Impact of Climate Change on Yield of Major Food Crops in Pakistan

a Shabir Hussain, b Imran Sharif Chaudhry

a Department of Agronomy, BahauddinZakariya University, Multan, Pakistan
Email: shabirhussain@bzu.edu.pk
b Professor, School of Economics, BahauddinZakariya University, Multan, Pakistan
Email: imran@bzu.edu.pk

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ABSTRACT

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Nowadays, global warming is increasing in response of climate change which affects almost every sector including the agriculture sector. Therefore, there is a need to confirm the policies for policymakers and government officials to minimize the monetary loss in response to climate change. In doing so, our study reveals the effect of climate change on the yield of major food crops in Pakistan. To check the existence of long-run association among the variables, we employ Johansen co-integration technique from 1990 to 2019. The results prove that co-integration exists among the variables in the long run. Hence, this study suggested policy formulation for policymakers and government officials that should focus on the harmful effect of climate change on the agriculture sector to rebuild the resilient and sustainable agriculture sector of Pakistan.

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1. Introduction

The impact of climate change on food crop production in Pakistan is very substantial (Kamitewoko, 2021). Wheat is an important staple food crop in Pakistan, and it is used extensively for human food as well as for animals (Gul et al., 2021). It is relatively a cheaper source of food; therefore, its production is focused on food security policies. Among the cereal crops, wheat is ranked as the most susceptible crop, whose production is expected to decrease up to 72% this year and the following year. It is a dire need to increase the world average yield of wheat from 2.6 to 3.5 tons/ha by the next coming 25 years. This increase in the yield of wheat is very essential to sustain global food security and required an uninterrupted supply of improved germplasm and suitable agronomy to endure increased production and preservation of natural resources. The world man population is prospective to increase by nine billion up to 2050 (UNO, 2011). In this scenario the estimated population growth, climate change can adversely affect the global plant production (Rosenzweig et al., 2001).
In Pakistan, a large area of land is under rice cultivation directly or indirectly which is about 11 percent of the total agricultural area containing Basmati and IRRI varieties (Ahmed and Schmitz, 2011; Ali et al., 2017). While Sindh and Punjab provinces are contributing about 90 percent of the produce of Pakistan (Chandio and Jinag, 2018). The growth of rice production was three percent during 2014-15 over 2013-14. Rice is not only the source of foreign exchange but also used as a staple food in Pakistan as well as around the world. Low temperature is more suitable for its growth and high temperature is not favourable. Pakistan earned US$ 1.53 billion from the export of rice during the fiscal year 2014 and year 2015. A decline in rice cultivation, as well as productivity, is observed during the previous decade. This declining trend might be related to the negative impact caused by the abrupt weather changes (Joyo et al., 2018), and that of degradation of the lands (Magsi and Sheikh, 2017).

Maize provides raw material in many foods manufactured products in Pakistan. The use of maize in the feed and wet milk industries is rising. Pakistan is self-sufficient in maize production to cater. The need of the country and its average production is 2850kg/ha. However, Pakistan is not so sufficient to export maize. Sugarcane is a cash and industrial crop and also in other countries of the world. The average production of sugarcane is about 470 maunds/acre in Pakistan. This average production is very low as compared to sugarcane production in other parts of the world. Agronomic factors including water availability, bed preparation, planting techniques and time, fertilizers, harvesting times, and timely plant protection are major factors of sugarcane production. Climate change including minimum temperature, maximum temperature, average temperature, rainfall, drought and humidity have also a relationship with sugarcane production. This study is proposed with the following objective;

1. To analyze the impact of variations in climate change on the production of major food crops in Pakistan

2. To explore guidelines for academic research and policymakers.

3. To device strategies for future production of food crops.

The remaining parts of the paper are as follows: Section 2 express the literature review of the previous studies. Section 3 outlines the material and methods. Section 4 reports the empirical findings. The last section is about the concluding remarks.

2. Literature Review

The world man population is prospective to increase by nine billion up to 2050 (UNO, 2011). In this scenario the estimated population growth, climate change can adversely affect the global plant production and will cause threat to the world food productivity and food security (Rosenzweig et al., 2001). About 21% of the global food supply is fulfilled by the wheat (Triticum aestivum) crop, which grows a large area of about 200 million hectares around the globe. Wheat ranks third in the world annual production of produces about 651 million tons in 2010 (FAO, 2012). Though wheat is merchandised internationally and the main importers of this commodity are developing countries which import about 43% of food, it is a reality that about 81% of wheat is used in the developing countries is produced and consumed within the same country, if not the same community (CIMMYT, 2005). Another emerging challenge faced by humanity is food security by enhancing world food supply which is about 70% up to 2050. To achieve the target a volume of productivity is required (Parry et al., 2004; Reynolds et al., 1994). Climatic and environmental fluctuations severely inhibit the productivity of wheat. As a result, weather patterns are being shifted...
and an increased frequency of extreme and hazardous events is resulting in global warming (Lobell et al., 2008). Growing mercury and the occurrence of water stress associated with global warming are imposing a severe risk (Lobell et al., 2008). So, climate change is representing a substantial challenge in attaining the about 70%-increased goal in world food production. In the latest years, noticeable changes in mercury and precipitation are considered in global and regional phases as climate change phenomena in terms of extent and time of incidence and resultantly have imposed different influences on the inputs and productivity in agriculture.

It looks that in the last few decades the effects of climate change on ecological concerns have been apparent and many of the contradictions are fixed. Some of the gases such as CO2, N2O, CH4 and halocarbons eg. CFC are the major factor causing the greenhouse effect because of human activities; such gases play a significant role in absorbing the solar radiation and thus the climate system itself is affected by this subject (Tubiello et al., 2000). The hot and dry areas will be more severely influenced negatively by these changes in climatic conditions (Parry et al., 2004; Gregory et al., 2005), therefore, developing countries are at high risk from these rising temperatures and reduced precipitation (Sivakumaret al., 2005), and the intensity and frequent occurrence of these climatic phenomena such as drought, heat, coldness and flood will be increased. No doubt that any climate change will severely hamper the agricultural production systems across the globe. It is obvious that the growth and development of plants depend on the atmospheric temperature of the surroundings and more sensitive is that every specific crop/plant needs a specific temperature range i.e. minimum, maximum, and optimum. Hatfield et al. (2011) observed that expected changes in temperature during the upcoming 30 to 50 years are expected to be found in the range 2-3 °C. An increase in frequency and intensity of extreme events such as heatwaves or extreme temperature is expected to be more intense, frequent, and will remain longer than that observed during recent years (Meehle et al., 2007). It is being expected that extreme temperature events can remain for a short duration for some days with a high-temperature raise of 5 °C over the normal temperature. However, these extreme events if occur in hot months the impact would be more dramatic on crop production; whereas, little research work has been documented up till now as found by Kumudini et al. (2014) study on the impact of heat, coldness and temperature extremes on wheat crop depicted sever cold stress caused that grains sterility and abortion whereas, high heat resulted in reduced grain number and thus less grain filling period.

Another issue relevant to grain growth is day length sensitivity as it is the result of shorter heat (Midmore et al., 1982). Similarly, grain filling is also severely affected as a result of plant senescence and photosynthesis (Wardlaw et al., 1980). Under such circumstances, those wheat cultivars which can maintain high 1000-grain weight under high-temperature stress can tolerate such harsh environments (Reynolds et al., 1994). Among the most phonological stages which are most sensitive to the rise in temperature, the pollination stage is most critical. At this stage, pollen viability is severely reduced by a temperature above 35 °C (Dupuis and Dumas, 1990). Pollen viability is a function of pollen moisture contents which are negatively affected by high-temperature stress and mostly depend on vapour pressure deficit (Fonseca and Westgate, 2005). The potential grain rate and its size are significantly reduced if a rise in temperature from 30 to 35 °C is imposed at the endosperm division stage even if the plant was returned to 30 °C. It is found that an exposure of above 30 °C temperature severely stopped the cell division and amyloplast replication and thus reduced the grain size and resulted in less yield (Commuri and Jones, 2001). The possible effects of climate change in the near future on wheat production around the globe are very complicated and the interaction of different abiotic stresses such as rising temperature and that of CO2 and humidity...
are poorly understood. In the real sense, still, an uncertainty prevails there that how can climate change and environmental changes can affect the potential yield of wheat and that of the rest of the food crops (Gornallet al., 2010). Furthermore, an interaction of biotic stress can be either positive or negatively affect crop productivity in future and also the food supply (Boonekamp, 2012). Most of the biotic factors that reduced the crop yield such as disease are highly neglected as the current studies revealed (Gregory et al., 2005).

Fungal pathogens listed below are a severe and real biotic threat to the crop productivity and wheat production system across the globe will be presented in this paper. Some obligate pathogens cause different diseases of wheat such as powdery mildew, stem rust, leaf rust, and that stripe rust. Another type of pathogens is necrotrophic pathogens which are borne from crop residues and cause various diseases like tan spot, leaf blotch, blotch, spot blotch, and Fusariumgraminearum and Fusarium head and ear blight. TA huge number of fungal pathogens exist that cause different wheat diseases like soil-borne root rots (Duveiller et al., 2007). Those regions where which obtained low productivity experienced less seed dressing got more disease in terms of smuts and bunts. By changing climatic conditions there is observed a shift of wheat diseases as altered precipitation and temperature includes: seasonal phenology, the dynamics of the population and distribution of geographic (Chakraborty et al., 2000; Melloy et al., 2010). An excessive increase of greenhouse gases such as CO₂ and other gasses directly excelling in the atmosphere is the major source of climate change. Climate directly affects agricultural productivity significantly i.e. There is a direct relationship between climate change and agricultural productivity and is a big concerning issue because the world’s food production resources are experiencing huge pressure due to a rapid increase in the human population. Climate change is affecting both the land-use patterns as well as crop productivity (Solomon and Leemans, 1990). It is of prime importance to understand, not only the process of climate change occurring but also the effects either positive or negative on the growth and development of the plants. Furthermore, climate change aggravates an interest in the rice-growing regions on one hand as a food source all over the world and on the other hand its intensive cultivation especially in the Asian region it is itself a source of global warming by emitting methane (CH₄) gases in the atmosphere. Methane gas alone contributes about 15-20% of the total greenhouse gases (Bouwman, 1991).

Almost maximum plant species on the earth are sensitive to temperature fluctuations, where a little increase in daily temperature can adversely affect crop productivity and agriculture itself. Pakistan was the most affected country during 2011, from climate change as weather changes during 2010 severely affected the agriculture sector of Pakistan and climate-related disasters (Siddiqui et al., 2012; Ali et al., 2017). A number of scientists and researchers are working on climate change in Pakistan and determining the effects of climate change on agriculture productivity and have conducted various studies on adaptation strategies of agriculture to changing climate (Ali and Erenstein, 2017; Abid et al., 2018; Arshad et al., 2016).

Some unseen changes in climatic conditions due to global warming associated with high temperature, rainfall and CO₂ the expected rice production will severely influence. Due to changing climatic variations a quick and rapid influence can be observed on rice production systems as well on food security. The studies conducted on climate change revealed that a sudden increase in temperature not only affects the rice productivity and thus finally the crop yield and quality is also degraded (Joyo et al., 2018). A comprehensive study was carried out which depicted that since 1960 a
12.4% decrease in rice yield was observed and mainly this was because of lower radiation contribution. Statistical analysis was made in different regions based on its positive and negative yield response between climate variables and yield. It was found that fluctuations in mean temperatures, enhanced weather changes and increased sea level expected less but perhaps have a significant effect on rice productivity.

Several studies conducted on climate change revealed that the productivity of rice crops and other tropical plants will be severely hampered due to global warming and increased temperature. Mohandrasset al. (1995) used the Hadley-coupled model to find out the response of yield which decreased by 14.5% for summer rice in nine different experiments conducted at different research stations of India during 2005. Peng et al. (2004) observed that by an increase in temperature by 1°C a decrease in the yield of rice by about 15% was noticed during the dry season in the Philippines. Maclean et al., (2002) reported that currently about 40% of the area under rice cultivation is categorized as rain-fed (lowland or upland), whereas about 3.5 million ha area under rice cultivation is yet being categorized as deep-water or flood-prone. The difference of amount and that of its distribution of precipitation is of great concern that limits crop yield of rice under rainfed conditions. Similarly, in rainfed areas the planting season is determined by the onset of the rainy season thus variation in the onset of the rainy season leads to dissimilarity to begin planting. Furthermore, those areas experiencing uneven precipitation i.e. during one day it receives as much as 200mm in a day and then experiences no precipitation during the coming 20 days, under such conditions the moisture stress harshly damages or even kills rice plants. A complete crop failure may be observed under such circumstances when heavy water stress occurs at the reproductive phase. Rice cultivation under low lying areas experiences mostly flooded conditions that is a major constraint of these areas. Rice varieties in maximum are as harsh that they can tolerate complete submergence of about 6 days before they die about 50%, however, they die completely if submergence experienced about 14 days in rain-fed, deep water, low land and irrigated ecosystem. Another indirect damage caused to the rice production system is damage caused to farmers land, property and infrastructure that supports the rice production system (e.g. dams, dikes and roads). Rainfall patterns and their distribution may lead to increased frequency and intensity of floods and that of drought periods in various parts of the world.

A large number of factors are involved that cause damage to the crop directly or indirectly as a result of climate change might be a loss caused by disease. Increased CO2 concentration will lead to a change in radiation interception directly and would alter the physiology and morphology of the host, and thus the disease epidemiology would change the canopy structure and microclimate. Because of some diseases, occurrence plant growth is hampered severely under both ambients compared to ambient CO2 under controlled conditions (Hibberdet al., 1996b). Most of the diseased plants experience reduced growth even despite that of lowering of disease severity under increased CO2 (Coakley, 1999). In summary, the analysis suggests that there will be serious inferences for world food security if no serious efforts would be made to cope with these climate changes under wheat and rice production.

3. Material and Methods

Previous research on climate change applies various methods such as dynamic conditional correlation-GARCH model, impulse response function and vector auto-regression model. But our study employed Johansen co-integration test to check the existence of co-integration among variables in long run. Before going to apply any methodology it is necessary to check the stationary of the
variables. The results of the unit root test guided further econometric methodology. Basically unit root test is a random walk and the properties of the equation have a unit root of one. Different types of unit root tests are applied in time series data. The results of the unit root directed different orders of integration. If all variables are on the same order of integration like $I(0)$ or $I(1)$ that would guide further for the ordinary least square method and Johansen co-integration test, respectively. If variables are mixed order integration then it would direct to Autoregressive distributed lag model (ARDL).

Two approaches are commonly applied in the previous literature to test for the co-integration relations. The first approach is the Engle-Granger procedure. The second method, the Johansen co-integration test (1990), is based on the likelihood ratio test. The Johansen co-integration method is more suitable as compared to another one as it is a multivariate co-integration method. To solve the problem Johansen (1990) proposes two likelihood ratio based co-integration tests for problem-solving that are the maximum Eigenvalue test and trace test.

4. Results and Discussion

Descriptive statistics and correlation analysis is explained in table 1 and 2. Table 4 to 5 is about the unit root test. Table 3 is about the Johansen co-integration test that is based on trace and maximum Eigenvalues. The last table 6 is about long results of all three models wheat yield, rice yield and combined wheat and rice yield.

4.1 Descriptive Statistics and Correlation Analysis

The descriptive statistics shows the overall structure of the data. The mean, median, maximum and minimum value for YIELDW, is 4576.8, 4635.0, 5487.0 and 3384.0; for WHEAT is 2465.9, 2519.0, 2973.0 and 1841.0; for RICE is 2110.9, 2050.0, 2568.0 and 1543.0; for LFPR is 51.2, 51.1, 53.0 and 49.2; for K is 122.8, 123.5, 158.0 and 83.6; for ILA is 18.6, 18.8, 20.1 and 16.8; for GHGE is 73.3, 73.4, 142.6 and 1.8; for CREDIT is 144980.3, 58915.0, 598287.0 and 704.5. The standard deviation for YIELDW, WHEAT, RICE, LFPR, K, ILA, GHGE and CREDIT is 619.0, 336.4, 299.8, 0.9, 21.1, 0.9, 44.6 and 165957.4, respectively.

Table1: Descriptive Statistics of Key Variables (1990-2019)

|          | YIELDWR | WHEAT  | RICE   | LFPR  | K     | ILA   | GHGE  | CREDIT |
|----------|---------|--------|--------|-------|-------|-------|-------|--------|
| Mean     | 4576.8  | 2465.9 | 2110.9 | 51.2  | 122.8 | 18.6  | 73.3  | 144980.3 |
| Median   | 4635.0  | 2519.0 | 2050.0 | 51.1  | 123.5 | 18.8  | 73.4  | 58915.0  |
| Maximum  | 5487.0  | 2973.0 | 2568.0 | 53.0  | 158.0 | 20.1  | 142.6 | 598287.0 |
| Minimum  | 3384.0  | 1841.0 | 1543.0 | 49.2  | 83.6  | 16.8  | 1.8   | 704.5   |
| Std. Dev.| 619.0   | 336.4  | 299.8  | 0.9   | 21.1  | 0.9   | 44.2  | 165957.4|
| Skewness | -0.3    | -0.4   | -0.2   | 0.2   | -0.2  | -0.4  | -0.1  | 1.3     |
| Kurtosis | 1.9     | 1.9    | 2.0    | 2.6   | 2.0   | 2.1   | 1.6   | 3.7     |
| Jarque-Bera | 1.7   | 2.0    | 1.3    | 0.3   | 1.2   | 1.8   | 2.1   | 7.6     |
| Probability | 0.4   | 0.4    | 0.5    | 0.8   | 0.5   | 0.4   | 0.4   | 0.0     |
| Observations | 27   | 27     | 27     | 27    | 27    | 27    | 27    | 27      |

The following Table2 shows the association between the variables. The association is different among variables. Some variables show very high association and some shows high and low association.
Table 2: Correlation Analysis of Key Variables (1990-2019)

| Correlation | YIELDWR | WHEAT | RICE | LFPR | K | ILA | GHGE | CREDIT |
|-------------|---------|-------|------|------|---|-----|------|--------|
| YIELDWR     | 1.00    |       |      |      |   |     |      |        |
| WHEAT       | 0.98    | 1.00  |      |      |   |     |      |        |
| RICE        | 0.97    | 0.89  | 1.00 |      |   |     |      |        |
| LFPR        | 0.82    | 0.83  | 0.77 | 1.00 |   |     |      |        |
| K           | 0.97    | 0.94  | 0.94 | 0.85 | 1.00 |
| ILA         | 0.88    | 0.86  | 0.84 | 0.63 | 0.87 | 1.00 |
| GHGE        | 0.98    | 0.95  | 0.95 | 0.85 | 0.98 | 0.87 | 1.00  |
| CREDIT      | 0.56    | 0.53  | 0.56 | 0.48 | 0.54 | 0.58 | 0.58  | 1.00   |

4.2 Unit Root Analysis
The following Table 3 shows the results of Augmented Dickey Fuller test. The results show all variables are non-stationary at level and it becomes stationary at first difference.

Table 3: Results of ADF Unit Root Test

| Variable | Intercept | Lag | Trend and Intercept | Lag | None | Lag | Conclusion |
|----------|-----------|-----|---------------------|-----|------|-----|------------|
| CREDIT   | 2.1748    | 6   | -2.4714 (0.9996)   | 6   | 1.6580 (0.9714) | 3   | I(1)       |
| GHGE     | -0.0484   | 0   | -1.8876 (0.9461)   | 0   | 0.3291 (0.7730) | 0   | I(1)       |
| ILA      | -1.6162   | 0   | -1.9524 (0.9599)   | 0   | 0.9983 (0.9114) | 0   | I(1)       |
| K        | -0.3525   | 6   | -10.0787 (0.9020)  | 4   | 5.0265 (0.0000) | 5   | I(1)       |
| LFPR     | -0.7924   | 0   | -3.1216 (0.8064)   | 0   | 0.7966 (0.8794) | 0   | I(1)       |
| RICE     | -1.4973   | 2   | -5.3030 (0.5196)   | 0   | 2.6432 (0.9970) | 0   | I(1)       |
| WHEAT    | -1.2437   | 1   | -5.2012 (0.6408)   | 0   | 2.1237 (0.9900) | 1   | I(1)       |
| YIELDWR  | -1.4449   | 1   | -3.8324 (0.5460)   | 0   | 2.5519 (0.9963) | 1   | I(1)       |

4.3 Johansen-Juselius Cointegration Analysis
The unit root results indicated that all variables are integrated at first order. So possible estimation method for cointegration is Johansen Juselius cointegration and findings indicated the long association confirmation.

4.4 Cointegration Test for Wheat Yield
The Johansen cointegration test decision is dependent on the trace statistic and maximum-eigenvalue which is presented in the following tables 5.4 and 5.5. Based on the results we reject the null hypothesis of no cointegration and conclude that cointegration exists between dependent and all independent variables.
Table 4: Unrestricted Cointegration Rank Test (Trace)

| Theorized No. of CE(s) | Eigenvalue | Trace Value | 0.05 Critical Estimate | Prob  |
|------------------------|------------|-------------|------------------------|-------|
| None *                 | 0.937073   | 131.1473    | 95.7536                | 0.0000|
| At maximum 1 *         | 0.850523   | 73.06597    | 69.8188                | 0.0269|
| At maximum 2           | 0.587695   | 33.15304    | 47.8561                | 0.5484|
| At maximum 3           | 0.380427   | 14.54722    | 29.7970                | 0.8085|
| At maximum 4           | 0.192073   | 4.493996    | 15.4947                | 0.8600|
| At maximum 5           | 0.000716   | 0.015043    | 3.84146                | 0.9022|

Table 5: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| Assumed No. of CE(s) | Eigen Stat | Trace Value | 0.05 Critical Estimate | Prob  |
|----------------------|------------|-------------|------------------------|-------|
| None *               | 0.937073   | 58.08129    | 40.0775                | 0.0002|
| At maximum 1 *       | 0.850523   | 39.91293    | 33.8768                | 0.0084|
| At maximum 2         | 0.587695   | 18.60583    | 27.5843                | 0.4456|
| At maximum 3         | 0.380427   | 10.05322    | 21.1316                | 0.7397|
| At maximum 4         | 0.192073   | 4.478953    | 14.2646                | 0.8057|
| At maximum 5         | 0.000716   | 0.015043    | 3.84146                | 0.9022|

4.5 Cointegration Test for Rice Yield

The Johansen cointegration test decision is dependent on the trace statistic and maximum-eigenvalue which is presented in the following tables 5.6 and 5.7. Based on the results we reject the null hypothesis of no cointegration and conclude that cointegration exists between dependent and all independent variables.

Table 6: Unrestricted Cointegration Rank Test (Trace)

| Hypothetical No. of CE(s) | Eigen Stat | Trace Value | 0.05 Critical Estimate | Prob  |
|---------------------------|------------|-------------|------------------------|-------|
| None *                    | 0.861334   | 97.6338     | 95.7536                | 0.0369|
| At maximum 1              | 0.723297   | 56.1443     | 69.8188                | 0.3722|
| At maximum 2              | 0.556962   | 29.1633     | 47.8561                | 0.7605|
| At maximum 3              | 0.306841   | 12.0672     | 29.7970                | 0.9295|
| At maximum 4              | 0.181834   | 4.37086     | 15.4947                | 0.8714|
| At maximum 5              | 0.007418   | 0.15636     | 3.84146                | 0.6925|
Table 7: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| Hypothetical No. of CE(s) | Eigen Stat | Trace Value | 0.05 Critical Estimate | Prob  |
|---------------------------|------------|-------------|------------------------|-------|
| None *                    | 0.861334   | 41.4894     | 40.0775                | 0.0344|
| At maximum 1              | 0.723297   | 26.9810     | 33.8768                | 0.2644|
| At maximum 2              | 0.556962   | 17.0960     | 27.5843                | 0.5717|
| At maximum 3              | 0.306841   | 7.69642     | 21.1316                | 0.9213|
| At maximum 4              | 0.181834   | 4.21450     | 14.2646                | 0.8361|
| At maximum 5              | 0.007418   | 0.15636     | 3.84146                | 0.6925|

4.6  Cointegration Test for Combined Yield (Wheat and Rice)

The Johansen cointegration test decision is dependent on the trace statistic and maximum-eigenvalue which is presented in the following tables 5.8 and 5.9. Based on the results we reject the null hypothesis of no cointegration and conclude that cointegration exists between dependent and all independent variables.

Table 8: Unrestricted Cointegration Rank Test (Trace)

| Hypothetical No. of CE(s) | Eigen Stat | Trace Value | 0.05 Critical Estimate | Prob  |
|---------------------------|------------|-------------|------------------------|-------|
| None *                    | 0.853714   | 105.9060    | 95.7536                | 0.0083|
| At maximum 1              | 0.746720   | 65.53989    | 69.8188                | 0.1046|
| At maximum 2              | 0.575034   | 36.70144    | 47.8561                | 0.3618|
| At maximum 3              | 0.486125   | 18.73079    | 29.7970                | 0.5124|
| At maximum 4              | 0.202318   | 4.749504    | 15.4947                | 0.8348|
| At maximum 5              | 0.000121   | 0.002549    | 3.84146                | 0.9573|

Table 9: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| Hypothetical No. of CE(s) | Eigen Stat | Trace Value | 0.05 Critical Estimate | Prob  |
|---------------------------|------------|-------------|------------------------|-------|
| None *                    | 0.853714   | 40.36609    | 40.0775                | 0.0464|
| At maximum 1              | 0.746720   | 28.83845    | 33.8768                | 0.1775|
| At maximum 2              | 0.575034   | 17.97065    | 27.5843                | 0.4976|
| At maximum 3              | 0.486125   | 13.98128    | 21.1316                | 0.3666|
| At maximum 4              | 0.202318   | 4.749555    | 14.2646                | 0.7734|
| At maximum 5              | 0.000121   | 0.002549    | 3.84146                | 0.9573|
4.7 Long run Analysis

The following Table 10 explains the long-run association between a dependent variable and all explanatory variables in three models. In the first model when we take the wheat model. The results show all variables like ILA, LFPR, K, log (CREDIT) are significant with a positive sign while GHGE is with a negative sign in long run. In particular, 1 % increase in ILA increased 0.04% in wheat.

In the second model when we take the rice model. The results show all variables like ILA, LFPR, K, log (CREDIT) are significant with a positive sign while GHGE is with a negative sign in long run. In particular, 1 % increase in ILA increased 0.02% in rice.

In the third model when we take the wheat and rice yield combined model. The results show all variables like ILA, LFPR, K, log (CREDIT) are significant with a positive sign while GHGE is with a negative sign in long run. In particular, 1 % increase in ILA increased 0.03% in YIELDWR.

Table 10: JJ Estimates of Climate Change and Food Crops

| Explanatory Variables | Dependent Variables | LOG(WHEAT) | LOG(RICE) | LOG(YIELDWR) |
|-----------------------|---------------------|------------|-----------|--------------|
|                       | C                   | -8.732572  | -9.156325 | -9.495845    |
|                       | ILA                 | 0.045169 (0.01458) [3.09869] | 0.029282 (0.01035) [2.82980] | 0.030346 (0.01490) [2.03633] |
|                       | LFPR                | 0.061941 (0.01501) [4.12644] | 0.052459 (0.00941) [5.57612] | 0.056564 (0.01413) [4.00219] |
|                       | K                   | 0.021762 (0.00158) [13.7618] | 0.009457 (0.00101) [9.34031] | 0.015679 (0.00151) [10.3731] |
|                       | Log(CREDIT)         | 0.087468 (0.03895) [2.24546] | 0.061021 (0.02534) [2.40842] | 0.073633 (0.04143) [1.77735] |
|                       | GHGE(-1)            | -0.007567 (0.00117) [-6.48978] | -0.001635 (0.00076) [-2.15598] | -0.004825 (0.00125) [-3.85511] |

Note: Standard errors in ( ) & t-statistics in [ ]

5. Conclusion

The agriculture sector is the most contributing sector including other sectors that contributes to Pakistan real gross domestic product. This sector is highly affected by the drastically climate during the last decades. So, there is a need to confirm the policies for this sector to minimize the monetary loss in response to climate change. Therefore, our study examines the impact of climate change on the yield of major food crops in Pakistan. We employ Johansen co-integration technique to check the existence of long-run association among the variables, from 1990 to 2019. The results prove the existence of co-integration among the variables in the long run. Hence, this study suggested policy formulation for policymakers and government officials that should focus on the harmful effect of climate change on the agriculture sector for the sustainable agriculture sector of Pakistan.
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