DOI: 10.52131/pjhss.2025.v13i4.3233

Pakistan Journal of Humanities and Social Sciences

Volume 13, Number 04, 2025, Pages 346-356
Journal Homepage:
https://journals.internationalrasd.org/index.php/pjhss

Climate Change and Food Security: Panel Data Evidence from D-8 Countries

Usama Shehzad[1], Sadia Bibi[2], Muhammad Atiq-ur-Rehman[3], Rashid Ahmad[4]

[1] Graduate Student, Superior University, Lahore, Pakistan. Email: mailofusamashehzad@gmail.com
[2] Assistant Professor, School of Economics, Bahauddin Zakariya University, Multan, Pakistan. Email: sadia.bibi@bzu.edu.pk
[3] Assistant Professor, Higher Education Department, Punjab & Superior University, Lahore, Pakistan.
Email: atiq164@live.com
[4] Assistant Professor, School of Economics, Bahauddin Zakariya University, Multan, Pakistan.
Email: rashidahmad@bzu.edu.pk

ARTICLE INFO

Article History:

Received:	November 18, 2025
Revised:	December 28, 2025
Accepted:	December 29, 2025
Available Online:	December 30, 2025

Keywords:
Climate Change
Food Security
Agricultural Credit
Green Finance
Panel Data
D-8 Countries

Funding:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

Climate change is one of the main risks for food security, especially in the developing economies where agricultural practices rely on the weather. This study investigates the impact of climate change on food security in the D-8 countries, taking into account the influence of agricultural credit while considering population growth and agricultural land area. The Food Production Index (FPI) is used as a proxy for food security, and annual precipitation and average temperature as indicators of climate change. Based on annual panel data set for the period 1990 -2024, this study uses the fixed effects estimator as the primary estimation approach; however, the random effects method is also employed for assessing the robustness of empirical results. It is found that precipitation and temperature exert a positive and significant influence on food production.. The population exhibits a negative and significant effect on food production. Agricultural land has a positive impact on food production. The robustness analysis using the random effects shows that the impacts of explanatory variables remain robust in general. The research suggests that there should be an increase in agricultural credit, adoption of climate-smart agricultural techniques, improvement of water resource management, land protection for agriculture, and regional collaboration within the D-8 countries.

Corresponding Author's Email: sadia.bibi@bzu.edu.pk

1. Introduction

Food Security is described as a situation in which all people have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs (Food and Agriculture Organization). There is a four pillar approach that splits the problem of food security into four elements, namely availability, access, utilization and stability which still serve as the basis for most empirical researches on food security (Food and Agriculture Organization, 2018). The problem of food security is among the most important development challenges of the 21st century. The challenge of building resilient food systems in the face of climate change is slowly making its way into policy discussions especially in the developing countries where agriculture is the main source of livelihood, exports and employment. Average temperatures are rising, rainfall patterns are changing and there are more reports about extreme weather phenomena.

This link can be examined for an important group of countries from analytical point of view, the Developing-8 (D-8) Organization for Economic Cooperation which includes Bangladesh, Egypt, Iran, Indonesia, Malaysia, Nigeria, Pakistan and Turkey. The D-8, taken together, account for a significant portion of the world's Muslim population spread out across four continents and covering a variety of climatic zones from arid and semi-arid in Egypt, Iran, Nigeria and Pakistan, humid tropical in Indonesia, Malaysia and Bangladesh. Despite this diversity, the study conducted by the panel is still meaningful, as agriculture remains an important contributor to GDP and employment in most member economies, population growth rates have been high overall, and the reliance on food imports has increased over the past few decades, whilst the growth of agricultural productivity has reduced. The fact that these vulnerabilities are common across the D-8 countries, along with the agenda of the D-8 on strengthening cooperation in agriculture and food security justifies the analysis of the group as a cluster of country cases. Several adaptive measures have been suggested to enhance food security under climate change. Climate-smart agriculture (CSA) is a concept that combines sustainable agricultural intensification along with strategies for building resilience and reducing greenhouse gas emissions (Lipper et al., 2014). As shifting seasonal patterns are already impacting cropping calendars across South Asia, Abbas et al. (2017) demonstrate that the maize-growing season in Pakistan shortened by an average of 4.6 days per decade from 1980 to 2014, and lengthened by an average of 3 days per decade in the maize-planting season, respectively, during the spring and autumn seasons. Crop diversification, efficient irrigation, and agroforestry are some of the most promising strategies to make the resilience of farming systems more resilient to climate variability (Altieri et al., 2015), while Food and Agriculture Organization (2018) emphasizes that social protection measures, investment in climate-resilient food systems, and coordinated policy action can complement these measures to improve food security in the face of climate change(Ragmoun, 2023, 2024; Ragmoun & Alfalih, 2024).

The unpredictable climate in semi-arid areas are likely to lead to declines in yields of major staple crops which will have major effects on food security (Intergovernmental Panel on Climate Change, 2014; Lobell, Schlenker, & Costa-Roberts, 2011). Lack of technological options and adaptive capacity in poorer farming communities tends to exacerbate their exposure to these risks, and market and cultural factors can render adaptation measures – especially crop diversification – challenging in many developing country contexts. There are many country level empirical studies that have been conducted at over time or by regressing cross sections at a given point in time on the climate-agriculture nexus or climate-food security nexus. This study examines the available evidence on the relationship between climate change and agricultural production and food security, focusing on the specific context of developing countries, and the implications the estimated relationships have for a broader policy agenda for food and agriculture cooperation in the D-8 region. The rest of the paper is organized as follows. Objectives of the literature review are presented in Section 2. The data, empirical model and the estimation strategy are presented in Section 3. The interpretation of the results of the fixed effects is presented in Section 4, the robustness check in Section 5 and the study's limitations in Section 5, and the policy recommendations in Section 6.

2. Literature Review

Climate change is one of the contemporary global crises with a significant influence on water resources, and agricultural production, food delivery systems, and productivity. The section synthesizes relevant literature related to climate change and food security, highlighting the main pathways by which climate change impacts food availability, access, use and security. Eswaran and Kotwal (1986) and Carter and Wiebe (1990) suggest that financial problems have a significant

DOI: 10.52131/pjhss.2025.v13i4.3233

impact on agricultural productivity, especially small-scale farmers. Availability of agricultural credit leads to investment in better varieties of crops and better cultivation methods which leads to improved food production. Zeller (2003), for his part, states that rural credit programs and microfinance can promote the empowerment of smallholder farmers and their ability to escape poverty and achieve food security, whereas Sharma and Buchenrieder (2002) conclude that agricultural credit can stabilize farmers' incomes thus reducing the threat of food insecurity. In spite of these advantages, farm credit is still a constant constraint in most developing countries: For instance, Swinnen and Gow (1999) demonstrate that the lack of good institutions, high interest rates and absence of collaterals are important factors limiting access to farm credit for small farmers. Agriculturally important changes in precipitation and temperature patterns resulting from climate change impact agricultural productivity and yields (Lobell, Schlenker, & Costa-Roberts, 2011). The negative impacts of temperature rise will include reduced production of staple crops like wheat, rice and maize (Intergovernmental Panel on Climate Change, 2014), and a drop in yields of 10-25 % for tropical and subtropical crops when global average temperatures rise by 2°C (Roberts & Schlenker, 2011). As demonstrated by Falkenmark and Rockström (2004), groundwater depletion is affected by precipitation changes and therefore by river flow – the latter decreasing irrigation potential and limiting agricultural productivity, especially for rain-fed agriculture which prevails in most parts of the D-8 region.

This literature is also beginning to focus on renewable energy applications in agriculture. Evidence is also starting to emerge that it is possible to increase productivity while reducing the carbon footprint of irrigation and on-farm energy use technologies that require renewable energy, and that more readily available funding for clean energy can be an enabling condition for their uptake (Rahman & Alam, 2021). Bellemare (2015) reports a link between food-price increases, often exacerbated by climate-induced production shocks, and increased social unrest, and that such price shocks negatively impact food access of low income and vulnerable households. Hallegatte (2016) project that, without a swift and inclusive climate-smart development, climate change could deprive over 100 million more people of their livelihoods by 2030, and the main determinant of this impact is agricultural and food-price shocks. Beyond the simple dietary benefit of calories, Myers et al. (2014) demonstrate reductions in protein, iron and zinc levels of staple C3 crops as a consequence of higher CO2 levels in the atmosphere. Based on this, related work by Myers et al. (2017) further examines how climate change impacts global food systems and under-nutrition through other pathways, including the loss of food due to the impacts of climate change and pest pressure, which can further impact dietary diversity and increase micronutrient deficiencies. In the tradition of Arellano and Bond Das and Hossain (2019) explore the relationship between agricultural credit and agricultural output in Bangladesh using a dynamic panel data model and conclude that there is an overall positive and statistically significant relationship between agricultural credit and agricultural output. Ahmad, Alam and Haseen (2011) review the evidence of climate change and evaluate its effects on agriculture and food security in India.

They highlight the fact that agriculture itself is a big contributor to land-use change and GHGs emissions in India (e.g. rice farming, livestock production, etc.) and that this in turn contributes to the climate change threatening agriculture, water availability, biodiversity and rural livelihoods. Their analysis also reveals significant reduction in the area under food grains in India over the past few decades along with a corresponding increase in the yields per hectare, and significant inter-seasonal variability in the area sown during Kharif season, mainly due to change in rainfall and temperature patterns. One of the earlier and most influential reviews available on the potential climate change effects on the four pillars of food security was made by (Schmidhuber & Tubiello, 2007). They discover that most research on climate change and access has been developed through crop-yield modelling, and that the impacts of climate change on access, utilization, and stability have not been well documented. The projected increase in the number of hungry people varies between about five million and upwards of 170 million people, depending on the socio-economic development scenario on which they are based, according to their review. This finding corroborates an inverse theme that has been echoed in the literature: the importance of economic and institutional attributes of the system (alongside climatic ones) for the nature of food security outcomes is often more relevant than the size of the climatic change itself, making the integration of economic and institutional variables more important in empirical models like the one developed in Section 3 than purely climatic variables.

The methodological literature that underlies the empirical method that is used in this paper is based on Pesaran, Shin and Smith (1999) who suggest the Pooled Mean Group (PMG) estimator as a middle ground between the Fully Homogeneous Dynamic Fixed Effects (DFE) estimator and the Fully Heterogeneous Mean Group (MG) estimator. The PMG estimator makes no equality restrictions on the short-run coefficients, the speed of adjustment, or the error variances between countries, a compromise that the authors demonstrate to be efficient when the short-run dynamics are the same across countries. Another reason for the appeal of the ARDL family is that the bounds-testing variant of the single-equation ARDL model (Pesaran, Shin, & Smith, 2001) provides valid co-integration tests when the underlying regressors are not necessarily all integrated of the same order; this is a characteristic of macro-panels that include climatic series (often trend-stationary) and economic series (often difference-stationary) for which panel unit root tests like that of Im, Pesaran and Shin (2003) are often used. Studies using a combination of panel ARDL and Westerlund (2007) co-integration tests along with quantile regression techniques in a panel of low and lower middle income countries show that rainfall, CO2 emissions and temperature jointly influence cereal production and that the impact of climate fluctuates significantly across the conditional distribution of cereal output. Food security indexes that are based on dietary energy and protein-supply inadequacies also find climatic variables to be a strong correlate of food security outcomes across North and East Africa from 2000-2012, even after accounting for economic development.

In "Food security in South Asia using machine-learning approaches", Atiq-ur-Rehman et al. (2026) analyze food security in South Asia by applying machine-learning methods. The analysis, which uses Error Trend Seasonal (ETS) forecasts, suggests that food security growth is projected to slow in the larger, largely agrarian economies of the region, and that the uncertainty in forecasts is higher for smaller, more climate vulnerable states over the longer term (until 2035). While large economies continue to drive the bulk of production across the region, the study shows that there is a significant structural difference in the food-security trends of nations in the region, and identifies gaps in food security that cannot be deduced from aggregate indicators, thus demonstrating that country-specific policy measures are needed and cannot be substituted for a region-wide solution. The present paper tries to provide comparable evidence for the D-8 countries and to provide policy insights from the estimated relationships.

3. Empirical Model and Methodology

3.1. Econometric Model and Data

The econometric model is specified as follows:

$$FPI_{it} = \beta_0 + \beta_1 GF_{it} + \beta_2 PRECI_{it} + \beta_3 TEMP_{it} + \beta_4 POP_{it} + \beta_5 LAND_{it} + \eta_i + u_{it}$$

Food Production Index (FPI) is an indicator of food security, derived from World Bank's World Development Indicators (WDI). Agricultural credit disbursed to the farm sector - compiled from FAOSTAT - is used to approximate green finance (GF); harmonized, D-8-wide indicators of green or climate finance are not yet publicly available, so agricultural credit is used here as the closest available proxy, and this approximation is noted as a limitation of the study in Section 5.2. Climate variables include annual precipitation (PRECI), and annual average temperature (TEMP), both from FAOSTAT. The data for total population (POP) and percentage of land area used in agriculture (LAND) is from the WDI. η_i represents country fixed effects which account for time-invariant country-specific characteristics and u_{it} represents the unobserved idiosyncratic error term. The study employs annual panel data for the eight D-8 member countries (Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey) for the period 1990-2024. There are some country-year combinations where observations are missing so that the resulting panel is unbalanced.

3.2. Empirical Results

Tables 1-4 below give, in turn, the descriptive statistics, the pairwise correlation matrix, the Hausman (1978) specification test, and the fixed affects regression results.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
FPI	280	82.05	22.644	39.15	146.52
GF	280	3.426	0.740	1.601	5.066
PRECI	280	-0.021	0.620	-2.465	3.638
TEMP	280	6.464	1.606	2.896	7.964
POP	280	0.494	0.444	-1.827	1.207
LAND	280	3.434	0.921	0.976	4.379

Note: All variables are expressed in natural log form.

Table 2: Pairwise Correlations

Variable	(1) FPI	(2) GF	(3) PRECI	(4) TEMP	(5) POP	(6) LAND
(1) FPI	1.000					
(2) GF	0.163	1.000				
(3) PRECI	0.468	0.012	1.000			
(4) TEMP	-0.001	0.076	-0.277	1.000		
(5) POP	-0.460	-0.235	-0.157	-0.133	1.000	
(6) LAND	0.003	-0.329	-0.202	0.724	-0.141	1.000

Note: All variables are in log form.

Table 3: Hausman (1978) Specification Test

Statistic	Value
Chi-square test value	187.072
P-value	0.000

Table 4: Fixed Effects Regression Results (Dependent variable: FPI)

Variable	Coef.	St. Err.	t-value	p-value	Sig.
GF	0.297	0.142	2.09	0.075	*
PRECI	0.149	0.042	3.53	0.010	***
TEMP	26.171	10.344	2.53	0.039	**
POP	-0.324	0.171	-1.90	0.099	*
LAND	0.796	0.389	2.05	0.080	*
Constant	-168.397	66.569	-2.53	0.039	**

*Note: All variables are in natural log form. Robust standard errors are reported. *** p<.01, ** p<.05, * p<.1.*

3.3. Interpretation of Results

Descriptive statistics of the study variables for D-8 countries are summarized in Table 1 with all variables except FPI are in natural log form. The standard deviation of the Food Production Index is 0.287 (log form) which suggests moderate variation in food production in the sample as a whole. The spread between the lowest and highest values indicate that there are significant disparities in agricultural performance among D-8 economies. There is quite a bit of variation in the availability of agricultural credit, with the mean value being 3.426 and the standard deviation being 0.740. The data are also found to vary in meaningful ways in terms of precipitation, temperature, population, and agricultural land use, which are the variables used in the study, thus justifying the panel estimation.

The pairwise correlation matrix is presented in Table 2, which provides the first impression of the relationships between the variables. Agricultural credit has a positive correlation with the Food Production Index ($r = 0.163$) implying access to agricultural credit is associated with increased food production while precipitation is positively correlated with the Food Production Index ($r = 0.468$) implying wetter conditions are associated with increased food production. Food production reduced also moderately ($r = -0.460$) with the increase in population, which is in accordance with the assumption that fast population growth increases demand for agricultural output and food availability. The correlation between temperature and food production is very small ($r = -0.001$), so the influence of temperature can only be seen when the other factors in the multiple regression are held constant. The agricultural land also exhibits a low value of the simple correlation coefficient ($r = 0.003$) with food production. The explanatory variables are not too highly correlated with each other, the highest being between temperature and agricultural land ($r = 0.724$) which is relatively high, but not high enough to cause multicollinearity to be a serious concern in the regression analysis ($r < 0.80$).

The Hausman (1978) specification test for selection of the fixed effects and random effects estimators are reported in table 3. The test gives the chi-square statistic of 187.072 ($p = 0.000$), which rejects the null hypothesis that the random effects estimator is consistent. This means that the effects are country-specific and are correlated with the explanatory variables and thus the fixed effects estimator is preferable; hence, as main specification, it is used in the following analysis and results are consistent and unbiased after controlling for the unobserved country-specific heterogeneity which is time-invariant. The fixed effects results are presented in Table 4. The overall model is highly significant: F-Statistic = 160.390, $p< 0.01$. The coefficient of determination ($R^2 = 0.554$) suggests that the variation in the Food Production Index for the D-8 countries can be explained by agricultural credit, precipitation, temperature, population and agricultural land by about 55.4 percent, indicating that the explanatory variables selected are reasonably sufficient to explain Food Production Index in the D-8 countries.

Agricultural credit's coefficient is positive ($\beta = 0.297$), and it is statistically significant at the 10 percent level ($p = 0.075$). The coefficient can be read as an elasticity, since the model is written in log-log form: A 1 percent increase in agricultural credit would lead to an increase of about 0.297 percent in the Food Production Index, barring any changes in other factors. This discovery highlights the importance of access to agricultural finance, which helps farmers upgrade their seed, fertilizer, irrigation, farm machinery, and climate-smart technologies and consequently boosts agricultural production and resiliency to food security. Raising the issues of financial support in agricultural production in the D-8 economies, the result was evident. The coefficient of precipitation is also positive and highly significant (0.149, $p = 0.01$), indicating its positive effect on food production. An increase in precipitation by 1 per cent corresponds to an increase in the Food Production Index (FPI) by about 0.149 per cent, all other factors being constant. This means that, in a region where many countries use dryland agriculture, sufficient rainfall is important for soil moisture, crop growth and agricultural production, and validates the importance of rainfall as a major factor in food production and food security in D-8 nations.

The point estimate for the coefficient of the temperature log is 26.171 with a p-value of 0.039 and a positive sign -- that is, temperature is positively associated with the Food Production Index, controlling for the other variables. This coefficient is statistically significant but too large economically to be believed, and should be viewed with a great deal of skepticism. The other regressors vary significantly across country-years, as does the dependent variable, whereas the implied elasticities are large even when small fractional changes are made in the use of the temperature variable, as a common result of using a variable with relatively small variance as a log-log regressor. Another possible effect of moderate warmings is to boost agricultural production in some relatively cooler parts of the D-8 region or some specific time of the growing season, but beyond some optimum point, additional warming would likely lead to a decline in production - a non-linear relationship which a log-linear specification cannot be captured. In future, it is necessary to test the quadratic or spline specification of temperature, and to try other units of measurement, before reaching firm conclusions on the magnitude of this relationship. At the 10 percent level of significance (p = 0.099), the coefficient on population is negative (β = -0.324), indicating a negative link between population growth and the Food Production Index: An increase of 1 percent in population would decrease the Food Production Index by about 0.324 percent, holding other factors constant. This finding indicates that agricultural resources, arable land and food supply is being stressed with increasing population growth rate. If the growth of food demand is faster than the growth of agricultural production, the ability of the agriculture sector to sustain sufficient food availability can be weakened, which has a negative impact on food security.

The coefficient on agricultural land is positive (0.796) and statistically significant at the 10 percent level (p = 0.080): An increase of 1 percent in agricultural land is accompanied by an approximate 0.796 percent rise in the Food Production Index, ceteris paribus. This underscores the need to maintain and optimally utilize agriculture land because more agriculture land implies more food production and hence more food security. All variables are log-form and robust standard errors are employed to take account of the heteroskedasticity and autocorrelation. The empirical results found that overall, agricultural credit, precipitation, temperature and agricultural land are positively correlated with food production, whereas population growth is negatively correlated with food production in the D-8 countries. The results suggest that the food security can be achieved by expanding agricultural credit, enhancing the sustainability of land-use practices, and improving the resilience of agriculture to climate change. This particular relationship should be interpreted with caution and further tested with another specification because of the very large magnitude of the temperature coefficient. Overall, the model has a good explanatory power, and climatic and socioeconomic variables are found to be important drivers of food production for both the D-8 economies.

3.4. Robustness Checks

Table 5: Random Effects Regression Results (Dependent variable: log FPI)

Variable	Coef.	St. Err.	t-value	p-value	Sig.
GF	0.086	0.029	2.99	0.003	***
PRECI	0.201	0.024	8.30	0.000	***
TEMP	-0.013	0.020	-0.68	0.498	
POP	-0.281	0.036	-7.81	0.000	***
LAND	0.047	0.036	1.31	0.191	
Constant	4.143	0.143	29.04	0.000	***

*Note: All variables are in natural log form. *** p<.01, ** p<.05, * p<.1.*

4. Discussion of the Random Effects Results

In tandem with this, the study also estimates a random effects model to check for sensitivity of the main relations to the choice of panel estimator as robustness check. The fixed effects test is used to see if the Hausman test prefers the fixed effects model; the random effects test are results that are used to check the consistency of the estimated relationships. The overall model has a Wald chi-square of 202.289 (p < 0.01) and the reported R-squared values (overall = 0.384; within = 0.483; between = 0.445) show that the study variables account for a significant proportion of the variance in the Food Production Index within and between countries. The estimated coefficient for agricultural credit is still positive and significant ($\beta = 0.086$, $p = 0.003$): For every 1 percent rise in agricultural credit, the Food Production Index will rise by approximately 0.086 percent, other factors constant. While lower in magnitude than the fixed effects estimate, the sign and significance remain consistent and provide further evidence of the robustness of this relationship and the conclusion that access to agricultural credit allows farmers to invest in irrigation, climate-resilient farming and modern technologies. The impact of precipitation is also found to be positive and highly significant ($\beta = 0.201$, $p < 0.01$) and consistent with the other two estimators, which show that sufficient precipitation is one of the most steady food production determinants across the D-8 countries.

In the random effects specification, however, the temperature coefficient is negative and not statistically significant ($\beta = -0.013$, $p = 0.498$). This loss of significance compared to the fixed effects model is certainly not surprising and indicates that the estimated temperature effect is rather sensitive to the choice of estimator and to unobserved, country-specific characteristics; together with the implausibly large fixed effects coefficient discussed in Section 4, this instability suggests that the present specification does not adequately explain the true relationship between food production and temperature, and that one cannot draw any strong conclusions from the present analysis about this relationship. Population has a negative and highly significant relationship with Food production ($\beta = -0.281$, $p < 0.01$): An increase in population by 1percent results in a corresponding decrease in Food production by approximately 0.281percent with control variables remaining constant. This is similar to the fixed effects results and confirms the conclusion that high population growth rates are maintaining a high pressure on agricultural resources, food demand and land availability. The coefficient of agricultural land is positive ($\beta = 0.047$) but not statistically significant anymore ($p = 0.191$), meaning that the relationship between agricultural land and food production is likely to be more country-specific and structural than temporal and should therefore be interpreted with caution. Overall, the results with the random effects model are very similar to those with the fixed effects model: the signs and significance of the relationships of agricultural credit, precipitation, and population remain stable across both estimators, providing greater confidence in these three relationships, in particular.

5. Conclusion and Policy Recommendations

This research analyzes the impact of climate change on food security of the D-8 countries from 1990 to 2024. For this purpose, the fixed effects estimator has been adopted as the main specification, and the random effects model has been used as the robustness test. Findings indicate that agricultural financing plays a significant role in increasing food production and, consequently, food security in the D-8 countries. The positive and statistically significant coefficient shows that agricultural financing is associated with increased adoption of new technologies of agricultural production, procurement of better seeds and fertilizers, investments in irrigation facilities, and application of climate-smart farming techniques, which in turn increase food production and agricultural resilience against climate change. Another implication from the analysis is that precipitation emerges as one of the key factors determining food production. The positive and significant correlation between precipitation and the Food Production Index for both estimations implies that sufficient precipitation promotes soil moisture, helps crops grow, and ensures higher levels of agricultural productivity especially in the rain-fed farming system which predominates in many countries of the D-8 region. With an increase in climate variability that leads to more frequent occurrences of droughts and floods, the dependence of agriculture on steady precipitation becomes a serious agricultural risk requiring an advanced water management strategy. In contrast to the previous results, there is much less evidence regarding the effect of temperature. While fixed effects regression reveals a positive and significant, but implausibly large, relationship, random effects estimation does not reveal any statistically significant effect.

The aggregate effect of temperature on the level of food production in the D-8 countries can therefore depend on the particular climates, agricultural practices, and resilience of farmers in the region, and this should be studied further using more sophisticated models to draw appropriate policy recommendations. The increase in population negatively and significantly influences the level of food production for both estimations. With the increase in the population, the pressure on agricultural resources, agricultural land, water resources, and the food supply system would be expected to increase. When the growth in food demand is higher than the growth in agricultural productivity, food security becomes threatened. Agricultural land positively influences the level of food production in the fixed effects model, but this variable does not have a significant influence in the random effects model, indicating that this influence comes through differences among countries rather than annual changes. Green finance, represented in this case study through agricultural finance, along with rainfall, has been found to have a positive relationship with agricultural output, while population growth has a negative impact on food production. The resilience of agriculture in the face of climate change in D-8 countries would need to employ an integrated strategy that uses financial, natural, technological, and climate adaptation measures, while the significance of temperature needs further analysis.

Based on these findings, the study offers the following policy recommendations for D-8 governments and policymakers.

First, increase farmers' access to agricultural credit, especially small farmers, through wider access to cheaper and prompter sources of finance. Banks and other financial institutions can be advised to design specialized financial services that suit climate resilient agriculture, sustainable irrigation, renewable energy in agriculture, and environmentally friendly practices. Second, climate adaptation should be made a priority investment for the country. Governments should focus on improving irrigation systems, rain harvesting, floods management, and drought management programs, along with improving climate information services and weather forecasting to assist farmers in making production decisions. Third, governments should invest more in agricultural research and development to speed up the development of drought resistant crops, precision farming, and efficient use of water.

Fourth, formulate policies to enable the sustainable stewardship of agricultural lands by preventing the diversion of productive agricultural lands for other purposes, backed up by soil conservation, afforestation, and sustainable land-use practices. Fifth, incorporate human capital development in population policy as investments in education, health care, family planning, and rural development could relieve pressure on agricultural resources, as well as improve agricultural efficiency, rural employment, and household food security. Sixth, promote cooperation among the D-8 member states in areas of climate change and food security through cooperation in agricultural research, sharing of climate information and technology, disaster-risk management, and cooperative investments in sustainable agriculture, regional green finance, and renewable energy in agriculture. In short, addressing food security issues in the D-8 countries necessitates a comprehensive strategy where climatic risks, financial problems, demographic pressure, and natural resource management should all be considered simultaneously. Expansion of green finance, climate adaptation efforts, sustainable agricultural development, and cooperation are vital in creating resilient agricultural systems that could deal with climate change challenges.

References

Abbas, G., Ahmad, S., Ahmad, A., Nasim, W., Fatima, Z., Hussain, S., Rehman, M. H. U., Khan, M. A., Hasanuzzaman, M., Fahad, S., Boote, K. J., & Hoogenboom, G. (2017). Quantification the impacts of climate change and crop management on phenology of maize-based cropping system in Punjab, Pakistan. *Agricultural and Forest Meteorology*, *247*, 42-55. https://doi.org/10.1016/j.agrformet.2017.07.012

Ahmad, J., Alam, D., & Haseen, M. S. (2011). Impact of climate change on agriculture and food security in India. *International Journal of Agriculture, Environment and Biotechnology*, *4*(2), 129-137.

Altieri, M. A., Nicholls, C. I., Henao, A., & Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development*, *35*(3), 869-890. https://doi.org/10.1007/s13593-015-0285-2

Atiq-ur-Rehman, M., Mustafa, S., Hussain, A., Khan, I. H., Akhtar, F., Javed, S., & Batool, A. (2026). Food security dynamics in South Asia: a multi-method analysis using Random Forest and Error Trend Seasonal models. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-026-07940-y

Bellemare, M. F. (2015). Rising Food Prices, Food Price Volatility, and Social Unrest. *American Journal of Agricultural Economics*, *97*(1), 1-21. https://doi.org/10.1093/ajae/aau038
Carter, M. R., & Wiebe, K. D. (1990). Access to Capital and Its Impact on Agrarian Structure and Productivity in Kenya. *American Journal of Agricultural Economics*, *72*(5), 1146-1150. https://doi.org/10.2307/1242523
Eswaran, M., & Kotwal, A. (1986). Access to Capital and Agrarian Production Organisation. *The Economic Journal*, *96*(382), 482. https://doi.org/10.2307/2233128
Falkenmark, M., & Rockström, J. (2004). *Balancing water for humans and nature: the new approach in ecohydrology*. Earthscan.
Food and Agriculture Organization, F. (2018). The state of food security and nutrition in the world 2018: Building climate resilience for food security and nutrition. Rome: FAO.
Hallegatte, S. (2016). *Shock waves: managing the impacts of climate change on poverty*. World Bank Publications.
Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica*, *46*(6), 1251. https://doi.org/10.2307/1913827
Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1), 53-74. https://doi.org/10.1016/S0304-4076(03)00092-7
Intergovernmental Panel on Climate Change, I. (2014). Climate change 2014: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Fifth Assessment Report. Cambridge: Cambridge University Press.
Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., . . . Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068-1072. https://doi.org/10.1038/nclimate2437
Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate Trends and Global Crop Production Since 1980. *Science*, *333*(6042), 616-620. https://doi.org/10.1126/science.1204531
Myers, S. S., Smith, M. R., Guth, S., Golden, C. D., Vaitla, B., Mueller, N. D., Dangour, A. D., & Huybers, P. (2017). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health*, *38*(1), 259-277. https://doi.org/10.1146/annurev-publhealth-031816-044356
Myers, S. S., Zanobetti, A., Kloog, I., Huybers, P., Leakey, A. D. B., Bloom, A. J., Carlisle, E., Dietterich, L. H., Fitzgerald, G., Hasegawa, T., Holbrook, N. M., Nelson, R. L., Ottman, M. J., Raboy, V., Sakai, H., Sartor, K. A., Schwartz, J., Seneweera, S., Tausz, M., & Usui, Y. (2014). Increasing CO2 threatens human nutrition. *Nature*, *510*(7503), 139-142. https://doi.org/10.1038/nature13179
Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289-326. https://doi.org/10.1002/jae.616
Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association*, *94*(446), 621-634. https://doi.org/10.1080/01621459.1999.10474156
Ragmoun, W. (2023). Ecological footprint, natural resource rent, and industrial production in MENA region: Empirical evidence using the SDM model. *Heliyon*, *9*(9), e20060. https://doi.org/10.1016/j.heliyon.2023.e20060
Ragmoun, W. (2024). The Analysis of Trigger Factors of the Environmental Entrepreneurship Process in Saudi Arabia: An Innovative Approach. *Economies*, *12*(9), 254. https://doi.org/10.3390/economies12090254
Ragmoun, W., & Alfalih, A. A. (2024). Inclusive Special Needs Education and Happiness of Students with Physical Disabilities in Saudi Arabia: The Role of School Satisfaction and Self-Concept. *Education Sciences*, *14*(2), 209. https://doi.org/10.3390/educsci14020209
Rahman, M. M., & Alam, K. (2021). Clean energy, population density, urbanization and environmental pollution nexus: Evidence from Bangladesh. *Renewable Energy*, *172*, 1063-1072. https://doi.org/10.1016/j.renene.2021.03.103

Roberts, M. J., & Schlenker, W. (2011). The evolution of heat tolerance of corn: Implications for climate change. In *The economics of climate change: adaptations past and present* (pp. 225-251). University of Chicago Press.

Schmidhuber, J., & Tubiello, F. N. (2007). Global food security under climate change. *Proceedings of the National Academy of Sciences*, *104*(50), 19703-19708. https://doi.org/10.1073/pnas.0701976104

Sharma, M., & Buchenrieder, G. (2002). Impact of microfinance on food security and poverty alleviation: A review and synthesis of empirical evidence. *The triangle of microfinance: financial sustainability, outreach, and impact*, 221-240.

Swinnen, J. F. M., & Gow, H. R. (1999). Agricultural credit problems and policies during the transition to a market economy in Central and Eastern Europe. *Food Policy*, *24*(1), 21-47. https://doi.org/10.1016/S0306-9192(98)00067-0

Westerlund, J. (2007). Testing for Error Correction in Panel Data*. *Oxford Bulletin of Economics and Statistics*, *69*(6), 709-748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

Zeller, M. (2003). Models of rural financial institutions. paper for “Paving the Way Forward: An International Conference on Best Practices in Rural Finance”, Washington, DC,