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Food Security Challenges in SAARC Region: Do Agricultural Credit and Renewable Energy Enhance Food Production?

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ABSTRACT

The climate changes in the member states of South Asian association of regional corporation (SAARC) are gravely affecting the food crop production and posing different challenges to food security. This study aims to examine the effect of climate change on food security by incorporating the role of agricultural credit in climate adaptation. A panel data set for the SAARC economies for the period 1999-2023. After testing the stationarity, the Pooled mean group autoregressive distributive lag (PMG-ARDL) approach is used for the estimation. The empirical findings show that climate changes including carbon dioxide emissions, precipitation, and temperature changes significantly affect food production in South Asia. The carbon emissions and temperature vagaries affect food production negatively while the precipitation affects food production positively in the long run. The agricultural credit encourages farmers and stimulates food production in the region. The coefficient on agricultural credit is found to be positive and statistically significant indicating that the adverse effects of climate change on food security may be reduced by using agricultural credit as a tool for the climate adaptation and climate-resilient infrastructure in the SAARC region.

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1. Introduction

Climatic change is one of the key issues for the SAARC region countries. Climatic adaptation has been neglected by public policymakers in the region in devising growth-oriented policies. The South Asian leaders are more concerned about economic growth, investment, health, education etc., because people don't ask for policy measures to cut environmental emissions. Last year, 24 cities in India saw a decrease in precipitation and extreme rainfall in some cities, according to Intergovernmental Panel reports. Rao and Sinha (1994) describe the reduction of wheat production that would occur in most parts of the region with a rise in temperature. According to Saseendran et al. (2000), an increase in temperature of 1°C would result in a reduction of 6% in the yield of the rice crop. It is anticipated that the food prices will fluctuate. Between 2000 and 2050, the major food crops such as wheat, rice, maize and soybeans will cost 2.5 times more. SAARC's annual losses in terms of GDP on climate change adaptation measures are 1.8 per cent by 2050 if they are not taken. Since a major proportion of the population makes their living from agriculture, according to Asian Development Bank, most of SAARC countries are expected to experience average economic losses of 6 percent, and 12 percent due to climatic changes. Long-term variations in temperature and precipitation patterns have a threat to alter cropping seasons which will have an impact on food markets, and crop yields (Bezner, 2022). For example, the seasonal shifting of plantings of spring maize in Pakistan was 4.6 days earlier on an average per decade between 1980 and 2014, while the shifting of the fall maize was 3 days later on an average per decade (Abbas et al., 2017). A number of studies have examined climate change impacts on South Asia's major food crops such as wheat, rice and maize over the past few decades.

The difference in water availability is directly related to the change of water temperature and only a few research contributions have assessed the impacts of water variability on crop productivity in South Asia. The reduction of 19% in summer monsoon rainfall can reduce food grain production by about 17-18%. SAARC has a large landmass with a high population density, which is predominantly engaged in agriculture-based activities for food and livelihoods. This study is very important for the food security in the region because the instability of climate which manifests itself in the form of changes in the amount of precipitation, the rise in temperatures, climatic vagaries etc. is dangerous for yields of crops. Climate variability affects the production of crops, availability of water and soil productivity and is one of the most serious threats to food production. These effects can be mitigated by policy and stakeholder actions and a comprehensive understanding of these effects will enable them to do this. Alternative energy sources such as solar and wind power can help reduce agriculture's reliance on fossil fuels, lower carbon emissions, and increase productivity. The study highlights the importance of renewable energy in achieving a sustainable and climate-resilient agriculture sector. Green credit provides economic motivation for farmers and agribusiness to adopt more sustainable farming methods, such as optimizing irrigation systems and using renewable energy in farming. This study also addresses the issue, how green financing will push for the development of sustainable agriculture. This study provides valuable policy recommendations to policy makers on the integration of RE, as well as green credit policies in national food security policy in view of its high exposure to climate change.

2. Review of Literature

Climate variation is one of the tenacious global issue and has a significant impact on food security, affecting agricultural productivity, water resources, and the food supply chain. This literature review is a synthesis of some of the landmark studies on climate change and food security, and the primary pathways by which climate change impacts food availability, access, utilization and stability. Zeller (2003) contend that rural credit programs and microfinance help in poverty reduction and enhanced food security through the empowerment of smallholder farmers. Sharma and Buchenrieder (2002) hypothesize that agricultural credit would make income more stable, reducing the risk of food insecurity. Even though it has benefits, farm credit is still an issue in most developing countries. Studies such as Swinnen and Gow (1999) establish the institutional factors, high interest rates and lack of collateral as key constraints that affect accessibility of credit for smallholder farmers. Climate change affects temperature and rainfall, which affects crop yields and agricultural productivity (Lobell, Schlenker, & Costa-Roberts, 2011). Staple food crops like wheat, rice and maize are expected to have reduced yields in the face of rising temperatures (IPCC, 2014). Research studies have shown that crop production in the tropics and subtropics will drop 10-25% with a 2°C increase in global temperatures (Roberts & Schlenker, 2011).

The impact of changed precipitation patterns is a reduction in river flows and decreased groundwater recharge, reducing irrigation potential and affecting agricultural productivity (Church et al., 2011; Falkenmark & Rockström, 2004). A 1% drop in water availability leads to a 0.5% drop in agricultural productivity, a study found (Molden, 2013). If solar irrigation systems are added, as done by Khan and Arsalan (2016), it leads to increased crop production while reducing carbon footprints. Bellemare (2015) find that the climate-driven disturbances in the food supply chains impact food access and prices, and disproportionately hit vulnerable groups. Research highlights that weather events cause price volatility and food is unaffordable to the poor. According to the Valavanidis (2023) estimates that by 2050, climate change will push over 100 million people into poverty, thus exacerbating food insecurity. These pressures were exacerbated by drought, floods and other weather extremes. Myers et al. (2017) explore that climate change impacts not just the quantity of food but also its quality and nutritional content. Attain higher CO2 concentrations in the atmosphere reduce the iron, protein, and zinc content of crops, resulting in a negative impact on the world's nutritional security. Moreover, crop losses and outbreak of pests due to climate change reduce the diversity of food intake, leading to micronutrient deficiencies.

Das and Hossain (2019) explore how to use agriculture credit to improve agriculture production. Arellano & Bond have developed Dynamic Panel Data model to investigate the positive and statistically significant effect of agriculture credit on agriculture output in Bangladesh. Rahman and Alam (2021) found that credit-constrained farmers are more inclined to adopt green energy technologies, increasing the productivity and sustainable food production in agriculture. While some experts, like Rahman and Alam (2021) theorize that the upfront expenses of green energy technology are high, the benefits are lower running costs and better agricultural productivity. The role of government subsidies and private sector investments are very important in encouraging the adoption of renewable sources in rural areas. There are multiple adaptive solutions suggested for improving food security in the context of climate change. Climate-smart agriculture may integrate sustainable agriculture methods with approaches of building climate resilience (Libecap & Steckel, 2011). Crop diversification, efficient irrigation systems and agroforestry are key strategies to mitigate the effects of climate change on food production. Other policy measures such as social protection measures and investments in resilient food systems are also relevant to food security. Researchers point out that rising temperatures and reduced precipitation in semiarid areas are likely to decrease the yields of major crops like corn, wheat, and rice, which would have a major effect on global food security. Since the 1990s, increased commodity prices and a declining cultivated area per capita have led to decreased food production and food insecurity in most communities.

3. Empirical Methodology

There is a large significant impact of food production on food security. A good food production is required to combat food insecurity and vulnerability of people in an economy. The empirical analysis of this study employs the use of a food production index to measure food security. Mahrous (2019) and Rehman et al. (2024) used this index to measure food security. From a theoretical perspective food security is a function of the different factors including climatic change, agricultural credit, and renewable energy consumption. The proxy for sustainable production technologies is renewable energy consumption because most renewable energy sources are replenished naturally and have a significantly lower environmental footprint compared to fossil fuels, placing them at the core of the sustainable energy system; it should be noted that 'sustainable ' encompasses more than just sources of energy and it cuts across issues of resource management and reductions in greenhouse gas emissions. Green credit can motivate farmers to practice sustainable agriculture through organic farming, agroforestry, and conservation agriculture. Such practices enhance soil health, and biodiversity along with ecosystem services. In this regard, green credit will help in the reduction of greenhouse gas emissions while mitigating climate change influences on food security. Small-scale farmer support: green credit would support small-scale farmers in getting crucial financing that could help them embrace sustainable practices and improve their productivity and incomes.

3.1. Data and Model Estimation

This research adopts the empirical model developed by Chandio et al. (2023). The mathematical farmwork can be written as given below,

$$FS = f\,(CO2, TEMP, PRECI, ACRED, RENE, GDP)$$

In the equation, FS is the food security which is my dependent variable. It is measured by the food production index. The independent variables to represent climate change include CO2 emissions, temperature (TEMP), precipitation (PRECI). The notation ACRED represents agricultural credit, RENE denotes renewable energy consumption, and GDP is the gross domestic product. We use the following general econometric model specification.

$$FSit = \beta 0 + \beta 1\, CO2it + \beta 2\, TEMPit + \beta 3\ PRECIit + \beta 4\, ACREDit + \beta 5\, RENEit + \beta 6\, GDP + \mu it$$

All the variables in equation are mentioned above. The notations μ is the error terms where 'i' denotes the cross sections and 't' shows the time period. All variables are in log form. A panel data set for the period 1999-2023 has been collected on SAARC countries namely Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri-Lanka. Food security (FS) represented by food production index has been collected from the World Development Indicators (WDI). Carbon-dioxide (CO2) total emissions MT and GDP as gross domestic product at current prices in dollars also came from WDI. The renewable energy (RENE) is the renewable energy consumption as percentage of total final energy consumption as proxy of agricultural credit is also collected from WDI. Temperature (TEMP) is the annual temperature in Celsius, and agricultural credit (ACRED) are the loans provided to the agriculture sector. The data on Precipitation (PRECI) is the average precipitation in milli-meters is also collected from FAO.

3.2. Unit root tests

We employ two different panel unit root tests including Levin, Lin, and Chu (LLC) and Im, Pesaran, and Shin (IPS) to check stationarity. Both tests are categorized as the first-generation panel unit root testing as they assume cross-sectional independence in the panels. It is the main feature that differentiates these tests from the second-generation tests accounting for the cross-sectional dependence. The LLC and IPS tests follow assumption that the cross-sections or panels are independent of each other.

3.3. Pooled Mean Group ARDL Model

The PMG-ARDL stands for Pooled Mean Group Autoregressive Distributed Lag approach which was developed and introduced by Pesaran, Shin and Smith (1999). This model is a an estimation technique in panel data structures that allows for both short-run heterogeneity across different groups while assuming long-run homogeneity in the coefficients, making it very useful for comparing relationships across different firms, states, countries or regions. It allows for pooling of information across different panels while still considering individual country-specific dynamics panel is used to examine the long-run relationships between variables in panel data where the variables might have different orders of integration like I(0) or I(1). This approach can be written mathematically as

$$\Delta lnFs_{i,t} = \phi ECT_{t-1} + \sum_{j=1}^{p} \alpha_{ij}\, \Delta lnCO2_{i,t-1} + \sum_{j=1}^{p} \beta_{ij}\, \Delta lnTEMP_{i,t-1} + \sum_{j=1}^{p} \gamma_{ij}\, \Delta lnPRECI_{i,t-1} + \sum_{j=1}^{p} \delta_{ij}\, \Delta lnACRED_{i,t-1} + \sum_{j=1}^{p} \eta_{ij}\, \Delta lnRENE_{i,t-1} + \sum_{j=1}^{p} \psi_{ij}\, \Delta lnGDP_{i,t-1} + \epsilon_{i,t}$$

Where FS is food security which is a dependent variable measured by food production index. CO2 emissions total in MT. TEMP is maximum average temperature annually and PRECI is the average precipitation on annual basis. ACRED is total agricultural credit, and RENE is renewable energy consumption as percentage of total final energy consumption. GDP is the gross domestic product at current US dollars. The notation Δ stands for the difference operator. The notation t is for time, i is for the cross-section and j represents the number of lags. The coefficients with lags represent the long-run while the coefficients with difference operators indicate the short run. The ECT stands for error correction term which reflects the short-run dynamic adjustment towards the long-run. The negative and significant ECT shows the convergence towards the equilibrium path.

4. Empirical Results

The empirical results are presented in the following tables.

Table 1: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
FS	175	92.355	22.517	48.8	171.25
CO2	175	299.955	675.034	.348	2955.182
TEMP	175	26.973	5.689	15.36	31.61
PRECI	175	1822.981	866.116	264.12	4084.98
ACRED	175	132197.59	325386.85	117	1731127
RENE	175	50.403	27.638	1.2	92
GDP	174	3.196e+11	6.949e+11	3.993e+08	3.568e+12

Table 2: Pairwise correlations

Variables (log form)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) FS	1.000						
(2) CO2	-0.034	1.000					
(3) TEMP	0.157	0.551	1.000				
(4) PRECI	0.037	-0.577	-0.473	1.000			
(5) ACRED	0.054	0.966	0.543	-0.431	1.000		
(6) RENE	-0.441	0.239	-0.471	0.046	0.256	1.000	
(7) GDP	0.040	0.981	0.573	-0.533	0.983	0.251	1.000

4.1. Unit Roots Test Results

Testing the stationarity level and determining the integration order between the series is an important step. Analyzing the stationarity of the variables is critical when investigating panel data. Existing literature shows that non-stationarity in data might result in flawed and inconsistent findings (Haldar & Sethi, 2022; Huang et al., 2022). To check for unit roots in panel data, the two commonly used tests are employed namely the LLC test and the IPS Test. The LLC makes assumption about a common unit root process across the cross-sections. The IPS allows for individual unit root processes across cross-sections. As no cross-sectional dependence exists, we may use the first generation unit root tests including LLC and IPS.

Table 4: LLC unit root test

Variable	Level		First difference	
	Stat.	**p-value**	**Stat.**	**p-value**
FS	-0.8404	0.2004	-5.4414*	0.0000
CO2	-1.9086**	0.0281	------	------
TEMP	-4.4057*	0.0000	------	------
PRECI	-4.5842*	0.0000	------	------
ACRED	-3.3361*	0.0004	------	------
RENE	-1.5580	0.0597	-3.3838*	0.0004
GDP	0.2064	0.5817	-10.28*	0.0000

Note: *= 1%, and ** = 5% significance level. All variables are in log form.

Table 5 : IPS unit root test

Variable	Level		First difference	
	Stat.	**p-value**	**Stat.**	**p-value**
FS	-1.9421	0.9739	-7.6239*	0.0000
CO2	1.5743	0.9423	-6.8433*	0.0001
TEMP	-5.2201*	0.0000	-------	------
PRECI	-6.3331*	0.0000	-------	-------
ACRED	-0.8702	0.1921	-4.7403*	0.0001
RENE	0.9146	0.8198	-6.9028*	0.0000
GDP	0.0854	0.5340	-6.2252*	0.0000

Note: *= 1% level of significance. All variables are in log form.

4.2. PMG-ARDL Results

The PMG-ARDL results are presented in table 6.

Table 6: ARDL Model Results

Variables (log form)	Coefficient	Std. Error	t-Statistic	Prob.
CO2	-0.1897**	0.08011	-2.3665	0.020
TEMP	-0.9922**	0.4041	-2.4557	0.016
PRECI	0.7147**	0.2772	2.5794	0.011
ACRED	0.2427***	0.1416	1.7153	0.089
RENE	-0.3524	0.2158	-1.6343	0.11
GDP	0.08439	0.1209	0.6802	0.497

Dependent Variable: Dlog (FS)
Long Run Equation

Short Run Equation

ECT (-1)	-0.09024**	0.03977	-2.2691	0.0251
DCO2	0.0566	0.0833	0.6794	0.4982
DTEMP	-1.0259	1.0454	-0.9813	0.3284
DPRECI	0.0159	0.0766	0.2086	0.8351
DACRED	-0.00129	0.04754	0.02729	0.9783
DRENE	-0.3525	0.2157	-1.6343	0.1054
DGDP	0.1216	0.0805	1.5091	0.1339

5. Findings and Discussions

Table 1 presents the summary statistics including the number of observations, mean, standard deviation, and minimum and maximum value for each variable. Table 2 gives the pairwise correlations across all the variables under consideration. Table 3 shows the outcomes of the cross-section dependence test. Testing the stationarity level and integration order between the series is critical when investigating the panel data. Existing literature shows that non-stationarity in research data might result in flawed and inconsistent findings (Haldar & Sethi, 2022; Huang et al., 2022). This study uses the LLC and IPS tests of unit root to look at the stationarity of the series. Table 4 presents the findings of the LLC unit root test while Table 5 demonstrates the results of IPS unit root test. A mixed integration order like I (0) and I (1) of variables is found by using both unit root tests. According to the LLC unit root test, the variables CO2, precipitation, agricultural credit, and temperature become stationary at level, so they are declared to be integrated of order zero or simply I (0). The variables food security, renewable energy, and GDP are non-stationary at the level but become stationary after taking the first differences, so these variables are declared to be integrated of order one or I (1). The IPS unit root test demonstrates that the variables precipitation and temperature become stationary at level, so they are I(0) while food security, CO2, agricultural credit, renewable energy, and GDP are integrated of order one; I (1).

Table 6 shows the results of PMG-ARDL estimation. These results of the model exhibit the independent variable effect on the food production index in the long-run. In the long-run equation, the climate variables CO2, and temperature have negative and statistically significant coefficients. CO_2 is a major greenhouse gas, causing global temperature to rise. Increased CO_2 causes water evaporation which contributes to water shortage. It may lead to the climate instability droughts, and storms. So, higher CO_2 emissions undermine food security. The temperature is negatively and significantly associated with food production at a 5% level, in the long-run meaning temperature change negatively affects food crop production. A one percent increase in temperature reduces food production by 0.99 percent or vice a versa. Rising temperatures reduce the crop yields decreasing food production. Increasing temperatures have negative effects on crop yields and food production by several mechanisms. For instance, heat stress diminishes photosynthesis, grain formation, and total yield in cereal crops such as wheat, rice, and maize. Enhanced Water Evaporation could contribute to draughts. The intense Weather Events such as floods, and storms ruin crops and disturb food chains. The heat waves in Indian Punjab and Haryana, reduced wheat yield during 2022. Thus, increasing temperatures endanger world food security demanding immediate climate adaptation strategies like drought-tolerant crops, enhanced irrigation, and eco-friendly farming. Our results are in line with Boukhris et al. (2025); Chandio et al. (2023) and Mirzabaev et al. (2023) and showing the negative impact of temperature rise on food production.

The precipitation variable is positive and statistically significant at 5% level. The coefficient shows that a one percent increase in precipitation leads to increase food security by 0.71 percent. The precipitation boosts food security in the long run. The precipitation encourages food production by providing moisture to the crop. It indicates that more precipitation is associated with a higher likelihood of food security. Food security is the state of having access to enough nutritious food at an affordable price. Precipitation is a climate variable that can affect food security by influencing not only crop yields but also food quality. The studies by Jiang et al. (2024); Nguyen, Randall and Lewis (2024), and many others found that increased rainfall frequency was associated with higher crop yields and better food quality. The precipitation encourages food production. More

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precipitation leads to moisture which increases the crop yields encouraging food production. A positive coefficient for precipitation with food security as a dependent variable indicates that more precipitation is associated with a higher likelihood of food security. Food security is the state of having access to enough nutritious food at an affordable price. Precipitation is a climate variable that can affect food security by influencing crop yields, food quality, and prices. A study found that increased rainfall frequency was associated with higher crop yields, better food quality, and more food variety (Budin et al., 2025). A study found that rainfall had a positive effect on food security, while temperature had a negative effect (Jiang et al., 2024). A study found that a positive coefficient for rainfall indicated that more rainfall increased the likelihood of food. Reliable rainfall patterns are important for food security, especially in rain-fed areas. Climate change can cause unstable rainfall and increased temperatures, which can negatively impact food production. To mitigate these effects, policymakers can implement water management strategies and modern agricultural techniques. These results are also in line with Chandio et al. (2023).

The coefficient on agricultural credit is positive and statistically significant at 10% level advocating a weaker but supportive role of agricultural credit in increasing the crop yield and promoting food security. The weak significance level may be due to the shortage of finances and a fragile credit distribution mechanism in the developing countries (Boukhris et al., 2025). Agricultural credit is crucial for boosting crop productivity and food security by supporting farmers to invest in improved inputs, modern technology, better irrigation, and improved market access. It smoothens out seasonal income variations, and encourages diversification of crops, resulting in greater productivity and stability. India's Kisan Credit Card facility with Low-interest loans enables farmers to invest in high-yielding seeds and irrigation, which improves productivity (Rehman et al., 2024). With Pakistan's ZTBL Loans, the farmers experienced an increase in wheat and rice yield. Bangladesh's Microfinance Grameen allowed smallholder farmers, particularly women, to invest in livestock and better crops, raising food self-sufficiency. Nepal's Agricultural Development Bank credit facilitated climate-resilient agriculture, enhancing yields and lowering seasonal food shortages (World Bank Climate Change Knowledge Portal). So, increasing low-cost agricultural credit schemes can increase food production, stabilize prices, and provide long-term food security in the region. The coefficient on renewable energy is statistically insignificant. In SAARC, the concept of renewable energy is relatively novel in the agriculture sector and there is not much trend of using renewable energy for the food production. That is why renewable energy variable is statistically insignificant. The error correction term in our results is negative and significant which confirms the convergence to the long-run equilibrium at a speed of 9% per period. In other words, the ECT exhibits short-run dynamic adjustment towards the equilibrium at the rate of 9% per period.

6. Conclusion and Policy

The climate changes pose a threat to the food security due to declining crop yield in the SAARC region. The main motive of this study is to investigate the impact of climate change on food security by integrating the roles of agricultural credit and renewable energy in the SAARC countries for the period 1999-2023. After testing stationarity, the PMG- ARDL method is employed for estimation. The empirical findings indicate that climate changes such as carbon emissions, temperature, and precipitation have statistically significant influence on food production in South Asian countries. The Carbon emissions and temperature impact food production negatively whereas precipitation influences food production positively and significantly in the long-term. The agricultural credit is also positively and significantly correlated with food security. However, the coefficients on renewable energy and GDP remain statistically insignificant. The empirical findings show that the adverse impact of climate change on the food security of SAARC nations can be minimized by employing agricultural credit. The availability of finances in the agriculture sector especially, the agricultural credit is pivotal for the poor small landholders in South Asia, but availability and affordability remain the key bottlenecks. Strengthening rural banking facilities, leveraging technology, and financial inclusion approaches are capable of bridging the gap in credit availability and enhancing regional agricultural growth. Climate adaptation and climate-resilient infrastructure can ensure sustaining the food security in the region.

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