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Research Article

ANALYZING THE CAUSES OF WATER SHORTAGE, LOW CROP YIELD, AND FOOD CRISIS IN PAKISTAN: A LONGITUDINAL ANALYSIS (1991-2019)

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Abstract

Pakistan has been facing problem of low crop yield, food shortage, and high prices of food items, and it has to import food items for billions of dollars every year to meet domestic needs. The literature shows a sufficient gap to investigate the causes of low crop yield. This motivates the authors to investigate the causes of water shortage, low crop yields, and high prices of agriculture inputs, using 28 years of data spanning from 1991 to 2019. The selected variables include crop yield as the dependent variable and water availability, precipitation, seed, fertilizer, and pesticides as independent variables. Various statistical techniques such as descriptive statistics, Correlation matrix, ADF test, ARDL Model, Bound test, and Error Correction model were employed to determine the relationship between variables. The findings reveal that all independent variables except precipitation have a positive association with crop yield. The comparison of the results of ARDL and ECM Models shows that the variables water, seed, fertilizer, and pesticides have a significant and positive relationship with crop yield in the short run rather than in the long run. In light of these findings, the study suggests that the Government of Pakistan should build water storage, ensure the availability of agriculture inputs at subsided prices, and introduce modern agriculture technologies to enhance crop yield to ensure food security and save billions of dollars being spent on the import of food items every year.

Keywords: Water shortage; low crop yield; high prices of agricultural inputs; food crisis.
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1. INTRODUCTION

Pakistan is facing severe water shortage due to inefficient irrigation systems, over-exploitation of groundwater, inadequate storage capacity, and contamination of surface and groundwater, and these factors have a collectively negative impact on the quantity and quality of water. The decline in water availability, which would shift crop rotation and change sowing and harvesting patterns for a long, caused a decline in the country's main cash crop production, affecting cereal production in South Pakistan by up to 20% and minor crop production in the Northern Belt. The level of precipitation is the major factor that contributes to the production of crops. Precipitation has increased by 25% across Pakistan over the last few decades. It has increased mostly in hilly areas (Aslam., 2016). Among these are the Coastal areas and western Baluchistan province, where precipitation has decreased. Heavy precipitation occurs during high temperatures due to floods and droughts. Pesticides are used to kill insects and to enhance crop production (Zhu, 2013). Another input that is used to increase crop yield is fertilizer. Fertilizer is the main input used to achieve high yield. Fertilizers such as nitrogen, potassium phosphorus, urea, and DAP are mostly used to improve soil fertility. One of the main inputs of increasing crop yield is seed, which is an important element used for high crop production, and if certified seed is used, it will enhance crop production (Mubarak, (2020). Access to improved seeds ensures food security and prosperity for the farmers. All these inputs are widely used in Pakistan to increase crop yield, but even then, the crop yield in Pakistan is around 30% less than in other Asian countries (Aldawadahi,2022). So, the question arises as to why crop yield is low in Pakistan. Is it due to a shortage of water, due to the use of low-quality inputs or unfavourable weather conditions? Although many studies have been conducted on this issue, the low crop yield problem still exists, demanding a further deeper investigation into the causes of low crop yield and the resulting food crisis in Pakistan, where the population has been rising steeply, putting the country's future food security in threat. The current study aims to analyse the current water shortage situation and the availability of other inputs for the cultivation of different crops, as well as examine their impact on crop yield in Pakistan.

This study will contribute to existing body knowledge in such a way that it will suggest strategies to enhance crop yield, food production, and modern agriculture technologies. It will provide valuable insights to policymakers about the factors responsible for low crop yield. The findings of this study will be beneficial for other developing countries that have also been facing food shortages as it offers insights and potential solutions that can be executed in a similar context.

2. Analysis of relevant Studies

Water availability is widely recognized as a crucial factor in increasing crop yield. Various authors conducted research on this issue by using different dataset, different analytical techniques and drawing different conclusions. A brief analysis of different relevant studies is given below: -

Turral (2006) investigated the relationship between water and rice production, specifically comparing transplanted techniques and direct dry seed methods. The study highlighted that during water shortages, the methods used to increase crop production become even more important.

Costa, et al. (2007) and (Berry, W. et al. (2007). contended that the impact of water stress on crops are vary on account of species, genotype, soil characteristics, and climatic conditions. Due to these factors, discrepancies in yield responses to deficit irrigation within the same species have been reported. Soil texture is the core soil characteristic that affects plant-water relationships due to its effective role in determining water infiltration, drainage, hydraulic conductivity, soil water holding capacity, plant, available water, and soil aeration. In this situation, it is expected that plants respond differently to deficit irrigation under different soil textures.

Shafique (2009) explored the positive impact of water management on agriculture output, examining various factors essential for enhancing crop yields. He concluded that water management had a positive effect on crop yields. Haider (2010) analysed the relationship between precipitation and crop yield in Pakistan, emphasizing the country's water stress conditions and its dependence on alternative climate patterns for higher yields. Ahmadi et al. (2010) noted different effects on potato plant growth and yield due to water shortage. They further stated that soil texture also affects crop-water relationships. Zotarelli et al. (2010) emphasize that crop evapotranspiration demand is affected by different factors like radiation, humidity, wind speed, and temperature. In dry climate regions advection heat enhances water shortage and has negative impact on plant-soil system. Similarly, Januja (2011) examined the precipitation patterns and their negative impact on major crops like wheat and cotton in Pakistan. Siddiqui (2012) focused on the relationship between precipitation and major crops, but the findings were overall insignificant. Baksh (2012) examined the association between temperature and precipitation in the context of rice-wheat crop pattern, discovering a negative correlation between temperature and precipitation. Hussain (2012) emphasized positive impact of water availability on agriculture production, specifically in the case of rice crops. Khan (2013) analysed the relationship between climate factors, including precipitation and water, with wheat yields, revealing a negative impact of precipitation on wheat production. Kiani and Tahmeena (2018) found a negative relationship between precipitation and wheat yield due to changing monsoon patterns. Abbas (2018) emphasized the overall positive impact of water availability on crop yield, asserting that water scarcity leads to reduced crop production. Mahmood (2020) explored variations in crop yield across Asian countries, specifically focusing on rice, wheat, and maize crops in Pakistan, and demonstrated the negative impact of changing weather conditions and precipitation on crop yield. Aslam (2021) conducted a comprehensive analysis of agriculture productivity and constraints in Pakistan. The study highlighted the yield gaps of major crops, such as wheat, cotton, rice, maize, and sugarcane, and the significant difference between average and potential yields. The author recommended the adoption of new technologies and efficient cultivation methods to bridge this yield gap. Khan (2021) highlighted Pakistan's significant expenditure on importing agricultural products and its negative effects on the trade balance. The author stressed the importance of increasing per acre yield, reducing wastage, and enhancing storage capacity of food items. Dietz, et al. (2021) argued that most of the regions of the world are facing water shortage problems but their duration and intensities trigger and their seasonal timing alters with the change of climate. It affects badly crop production because genetic cycle of crop planting and the development stage of seed germination, seedling formation, vegetative root and shoot growth, flowing, pollination, seed and fruit emergent are very sensitive to dehydration. Moreover, desiccation threatens yield and leads to specific patterns, which depends upon type of crop plant and the harvested segments of plant like leafy vegetables, tubers, tap roots or fruits. They suggested that control of shoot transpiration and the reorganization of root architecture are of vital need for maintaining proper plant and water relationship. Singh, et al (2021) examined 425 yield and 388 water productivity comparisons of different deficit irrigation levels to full irrigation (FI), using 185 published studies representing 30 countries. Moving from highest (> 80%FI) to lowest (< 35%FI) irrigation level, the overall yield decline was 6.9 to 51.1% compared to full irrigation, respectively. The water productivity gains ranged from 8.1% to 30.1%, with 35–50% full irrigation recording the highest benefits. They also noted that Soil texture affected the yield significantly only under the least irrigation class (< 35%FI), wherein sandy clay and loam recorded the highest (82.1%) and the lowest (26.9%) yield decline, respectively. Among the climates, temperate climate was overall the most advantageous with the least yield penalty (21.9%) and the highest water productivity gain (21.78%) across various deficit irrigation levels. They concluded that deficit irrigation affects crop yield and water productivity may be different with different climatic zones.

In light of the reviewed studies, it is evident that water availability is a critical input for increasing crop yield. While other inputs also play important roles, water remains indispensable. Most of previous studies focus on water shortage and measured its impact on crop yield. But this study has taken fertilizers, seeds, pesticides and precipitation in addition to water shortage to determine their impact on crop yield. In this way this study is unique from previous studies. The author found a gap in the literature and has intended to fill it through current study.

3. Results and Discussion

Secondary data spanning from 1991 to 2019 was used in this study and the data was collected from Pakistan Economic Survey (various issues), World Development Indicator, Federal Seed certificate and Registration Department, National Fertilizer Development Corporation and Metrological Department of Pakistan. The sample of study was agriculture sector. The variables selected for this study include: Water availability, Precipitation, Crop yield, Seed, Fertilizer and Pesticides. Crop yield is the dependent variable while water availability, fertilizers, seed, precipitation and pesticides are independent variables. The following econometric model has been built to determine relationship between independent and dependent variables. –

CP =Bo+B1(WA)+B2(P)+B3(SE)+B4(FZ)+B5(PS)+Ut ...

Where

● Crop yield is a dependent variable

● Water availability, precipitation, Seed, Fertilizer and Pesticides are independent variables.

• B1 = parameter of water availability
• B2 = parameter of perception
• B3 = parameter of seed
• B4 = parameter of fertilizer
• B5 = parameter of pesticides
• Ut = error term.

Various statistical techniques such as descriptive statistics, correlation matrix, ADF Test, ARDL approach, Bound Test and Error Correction model will be employed to analyze the data.

4. Results

4.1. Descriptive Analysis

Descriptive statistics techniques are used to summarize and describe the main characteristics of a dataset or sample. They provide a concise and meaningful way to analyze and present data, offering insights into its characteristics and patterns. Table 1 provides various descriptive statistics for different variables.

The Mean represents the average value of each variable. For example, the mean values for the variables, CY, FZ, WA, SE, PS, and P, are 43613.66, 19071.43, 817428.6, 2184.729, 3530.032, and 1460.714, respectively. The Median represents the middle value of each variable when the data is arranged in ascending order. The median values for the variables CY, FZ, WA, SE, PS, and P, are 30150.00, 19000.00, 897500.0, 999.0000, 2517.500, and 1400.000, respectively. The Maximum shows the highest value observed for each variable. The maximum values for the variables CY, FZ, WA, SE, PS, and P, are 117950.0, 25000.00, 1260000.0, 6134.000, 7442.600, and 2500.000, respectively. The Minimum reflects the lowest value observed for each variable. The minimum values for the variables CY, FZ, WA, SE, PS, and P, are 20633.50, 14000.00, 380000.0, 847.5000, 1973.400, and 500.0000, respectively. The Standard Deviation measures the dispersion or variability of the data around the mean. The higher the standard deviation, the greater the variability. The standard deviation values for the variables CY, FZ, WA, SE, PS, and P, are 29845.74, 3721.097, 320607.0, 1838.414, 1893.662, and 451.6138, respectively. The Skewness indicates the symmetry of the distribution of the data. A skewness value of 0 shows a perfectly symmetrical distribution. Positive skewness (greater than 0) suggests a longer tail on the right side of the distribution, whereas negative skewness (less than 0) reflects a longer tail on the left side. The skewness values for the variables, CY, FZ, WA, SE, PS, and P, are 1.458334, 0.237084, -0.118103, 0.981298, 1.121866, and 0.411818, respectively. The Kurtosis measures the "Peakedness" of the distribution compared to a normal distribution. Kurtosis values greater than 3 reflects heavier tails, while values less than 3 indicate lighter tails. The kurtosis values for the variables CY, FZ, WA, SE, PS, and P, are 3.738445, 1.652729, 1.376919, 2.308597, 2.496635, and 3.508397, respectively. The Jarque-Bera statistical test measures whether the data follows a normal distribution based on skewness and kurtosis. The lower the Jarque-Bera

Table 1: Result of Descriptive Statistics

	CY	FZ	WA	SE	PS	P
Mean	43613.66	19071.43	817428.6	2184.729	3530.032	1460.714
Median	30150.00	19000.00	897500.0	999.0000	2517.500	1400.000
Maximum	117950.0	25000.00	1260000.	6134.000	7442.600	2500.000
Minimum	20633.50	14000.00	380000.0	847.5000	1973.400	500.0000
Std. Dev.	29845.74	3721.097	320607.0	1838.414	1893.662	451.6138
Skewness	1.458334	0.237084	-0.118103	0.981298	1.121866	0.411818
Kurtosis	3.738445	1.652729	1.376919	2.308597	2.496635	3.508397
Jarque-Bera	10.56097	2.379970	3.138551	5.051455	6.168990	1.092984
Probability	0.005090	0.304226	0.208196	0.080000	0.045753	0.578977
Sum	1221182.	534000.0	22888000	61172.40	98840.90	40900.00
Sum Sq. Dev.	2.41E+10	3.74E+08	2.78E+12	91253693	96820855	5506786.

Source Authors Calculations

statistic, the closer the data is to a normal distribution. The Jarque-Bera values for the variables CY, FZ, WA, SE, PS, and P, are 10.56097, 2.379970, 3.138551, 5.051455, 6.168990, and 1.092984, respectively. The probability values for the variables CY, FZ, WA, SE, PS, and P, are 0.005090, 0.304226, 0.208196, 0.080000, 0.045753, and 0.578977, respectively. The Sum represents the sum of all values in each variable. The sum values for the variables CY, FZ, WA, SE, PS, and P, are 1221182, 534000.0, 22888000, 61172.40, 98840.90, and 40900.00, respectively. The Sum of Squared Deviations measures the sum of the squared differences between each observation and the mean. This value is useful in calculating variance and standard deviation. The Sum Sq. Dev. values for the variables CY, FZ, WA, SE, PS, and P, are 2.41E+10, 3.74E+08, 2.78E+12, 91253693, 96820855, and 5506786, respectively.

4.2. Correlation Analysis

Correlation analysis measures the degree of strength and direction of the linear relationship between pair of variables. The estimated results of correlation matrix are given in Table 2.

The coefficient value of correlation between CY and WA is 0.691627, which indicates a positive correlation, suggesting that as the values of CY increase, the values of WA also tend to increase, though not very strongly. The correlation coefficient between CY and FZ is 0.757309. It shows a positive correlation between crop yield and fertilizers, suggesting that there is a moderate positive relationship between CY and FZ. As CY increases, FZ also tends to increase. The correlation coefficient between CY and SE is 0.856179. This indicates a strong positive correlation, suggesting that there is a strong linear relationship between CY and SE. As CY increases, SE tends to increase. The correlation coefficient between CY and PS is 0.902179, which reveals a very strong positive correlation, suggesting a highly positive linear relationship between CY and PS. As CY increases, PS tends to increase. The correlation coefficient between CY and P is 0.015176. This value is close to zero, indicating a very weak correlation or almost no linear relationship between CY and P. The positive sign suggests a slightly positive relationship, but it is too weak to be practically significant. The correlation coefficient between WA and FZ is 0.819656. This indicates a strong positive correlation, suggesting that there is a strong linear relationship between WA

Table 2: Correlation Analysis

Variables	CY	WA	FZ	SE	PS	P
CY	1.00000	-	-	-	-	-
WA	0.691627	1.00000	-	-	-	-
Fz	0.757309	0.819656	1.00000	-	-	-
SE	0.856179	0.709443	0.733479	1.00000	-	-
PS	0.902179	0.703677	0.708628	0.971885	1.00000	-
P	0.015176	-0.000544	0.065646	-0.050979	-0.010241	1.00000

Source Authors Calculations

and FZ. As WA increases, FZ tends to increase. The correlation coefficient between WA and SE is 0.709443. This indicates a moderate positive correlation, indicating that there is a moderate positive linear relationship between WA and SE. As WA increases, SE tends to increase. The correlation coefficient between WA and PS is 0.703677. This indicates a moderate positive correlation, indicating that there is a moderate positive linear relationship between WA and PS. As WA increases, PS tends to increase. The correlation coefficient between WA and P is -0.000544. This value is very close to zero, indicating no substantial linear relationship between WA and P. The negative sign indicates a very weak negative relationship, but it is practically insignificant. The correlation coefficient between FZ and SE is 0.733479. This indicates a moderate positive correlation, suggesting that there is a moderate positive linear relationship between FZ and SE. As FZ increases, SE tends to increase. The correlation coefficient between FZ and PS is 0.708628. This indicates a moderate positive correlation, suggesting that there is a moderate positive linear relationship between FZ and PS. As FZ increases, PS tends to increase. The correlation coefficient between FZ and P is 0.065646. This value is close to zero, indicating no significant linear relationship between FZ and P. The positive sign suggests a slightly positive relationship, but it is too weak to be practically significant. The correlation coefficient between SE and PS is 0.971885. This indicates a very strong positive correlation, suggesting a highly positive linear relationship between SE and PS. As SE increases, PS tends to increase. The correlation coefficient between SE and P is -0.050979. This value is close to zero, indicating no signficant linear relationship between SE and P. The negative sign suggests a slightly negative relationship, but it is too weak to be practically significant. The correlation coefficient between PS and P is -0.010241. This value is close to zero, indicating no substantial linear relationship between PS and P. The negative sign suggests a very weak negative relationship, but it is practically insignificant.

4.3. ADF Unit Root Test

ADF test is used to test for the existence of a unit root in a time series data, which indicates whether the series is stationary or not. The results of this test enable the author to use correct model for analysis of data. If the variables are stationers at the same level, then Ordinary Least Square (OLS) method is used and if the variables at stationers at different levels, then ARDL model can be used. To make this decision the results of ADF test is presented in Table 3.

Table 3 shows the results of the Augmented Dickey-Fuller (ADF) test conducted on different variables at the level and first difference. The variables tested in the ADF test are Water availability (WA), precipitation) P), Seed (SE), Fertilizer FZ), and Pesticides (PS) and crop yield. (CY). Level: This column of variables represents

Table 3: Estimated result of ADF Test

Variables	Level			1st difference		
	intercept	T $ I	None	Intercept	T $ I	None
WA	-	-	-	-5.0760 P (0.0004) *	-5.0153 P (0.0023)	-4.5319 P (0.0001)
P	-4.6502 P (0.0009) *	-4.5682 P (0.005)	2.294 P (0.08)	-	-	-
PS	-	-	-	-7.7430 P (0.000)	8.55183 P (0.000) *	-2.4665 P (0.0158)
FZ	-	-	-	-10.482 P (0.000) *	10.269 P (0.000)	-10.486 P (0.000)
SE	-	-	-	-4.6545 P (0.010)	4.8925* P (0.002	-4.1146 P (0.002)
CY	2.6888 P (0.090)	2.603 P (0.07)	3.5217 P (0.090)	-	-	-

Source: Authors Calculations

the results of the ADF test conducted on the variables in their original form (level). The results are provided in the format of "intercept T $ I" and "p-value". For WA, the ADF test shows a significant negative value of -5.0760 with p-value of 0.0004 indicating that the variable WA is stationary at the level. For P, the ADF test shows a negative value of -4.6502 with a p-value of 0.0009, suggesting that the variable P is stationary at the level. For FZ, the ADF test reveals a negative value of -10.482 with a p-value of 0.000, indicating that the variable FZ is stationary at the level. For SE, the ADF test shows a negative value of -4.6545 with a p-value of 0.010, suggesting that the variable SE is stationary at the level. For CY, the ADF test reflects a positive value of 2.6888 with a p-value of 0.090, indicating that the variable CY is not stationary at the level 1st difference: This column represents the results of the ADF test conducted on the variables after taking the first difference. Again, the results are provided in the format of "intercept T $ I" and "p-value". For WA, the ADF test shows a negative value of -5.0153 with a p-value of 0.0023, suggesting that the variable WA is stationary after the first difference. For P, the ADF test indicates a negative value of -4.5682 with a p-value of 0.005, indicating that the variable P is stationary after the first difference. For PS, the ADF test reveals a positive value of 8.55183 with a p-value of 0.000, suggesting that the variable PS is stationary after the first difference. For FZ, the ADF test shows a positive value of 10.269 with a p-value of 0.000, indicating that the variable FZ is stationary after the first difference. For SE, the ADF test indicates a positive value of 4.8925 with a p-value of 0.002, suggesting that the variable SE is stationary after the first difference. For CY, the ADF test shows a positive value of 2.603 with a p-value of 0.07, indicating that the variable CY is not stationary after the first difference. Thus, the results prove that the variables are stationers at different level so we can use ARDL approach to analyze the data.

4.4. ARDL Approach

The ARDL (Auto-regressive Distributed Lag) model is used to analyze relationship between dependent variable (crop yield), and independent variables, Water availability (WA), precipitation (P), Seed (SE), Fertilizer FZ) and Pesticides (PS) and crop yield. (CY) WA, FZ, SE, PS, P, and C. The estimated coefficients show the effect of each independent variable on the

Table 4: Estimated results of ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
WA	0.010216	0.003161	3.231726	0.0232
FZ	1.321487	0.270762	4.880615	0.0046
SE	9.773857	3.420452	2.857476	0.0355
PS	25.144135	3.175702	7.917661	0.0005
P	-0.481481	1.024190	-0.470109	0.6581
C	-3100.716440	5163.494675	-0.600507	0.5743

Source Authors Calculations

dependent variable. The results of ARDL approach are presented in Table 4.

For water availability (WA), the coefficient is 0.010216. This suggests that a one-unit increases in the water availability will lead to an increase in crop yield by 10% in the long run, assuming other variables are constant. For Fertilizers, (FZ), the coefficient is 1.321487. This indicates that a one-unit increases in the use of fertilizers will likely to increase crop yield by 13.21% in the long, holding other variables constant. For Seed (SE), the coefficient is 9.773857. This suggests that a one-unit increases in the use of quality seed will likely to increase crop yield by 97.73% in the long run 9.773857, holding other variables constant. The value of the coefficient of Pesticides (PS) is 25.144135, which indicates that a one-unit increases in the use of quality pesticides will likely to increase in crop yield by 251.44% in the long run, assuming all other variables as constant. The coefficient value of precipitation is -0.481481, which suggests that one-unit increases in the precipitation (P) will lead to an estimated decrease in crop yield by 48.14%, holding all other variables constant. For C, the coefficient is -3100.716440. which captures the estimated value of the dependent variable when all independent variables are zero. The standard error provides the standard error of the coefficient estimates. It measures the precision or reliability of the coefficient estimates. Smaller standard errors indicate more precise estimates. The t-Statistic is calculated by dividing the coefficient estimate by its standard error. The t-statistic measures the statistical significance of the coefficient estimate. Generally, larger absolute t-statistics indicate greater significance. The Prob. provides the p-value associated with the t-statistic. The p-value indicates the probability of observing the estimated coefficient by chance if there were no true relationship between independent and dependent variables. Smaller p-values (typically below a certain threshold, e.g., 0.05) suggest that the coefficient estimate is statistically significant. These results demonstrate that all independent variables such as water availability, fertilizers, seeds and pesticides have positive and significant relationship with dependent variable, crop yield, while precipitation has negative association with it in the long run. These findings support the results of. Januja (2011) and Kiani, Tahmeena (2018) and Mahmood (2020) who found positive relationship between water availability, seeds, pesticides, fertilizers and crop yield and negative association between precipitation and crop yield in the long run.

4.5. Bound Test

The Bound test is applied to get confirmation of the long run results of ARDL model. This test determines long run relationship between variables of the model. It also helps us test Null and Alternative hypotheses. Null hypothesis states that there is no relationship between independent and dependent variables whereas alternate hypothesis states that there is significant relationship between

Table 5 Estimated results of Bound Test

Null Hypothesis: No long-run relationships exist

Test Statistic	**Value**	**k**
F-statistic	3.5095	5
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Source Authors Calculations

Table 6: Estimate results of Error Correction Model

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(CY(-1))	3.447647	0.682609	5.050688	0.0039
D(WA)	0.361453	0.090350	-4.000573	0.0103
D(WA(-1))	-0.250131	0.080627	-3.102338	0.0268
D(WA(-2))	0.127354	0.031967	3.983977	0.0105
D(FZ)	0.791445	0.778991	-1.015987	0.3562
D(SE)	43.063032	15.304551	-2.813740	0.0374
D(SE(-1))	47.173754	13.541779	3.483571	0.0176
D(PS)	29.406158	5.908163	4.977209	0.0042
D(PS(-1))	-71.179600	17.987013	-3.957277	0.0108
D (PS (-2))	19.494236	2.984939	6.530865	0.0013
D(P)	17.749591	6.317015	2.809807	0.0376
D (P (-1))	4.607576	2.424408	1.900495	0.1158
D (P (-2))	14.716289	5.642256	2.608228	0.0478
Conte (-1)	-0.235545	0.581282	-7.286554	0.0008
Counted = YP - (0.0102* WA +1.3215*PS. +9.7739*SE + 25.1441*FZ				
-0.4815*P -3100.7164)				

Source Authors Calculations

independent and dependent variables. The F-statistics is applied to compare whether calculated value is greater than lower bound and upper bound values at the significance of 1%, 2.5%, 5% and 10% level. F-statistics distribution is non-standard irrespective of where variables are stationers at I (0) and I (1). These values are mixture of two sets, one set is I (0) and other set is I (1). The estimated results of Bound Test are highlighted in Table 5.

The results of Bound Test clearly indicate that calculated value of F-statistics is 3.5095, which is greater than the lower bound values, which are 3.79,4.18,4.68 at 5%,2.5% and 1% significance level, revealing the existence of long run relationship between variables. Thus, Null hypothesis is rejected and alternate hypothesis is accepted.

4.6. Error Correction Model

The ECM is widely used for short-term forecasting by incorporating the error correction term and the lagged values of the variables. This allows for better prediction by capturing both short-term dynamics and long-term equilibrium. The ECM helps in assessing the effectiveness of policy interventions and understanding the dynamics of the relationship between policy variables and their impact on the target variable s. The ECM helps capture the co-integration relationship, correct short-term deviations, analyze causality, make forecasts, and evaluate policy interventions. The results of Error Correction Model are presented in Table 6. The results of ECM show that the variable D (CY (-1)) represents the first difference of a variable called CY lagged by one period. The coefficient of 3.447647 suggests that a one-unit increases in D (CY (-1)) is associated with an average increase of 3.44% in the dependent variable. The t-Statistic of 5.050688 indicates that this coefficient is statistically significant at the 5% level (assuming a two-tailed test), as the associated probability (p-value) is less than 0.05. The variables D(WA), D (WA (-1)), D (WA (-2)) represent the first differences of a variable called WA at different lags. The coefficients indicate the impact of each lagged variable on crop yield. For example, a one-unit increases in D(WA) leads to an average increase of 0.361453 units in crop yeid. The negative coefficient for D (WA (-1)) (-0.250131) suggests that an increase in the lagged value of WA leads to a decrease in the dependent variable. All three coefficients are statistically significant at the 5% level. The coefficient values of variables: D(FZ), D(SE), D (SE (-1)), D(PS), D (PS (-1)), D (PS (-2)), D(P), D (P (-1)), D (P (-2)) are 0.791445, 43.063032, 47.173754, 29.406158, -71.179600, 19.494236, 17.749591, 4.607576 and 14.716289, respectively. The values of standard deviation are 0.778991, 15.304551, 13.541779, 5.908163, 17.987013, 2.984939, 6.317015, 2.424408, 5.642256 The t-Statistics: of these variables are -1.015987, -2.813740, 3.483571, 4.977209, -3.957277, 6.530865, 2.809807, 1.900495 and 2.608228. The Probs: 0.3562, 0.0374, 0.0176, 0.0042, 0.0108, 0.0013, 0.0376, 0.1158, 0.0478. These variables represent the first differences of various other variables. The coefficients highlight the impact of each variable on the dependent variable. For example, a one-unit increase in D(FZ) leads to an average increase of 0.791445 units in the crop yield. The t-Statistics and associated probabilities indicate the statistical significance of these coefficients. The variable CointEq (-1) represents the lagged value of a variable called CointEq. The coefficient of -0.235545 suggests that a one-unit increases in CointEq (-1) leads to a decrease of 0.235545 units in the dependent variable. The t-Statistic of -7.286554 shows that this coefficient is highly statistically significant at the 1% level, as the associated probability (p-value) is very low (0.0008). The equation Cointeq = YP - (0.0102WA + 1.3215PS + 9.7739SE + 25.1441FZ - 0.4815*P - 3100.7164) represents the cointegrating relationship in the model. It shows the long-term equilibrium relationship between the dependent variable (denoted as YP) and the independent variables (WA, PS, SE, FZ, P). The coefficients attached to each independent variable indicate the impact of that variable on the dependent variable in the short run. These results are consistent with the findings of Bastiaanssen (2004) who found that water availability has positive impact on crop yield but precipitation has negative relation with it due to changing pattern of monsoon. The results of this study also support the findings of Shafique (2009), Siddiqui (2012) Amjad (2014) who explored relationship between water management and crop yield and analyzed the impact of water availability, precipitation on yield of major crops such as rice, maize and wheat and other minor crops.

5. Discussion

This research sheds light on different issue of water shortage, low crop yields, and food crisis in Pakistan. Time series data spanning from 1991-2019 collected from Pakistan Economic Survey (various issues), World Development Indicators, Federal Seed certificate and Registration Department, National Fertilizer Development Corporation and Metrological Department of Pakistan were used. The sample of study was agriculture sector. The variables selected for this study include: Water availability, Precipitation, Crop yield, Seed, Fertilizer and Pesticides. Crop yield was the dependent variable while water availability, fertilizers, seed, precipitation and pesticides were independent variables. Various econometric techniques such as Descriptive Statistics, Correlation Matrix, ADF Unit Root Test, ARDL Model, Bound Test and Error Correction Model were employed to determine relationship between variables in the long and short run. The research methodology of this study is rigorous and well-structured and it has facilitated to capture the complex relationship between different factors affecting agriculture production. The use of ADF test for assessing stationarity reveal that the variables are stationers at different levels and as such we can apply ARDL Model. Similarly, the use of Correlation Matrix shows the positive linear association between all variables except Seed and Pesticides. The use of ADF Test and Correlation matrix enhanced the credibility of the research methodology. The application of ARDL model enable us to determine relationship between variables in the long run. The statistical analysis reveals positive association between water availability (WA) and crop yield as their coefficient value is 0.010216. This indicates that one-unit increases in the water availability will likely to cause an increase in crop yield by 10.21% in the long run, assuming other variables are constant. Similarly, the association between fertilizers (FZ) and crop yield is also positive because their coefficient value is 1.321487. It suggests that if one-unit increases in the use of fertilizers will likely to improve crop yield by of 13.21% in the long, holding other variables constant. The relationship between Seed (SE) and crop yield is also positive and their coefficient value is 9.773857. This numerical value reveals if one unit increases in the application of quality seed it will likely to enhance crop yield by 97.73 % and this association between two variables is statistically significant in the long run. It also suggests that the farmers should give priority to quality seed in cultivation of crops and resultantly they will get high return on their investment and efforts in the form of high crop yields. Moreover, the relationship between Pesticides and crop yield is also statistically significant because the coefficient value of Pesticides is 25.144135, which indicates that if one-unit increases in the use of quality pesticides it will likely to boost crop yield by 251.44% in the long run. However, the relationship between precipitation and crop yield is negative because the coefficient value of precipitation is -0.481481 and it suggests if one-unit increases in the precipitation (P) will likely to decrease in crop yield by 48.14%, In other words, Precipitation has negative effect on crop yield in the long run. These results show that all independent variables such as water availability, fertilizers, seeds and pesticides have positive and significant relationship with dependent variable, crop yield, while precipitation has negative association with it in the long run. The Bound Test also confirms the results of ARDL Model. The Error Correction Model used in this study enable us to assess the speed of adjustment of variables. It also enhances the robustness of the analysis. The findings of study highlights may key insights. For example, all independent variables except precipitation show positive association with crop yield. This indicates that variables such as Seed, Pesticides, Fertilizers and water availability have significant impact on crop production. However, it may be noted that the impact of these variables on crop yield is more pronounced in the short run as compared to the long run. This is major difference between the results of ARDL and Error Correction Models. These findings support to the results of. Januja (2011) and Kiani, Tahmeena (2018) and Mahmood (2020) who found positive association between water availability, seeds, pesticides, fertilizers and crop yield and negative association between precipitation and crop yield in the long run.

6. Conclusions

We can conclude the study by highlighting the challenges faced by Pakistan in sustaining food security. The root cause of the food crisis is that water scarcity and unavailability of quality seeds, fertilizers, and other essential agricultural inputs at affordable prices trigger the food crisis and inflate prices of good items year by year. To cope with the food crisis, the Government of Pakistan has to import food items and spend billions of dollars annually. This situation demands investment in building water reservoirs and the provision of quality seeds, fertilizers, and pesticides at affordable prices to enable the farmers to use these inputs timely and get high returns on their investments and efforts in the form of high crop yield and profit. Otherwise, it would discourage the farmers and force them to shift to other profitable businesses. Awareness must be generated among the farmers through media about the use of modern farming technologies to increase crop yield. Pakistan is getting 30% less crop yields than the world's average crop yield. It will have to take proper policy initiatives to come at par with its peers by providing agriculture inputs at subsidized prices and giving fiscal incentives to farmers by fixing prices of cash crops. It will motivate the farmers to make efforts to use quality seed, fertilizers and pesticides to enhance the production of food grains. It will save billions of dollars being spent on import of food items annually. It will significantly reduce Pakistan's balance of payment problem and ensure the availability of food grains at normal prices in the domestic market.

6.1. Theoretical contribution

The theoretical contribution of this study is that it has examined the relationship between various factors (water availability, seed, fertilizer, pesticides, precipitation) and crop yield. The study provides insights into the factors that influence crop production by investigating these relationships. The study also emphasizes the importance of water availability as a fundamental requirement for higher crop yield. This theoretical contribution reinforces the existing knowledge about the significant role of water in agricultural production. The study's findings support economic theories that suggest a positive impact of water, seed, fertilizer, and pesticides on crop yield. By validating these theories, the study strengthens the understanding of agricultural production's economic principles.

6.2. Practical implications

The practical implications lie in providing empirical evidence that these factors significantly affect crop productivity, both in the short and long run. In this study, there is valuable insight for policymakers, farmers, and stakeholders of agriculture sectors regarding effective water management practices, selection of seeds, and use of fertilizers and pesticides for increasing crop yield. The study conducts a comparative analysis of different models (ARDL, Bound test, and Error Correction Model) to evaluate the impacts of specific variables on crop yield. This practical contribution enhances understanding of the factors, which have stronger effects on crop yield in the short run versus the long run, providing valuable insights for decision-making in agricultural planning and resource allocation.

6.3. Limitations and suggestions for further research

Other researchers can expand this study by increasing sample size, datasets, number of variables, and latest analytical techniques. It has used 28 years of data on major agricultural crops in order to predict the production of these crops. Future researchers may expand this period and include more variables in their studies to broaden the results. The author selected five variables: water, seed, fertilizer, pesticide, and precipitation, as independent variables to check their impact on crop yields. More variables can be included in future studies. The new researchers can also use technology to impact crop yield and to predict weather conditions. This study did not measure the impact of the prices of inputs on the production of agricultural crops and the behaviors of farmers. Other researchers may analyze the impact of prices on crop yield and farmers' behaviors.

6.4. Data availability statement

The corresponding author will provide the data supporting this study's findings on reasonable request.

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8. Declaration of Conflict of Interest

The authors declared no potential conflicts of interest concerning the research, authorship and publication of this article.

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