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IMPACT OF WATER CRISIS ON FOOD PRODUCTION IN PAKISTAN: A TIME-SERIES ANALYSIS

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ABSTRACT

The food production process across the developing world is under huge pressure pertaining to mounting challenges like water shortage, low fertility of land, climatic variations, lack of technological progress, and many other unforeseen challenges. This study explores the impact of water crises on food production. The food production index was used for food production and water crises relationship measured in water availability (million-acre feet). Other explanatory variables, remittances, fertilizer, number of tractors, agricultural land, were used as control factors for the period 1975 to 2017. The autoregressive distributive lag (ARDL) model was used for the analyses. Water crises had significant and negative effects on food production. Besides, that other control factors like, fertilizer, remittances, agricultural land, and numbers of tractors also had a substantial and positive impact. The results indicate a long-run relationship between water crises and food production because the error correction term is significant and negative. Water crises (shortage of water availability) decreases the capacity of the land to produce low crop yields. In order to meet the food demand, water scarcity needed to be addressed in the policies. Moreover, government should encourage the small farmers in particular by providing them fertilizers, high efficiency irrigations system and machinery (i.e., tractors) at subsidized rates. .

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INTRODUCTION

The concept of food security emerged after the mid-1970s when discussions were held on international food's complexity during the global food crisis. Initially, the main focus was on food supply issues - announcing critical food availability and, to some extent, stabilizing its international and domestic prices. All global and institutional concerns about supply reflect the World Food Program's growth, which led to the crisis (Regmi and Paudel, 2016). This was followed by the launch of the International Franchise Process, which was crucial for the 1974 World Food Conference, and the launch of a series of institutional innovations, including information and resources to achieve food security. Since the mid-1970s, there has been extensive research on poverty, hunger, and the food crisis. McKinsey & Co (2009) has identified a worldwide shortage of freshwater. The gap between the rising demand and supply for freshwater is likely to widen by 2030. Agriculture sector in Pakistan is regarded as lifeline for the national economy. It accounts for 19.2% of GDP and absorbs 38.5% of the labour force (Government of Pakistan, 2021). It is also an essential source of foreign exchange earnings and stimulates the growth of other allied sectors. Support to the farmers and adoption of modern technologies are deemed necessary to achieve the targeted growth. According to the report of Pakistan's sixth population and residential census (2017)[1], the population of Pakistan grew on an average of 2.4% per year. Rapid population growth has increased the demand for agricultural products (Abadi *et al.*, 2018). Debt, fertilizer, prices for agricultural tube wells, and cheap electricity, in the last 13 years, has experienced moderate and negative growth in farming seasons. Which could leverage and adverse impacts on agriculture sector in Pakistan. Several studies have reported that production of major crops in Pakistan is less than the potential for many reasons including water shortage (Arifullah *et al.*, 2009; Rehman *et al.*, 2015; Abro and Awan, 2020).

Water scarcity has adverse impacts on agricultural production especially when farmers are unable to irrigate their crops timely. Agriculture, which accounts for over 70% of global water withdrawals, is continually fighting for a limited water supply with home, industrial, and environmental applications (Rosegrant *et al.*, 2002). Many people have sought to develop more effective water management methods in an attempt to solve this ever-growing challenge. Irrigation management is a strategy to manage and judicious application of water to crops to increase agriculture yield. Many of the irrigation systems in place are inefficient in their utilisation of water. Levidow *et al.* (2014) argued that technological advancements in water sector have not brought full benefits through water efficiency. Farmers do not have adequate access to the sources to explore the current on-farm water efficiency levels. Improper irrigation techniques and agricultural practices are regarded as driving forces behind water use inefficiency (Bjornlund *et al.*, 2020). Socio-economic attributes such as education, farm income, land size and membership of water user associations are also regarded as the factors behind low water use efficiency (Chuchird *et al.*, 2017).

The study aims to explore the relationship between water crises, fertilizers, agricultural land, remittances and the use of tractors in Pakistan. The study explained how water scarcity reduces food production. Further, it explained how remittances, fertilizers, and agricultural land impact the food production.

LITERATURE REVIEW

Iqbal *et al.* (2001) analyzed the factors of higher wheat productivity in Pakistan's cropping zones using the primary data collected through a structured questionnaire from 643 wheat growers. The researcher has measured the wheat yield as the dependent variable. The independent variables were standard cultivator numbers, seed rate, irrigation, fertilizers, sowing method, chemical weed control. The effects of these factors on wheat yield were examined through a statistical package for social scientists' descriptive analysis. The Cobb Douglas function was estimated for that model. The results showed that the land preparation, seed rate, fertilizer use, sowing wheat, weeding, irrigation had significantly changed between the current and previous Rabi season. and suggested to need adequate resources to research Another study Hanjra and Qureshi (2010) used date from 1971-2000 and found that with the increase in population and likelihood of bringing an increase in income would accelerate the demand for food and water. They concluded that food consumption and its massive role in the market, type of food and volume of available water and unjust trade relation must be a challenge to food security. There is a need to raise awareness about the types of crops that use less fertilizers and less water intensive,

Khanom (2016) investigated the effect of salinity on food security. The primary data was collected through five focus group discussions and eight in-depth interviews with key informants. The dependent variable was soil water crises and crop yield. The independent variables were salinity and soil wetness, saline soils; crank Nicolson method of finite differing was used to solve the differential equation of soil water. The relationship among salt concentration matric potential, moisture deficit, and actual transpiration was also established to provide better considerate about Stalinization's impact and provide guidelines for obtaining improved crop Yield in salty soil (Lamsal *et al.*, 1999).

Niang *et al.* (2017) investigated for unpredictability and determination of yield in rice making system of West Africa. The data from farmers' on adopted agricultural practices was collected through interviews. Rice production was taken as a dependent variable. The independent variables were the Edaphic attribute, climate attribute, Agricultural practice, Land preparation, planting material and establishment,

[1] https://www.pbs.gov.pk/content/provisional-summary-results-6th-population-and-housing-census-2017-0

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Fertility Management weed, and pest control. The cumulative distribution, probability distribution technique was used. There was a negative effect of soil clay content on yield in irrigated and rain-fed lowland systems. Remittances reduced the likelihood of unsafe households. This study urged investment in irrigation in Ghana to ensure a year-round supply of water for growing crops (Atuoye *et al.*, 2017). Remittances have a positive relationship with food security. It is essential to know that international transfers were necessary for improving domestic food security. African governments can benefit from international migration by enhancing the food security status of their citizens to reduce political instability (Sulemana *et al.*, 2018). Another study, Kiawu and Jones (2013) used the Central Bureau of Statistics (CBS) model to study the effects of food aid and remittances on food import demand in West Africa. The figures include food imports from West Africa and expenditure for five major food categories: milk, animal products, fruits and vegetables, oilseeds, staple foods, and all other foods. Imported foods, including beverages, dairy products include all dried, condensed, and evaporated milk, whole milk, milk, butter, and poultry eggs. They found remittances and expenditures made to access the food were significantly associated, From the above research literature, a relationship between water shortage, fertilizers, and food availability is established. However, economic factors are not brought under debate neither it was explored that how these factors play a role as catalysts to overcome the water crises and increase food production. In the current study, we take remittances as an economic factor in the model and capture its effect as a catalyst to boost up the relationship between water availability and food production.

METHODOLOGY

To see the impact of remittances, fertilizer, water crises, agricultural land, and the number of tractors on food production, the following model was developed.

Food Production = f (Remittances, Fertilizer, Water crises, Agriculture land, Number of Tractors)

The data set covers the period from 1975 to 2017. Data on food production, remittances, water crisis, fertilizer, number of tractors, and agricultural land are consistently available for the chosen period that was considered for the analysis. Because of the missing data on some variables, it was adjusted by taking the averages. Data was gathered and verified from two sources, i.e., World Development Indicator[2] (WDI, 2019) and Pakistan Economic Survey (2010 & 2017). The econometrically form of the model is as follows.

Food = β0+ β1 (Remittances) + β2 (Water) + β3 (Fertilizer) + β4 (Agriculture Land) + β5 (Number of Tractors) + μ

Where;

Food Availability = Food Production Index (2004-2006 = 100)

Remittances = Personal Remittances, Received (% of GDP)

Agriculture Land = Agricultural Land (% of Land Area)

Water crises = MAF (million-acre feet)

Number of Tractors = Total Numbers of Tractors

Fertilizer = Fertilizer off take

To estimate the model, the Augmented Dickey-Fuller (ADF) test was applied to check the stationary of variables. Some variables were stationary at the first difference; it means some were I (1), and some variables were stationary at the level; it means some were I (0). This status of variables allows applying the Autoregressive dependent lags (ARDL) test to check the long-run relationship among variables. After reviewing the stationary, ARDL Tests were applied to the data. The time-series data for all the variables are used from 1975 to 2017.

The representation of the equation in the ARDL approach can be expressed by as:

$$Food_t = \alpha_o + \sum_{i=1}^{p} \alpha_1 \Delta food_{t-1} + \sum_{i=0}^{p} \alpha_2 \Delta remittances_{t-1} + \sum_{i=0}^{p} \alpha_3 \Delta water_{t-1} + \sum_{i=0}^{p} \alpha_4 \Delta fertilizer_{t-1} + \sum_{i=0}^{p} \alpha_5 \Delta agriland_{t-1} + \sum_{i=0}^{p} \alpha_6 \Delta tractor_{t-1} + \alpha_7 food_{t-1} + \alpha_8 remittances_{t-1} + \alpha_9 water_{t-1} + \alpha_9 fertilizer_{t-1} + \alpha_{10} agriland_{t-1} + \alpha_{11} tractor_{t-1}$$

[2] https://data.worldbank.org/country/pakistan

Table 1. Variable's definition and their expected signs.

Variable	Definition	Measurement	Sources of Data	Expected Sign
Food production	Food production is the proxy of food availability. The food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because of no nutritive value.	Food production index (2004-2006 = 100)	World Development Indicator	(Dependent Variable)
Agriculture land	Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures.	Agricultural land (% of land area)	World development indicator	Positive
Remittances	Personal remittances comprise personal transfers and the compensation of employees. Private transfers consist of all current transfers in cash, or in-kind made or received by resident households to or from non-resident households	Personal remittances received (% of GDP)	World development indicator	Positive
Number of Tractors	The total number of tractors produced	Total numbers of tractors	Pakistan Economic survey	Positive
Fertilizer	Fertilizer offtake measured in thousands of nutrient tons	Fertilizer offtake room/T	Pakistan Economic survey	Positive
Water crises	Water crises measured in a million acre-feet (Appears to be a shortage of water). Water availability per person in Pakistan today is 1,000 cubic metres, down from 5,600 cubic metres per person in 1947, There were about 35 million people in Pakistan in 1947. Today there are over 220 million, but water availability is on decline gradually.	MAF (million-acre feet)	Pakistan Economic survey	Negative

RESULTS AND DISCUSSION

In this section, the summary statistic is used to investigate the characteristics of the model's variables. Table 2 shows the descriptive statistics for all the important variables involved in this study to estimate the food production process in Pakistan.

Table 2. Descriptive statistic of variables involved in food production.

Variables	Obs.	Mean	St. Dev.	Min	Max
Agriculture Land	43	47.02	0.89	45.67	49.95
Remittances	43	5.20	2.18	1.45	10.25
Food Production	43	79.01	31.54	33.41	131.05
Water	43	120.33	17.98	84.57	142.44
Fertilizer	43	2453.82	1212.79	425.5	5040.1
Number of tractors	43	10.14	0.58	8.88	11.18

Table 3. Result of ADF Test.

Variables	Level		1st difference	Decision
	Intercept	Trend		
Food production index	-0.4760 (0.9839)	-2.7442 (0.2252)	-6.8967 (0.0000)	I(1)
Agriculture land	-7.5844 (0.0000)	-7.1228 (0.0000)		I(0)
Fertilizer	-0.0906 (0.9430)	-5.7306 (0.0001)	-3.7251 (0.0078)	I(1)

Number of tractors	-2.0844 (0.2517)	-2.6513 (0.2611)	-5.9755 (0.0000)	I(1)
Remittances	-1.5974 (0.4750)	-1.4984 (0.8144)	-7.2420 (0.0000)	I(1)
Water crises	-2.2925 (0.1791)	-0.1297 (0.9926)	-8.6742 (0.0000)	I(1)

Note: P-values in Parenthesis

Table 4. ARDL bound test Approach Based on (AIC).

Dependent Variable: Food				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
FOOD (-1)	0.674516	0.08339	8.08872	0.00
REMITTANCE	-0.56267	0.391645	-1.43668	0.169
REMITTANCE (-1)	0.158138	0.40231	0.393075	0.6991
REMITTANCE (-2)	0.620818	0.394918	1.57202	0.1344
REMITTANCE (-3)	0.909649	0.426303	2.133807	0.0477
REMITTANCE (-4)	-0.56405	0.27564	-2.04631	0.0565
TRACTORS	4.085691	1.133521	3.604424	0.0022
TRACTORS (-1)	-3.98834	1.491643	-2.67379	0.016
TRACTORS (-2)	3.791976	1.13527	3.340153	0.0039
WATER	-0.054536	0.082637	-0.659942	0.5181
WATER (-1)	-0.13912	0.085175	-1.633341	0.1208
WATER (-2)	-0.024168	0.092813	-0.260396	0.7977
WATER (-3)	-0.233566	0.080476	-2.902305	0.0099
WATER (-4)	-0.14309	0.101989	-1.40298	0.1786
FERTILIZER	-0.00072	0.001278	-0.56033	0.5826
FERTILIZER (-1)	0.004673	0.001543	3.027933	0.0076
AGRILAND	-0.14624	0.390127	-0.37486	0.7124
AGRILAND (-1)	0.966596	0.458685	2.107322	0.0502
AGRILAND (-2)	1.030524	0.572947	1.79864	0.0899
AGRILAND (-3)	-1.44988	0.429784	-3.37352	0.0036
AGRILAND (-4)	-1.71487	0.559971	-3.06243	0.007
Model Diagnostics				
R-squared				0.999154
Adjusted R-squared				0.998159
Durban Watson				2.041157

Table 5. Test for the existence of relationship among the variables.

F-Bounds Test				
Critical Value Bounds				
Test Statistic	Value	Significance	I0 Bound	I1 Bound
F-statistic	15.223	10%	1.81	2.93
K	5	5%	2.14	3.34
		2.50%	2.44	3.71
		1%	2.82	4.21

For the application of ARDL, the stationarity of all variables was investigated through the ADF test as shown in Table 3. The ARDL bound test approach was used to check the co-integration of the variables as shown in Table 4. The test reported the co-integration between the dependent (water crises) and independent variables (Agriculture Land, Remittances, Food Production, Fertilizer and Number of tractors). The findings of the foregoing test (see Table 5) demonstrate that food production, remittances, fertiliser, water scarcity, and the size of land, number of tractors had a long-term complementing relationship. We would estimate the long-term viability under ARDL by identifying a balanced relationship between the variables.

According to Table 6, Water crises (million acre-feet) have a detrimental influence on food production, whereas remittances (personal remittance received as a per cent of GDP), the number of tractors (total number of tractors), agriculture land (percentage of land area), and fertiliser had a favourable impact. Remittances had a large and positive impact on food availability in the long run since an increase in remittances leads to an increase in the country's income, which in turn leads to an increase in food availability. As a result, the overall effect revealed that there is an increase in food availability as a result of the increase in remittances (Pesaran *et al.*, 2001). Remittances had a coefficient of 1.726.

Fertilizer has a large and beneficial impact on food availability in the long run because proper fertiliser uses in food crops ensure increase in food output. Inadequate availability of water reduces the efficiency and potential production of crops. Thus, water crises had a large and negative impact on food availability. Land used for agriculture has a significant impact on food production. After all, expanding agricultural land boosts food production (El Benni and Finger, 2013). We check R^2 and adjusted R^2 values, which are respectively 99% each, indicating that independent variables explained 99% of the dependent variable, which is acceptable according to the Durbin Watson value of 2.04, indicating that the model is good because it is greater than 1.96.

The LM test for autocorrelation was used, and the results showed that there was no autocorrelation in the data. The probability value of the LM test is 0.2216, and the value of heteroscedasticity according to the Breusch-pagan-Godfrey test, which shows that there is no heteroscedasticity in the model, is 0.7932, hence the model is satisfactory. The error correction term is statistically significant and has a negative sign, indicating that the model will converge to equilibrium at a speed of adjustment of 0.32, or 32 per cent, implying that the model will converge to equilibrium in about three years.

Table 6. Estimated Long Run Coefficients using ARDL Approach.

ARDL long run form				
Dependent variable: FOOD				
Sample: 1975-2017				
Variable	Coefficient	SE	T-stat	Prob.
REMITTANCE	1.726	0.986	1.751	0.098
TRACTORS	11.949	4.449	2.686	0.016
WATER Crises	-0.947	0.307	-3.082	0.007
FERTILIZER	0.012	0.005	2.528	0.022
AGRILAND	4.037	1.108	3.643	0.002
Breusch-Godfrey Serial Correlation LM Test				0.2216
Heteroskedasticity Test; Breusch-Pagan-Godfrey				0.7932

Table 7. Short Run Estimates of Error Correlation Model.

Variable	Coefficient	SE	T-stat	Prob
D (REMITTANCE)	-0.5626	0.3916	-1.4366	0.1690
D (REMITTANCE (-1))	-0.6208	0.3949	-1.5720	0.1344
D (REMITTANCE (-2))	-0.9096**	0.4263	-2.1338	0.0477
D (REMITTANCE (-3))	0.5640*	0.2756	2.0463	0.0565
DLOG (TRACTORS)	4.0856***	1.1335	3.6044	0.0022
DLOG (TRACTORS (-1))	-3.7919***	1.1352	-3.3401	0.0039
D (WATER)	0.0545	0.0826	0.6599	0.5181
D (WATER (-1))	-0.0241	0.0928	-0.2603	0.7977
D (WATER (-2))	-0.2335***	0.0804	-2.9023	0.0099
D (WATER (-3))	0.1430	0.1019	1.4029	0.1786
D (FERTILIZER)	-0.0007	0.0012	-0.5603	0.5826
D (AGRILAND)	-0.1462	0.3901	-0.3748	0.7124

D (AGRILAND (-1))	-1.0305*	0.5729	-1.7986	0.0899
D (AGRILAND (-2))	1.4498***	0.4297	3.3735	0.0036
D (AGRILAND (-3))	1.7148****	0.5599	3.0624	0.0070
Coint Eq (-1)	-0.3254***	0.0833	-3.9031	0.0011

Note: *** indicates significance level at 1%, ** indicates significance level at 5%, and * tells the significance level at 10%, shows 10%.

DISCUSSION

Water scarcity, poor fertile soil, lack of technological innovation, and other issues plague the food production process in underdeveloped countries. This research looked into the effects of water shortages on food production. Food production and water emergencies are measured in water availability using the food production index (million-acre feet). For the period 1975 to 2017, other explanatory variables, such as remittances, fertiliser, the number of tractors, and agricultural land, were included as control factors. The analyses were conducted using the autoregressive distributive lag (ARDL) model. Water shortage shad a major and detrimental impact on agricultural production. Other control elements, such as fertiliser, remittances, farmland, and tractor numbers, also have a significant and favourable impact. Because the error correction term is substantial and negative, the results suggest a long-run link between water emergencies and food output. Water crises (a lack of water) reduce the land's ability to produce low agricultural yields that are insufficient to meet the food demand. The government should play a long-term role by giving low-cost fertiliser and tractors to poor farmers, as well as improving irrigation infrastructure and finding new markets for Pakistani agriculture products in wealthy countries. The impact of water scarcity on agricultural production is massive. Farmers who do not have intime access to water are unable to irrigate their crops, and as a result, are unable to get the targeted potential, much needed to meet the dietary requirements of the world's fast-growing population. Agriculture, which uses more than 70% of the world's water, is constantly contending for a limited supply of water for domestic, industrial, and environmental uses (Rosegrant *et al.*, 2002). In an attempt to address this ever-increasing problem, intensive work has been conducted to develop more effective water management technologies. One such method is High efficiency irrigation methods. Many of the existing irrigation systems are inefficient in terms of water usage. As a result, either too much water is consumed, or not enough water is available to maintain healthy crops. According to the World Bank in 2013, irrigation management entails updating and maintaining existing irrigation systems, such as groundwater irrigation, as well as increasing irrigation areas to increase crop yields.

Results of this study confirm that food production, remittances, fertiliser, water scarcity, and the number of land tractors had a long-term supportive relationship. We would estimate the long-term viability under ARDL by identifying a balanced relationship between the variables. Water crises (million acre-feet) was found negatively influencing the food production, while remittances (personal remittance received as a percent of GDP), the number of tractors (total number of tractors), agriculture land (percentage of land area), and fertilizer have a favourable impact. Remittances have a large and positive impact on food availability in the long run since an increase in remittances leads to an increase in the country's income, which in turn leads to an increase in food availability. However, onus remains on availability of water in order to irrigate the crops to ensure potential production. Thus, water scarcity needs to be addressed further with the emphasise to explore that what kind of strategies are required to enhance the water use efficiency.

CONCLUSION AND RECOMMENDATIONS

This study shows that independent variables remittances, water crises, fertilizer, number of tractors, agriculture land, significantly and positively determined the food production in Pakistan for the selected period 1975 to 2017. All the independent variables are significant both in the short-run and long run. Water crises was significant and negatively related to food production; when water is properly available for food crops, then food production will be increased otherwise food production will be decreased due to the shortage of water. Fertilizer is significant and positively associated with food availability because when the proper fertilizer is used in food production, then the total food production will be increased. The number of tractors, agricultural land is also significant and positively related to food availability.

Except for the water crisis, there are alternative ways where government should play its role by encouraging and supporting the poor farmer with debt financing at low rates and providing fertilizer and tractors at a low price to increase production. The government should improve irrigation systems like canals, tube-wells, solar energy systems for tube-well energy to improve per acre yield. Moreover, it is highly recommended that use of High Efficiency Irrigation System should be promoted on farm level.

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