 1 log of the odd ratio for average production less than 800 kg will increase by 1.445 kg relative to referent category (AVPRO> 2000 kg) but observed to be statistically significant with probability 0.134 for the AVPRO<800 kg. The farmers' incomes grow cause to increase in production in the agriculture sector (Byerlee et al. 2009). The credit provided to farmers seems to be beneficial for the improvement in production, if credit provided to the farmer increase by 1, the log of the odd ratio for average production less than 800 kg will decrease by 3.381 kg relevant to the reference category (AVPRO> 2000 kg). This implies that the credit facilities to the small farmers which help them to cultivate more efficiently. Farmers are not benefited from the use of credit for the production of crops because of high cost of borrowing and low rate of return from the agriculture sector. These outcomes attributed with Hanumantha (1975) and Subbarao (1985) stated a positive and significant association among farm size and crop production and associated with higher fertilizer application and other cash-intensive inputs on large size of farms.

Either farm size (1-10) acres, (11-20)acres, or (31-40) acres increase in farm size by 1 log of the odd ratio for average production 801-1200 kg will increase by 0.369 kg, 6.969 kg, and 0.705 kg respectively comparatively with base category (AVPRO> 2000 kg) but originated to be statistically insignificant in response to the base category of AVPRO> 2000 kg. it implies that the relation between farm size and output per acres may be due to the consequence of other inputs employed by small farms rather than diseconomies of scale. Change in temperature will have positive effect for the average production 801-1200 kg relative to the base category but found to be statistically insignificant in regard to the AVPRO (801-1200) kg. The impact of increasing farm size while other variables are taken constant, the results showed that farm size (1-10) acres were a positive but insignificant predictor for AVPRO (1201-1600) kg in comparison with the base group. The farm size 21 to 30 acres, increase or decrease in farm size by 1 log of the odds ratio will change AVPRO (1201-1600) kg in the same direction and found to be a significant estimator for average production (1201-1600) kg against the referent category.

[1] Note: The base categories are used for the variables in various models are as follows:
credit facility not availed, farm size above 40 acre, gender=1, marital status=1, ownership status=2, insurance =2, health care=2, Medicare=4, climate change awareness=2, temperature=3, rain=3, co2=2, humidity=3, multicroping=2, fragmentation=2, Multiplanting=2, crop diversification=2, organic crop=2, tree planting =2, covering crops=2, market access are used as base categories.

[2] *[ ] shows the P-Value.*

5.2 Estimates of Adaptation Strategies and Crop Production

The results of adaptation strategies to climate change on crop production are provided in the following.

Table 4. Estimates of Adaptation Strategies and Crop Production

Variables	AP < 800kg	AP(801-1200kg)	AP(201-1600kg)	AP(1601-2000kg)
Intercept	10.643[.000]	10.979[.000]	10.450[.000]	50.009[-.000]
INCOME	.00001[.001]	.00008[.000]	.00001[.000]	.00012[.000]
VFIELD	.074[.000]	.075[.000]	.074[.000]	.060[.010]
NFARM	-.457[.011]	-.430[.012]	-.479[.008]	-.716[.003]
[CREDF=1]	-3.120[.000]	-3.147[.000]	-3.110[.000]	-2.744[.001]
[FSIZE=1]	4.076[.000]	1.601[.143]	1.466[.182]	-38.213[.000]
[FSIZE=2]	7.287[.944]	3.751[.971]	3.639[.972]	-36.676[.727]
[FSIZE=3]	-.979[.258]	.503[.549]	-1.107[.190]	-40.842[.000]
[FSIZE=4]	1.120[.000]	1.259[.000]	3.638[.000]	-38.983[.000]
[MULTCRO=1]	-1.606[.049]	-1.601[.043]	-1.453[.076]	-2.062[.028]
[FRAGM=1]	-3.345[.000]	-3.350[.000]	-3.499[.000]	-2.422[.004]
[MULTPLN=1]	3.293[.000]	3.302[.000]	3.299[.000]	2.504[.004]
[CROPDIVR=1]	-2.070[.010]	-1.958[.012]	-1.723[.033]	-1.397[.166]
[ORGCROP=1]	-.579[.559]	-.522[.590]	-.560[.573]	-.745[.507]
[TREEPL=1]	-.405[.677]	-.663[.478]	-.478[.624]	.531[.696]
[COVCRO=1]	-1,271[.195]	-1.115[.242]	-1.236[.211]	-2.642[.011]

Source: Authors' calculations using SPSS.

Results indicate that the choice of suitable crops, harvesting systems, and sowing season can be an essential adaptation plan to climatic change. Farmers assumed that multi-cropping are obtained to be meaningful strategies then increase in multi-cropping by 1 log of the odd ratio for AVPRO< 800 kg will decrease by 1.606 kg in response to the AVPRO> 2000 kg, but is found to be insignificant for AVPRO< 800 kg.

5.3 Estimates of Climate Change Adaptation Strategies Index and Crop Production

The study constructed an Index for climate change adaptation strategies' using Principal Component Analysis (PCA) technique, which involves multi cropping, Multi-plant, Crop Diversification, Organic Crop, and Tree Planting. It is observed that increase in index by 1 log of the odd ratio for AVPRO<800 kg AVPRO (801-1200) kg, AVPRO(1201-1600) kg, AVPRO(1601-2000) kg will decline by 0.540 kg , 0.558 kg, 0.447 kg, 0.532 kg respectively and found an insignificant predictor. This implied that farmers associated with agriculture sector are not well aware to utilize better adaptation technology.

Table 5. Estimates of Climate Change Adaptation Strategies Index and Crop Production

Variables	AP < 800kg	AP(801-1200kg)	AP(201-1600kg)	AP(1601-2000kg)
Intercept	5.976[.002]	6.324[.001]	6.139[.001]	44.671[.000]
INCOME	.00001[.004]	.000002[.002]	.000003[.001]	.000001[.057]
VFIELD	.082[.001]	.082[.001]	.082[.001]	.066[.022]
NFARM	-.589[.008]	-.560[.008]	-.613[.006]	-.810[.006]
AINDEX	-.540[.069]	-.558[.052]	-.447[.133]	-.532[.142]
[CREDF=1]	-3.288[.000]	-3.319[.000]	-3.286[.000]	-2.846[.006]
[FSIZE=1]	4.375[.007]	1.969[.222]	1.806[.264]	-37.759[.000]
[FSIZE=2]	10.147[.921]	6.687[.948]	6.621[.949]	-34.563[.741]
[FSIZE=3]	-.738[.527]	.804[.484]	-.833[.469]	-40.386[.000]
[FSIZE=4]	1.575[.000]	1.785[.000]	4.163[.000]	-38.368[.000]

Source: *Authors' calculations using SPSS.*

5.4 Estimates of Farmer's Socio-Economic Status and Crop Production

The results for influence of socio-economic status on average crop production are presented in Table 6. Socio-economic variables, which include education level, access to credit, Insurance to crops, etc. are lies their importance in order to examine the adaptation capacity of the farmers against the climatic change.

Table 6. Estimates of Farmer's Socio-Economic Status and Crop Production

Variables	AP < 800kg	AP(801-1200kg)	AP(201-1600kg)	AP(1601-2000kg)
Intercept	13.888[.001]	15.974[.000]	15.565[.000]	48.061[.000]
NFARM	-.462[.003]	-.488[.002]	-.478[.002]	-.698[.003]
EDUYEARS	.348[.000]	.333[.000]	.339[.000]	.411[.000]
INCOME	.000012[.018]	.00012[.008]	.00001[.011]	.00002[.131]
AGEYEARS	-.325[.088]	-390[.034]	-.404[.034]	-.157[.564]
AGESQUARE	.005[.028]	.005[.009]	.006[.010]	.003[.383]
[FSIZE=1]	.616[.388]	-1.783[.013]	-1.946[.008]	-41.524[.000]
[FSIZE=2]	1.785[.986]	-1.950[.985]	-1.787[.986]	-43.528[.678]
[FSIZE=3]	-4.268[.000]	-2.699[.000]	-4.323[.000]	-43.940[.000]
[FSIZE=4]	[.000]	-1.075[.000]	[.000]	-41.363[.000]
[CREDF=1]	-3.598[.000]	-3.597[.000]	-3.622[.000]	-2.988[.000]
[GEND=0]	.790[.336]	.655[.400]	.818[.313]	-.230[.855]
[MSTAT=0]	1.468[.142]	.966[.323]	1.153[.267]	2.301[.073]
[OWNSTS=1]	-2.398[.000]	-2.019[.000]	-2.249[.000]	-2.043[.004]
[INSUR=1]	-7.462[.000]	-7.655[.000]	-7.701[.000]	-8.743[.000]
[HCERE=1]	2.343[.000]	2.237[.000]	2.460[.000]	2.358[.001]
[MCURE=1]	-4.011[.000]	-4.104[.000]	-3.789[.000]	-3.694[.001]
[MCURE=2]	.521[.482]	.663[.350]	.686[.360]	1.026[.320]
[MCURE=3]	.361[.642]	.298[.688]	.560[.472]	.776[.463]

Source: Authors' calculations using SPSS.

The outcome of the regression indicated various socio-economic variables, which includes household size, age, gender, years of education of respondents, climate change awareness), and some institutional variables, e.g., access to credit and social capital, have shown an impact on the farmers' choice for farm-level climatic change adaptation strategies. Our findings are matching with the conclusions of different studies (Zhang & Flick, 2001; Bekele & Drake, 2003; Featherstone & Goodwin, 1993) Age is found to be negatively related to the crop production. An increase in the number of households engaged in farming by 1 log of the odd ratio for AVPRO (801-1200) kg lead to significantly decrease by 0.448 kg. The increase in farmer's education diverts them to another sector instead of a development in agriculture production. Increase in farm size by 1, the log of the odd ratio for AVPRO (801-1200) kg will lower compared to AVPRO> 2000 kg and in all ranges, it was found to be significant except the farm size 11 to 20 acres. The increase in credit (Hassan et al., 1998) and Insurance facilities by 1 log of the odd ratio for AVPRO (801-1200) kg will significantly lower by 3.597 kg and 7.65 kg respectively as compared to AVPRO> 2000 kg. With the provision of health care facilities will lead to an increase in average production by 1 log of the odd ratio for AVPRO (801-1200) kg will increase by 2.237 kg ([Deressa et al. (2008), Adger et al. (2009), and Ciscar et al. (2011)].

5.5 Estimates of Climate Change, Adaptation Strategies and Crop Production

The results of combined impact of climate change and the adaptation strategies on average crop production are presented in Table 7. The combined insertion of socio-economic and adaptation variables into crop production have provided a more comprehensive look of the crop production.

Table 7. Estimates of Climate Change, Adaptation Strategies and Crop Production

Variables	AP < 800kg	AP(801-1200kg)	AP(201-1600kg)	AP(1601-2000kg)
Intercept	15.320[.056]	15.747[.997]	20.030[.996]	73.293[.986]
INCOME	.00001[.005]	.000002[.002]	.000002[.002]	.000012[.071]
NFARM	-.458[.011]	-.432[.011]	-.476[.008]	-.710[.004]
[CREDF=1]	-3.272[.000]	-3.306[.000]	-3.243[.000]	-2.749[.000]
[FSIZE=1]	2.575[.005]	.044[.962]	-.019[.984]	-39.381[.000]
[FSIZE=2]	7.451[.942]	3.869[.970]	3.853[.970]	-35.989[.732]
[FSIZE=3]	-2.305[.003]	-.861[.251]	-2.426[.001]	-41.840[.000]
[FSIZE=4]	.157[.000]	.245[.000]	2.697[.000]	-39.673[.000]
[CCTEMP=1])	.998[.240]	.481[1.000]	-2.320[1.000]	-17.378[.996]
[CCTEMP=2]	2.464[.000]	1.935[1.000]	-.879[1.000]	-17.383[.997]
[CCRAIN=1]	.102[.930]	.252[.823]	.308[.794]	.462[.755]
[CCRAIN=2]	-1.846[.018]	-1.738[.023]	-1.835[.020]	-1.095[.273]
[CCCO2=1]	-2.875[.000]	-2.879[.000]	-2.954[.000]	-3.225[.000]
[HUMDT=1]	.925[.362]	.594[.548]	.776[.445]	.686[.568]
[HUMDT=2]	-1.364[.113]	-1.543[.065]	-1.438[.094]	-1.609[.121]
[MULTCRO=1]	-1.018[.178]	-1.029[.161]	-.881[.245]	-1.571[.078]
[FRAGM=1]	-4.284[.000]	-4.180[.000]	-4.336[.000]	-3.081[.000]
[MULTPLN=1]	2.356[.001]	2.379[.000]	2.380[.000]	1.864[.026]
[CROPDIVR=1]	-1.759[.021]	-1.615[.026]	-1.417[.064]	-1.170[.230]
[ORGCROP=1]	-.392[.653]	-.338[.691]	-.350[.689]	-.524[.618]
[TREEPL=1]	-.566[.574]	-.815[.403]	-.638[.525]	.359[.800]
[COVCRO=1]	-1.243[.238]	-1.041[.316]	-1.211[.256]	-2.471[.030]
FERTAPP	.448[.952]	.917[.732]	-1.105[.877]	.028[.998]
[FERTAPP=2]	1.706[.819]	2.463[.732]	.045[.995]	1.490[.874]

Source: Author's calculations using SPSS.

Further results showed that number of household in farming increase by 1, the log of the odd ratio for average production less than 800 kg will lower by .458 kg, 0.432 kg, 0.476 kg, 0.710 kg for the average production (801-1200) kg, (1201-1600) kg, (1601-2000) kg respectively relative to reference category (AVPRO> 2000 kg) -- when farmer has production lower than 2000 kg compared to average production less than 2000 kg. The increase in number of farmers engaged in the farming have less marginal benefits Butt and Hassan (2010). AVPRO (1601-2000) kg also found to be significant, due to change in weather farmer adopt different strategies like small farm holder adopt multi-cropping adaptation strategies to enhance production significantly. The climate change due to change in temperature, insignificantly impact average production in all production categories. Additionally, study investigates the climate change and crop production further closely. It is shown that humidity plays a high role in climatic change relative to not effective role (base category). It has a positive impact on crop production but humidity play lesser role in climatic pattern, in this case. Statistical results indicated that increase in humidity by 1 log of the odd ratio for all production categories.

5.6 Estimates of Adaptation Strategies, Farmer's Socio-Economic Status and Climate Change, and Crop Production

The study also observed the combined impact of farmer's socio-economic status and the adaptation strategies on the average crop production. Results are explained in details in table 8.

Table 8. Estimates of Impact of Adaptation Strategies, farmer's Socio-Economic Status and Climate Change on Average Crop Production

Variables	AP < 800kg	AP(801-1200kg)	AP(201-1600kg)	AP(1601-2000kg)
Intercept	18.213[.000]	20.195[.000]	19.512[.000]	53.450[.000]
NFARM	-.316[.043]	-.302[.041]	-.330[.037]	-.572[.009]
EDUYEARS	.342[.000]	.327[.000]	.332[.000]	.408[.000]
INCOME	.000023[.047]	.0000001[.026]	.00001[.030]	.000461[.160]
AGEYEARS	-.306[.113]	-.372[.047]	-.378[.051]	-.143[.574]
AGESQUARE	.005[.034]	.005[.012]	.005[.014]	.003[.367]
[FSIZE=1]	1.349[.056]	-1.136[.109]	-1.198[.095]	-40.872[.000]
[FSIZE=2]	1.272[.990]	-2.543[.980]	-2.350[.982]	-43.295[.680]
[FSIZE=3]	-3.474[.000]	-1.989[.002]	-3.519[.000]	-43.279[.000]
[FSIZE=4]	-.714[.000]	-.595[.000]	1.852[.000]	-40.867[.000]
[CREDF=1]	-3.243[.000]	-3.250[.000]	-3.234[.000]	-2.735[.000]
[GEND=0]	.590[.483]	.454[.574]	.648[.439]	-.441[.704]
[MSTAT=0]	1.853[.079]	1.341[.198]	1.553[.155]	2.521[.048]
[OWNSTS=1]	-2.570[.000]	-2.196[.000]	-2.401[.000]	-2.173[.002]
[INSUR=1]	-7.811[.000]	-8.014[.000]	-8.017[.000]	-9.082[.000]
[HCERE=1]	2.421[.000]	2.301[.000]	2.558[.000]	2.453[.000]
[MCURE=1]	-3.531[.000]	-3.625[.000]	-3.344[.000]	-3.341[.002]
[MCURE=2]	.812[.286]	.956[.190]	.967[.207]	1.288[.201]
[MCURE=3]	.720[.377]	.656[.403]	.910[.266]	1.087[.299]
[CCAWR=1]	-1.853[.000]	-1.810[.000]	-1.997[.000]	-2.015[.003]
[MULTCRO=1]	-1.775[.004]	-1.771[.003]	-1.616[.010]	-2.378[.002]
[FRAGM=1]	-4.045[.000]	-3.964[.000]	-4.093[.000]	-2.893[.000]
[MULTPLN=1]	2.804[.000]	2.810[.000]	2.809[.000]	2.211[.004]
[CROPDIVR=1]	-1.985[.006]	-1.852[.008]	-1.655[.023]	-1.320[.156]
[ORGCROP=1]	-.871[.165]	-.796[.188]	-.875[.155]	-1.054[.185]
[TREEPL=1]	-.722[.317]	-1.006[.145]	-.833[.245]	.225[.845]
[COVCRO=1]	-1.174[.142]	-1.079[.164]	-1.178[.135]	-2.690[.003]

Source: Authors' calculations using SPSS.

This model 5.6 elaborated how the production of different level affected by the joint influenced of farmer's socio-economic status, climatic variation, and strategies to adapt by the farmers. The unmarried farmers engaged in farming activities have positive and significant impact on AVPRO<800 kg, AVPRO(801-1200) kg, AVPRO(1601-2000) kg, because they have more capability to save their money because of low expense in household budget and use it for the purchase of equipment's like purchase tractor, good fertilizer, and for the arrangement of better irrigation mechanization.

6. CONCLUSION AND SUGGESTIONS

The main focus of the study is to determine the impact of climate change, adaptation strategies, and the socio-economic status of the farmers on average crop production. Therefore, this research attempts to probe, based on primary data collected from three districts (Multan, Bahawalpur, D.G Khan) of South Punjab, Pakistan, that how the major crop production are changing its yield due to climate change. further, it makes a healthy endeavor to explore that how the adverse impact of climatic change can be checked. It also investigated the factors, can enhance farmers' capacity to address climate change. Multi-nominal Logit model is used for empirical analysis. Different categories of the average crop production are taken as a dependent variable. For the rigorous analysis, climate change variables, adaptation strategies and the farmers' socio-economic variables have been studied separately and contemporaneously. Results revealed a significant impact of climate change on the average crop yield. The farmers' socio-economic status has a positive and significant impact on crop production. Adaptations to climate changes have also affected the output in the agriculture sector compared to the situation when adaptation is not considered. The impact of adaptation to climate change on crop production gets increased positively, when the farmers' socio-economic status is controlled for the nexus. The outcomes of this study project to guide agricultural planners in designing the programs for agricultural development. The policy designing related with the increase in agriculture output and mitigating effects of climate change on crop production, in Pakistan, should focus on the awareness to climate change -- and the farmers' socio-economic status, to have a decent foundation to address climate change.

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