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Harvesting Resilience: Safeguarding Pakistan's Food Future Amidst Climate Challenges

ABSTRACT

As an integral part of Pakistan's agrarian economy, the agricultural sector is vital to the country's overall economic health. The country's strategic position and reliance on natural resources make it extremely susceptible to the negative consequences of climate change. Punjab Province produces over 80% of Pakistan's wheat and has over 90% of its farmers grow wheat. Researchers used to focus on average temperature and rainfall in the study area. However, this study incorporated new variables including CO_2's direct impact on crop growth, average temperature, and urbanization. This study examined how climate change affects Pakistani food security using 1990–2021 time-series data. The primary objective of this study is to shed light on the interconnected nature of climate change and Pakistan's agricultural sector for the benefit of scholars, policymakers, and those with an interest in the subject. To evaluate the long-term and short-term connections between climate change and agricultural productivity, this study uses the Autoregressive Distributed Lag (ARDL) model, which takes into consideration non-stationarity and endogeneity. Data The study's results point to climate change having a major negative effect on Pakistan's agricultural output. According to the extended analysis, the agricultural industry is seeing a continuous decrease because of climate change. The results highlight how critical it is to act quickly to help the agriculture industry adapt to and lessen the impact of climate change. Agricultural initiatives for climate resilience include research on heat-tolerant crop varieties, water management, sustainable farming, renewable energy adoption, carbon pricing, economic diversification, climate-resilient agriculture, improved irrigation systems, trade access, and rural development support.

Keywords
Food Security, Climate Change, Agriculture Production, CO_2 Emissions
JEL Classification
O13, Q18, Q54, F18

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Author's contribution in the article: 1- Conceived and designed the analysis, 2- Reviewed and compiled the literature, 3-Collected the data, 4- Contributed data or analysis tools, 5- Performed the analysis, 6- Wrote the paper, 7- Financial support for the conduct of the study, 8-Other

1. INTRODUCTION

Pakistan's agriculture economy is suffering from climate change. Due to precipitation and temperature swings, agriculture is at risk. Climate change hinders Pakistan's agricultural economy. Due to precipitation and temperature swings, agriculture is at risk. Greenhouse gases (GHG) like CO2, CH4, and N2O are a major cause of global climate change (Shakoor et al., 2011). Climate change is projected to cause sea level rise, precipitation pattern changes, and climatic zone shifts due to increased temperatures. Climatic changes will likely worsen droughts, storms, and floods.

Climate change, poverty, and food insecurity are the three main global issues facing humanity today. The reliance on fossil fuels makes no nation secure from the harmful impacts of climate change, and by 2050, 216 million people may be forced to leave their homes due to climate change. Human activities, such as incineration of non-renewable resources, deforestation, and industrial processes, are the primary cause of climate variation, with most of these changes being permanent (World Bank, 2021). Carbon emissions, including carbon dioxide (CO2), are the primary contributor to climate change, causing significant changes in global temperatures and weather patterns. In 2017, global carbon dioxide emissions reached an unprecedented level of 36.2 gigatons (Le Quéré et al., 2018). These emissions have adverse impacts, such as rising sea levels, increased frequency of extreme weather events, and changes to ecosystems and biodiversity. Figure 1 shows that 76% of greenhouse gases are carbon dioxide, 16% are methane, 6% are nitrous oxide, and 2% are HCF, PCF, and SF6 (EPA, 2017).

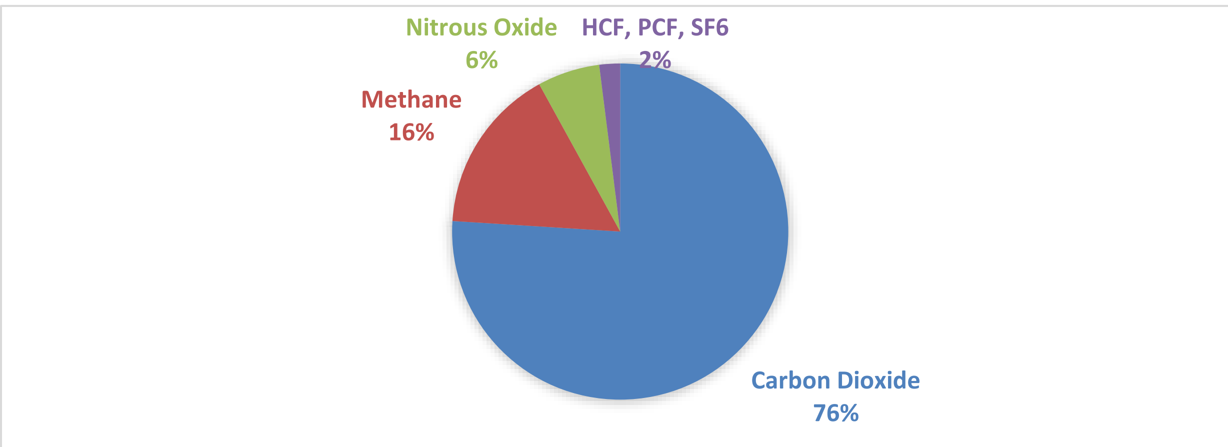

Figure 1: Global GHG emissions by gases.
Source: EPA (2017)

Various studies suggest reducing carbon emissions is essential to combat climate change, requiring switching to low-carbon energy sources, adopting sustainable land use practices, and implementing efficient policies and international agreements (Knutti et al., 2016). Atmospheric carbon dioxide is the major component of greenhouse gases, accounting for 76% of greenhouse gases. The global concentration of carbon dioxide has doubled since the 1700s, reaching 417 ppm (Met Office, 2021). This increase is almost double the pre-industrial era, taking over 200 years for CO2 emissions to increase by 25% by 1986, 40% by 2011, and 50% in just 10 years UNICEF, 2021). This situation is like Pakistan's CO_2 emissions situation, with increased flood frequency and heatwave incidents. Despite disaster management authorities, Pakistan has struggled to mitigate the effects of catastrophes, leading to food insecurity and a global crisis affecting around a billion children (Shahzad & Amjad, 2022).

Pakistan is facing significant challenges due to its geographical location and socio-economic conditions, which have led to significant changes in temperature, precipitation regimes, and severe weather phenomena.

These changes have resulted in increased heat events, droughts, and flooding, affecting agricultural infrastructure, crop loss, soil degradation, and irrigation mechanisms. The rising temperatures and changing precipitation patterns also pose significant threats to water resources, particularly the Himalayan glaciers. The agricultural industry, a crucial sector for Pakistan's GDP, has been significantly impacted by climate change, leading to diminished agricultural output and disrupted food production infrastructures (Haque et al., 2019). Heat stress, water scarcity, and increased pests and diseases have exacerbated the issue of food insecurity, exposing vulnerable demographics to insufficient well-being and nourishment (Akhtar et al., 2020).

The South Asian region, including Pakistan, has experienced a rise in both the frequency and intensity of extreme weather phenomena, posing a significant risk to food and water resources. The Intergovernmental Panel on Climate Change warns that the frequency of extreme weather events is expected to rise in the future, posing a substantial risk to Pakistan's food security (Mendelsohn et al., 2020). Pakistan's food production capacity is directly threatened by climate change, with the Himalayan glaciers experiencing a greater loss in mass since 2000 than they did over the 20th century. This poses a significant threat not only to agricultural activities and income sources but also amplifies the likelihood of water scarcity (Chaudary et al., 2009).

The highly productive regions of Punjab and Sindh are subjected to flash floods, property damage, and loss of life during the summer season due to heightened monsoon rains (Malik, 2022). The conflict in Ukraine has disrupted wheat exports from "Europe's breadbasket," causing damage to approximately 10-15% of their crops. The agricultural productivity of Pakistan may face impediments due to recurrent instances of severe climatic events, making it particularly vulnerable to climate change effects (Global Hunger Index, 2022; Mustafa, 2022).

Pakistan's reliance on natural resources and agricultural sector makes it vulnerable to climate change's adverse impacts on food production, availability, and accessibility. Climate change causes temperature alterations, rainfall patterns, and CO_2 emissions, affecting water availability, productivity, and agricultural yield. Severe weather events, such as cyclones and heat waves, also impact food security by affecting crop, livestock, and infrastructure. Marginalized communities and small-scale farmers are particularly affected due to limited resources and poverty. A comprehensive approach is needed to address these challenges, including implementing adaptable agricultural techniques, improving water management, promoting sustainable land use, and offering diverse livelihood opportunities. Urgent action is needed to mitigate climate change, enhance adaptive capabilities, and ensure sustenance for current and future generations in Pakistan.

Research Questions explored in this study regarding climate change impact on Pakistan's Agriculture:

- Examining short and long-term impacts of climate change on agricultural productivity and crops.
- Investigating socio-economic determinants affecting susceptibility to climate change impacts.
- Identifying vulnerabilities and risks to food security from CO_2 emissions, changing rainfall patterns, and temperature variations.

Climate change mitigation, adaptation, and sustenance for current and future generations are urgent in Pakistan. This study intends to further investigate the short run and long run correlation between climate change variables, namely temperature, and precipitation, CO_2 omissions and the overall agricultural production in Pakistan over both the short and long term. This article is structured as follows: Section 2 presents a review of the literature. Section 3 discusses Data and Descriptive. The econometric methodology is presented in Section 4. Section 5 analyzes Empirical results. Section 6 discusses results. Section 7 presents the Conclusion.

2. LITERATURE REVIEW

Climate change affects vital crop cultivation, affecting food security and agricultural productivity, particularly wheat production, according to numerous studies. Climate fluctuation affects food production, compromising long-term agricultural viability (Wheeler & Braun, 2013). Cold temperatures during wheat flowering are essential. Climate experts agree on two points: Due to rapid global climate change, heatwaves, floods, and droughts have increased by 0.8°C since the early 1900s. Warming might reach 2.4-6.4°C by the end of the century without carbon mitigation. Droughts and floods destroy agricultural production. Due to rising sea levels, arable land is scarcer (Gornal et al., 2010).

By 2080, food demand might rise 300%, but without climate change, supply may fall behind (Cline, 2008). Developing countries that depend on agriculture to reduce poverty are susceptible. The 2007-2008 food crisis showed this susceptibility, exacerbated by climate change (Bandara & Cai, 2014). South Asian countries, despite low greenhouse gas emissions, are hardest hit. Agriculture is affected by harsh weather and warming (World Bank, 2013). Climate change threatens Pakistani wheat, rice, cotton, sugarcane, and maize. Shifting precipitation patterns threaten rain-fed agricultural, which supports 60% of Pakistan's population (Syed et al., 2022). Global warming from greenhouse gas emissions makes Pakistan 12th most vulnerable to climate change (Awan & Yaseen, 2017).

Effective climate adaption is essential. Water management requires irrigation channel modifications. Major emitter livestock production needs sustainable greenhouse gas reduction practices (Baigal, 2016). Climate change increases food insecurity, disproportionately harming vulnerable groups. Yield and water availability affect food supply and diet. Climate-sensitive livelihoods are threatened, and water quality issues can worsen health (WFP, 2015). Climate change affects water supplies, agriculture, biodiversity, and human health worldwide, especially in poor countries (Barnett et al., 2014). Due to its mild climate and agricultural dependency, Pakistan is vulnerable to climate change-induced floods and droughts (Boone, 2008). In Pakistan, spate irrigation is popular in the agricultural industry, which employs 45% of the workforce and contributes 21% to GDP (Câmpeanu & Fazey, 2014).

Climate change impacts food security by reducing crop output, livestock health, and harsh weather (Mustafa et al., 2021). Main crops like maize, rice, wheat, and soybeans are not growing fast enough globally (Parry et al., 2004). Pakistan's irrigation-dependent agricultural industry faces climate change implications, threatening food security and economic stability (Ali et al., 2021). Droughts and floods increase due to climate change, making resource management, technology, investment, and infrastructure harder (Kiseleva, 2003). Water scarcity in Pakistan's Indus basin challenges farmers' livelihoods and food security as temperatures rise and precipitation patterns change (Sarkar, 2012). Climate change reduces agricultural output, causing economic instability, supply-demand imbalances, and commodity prices (Jayne et al., 2010). Due to labor-intensive technology and limited adaptation resources, developing nations are more vulnerable to climate change (ADB, 2009). Rising temperatures and unpredictable precipitation patterns affect Asian agriculture, especially subsistence farmers in rural and poor areas (Shakoor et al., 2011).

Pakistan's rural population depends on agriculture for income and food. The sector's success is essential for poverty reduction and economic growth. Climate change increases the frequency and severity of droughts, floods, and heatwaves, which reduce crop yields, especially for staples like wheat, rice, and maize (Ahmed, 2020; Hussain, 2020). Climate change reduces water availability, forcing farmers to grow water-efficient crops like sunflower and mung bean (Rehman, 2020). Pakistan's food production and accessibility are threatened by climate change. Food availability and pricing are affected by irregular rainfall, extended droughts, and extreme weather (Pakistan Economic Survey, 2021; FAO, 2023). Warming and shifting precipitation patterns reduce crop and livestock productivity, worsening food poverty (World Bank, 2012). Climate change worsens social inequities, especially for women and marginalized populations (Sage, 2014).

These impacts can be mitigated by encouraging resilient agricultural and urban food production (Ziervogel & Frayne, 2011). Managing climate change's many issues demand comprehensive food security and socioeconomic measures.

Agriculture provides food and money to Pakistan's rural population, reducing poverty and boosting economic growth. Climate change increases droughts, floods, and heatwaves, lowering wheat, rice, and maize yields (Ahmed, 2020; Hussain, 2020). Climate change scarcity forces farmers to use water-efficient crops like sunflower and mungbean (Rehman, 2020). Climate change threatens Pakistan's food security by causing unpredictable rainfall, droughts, and harsh weather (Pakistan Economic Survey, 2021; FAO, 2023). Warming and changing precipitation patterns reduce crop and livestock productivity, worsening food poverty (World Bank, 2012). Climate change worsens socioeconomic inequality, especially for women and marginalised groups (Sage, 2014). Resilient agriculture and urban food production can address these issues (Ziervogel & Frayne, 2011). Food security and socioeconomic policies are needed to address climate change's many effects.

To summarize, climate change poses a threat to agricultural and food security in Pakistan and around the world, necessitating strong strategies to offset its numerous consequences.

3. DATA AND DESCRIPTION

Our study includes variables from whom data is taken from secondary source. The sources for our variables are World Bank, World Development Indicators, and Economic Survey of Pakistan. Below is the table 1 that shows the complete description of data and variables that we have taken in our study.

Table 1: Description of Variables

Abbreviation	Name of variables	Unit	Data Source
PERC	Average precipitation in depth	mm per year	World Bank
CO2	CO2 emissions	metric tons per capita	WDI
AVEGT	Average temperature	Degree Celsius	World bank
TRADE	Trade	% of GDP	WDI
GDP	Gross Domestic Product	constant 2015 US$	WDI
URB	Urbanization	% of pop living in urban areas	WDI
AGRI	Total agriculture production	‘000 Bales	Economic Survey of Pakistan

Table 2 provides descriptive statistics for the study variables. AGRI (total agriculture production) displays dispersion with slight negative skewness and a moderately peaked distribution. CO2 emissions exhibit nearly symmetrical distribution. GDP demonstrates a stable distribution. AVEGT, PERC, TRADE, and URB show varying degrees of left skewness and kurtosis, with PERC deviating from normality.

Table 2: Summary Statistics of Variables

Statistics	AGRI	CO_2	GDP	AVEGT	PERC	TRADE	URB
Mean	5.955	69.480	11.17	20.86	29.68	32.22	32.9
Median	6.045	68.703	11.174	20.82	31.38	32.92	33.1
Maximum	7.06	104	11.533	22.67	39.68	38.5	37.4
Minimum	4.79	41.084	10.74	19.79	2.564	24.70	28.1
Std. Dev.	0.699	15.81	0.229	0.60	7.055	3.72	2.74
Skewness	-0.035	0.203	-0.196	0.373	-1.3	-0.41	-0.11
Kurtosis	1.6737	2.516	1.9642	3.449	6.259	2.21	1.84
Jarque-Bera	3.087	0.697	2.147	1.324	30.82	2.24	2.39
Probability	0.214	0.706	0.342	0.516	0	0.33	0.30
Sum	250.13	2918.19	469.28	876.37	1246.82	1353.42	1382.01
Sum Sq. Dev.	20.057	10243.6	2.165	14.77	2040.87	567.81	307.26

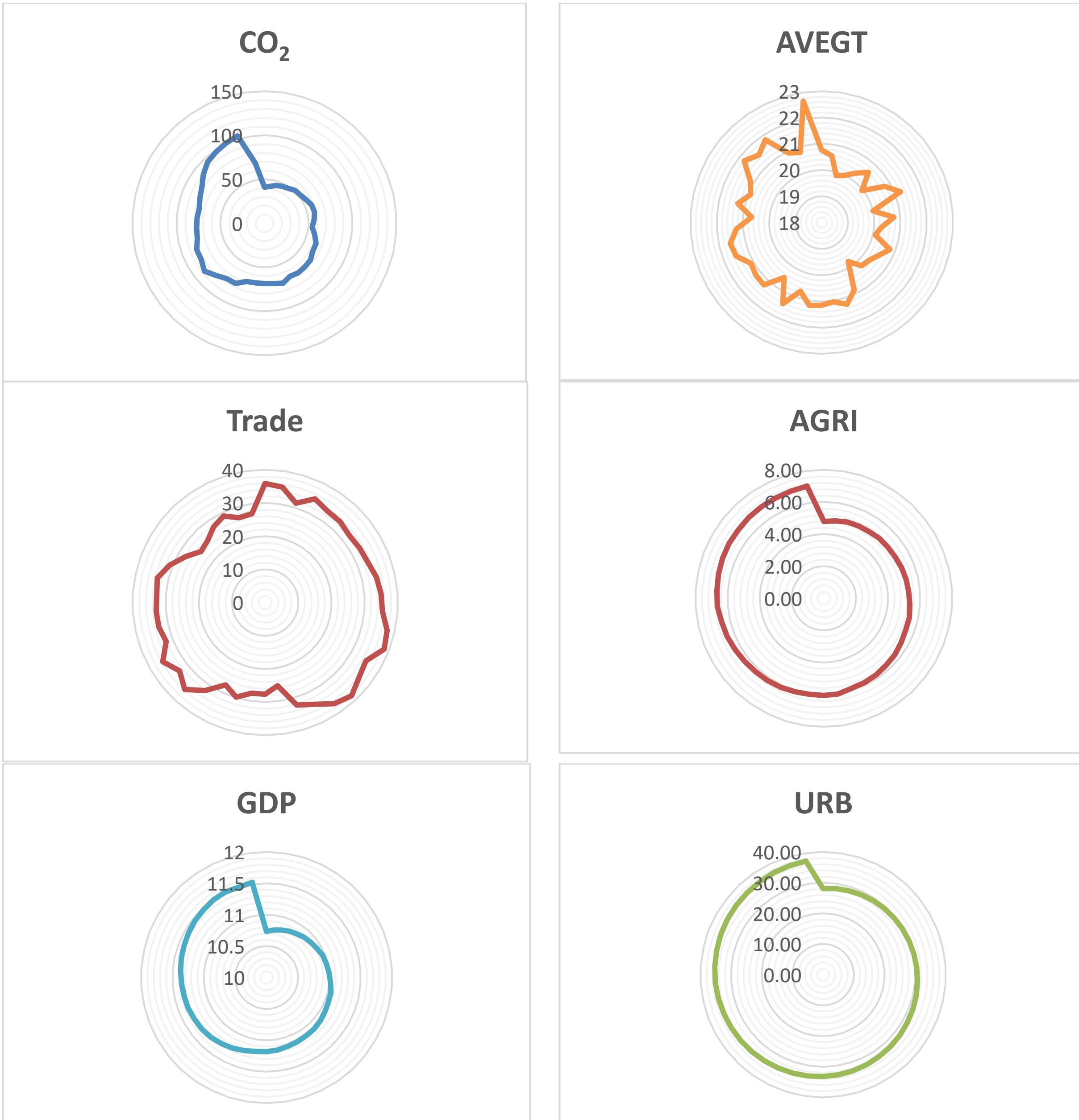

Figure 2: Graphical Illustration of Variables

Figure 2 shows the graphical illustrations of both the dependent and independent variables used in our model using radar chart.

4. METHODOLOGY

Following model has been proposed to determine the impact of CO2, precipitation, average temperature, trade, urbanization, and GDP the total agriculture production in Pakistan.

$$AGRI_t = f(CO2_t, PERC_t, AVEGT_t, TRADE_t, GDP_t, URB_t) \quad (1)$$

We can further specify the above general equation as:

$$AGRI_t = \beta_0 + \beta_1 CO2_t + \beta_2 PERC_t + \beta_3 AVEGT_t + \beta_4 TRADE_t + \beta_5 GDP_t + \beta_6 URB_t + \varepsilon_t \quad (2)$$

In the above equation, AGRI represents the total agriculture production of Pakistan, CO2 represent the total annual CO2 in metric ton per capita, PERC represents precipitation, AVEGT represents average temperature in the given time, TRADE represents trade in the given time frame, GDP represents gross domestic product, and URB stands for urbanization in Pakistan. β_0 is the intercept term in the equation whereas β_5 to β_6 are vectors of parameters. ε_t is the random error term, whereas t stands for the time series that range from year 1980 to 2021.

To construct our equation based on the approach Auto Regressive Distributed Lag (ARDL) which was put forth by (Pesaran et al., 2001), where (-1) with each variable represents the first difference of the variable lagged by one period η0 is the intercept and η1 toη7 are the parameters to be estimated for each variable. εt in the equation stands for the random error term.

$$AGRI_t = \alpha_0 + \sum_{i=1}^{n} \eta_2 \, \Delta CO_{2(t-1)} + \sum_{i=1}^{n} \eta_3 \, \Delta PERC_{(t-1)} + \sum_{i=1}^{n} \eta_4 \, \Delta AVEGT_{t-1} + \sum_{i=1}^{n} \eta_5 \, \Delta TRADE_{t-1} + \sum_{i=1}^{n} \eta_6 \, \Delta GDP_{t-1} + \sum_{i=1}^{n} \eta_7 \, \Delta URB_{t-1} + \varepsilon_t \quad (3)$$

ARDL Co-integration:

$$AGRI_t = \eta_0 + \sum_{i=1}^{q} \eta_2 \, \Delta CO_{2(t-1)} + \sum_{i=1}^{n} \eta_3 \, \Delta PERC_{(t-1)} + \sum_{i=1}^{n} \eta_4 \, \Delta AVEGT_{t-1} + \sum_{i=1}^{n} \eta_5 \, \Delta TRADE_{t-1} + \sum_{i=1}^{n} \eta_6 \, \Delta GDP_{t-1} + \sum_{i=1}^{n} \eta_7 \, \Delta URB_{t-1} + \lambda_2 (CO_2)_t + \lambda_3 PERC_t + \lambda_4 AVEGT_t + \lambda_5 TRADE_t + \lambda_6 GDP_t + \lambda_6 URB_t + \varepsilon_t \quad (4)$$

In equation (4) the term εt represents the error correction term. It captures the short-run adjustment towards the long-run equilibrium. It is noteworthy that the ARDL equation in the long-run encompasses the error correction term, which signifies the pace of adaptation towards the long-run equilibrium.

5. EMPIRICAL RESULTS

5.1 Unit Root Analysis

Table 3 illustrates that although certain variables exhibit stationarity at the level or the first difference, there are others that do not. Employing the Auto Regressive Distributed Lag (ARDL) method, we ascertain the impact of independent factors on the outcome variable in models that comprise both stationary and non-stationary variables.

Table 3: Unit Root Test Results

	ARGI	CO2	GDP	AVEGT	PERC	TRADE	URB
ADF test (at Level)	-0.646	-1.963	-3.1**	-2.99**	-6.4***	-1.999	0.558
Test-Stat (Prob.)	0.848	0.3014	0.036	0.043	0.000	0.286	0.986
ADF test (at first diff)	-6.4***	-2.601	-4.52***	-5.4***	-6.9***	-6.9***	-3.13**
Test-Statistic (Prob.)	0.000	0.101	0.001	0.0001	0.000	0.000	0.032
P-P tests (At Level)	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-.67
T-Stat (Prob.)	0.843	0.301	0.067	0.038	0.000	0.290	0.206
P-P test (at 1st difference)	-6.412	-2.595	-4.504	-11.867	-15.12	-6.948	-3.261

5.2 Short- and Long-run ARDL Analysis

Table 4 shows the immediate effects of trade, CO2 emissions, average temperature, precipitation, and urbanization on agricultural productivity. Our services include providing coefficients, t-statistics, standard errors, and probabilities. Probabilities less than 0.05 show statistical significance. The t-statistics of the significant independent variables (GDP, AVEGT, TRADE, CO_2, PERC, URB) are above 2, indicating a short-term connection to agricultural production. According to significant coefficients, a one percent increase in GDP results in a drop in agricultural production by 1.62539 percent. The agricultural productivity increases by 0.094168 units for every unit of AVEGT. An incremental rise in commerce by one unit leads to a corresponding increase in agricultural output by 0.012097 units. Agricultural production increases by 0.24214% for each 1% increase in urbanization. The presence of CO2 has an indirect negative impact on agricultural productivity, resulting in a decrease of 0.061160 units per unit. Based on the coefficient of precipitation, a one unit increase in precipitation results in a 0.016761 rise in agricultural production. An ECM score of -0.458527 indicates convergence and a 45% convergence will be achieved in a year. Automatic lag length selection criterion is adopted.

Table 4: Short run ARDL outcomes

Variable	Coefficient	Variable	Coefficient
C	10.47***	**D (CO2EMISSIONS (-1))**	-0.021
AGRI (-1) *	-0.46***	**D(GDP)**	0.538
CO2EMISSIONS (-1)	-0.06**	**D (GDP (-1))**	2.06**
GDP (-1)	-1.63***	**D(AVEGT)**	0.005
AVEGT (-1)	0.09***	**D (AVEGT (-1))**	-0.052***
PERC (-1)	0.017***	**D(PERC)**	0.00037
TRADE (-1)	0.013***	**D (PERC (-1))**	-0.013***
URB (-1)	0.24***	**D(TRADE)**	-0.003
D (AGRI (-1))	-0.35***	**D (TRADE (-1))**	-0.008***
D(CO2EMISSIONS)	-0.03**	**D(URB)**	0.571

In Table 5, the probability values, and t-statistics from the ARDL model reveal the long-term relationships between variables. CO2 emissions, GDP and AVEGT are indicating strong long-term associations. However, the probability of precipitation exceeds 0.05, suggesting no significant long-term correlation. Conversely, the probabilities for commerce and urbanization have strong and direct connections with agricultural productivity over time.

GDP, AVEGT, CO2EMISSIONS, PERC, TRADE, and URB exhibit significant long-term relationships with agricultural productivity. Notably, a one percent increase in GDP corresponds to a 3.54481 percent decrease in agricultural production, while a one unit increase in AVEGT leads to a 0.205371 unit rise in agricultural production. Similarly, each incremental increase in commerce boosts agricultural production by 0.026382 units. Conversely, a one percent decrease in urbanization results in a reduction of 0.528971 percent in agricultural production. Additionally, each unit increase in CO2 emissions corresponds to a decrease of -0.045413 units in agricultural production.

Table 5: Long Run ARDL outcomes

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO_2 EMISSIONS	-0.045***	0.012	-3.931	0.0057
GDP	-3.55***	1.053	-3.366	0.0032
AVEGT	0.21***	0.057	3.633	0.0018
PERC	0.013***	0.001	13.207	0.0000
TRADE	0.027***	0.009	3.01	0.0072
URB	0.53***	0.084	6.325	0.0000
C	22.84***	8.23	2.777	0.0120

Cointegration between variables is predicted by Bound's cointegration analysis. Table 6 shows that bound's test's f-stat value, 7.591514, is greater than both the upper and lower bound critical values at 5% significance.

Table 6: Bound's Cointegration Analysis

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	7.591514	10%	1.99	2.94
K	6	5%	2.27	3.28
		2.50%	2.55	3.61
		1%	2.88	3.99

The CUSUM and CUSUMSQ diagnostic tests are frequently employed in econometrics to evaluate the temporal stability of parameters in a regression model. Figures 3 and 4 depict the plots of CUSUM and CUSUMQ, respectively. The presented plots indicate that, at a 5% level of significance, the line is situated within the critical values of both the upper and lower bounds. This suggests that the model is stable.

Climate change significantly impacts global agricultural production, including Pakistan's vital agriculture sector, historically reliant on rainfall. Research indicates both favorable and adverse effects of climate change on Pakistan's agriculture. Rising temperatures and erratic precipitation patterns negatively impact agricultural productivity, confirmed by ARDL model analysis. Trade positively influences Pakistan's agriculture, facilitating access to inputs and markets. Urbanization and GDP exert significant effects, altering land use and labor availability. Economic progress often accompanies a shift away from agriculture, affecting productivity.

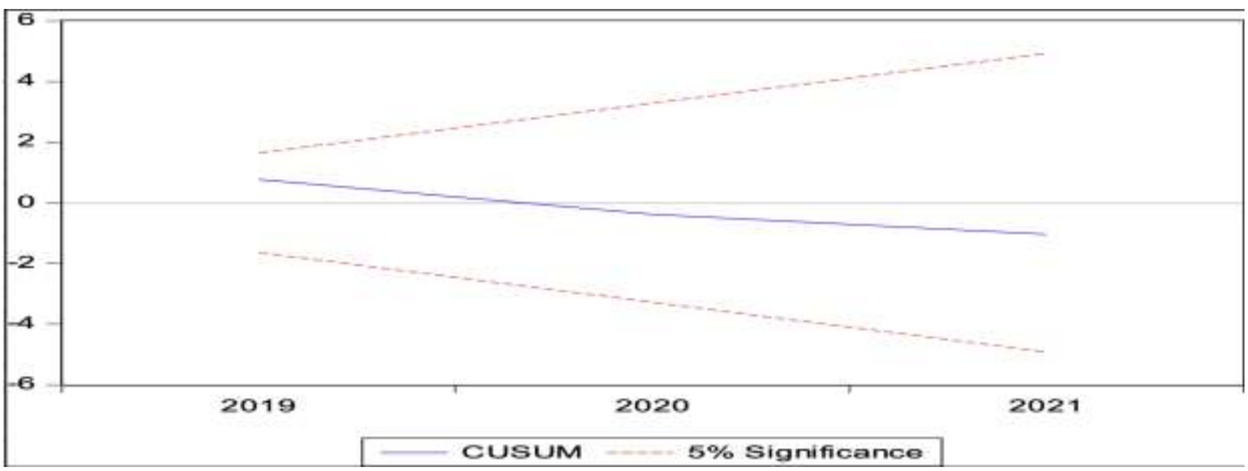

Figure 3: ARDL CUSUM at 5% level of significance.

Figure 4: ARDL CUSUM of Squares at 5% level of significance.

CO_2 emissions have mixed effects, potentially enhanced plant growth but also contributing to global warming's adverse impacts on crop production. Pakistan's agriculture is vulnerable to climate-induced water scarcity, affecting crop yields. Precipitation variability directly affects soil moisture and crop water needs. Insufficient or irregular rainfall leads to droughts, reducing agricultural productivity. Conversely, excessive precipitation causes soil degradation and crop damage. These findings align with previous research, highlighting the critical role of precipitation in Pakistan's agriculture.

6. CONCLUSION AND POLICY IMPLICATIONS

This study examines climate change's impact on Pakistan's agriculture, analyzing significant and insignificant independent variables. Findings reject the null hypothesis and indicate climate change and socioeconomic factors significantly affect Pakistan's food security by influencing total agriculture production. Strong positive correlations exist between total agriculture production, average temperature, precipitation, and urbanization. Conversely, significant negative relationships occur between agriculture production, GDP, and CO_2 emissions.

Climate change adaptation measures are crucial to mitigate rising temperatures' adverse effects on agriculture. Market access, international integration, and urbanization positively affect agriculture. GDP's inverse correlation with agricultural output reflects economic structural transformation during development. While economic growth can redirect resources from agriculture, prudent policymaking can foster sustainable agricultural practices amid economic progress. CO_2 emissions and precipitation play pivotal roles in climate change and water availability, directly or indirectly affecting agricultural results. Policymakers must consider these factors in devising strategies to improve agricultural resilience and sustainability amidst climate change challenges.

To align with the Paris Agreement and sustainable development goals, Pakistan might adopt sustainable policies to:

- Research for heat-tolerant crop varieties and water management systems.
- Implement water management practices and promote drought-tolerant crop varieties.
- Reduce greenhouse gas emissions through sustainable farming and renewable energy adoption.
- Diversify economy from high carbon emissions to sustainable sectors.
- Develop climate-resilient agriculture and improved irrigation systems.

Successful policy implementation requires political commitment, stakeholder collaboration, and financial support. Continuous monitoring and adaptive management are essential for ensuring the effectiveness and durability of climate change adaptation measures for food security in Pakistan.

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