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# Implications of climate change on food security in SAARC countries: A panel data approach

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## Abstract

Natural disasters, population growth, global climate change and political instability are threatening food security, especially in South Asia. The research study aims to determine the relationship between climate change and food security in South Asian Association for Regional Cooperation (SAARC) countries during the period from 2001 to 2021. The panel data technique is adopted for the empirical analysis because it addresses the time and country effect, providing accurate research findings. The Food Production Index is used as the dependent variable and works as proxy indicator for food security. Pre-estimation tests including, the Breusch-pagan test for heteroscedasticity, the Variance Inflation Factor (VIF) for Multicollinearity and Woolridge test for serial autocorrelation, are conducted before panel regression estimation. The model stability is tested by post regression diagnostics of Hansen and Hausman specification test. The empirical results revealed that temperature, rainfall and Gross Domestic Product (GDP) per capita are governing food security. In contrast, population growth has negative effect on food security, demonstrating that South Asia's burgeoning population hinders progress towards achieving food security. Inflation and land area under cereal cultivation exhibits insignificant influence. The findings showed that both climate-related and non-climate-related variables affect food security. Hence, the development of interdisciplinary and effective food security policies is essential for ensuring social protection and address food security challenges in SAARC countries.

## Keywords

climate change; food security; panel data; SAARC

## Introduction

Agriculture is the predominant activity in South Asia, where rural areas are home to 70 % of the total population. The agricultural sector contributes 15.98 % to Gross Domestic Product (GDP) and employs 41.6 % of the workforce (1). South Asia covers geographical area of approximately 5.1 million square kilometers with 39 % of its land classified as arable. However, it is one of the most susceptible regions to soil and land degradation (2). Despite being home to one quarter of the world population with rapid population growth, one third of the region's people continue to live in poverty. Food security in South Asia is closely tied to agricultural production. However, recent climate change impacts have hindered agricultural productivity, thereby affecting food security (3). Food security is achieved when all people, always, have physical and economic access to sufficient, safe and nutritious food that meets dietary needs and food preferences for an active and healthy life (4). The four main pillars of food security are food availability, food access, food utilization and food stability.

Climate change is one of the most pressing challenges faced by the global community. Extreme weather events are triggered by both natural and human factors causing significant threats to environment, political and social systems (5). The rise in $CO_2$ concentrations, global surface temperature, glaciers melting, unusual cyclones and biodiversity loss are all consequences of climate change. Agriculture and weather patterns are intrinsically linked, with climate change introducing challenges like drought, rainfall and heat waves resulting in yield and income loss to farmers (6). The global population is projected to reach 9.8 billion by 2050, driving 50 % increase in food demand (7). Currently, 30 per cent of the global population lives in food insecure conditions (8). Moreover, the global temperature has reached record high of 1.45 ± 0.12 ˚C above preindustrial era (9). Climate change is expected to exacerbate food insecurity in the future by increasing pressure on households due to increase in commodity prices. It is crucial to assess the social and economic implications of these changes, particularly in South Asia, where the performance in ensuring food security remains moderate (10). South Asia continues to experience higher rates of childhood stunting and wasting than other parts of the world. Economic disruptions brought on by the Covid-19 pandemic, inadequate macroeconomic management, armed conflicts and climate change have all contributed to the decline in food security. Hard-won gains have been reversed, with an additional 62-71 million people pushed into poverty in South Asia during the pandemic, delaying progress towards Sustainable Development Goals (SDG) of achieving food security. Several obstacles hinder the development and recovery of South Asia's food systems. Global disparities can further exacerbate access to necessities like food, water, health care and economic stability compounding climate change impacts.

The research study aims to estimate the effects of climate change on food security in SAARC countries. SAARC (South Asian Association for Regional Cooperation) is a transnational association of eight South Asian countries, established on December 8, 1985, with its headquarters at Kathmandu, Nepal. The member countries of SAARC are Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka (Fig. 1). The primary objective of SAARC is to enhance quality of life, promote economic growth and mutual self-reliance (11). These nations have made remarkable progress and undergone structural transformation in various sectors including decline in agricultural GDP and a shift where non -farm employment now surpasses farm employment. However, significant challenges remain in creating


**Fig. 1**. SAARC countries map.

equitable and sustainable food systems. The main food crops cultivated in this region are rice, wheat and maize which serve as staple foods for the SAARC population (12). Sectoral contribution to food security reveals that cereals play a much more significant role to other crops and livestock (Fig. 2). SAARC countries are particularly vulnerable to climate change, frequent natural disasters and pervasive poverty. Floods are the most common natural calamities followed by heatwaves and droughts (13). These recurring weather events severely impact agriculture production, jeopardizing food supply security (14). In the past two decades, ten earthquakes have been witnessed in countries of SAARC with India reporting the highest number. South Asia is also recognized as a drought sensitive global region (15). Projections for 2046-65 indicate a temperature rise of 2-4 degrees (16) which is expected to push a significant portion of the population into food insecurity (15). Key policy measures to address food security challenges include establishing a regional food bank, improvising the food distribution mechanisms, enhancing cooperation in agricultural policies and trade agreements.

South Asia and Africa are among the most severely impacted regions of malnutrition worldwide. South Asia has a higher prevalence of stunting (30.7 %) compared to

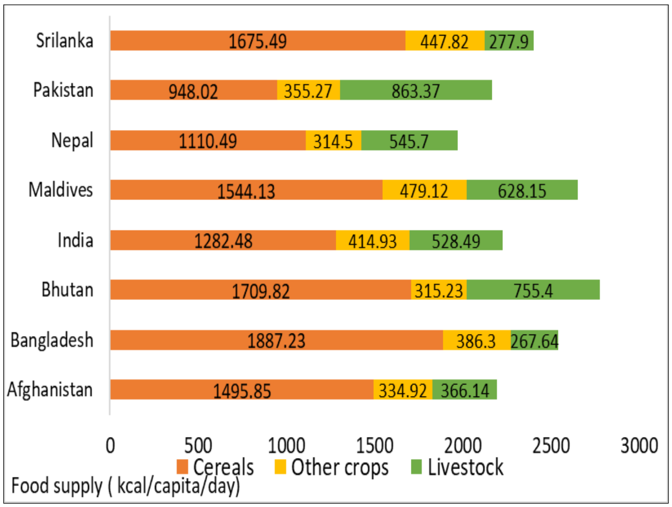


**Fig. 2**. Sectoral contribution to food security in SAARC.

the global average (22.0 %) (17). This region is home to 25 % of the world's population, a figure projected to increase by 40 % by 2050. Feeding this growing population will pose a significant concern in the future. South Asia faces unique vulnerabilities due to its rapid population expansion, depletion of natural resources, persistent food insecurity and widespread poverty (18,19). Given these pressing concerns, the study aims to analyze the relationship between climatic variables on food security in the member nations of South Asian Association for Regional Cooperation (SAARC). In recent years, ensuring continuous access to adequate, affordable and nutritious food for the population has become one of the greatest challenges of the region. Addressing these issues is critical to preventing hunger and achieving sustainable food security in the face of ongoing climate change and socio-economic pressures.

## Literature Review

***Climate change and food security: An empirical review :*** Climate Change impacts agricultural product supply both directly and indirectly. It directly affects agricultural yields, soil fertility, the prevalence of crop pests and disease and water retention capacity (20). The ecological changes induced by climate change create cascading effects on variables including the suitability of the land, the potential yield and the kinds of crops cultivated (21). Climate change has altered global production level of maize, rice and soybeans and wheat to varying degree with significant implications on global agricultural markets (22). A study on Japan's agricultural production, conducted using static and dynamic panel data for the year 1995 to 2006 and found that rising temperature and precipitation levels negatively affected vegetable and potato production (23). Globally, climate change has reduced rice yield by1.60 % to 2.73 %, whereas prices got increased from 7.14 % to 12.77 %and highlighting the significance of food security policies (24). In India, the effects of climate change on agricultural production and food security were investigated by analysing data for 13 states from 1980 to 2009. A regression model revealed that climatic changes had a detrimental impact on agricultural productivity, with a state-level food security indicator highlighting adverse effects (25). The relationship between climatic variability and food security was evaluated in a sample of 71 developing nations. The model effectively examined the causal relationship between climatic variability and food security (26)**.** In China a study on food security across 27 provinces found that the climate change has a negative effect on food supply (27). Similarly, research in Punjab revealed that the wheat and cotton were positively influenced by rainfall and temperature anomalies during the period 1970-2010 (28). In Iran, the impact of average temperature and annual rainfall on wheat production was found to be positive and significant (29)

Climate change has complex implications for every facet of food security. Extreme climate conditions-such as intense rainfall, drought, strong temperature fluctuations and variations in humidity-are a major cause of pre- and -post-harvest food losses (30). Furthermore, pest infestations and disease outbreaks exacerbate food loss and waste, further compromising food availability. Food availability is directly impacted through reduced agricultural production and disruptions to transportation networks. Conversely, economic access is affected by rising local food prices, declining purchasing power and an increase in malnutrition rates (31). However, mere physical availability of food does not ensure access, as factors such as poverty, insufficient infrastructure, high pricing and heightened transaction costs act as barriers (32).

Climate change impacts all four dimensions of food security: availability, access, usage and stability. Since 1990, empirical data has shown that climate change significantly affects these dimensions with availability, access, usage and stability being impacted to varying degrees roughly 70 %, 11.9 %, 13.9 % and 4.2 % per cent respectively, (33). Climate change negatively influences food consumption by influencing human health, encouraging the spread of illnesses and pests. Moreover, it has detrimental effects on food safety, increasing the transmission of foodborne and waterborne illnesses (34). The environmental changes caused by climate change further complicate the ability of people to utilize the available food resources (35). The linkages between climatic variables and food security are illustrated as given in Fig. 3.

The impact of climate change on food security has been studied in various literatures. The important reviews supporting our research study are listed below. In the Sub-Saharan African (SSA) region, the relationship of climatic factors like rainfall, temperature and $CO_2$ emissions with three dimensions of food security was analyzed for 25 nations in SSA. The study revealed that rainfall exhibited long-term beneficial influence on the three dimensions, $CO_2$ emissions improve the food availability and accessibility but not food consumption (36). In Nigeria, the threat of climate change to food and human security was investigated by using primary and secondary data from six geopolitical regions covering from November 2018 to 2019. A negative relationship was found between climate change and food security, with persistent armed confrontations further undermining the human security in the region (37). The linkages between climate change and food security in SSA was examined for the time span of 2000 to 2019 using generalized method of moments (GMM). The results conclude that increasing greenhouse gas emissions, soaring prices and climate change are pulling more people into undernourishment (38). The study recommends that SSA align its efforts towards achieving net-zero emissions and improving domestic food production to alleviate food insecurity.

The interconnection between climate change and life expectancy was explored through panel data analysis for 191 countries covering the period from 1940 to 2020. The analysis revealed that life expectancy is expected to decline by 0.44 years for every $1^0$C increase in temperature. Female life expectancy was found to be more severely threatened than male life expectancy and inverse relationship was found between the climate change index and life expectancy. The results stress the urgency to adopt climate mitigation effects for addressing health risks (39). In Middle East and North African Region (MENA), the

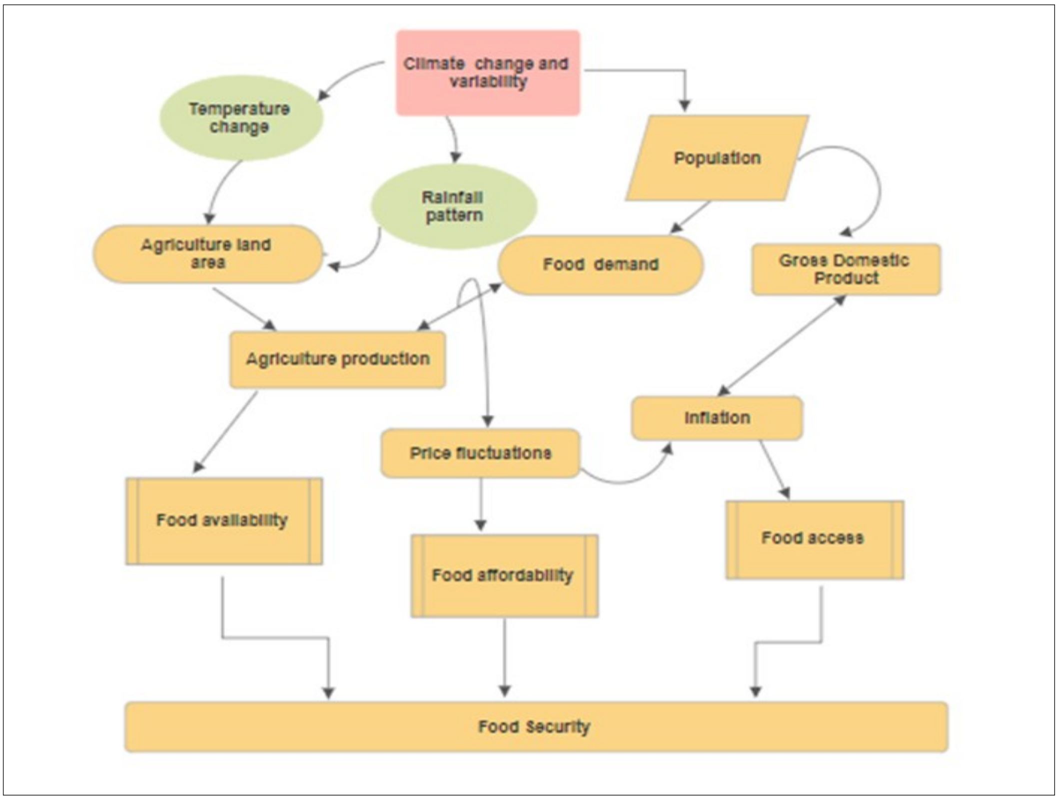


**Fig. 3**. Interactive linkages between climate change and food security.

effect of climate variability on agriculture production was analyzed for the period from 1961 to 2009 by using fixed panel regression and marginal impact analysis. This study found that temperature decreases agriculture production by 1.12 % (40). The impact of climate change on food security and social stability was studied in Afghanistan, where climate change was identified as a threat multiplier alongside political and financial factors, exacerbating food insecurity. The study suggests for the appropriate policy formulation to secure Afghanistan's future food security prospects (41). Extreme weather events like drought and flood causes indiscernible effect on food security in Nepal. Region-specific mitigation and adaptation policies are suggested to improve food security level (42). The importance of cereal production in ensuring food security in South Asia was highlighted, with the study concluding that an increase in cereal production can alleviate the undernourishment prevalence by 0.84 % (43).The computable general equilibrium model was used to examine the complete picture of climate change's influence of food prices and food security in South Asia (44).The climate change stands as a principal cause for catastrophic food shortages. The potential global consequences on food security due to climate variability, population growth and land use change was computed by FEEDME (Food Estimation and Export for Diet and Malnutrition Evaluation) until 2050. The important results showed that the countries with lower population growth had better food security than those with anticipated rapid population expansion. Despite climate change, population growth stands as primary driver for undernourishment prevalence (45).

## *Data and methodology*

To investigate the climate change consequence on food security, the panel data from SAARC countries covering the time frame of 2001 to 2021 was utilized. The Food Production Index is used as proxy for food security and modelled as a function of exogenous climatic and non-climatic variables. A brief description of the variables is listed in Table 1.

**Table 1.** Description of data and sources used in research study

| Variables | Unit | Symbol | Data sources |
|---|---|---|---|
| **Food production index** | | FPI | WDI |
| **Land under cereal production** | Hectares | LAN | WDI |
| **GDP per capita** | Constant 2015 US$ | GDP | WDI |
| **Population growth** | Annual % | POP | WDI |
| **Inflation, consumer prices** | Annual % | INF | WDI |
| **Temperature** | Celsius | TEM | NASA |
| **Rainfall** | mm | RFD | NASA |

## *Methodology*

Panel data regression is a combination of time series and cross section data, when cross sectional units are measured over the period of time. Panel data contains data of the same individuals measured in a specific period. For period T (t=1, 2,3…. T) and N number of individuals (I= 1,2…. n), the total number of observations in panel is N X T. The parameters of panel regression are estimate using ordinary least squares (OLS) and estimators will be of Best Linear Unbiased Estimation (BLUE) with exception on random effect were Generalized Least Square (GLS) technique is used.

## *Fixed effect*

Fixed effects suggest that individual differences (cross section) may be addressed by varied intercepts. The dummy variable technique is used to estimate the Fixed

Effects Model, allowing for distinct intercepts across the individuals. In this case, Least Squares Dummy Variable (LSDV) approach is commonly used to describe estimation models. The fixed effect panel data regression equation is

$$Y_{it} = \alpha_i + \beta X_{it} + \mu_{it} \quad \text{(Eqn. 1)}$$

### *Random effect*

This model is designed to analyze panel data where disturbance variables may be linked across time and between individuals. In the Random Effect, variations in intercepts are addressed through the error terms. The benefit of employing the Random Effect model is to eliminate heteroscedasticity. Unlike the Common Effects and Fixed Effect Models, the random effect does not apply the principle of ordinary least squares. Instead, it utilizes the principle of maximum probability or general least squares. In the Random Effect Model, residuals may be correlated across time as well as between individuals or cross sections. As a result, this model suggests that each individual has a different intercept. As a result of the random effect, there are two residual components. The first is the overall residual, representing the random characteristics of the $i^{th}$ unit observation. In equation (1) the general linear form econometric model is given.

$$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_i + \mu_{it} \quad \text{(Eqn. 2)}$$

Where $X_{it}$ represents explanatory variable in a country i at t period. $\alpha_i$ - unobserved country specific effects $\mu_{it}$ is unobserved error. The single multivariate equation is used to analyse the relationship between food security and climate change in SAARC region. The empirical model is

$$FPI_{it} = \alpha_i + \beta LAN_{it} + \beta GDP_{it} + \beta POP_{it} + \beta INF_{it} + \beta TEM_{it} + \beta RF_{it} + \mu_{it} \quad \text{(Eqn. 3)}$$

$Y_{it}$ are food production Index serves as food security proxy. To improve the robustness of the empirical results, two distinct panel data analyses, namely panel data analysis with fixed effect (FE) and panel data analysis with random effect (RE) were conducted. To know the time varying and non-varying influence both time and country effect were computed

## Results and Discussion

### *Food security status in SAARC*

Scaling up food security conditions is critical, as 2.3 billion population globally face food insecurity. The situational assessment of the nations is very important before preceding the analysis. The food security status is assessed by considering the dietary energy supply of the nation. A descriptive graphical depiction of food security trends from 2011 to 2021 is shown in Fig. 4. Among SAARC countries, Afghanistan faces the most severe food security. The persistent geopolitical conflicts pushed more people under poverty level and low income of nationals (46). In Sri Lanka, unprecedented weather extremes combined with development disparities have further decreased food security

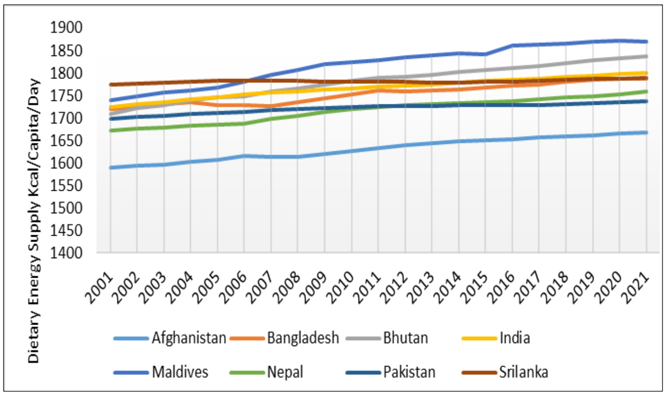


**Fig. 4**. Food security status and performance in SAARC countries.

(47). Conversely, the Maldives had shown positive progress in food security, largely due to a heavy reliance on food imports. These imports nearly meet 90 % of the nation's food demand. This success is attributed to the maintenance of the strategic relationship with trading partners (48). The food security in Nepal is in upper trend due to enactment of suitable food security acts. (49). In Pakistan, economic and political volatility has resulted in declining trend in food security (50). While Bangladesh has shown minimal improvement, a significant portion of population are in chronic food insecure situation due to climate hazards and inadequate social and economic access to food (51). Bhutan food security is on track besides the environmental barrier on agricultural production. India has shown an increasing trend driven by better performance of public distribution systems (PDS) which ensures the food and nutritional status of the population (52). The descriptive statistics and bivariate correlation analysis were conducted to explore the interaction and behavior of the data to be computed (Supplementary Table 1 and 2).

### *Impact of climatic variables on food security by fixed and random effect*

The results of pooled regression, fixed-effect and random-effect models are presented and labelled in columns 1, 2 and 3 of Table 2. From the result it is evident that rainfall, temperature and GDP per capita, population growth is important in determining food security level in South Asian countries. These variables exhibit a significant impact on the food production index.

**Table 2**. Static panel data estimation result of fixed effect and random effect

| Variables FPI | OLS Coefficient | FE Coefficient | RE Coefficient |
|---|---|---|---|
| LAN | -4.29<br>(5.05) | 4.66***<br>(1.60) | -4.63<br>(4.20) |
| GDP | 0.005***<br>(0.006) | 0.008***<br>(0.002) | 0.005***<br>(0.006) |
| POP | -7.468***<br>(1.498) | -9.688***<br>(1.626) | -7.468***<br>(1.498) |
| INF | -0.472<br>(0.327) | -0.377<br>(0.320) | -0.472<br>(0.327) |
| TEM | 0.0076***<br>(0.0028) | 0.009***<br>(0.0029) | 0.013***<br>(0.0028) |
| RF | 1.426***<br>(0.211) | -0.516<br>(0.645) | 1.011***<br>(0.211) |
| Constant | 36.38***<br>(11.25) | 33.51<br>(36.72) | 61.17***<br>(7.383) |
| R-square | 0.29 | 0.62 | 0.29 |

Note: *, **, *** indicate 10 %, 5 % and 1 % significant levels, respectively. Standard errors are in parentheses-Fixed Effect and RE-Random Effect

Examining the effects of individual variables, all factors except population growth positively influence food security. The results suggest food security increases by 0.01 per cent for one per cent increase in rainfall, emphasizing the importance of rainfall in agricultural production. Agriculture, being the prime contributor to household income in most of South Asia, ensures food security at grassroots level. Temperature is positively significant to food security and distinct to results given in Sub- Saharan region (36). The negative and significant relationship is seen with population growth and food security; Thus, increase in population growth will dwindle the food security. While food security is positively related to population, South Asia serves as home to 45 % of global population, burgeoning immense pressure on agricultural production due to limited arable land (47). GDP per capita represents the economic performance level of the country. A significant and positive relationship is seen between food security and GDP per capita. Food security level gets improvised with rise in per capita income. However, land area under cereal production does not significantly impact food security in South Asia, which contrast with findings from African countries (53). Additionally, inflation does not appear to influence food security in South Asia. These results highlight the importance of climatic factors in ensuring food security in the SAARC region and underscore the role of macroeconomic indicators.

### *Impact of climatic variables on food security by time effect and country effect*

Time effect and country effect on food security for climatic variables are summarized in Table 3. In the time effect the intercept varies with time, while in the country effect intercept varies with country. In both cases, the slope is assumed to be constant, with India considered as the base country. Considering the time-varying effect, the impact of population, GDP per capita, temperature and rainfall on food production index is significant, indicating that climate vulnerability is increasing year by year. Population pressure negatively affects the food production index. The significance of this effects begins from 2005 and the level of significance increases in subsequent years till 2021. This reflects the increasing climate vulnerability of South Asian

**Table 3.** Panel data estimated results of time and country effect

| Variable FPI | Time only | Country only | Both the Time & Country |
|---|---|---|---|
| | Coefficient | Coefficient | Coefficient |
| LAN | -2.930 | 4.660*** | 2.800* |
| | (4.250) | (1.60) | (1.530) |
| GDP | 0.003*** | 0.0082*** | -0.006** |
| | (0.000) | (0.002) | (0.027) |
| POP | -3.601** | -9.688*** | -4.951*** |
| | (1.541) | (1.62) | (1.632) |
| INF | -0.2518 | -0.3770 | -0.150 |
| | (0.3936) | (3.201) | (0.375) |
| TEM | 0.5441** | 0.5162 | 0.3757 |
| | (0.2190) | (0.645) | (0.622) |
| RF | 0.0039* | 0.0098*** | 0.0025 |
| | (0.0029) | (0.0029) | (0.002) |
| Constant | 52.75*** | -347.84** | -184.75 |
| | (8.792) | (163.3) | (156.09) |
| R- Square | 0.58 | 0.50 | 0.66 |

Note: *, **, *** indicate 10 %, 5 % and 1 % significant levels, respectively. Standard errors are in parentheses

countries, which is increasingly impacting food supply level. In the country effect, all SAARC countries differ in their food production index. It is positively influenced by land area under cereal production, GDP per capita, rainfall and negatively influenced by population growth as expected. These findings align with the previous research which emphasise the importance of cereal production in determining the extent of food and nutrition security in South Asia (42). In both time and country-varying effects, land area under cereal production contributes positively to food production index, while GDP per capita and population growth have a negative impact. This is largely due to the high population explosion in these countries, which significantly reduces the positive effect of GDP per capita.

### *Robustness test*

Robustness analysis is carried out to further validate the effectiveness of the computed model with results given in Table 4. The appropriate model was selected and verified through robustness check. The variables were found to be stationary at the level, as determined by the unit root test. Additionally, OLS violation test like Variance Inflation Factor (VIF), Wooldridge test, Breusch Pagan test was performed. The VIF value was below 3 indicating that the model is free from Multicollinearity (MC).

**Table 4**. Robustness test of panel estimation

| S.NO | Purpose | Test | Result |
|---|---|---|---|
| 1 | Stationarity | Unit root test | Stationary at level |
| 2 | Heteroscedasticity | Breusch Pagan test | Mild |
| 3 | Serial Correlation | Wooldridge test | Presence |
| 4 | Multicollinearity | VIF | No MC |
| 5 | Endogeneity | Hansen test | No |
| 6 | To find best model between FE and RE | Hausman Specification test | RE is selected |

**Note:** VIF: Variance Inflation Factor, MC: Multicollinearity

Similarly, the presence of serial correlation was within acceptable limits and heteroscedasticity was detected at only mild levels. Hence the formulated model is free from OLS violations. To determine the best effect between fixed and random effects, the Hausman Specification test was applied. The random effect model was selected as the estimated p-value was less than 0.05. Furthermore, the Hansen test detected no endogeneity, eliminating the need to perform GMM (Generalised Method of Moments) estimation.

## Conclusion

The main aim of this study is to explore the relationship between climatic variables and food security in SAARC countries. As anticipated, a prominent and significant relationship has been found with rainfall and temperature on food security. Food production is expected to increase marginally with a rise in temperature and rainfall, but not in substantial volume. However, a significant deviation in these climatic variables could hinder production. Only variations within a permissible range can ensure food security. In tropical regions, the temperatures are expected to trend warmer, with minimal immediate impact, but the severity of extreme events are expected to increase. Land under cereal production does not show significant impact on food security. Despite increase in cereal production, South Asian countries continue to face risks of hunger and poverty. Usually, Inflation affects the standard of living but in SAARC nations the results stand distinct due to stringent macroeconomic policy and resilience of agro food trade. Social protection policies can be framed to enhance the food security level amid the climate change conditions.


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## Authors' contributions

SE has done the data collection and analysis, drafting of original manuscript. KMS contributed to conceptualization, methodology, supervision, validation and editing of manuscript. DSK, KM, RP and MK all contributed to framing research concepts, results interpretation and final approval of manuscript. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None

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