



Research Article

## **Examining the Nexus between Climate Change and Food Security in South Asian Economies: Evidence from Panel Data**

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### **Abstract**

Extreme climate change has become a serious concern, posing challenges to human and economic welfare across many developed and developing countries. Based on empirical observation, it is claimed that the devastating floods, along with the threat of droughts, can account for variations in food security between different countries. This study uses the data from 1973 to 2021 to check the relationship between climate change and food security in a panel of SAARC countries (Afghanistan, Bangladesh, Bhutan, India, Nepal, Maldives, Pakistan, and Sri Lanka). Based on the statistical test diagnostics, we estimate a random effects model to examine the nexus between climate change and food security. Results indicated that land under cereal production, GDP per capita, and mean average temperature have a positive association. While Population growth and mean average rainfall have a negative association. Facing the issues of climate change, the governments of the economies under study may construct new dams to store water, which will also aid in flood control. Further, the increasing area of cultivation may boost the output level and cereal availability, which may help to sort out the main issue of food insecurity.

Keywords: Food security, Climate change, ADF, Fixed effect model, SAARC economies.

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## **Introduction**

Climate change has become an issue being discussed more frequently nowadays (Chauhan et al., 2020). The circumstances, such as storms, drought, and floods, become dangerous for the crops, land, food supplies, and livestock (Thornton & Herrero, 2021). The impact of climate change on economic growth has been a central topic of global policy talks for several decades (Barrera & Hertel, 2021). The changing climate is increasingly endangering human well-being worldwide. It is specifically credited to an increase in the level of available gases in the atmosphere that are greenhouse gases, as well as fluorinated gases, nitrous oxide, methane, and carbon dioxide (World Meteorological Organization, 2020). Climate change and global warming are two different terms. Global warming is only concerned with the increase in temperature, while climate change is a multidimensional concept (Mendelsohn & Wang, 2017). When economies move towards the modern age, a stable pattern of climate is disturbed, due to which human and natural activities are mutually affected. Climate change is responsible for modifying the time duration and pattern of rainfall, increasing trends in temperature level, and indirectly affecting the available resources like land for production or water (Thornton et al., 2011).

People face losses in their assets and their level of income also. So the process of economic development slows down (Barrera & Hertel, 2021; Chauhan et al., 2020). Bilal et al. (2020) revealed that land used for forest is alternatively used for other activities, and the deforestation trend has also risen. Due to which Carbon dioxide level has increased, which is a harmful greenhouse gas. These gases destroyed the ozone layer and become cause of an increase in temperature level. When the temperature increases, it melts the glaciers, and the water

from these melted glaciers flows toward the productive lands, which destroys the fields because it has a negative impact in the form of floods and drought (Mishra & Sahu, 2014). It decreases the productivity ratio of crops. So there is a need to adopt such policies that can mitigate the multifaceted and dual effects of climate change and food security. Climate change impacts both poor and developed nations differently based on their respective lifestyles and available resources (Nelson et al., 2009). Developing nations mostly rely on agriculture as the foundation of their economies, resulting in limited ability to reduce risks. It is causing significant transformations in global food systems, including changes in the availability, accessibility, quality, and stability of food (FAO, 2019; Easterling et al., 2000; Hossain et al., 2019). The region of the South Asian Association for Regional Cooperation (SAARC) places significant focus on climate change.

The main reason behind this is the heavy population, and the underdeveloped countries of that region depend mostly on available natural resources, rain-fed agriculture, and are located in a part of the geography where climate change poses severe threats. As the global population is increasing day by day, it puts pressure on food demand (FAO, 2019). When the population growth rate increases, food demand also increases, which creates a situation of food insecurity in the economy (Kumar & Sharma, 2022). According to Malthus theory, “food supply is rising exponentially while population is growing arithmetically”. As the population growth rate of SAARC nations becomes higher compared to other nations, the situation is becoming much more alarming in this region (World Bank, 2010). In 2020, nearly 690 million people (8.9% of the overall population) were likely to be in a state of food shortage. From the whole world number of hungry people is expected to have grown between 83 and 132 million and could reach 840 million (9.8%) by 2030 (Affoh et al., 2022). That’s why in 2015, the United Nations placed “end famine, attaining diet safety, improving food, and promoting sustainable agriculture” as the second of the 17 SDGs. The climate ranking of all SAARC nations is shown below in Table 1.

Table 1. The climate ranking score of all SAARC nations.

Country	CRI Ranking	CRI Score
Afghanistan	6	16.00
India	7	16.67
Nepal	12	20.00
Bangladesh	13	23.50
Pakistan	15	25.00
Sri Lanka	23	39.50
Maldives	111	97.33
Bhutan	130	118.00

Source: Eckstein et al. (2021).

Afghanistan is the most climate-affected country among the SAARC nations. Having a CRI score of 16.00 and ranking 6 among 180 countries globally in 2021. It exposes that Afghanistan’s economy is most affected by extreme weather events during this time as compared to all other SAARC countries. Bhutan has the lowest climate-affected country among the SAARC nations.

Climate change and food security have dual effects (Bilal et al., 2020). In one way, natural calamities and extreme weather events disturb the production process or output; on the other side contraction of agricultural land is another key factor that is responsible for the change in climate. Climate change affects food access through its negative impact on rural livelihoods and food prices. The shortage of food supply, caused by the adverse effects of climate change on production and yields, leads to an increase in food prices. This rise in food prices also has an impact on millions of low-income individuals living in regions already affected by high rates of poverty and hunger, such as Sub-Saharan Africa (Thamaga-Chitja & Tamako, 2017) and South Asia (Bandara & Cai, 2014). Figure 1 shows an overview of food development history throughout this specific time duration of each SAARC nation, which is under debate in this study.

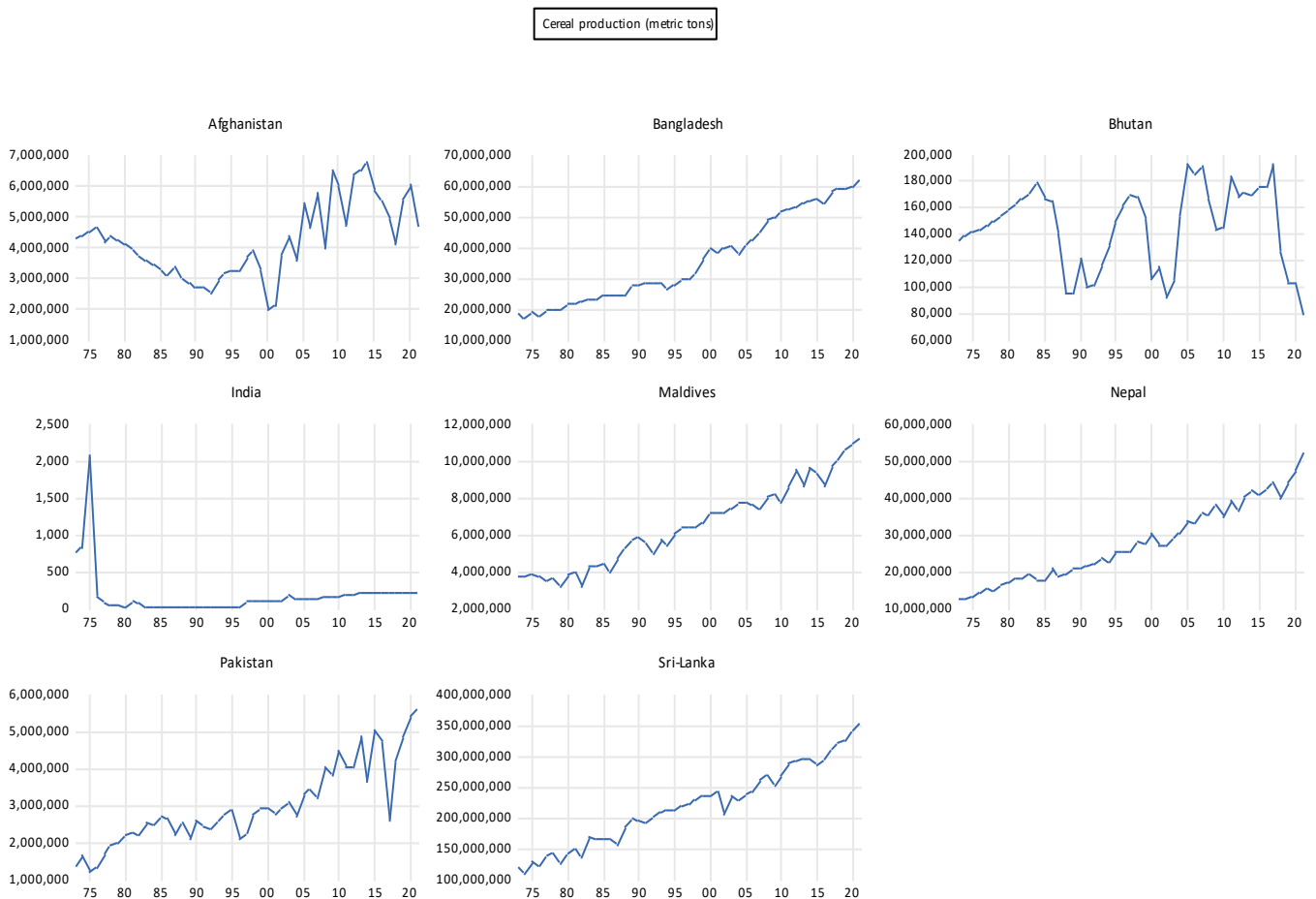


Figure 1. Plot of an average cereal production in SAARC countries (1973–2021).

Cereal availability in Afghanistan (especially wheat, which accounts for 77 percent of total cereal production) is determined by both domestic production and imports. Afghanistan's cereal production in 2021 was 4.66 million metric tons. Despite significant fluctuations in recent years, Afghanistan's cereal production increased from 1972 to 2021, reaching 4.66 million metric tons in 2021 (WB). Bangladesh is particularly prone to food insecurity due to a multitude of demographic, social, and environmental concerns. Climate change is becoming a cause of worsening of these difficulties. It is an agriculture-based country, and the expenses of imported fertilizers such as nitrogen, phosphate, and potash can have a significant influence on national productivity, boosting demand for rice imports. Meanwhile, FAO (2019) argued that Bangladesh has traditionally relied on rice for more than half of its calorie intake; however, wheat consumption has tripled since 2000 and now accounts for 7% of calories, with the remaining 80% bring in from other countries.

The majority of Bhutan's arable land is cultivated by tiny farm holdings averaging 1.2 hectares in size, which generate the majority of the crop and animals. In 2021, cereal output for each acre was estimated to be 3,342.400 kg/ha. This is a drop from the previous year's average of 3,439.500 kg/ha. In latest ages, India has achieved grain self-sufficiency and sustained economic progress. Regardless of this progress, the country has seen no reduction in poverty, food uncertainty, or hunger. Food insecurity affected 6.2 crores more individuals in India in 2019, a rise of 3.8% between 2014 and 2019. India would have over 200 million malnourished persons by 2020. Agriculture, along with fishing, has traditionally been important in the Maldivian community's survival. It is an important source of revenue, in that it provided foodstuff and earnings to households.

It has been seen that cereal production of a country continuously increasing from many decades. 4.6 million Individuals in Nepal are insecure about their diets, with 20% of families being moderately food insecure, 22% being somewhat or completely food vulnerable, and 10% being extremely food insecure (DHS, 2016). Rice, wheat, and maize are among the most important crops of cereals for the Nepalese supply of food, with annual rice crop output of 4.3 million tons (MT), 2.2 MT of maize, and 1.7 MT of wheat in 2015/16. Regardless of attempts towards improving accessibility to irrigation and chemical fertilizers, Nepal continues to be unable

to satisfy the nation's need for Cereal production (National Planning Commission, 2019). In Pakistan, agriculture accounts for 22.9 percent of GDP and 37.4 percent of job creation, maintains food security, and provides employment. According to the 2018 National Nutrition Survey, 36.9 percent of the overall population is food insecure. Cereals represent a share of 47 percent of the overall calorie intake per capita, and crops like cereals contribute 46 percent of the total protein consumption per capita (FAO, 2011).

Many other studies (Chandio et al., 2022; Abbas et al., 2021; Pickson, 2022; Fusco, 2022) focus on the burning issue of climate change and its severe effects, such as high temperature levels, extreme weather situations, and food production areas for other regions and countries. This study is unique for the reason that no one has investigated the impact of climate change on food security in the SAARC region. The study objective is to evaluate the impact of climate change on food security in the studied economies.

## **Literature Review**

An empirical literature review is a rigorous and comprehensive analysis of past scholarly research articles and studies in a specific field of study, which is based on empirical evidence. The primary purpose of a literature review is to provide a comprehensive examination of existing research and knowledge in a given academic field, with the goal of identifying and addressing any inconsistencies or gaps, as well as evaluating the strengths and flaws of prior studies. Multiple studies have identified the adverse effects of climate change on food security. Ensuring food security is a fundamental human entitlement that can be achieved by safeguarding a sustainable provision of food and maintaining the health standards of food (Pérez-Escamilla, 2017). Approximately 820 million people in developing and least-developed countries suffer from food shortages as a result of climatic disasters (WHO, 2018).

A lot of scholarly literature focuses on the climate change damages to agriculture (Hasegawa et al., 2018). Pant (2012) explored that raising the lowest temperature possible reduces the yield of rice in Nepal, enhancing the risk of food poverty. For instance, Boko et al. (2007) suggested that the crop production of African countries will decrease by about 50% by 2030, and crop income will reduce by about 90% by 2100 due to extreme climate change. Shah et al. (2009) argued that due to climate change, agricultural productivity could decrease by 8% by 2080 in Sub-Saharan Africa, while this will be by 4% in the case of Asia. Meanwhile, Zubair et al. (2015) indicated that the Rice-farming methods in Sri Lanka suffer from pressure because of insufficient earnings for landowners and challenges dealing with surprises caused by weather, insects, illnesses, and commodity pricing.

Solaymani (2018) revealed that rainfall-temperature fluctuation had an adverse effect on foodstuffs availability as well as accessibility to foods in each period in Malaysia, owing to a drop in agricultural goods production, rising prices for commodities, and a decrease in revenue from households. For instance, Maity et al. (2023) argued that the effects of climate change may have an influence on the conventional seeding mechanism, which largely promotes the maintenance of within the farm agro-biodiversity, in a variety of methods. There is an adverse correlation between variations in climate and agricultural product productivity in Ghana. Change in the climate had a variety of effects on the growth of crops, with a decrease in brown rice, wheat, and barley growth and a boost in potato and local bean output in Nepal's Karnali region (Thapa & Hussain, 2021). Moreover, Chandio et al. (2021) demonstrated that greenhouse gas emissions and temperatures both reduced maize productivity in the short and long run, whereas rainfall increased the harvest of maize in both of the instances. Abbas (2022) found that heavy rainfall had considerably unfavorable impacts on agricultural output in Pakistan.

For instance, Ali et al. (2017) showed that a high temperature has a negative impact on the wheat output, whereas a low temperature has a beneficial and important impact on crops of all kinds. Chen et al. (2021) and Sarker et al. (2012) argued that there is a positive association between high temperature and total agricultural fertility rates of Bangladesh. Munir et al. (2016) experienced a negative association between mean temperature and food availability. Further, it was revealed that the combined change in both temperature and precipitation reduced Malaysia's revenue growth in both the short and long term (Solaymani, 2018). Giulio (2022) argued that global warming had a negative impact on nutritional availability in Northern and Eastern African countries. The atmospheric warming would continue to have adverse consequences in the case of the African

nation of Kenya (Kogo et al., 2021). Bangladesh has been impacted by extreme weather events. Sarker et al. (2012) investigated that climate change caused food shortages and insecurity in the region. Several further studies have demonstrated that climate change is the primary cause of food insecurity in both households and nations in less developed countries (Nelson et al., 2009; Thornton et al., 2011; Connolly-Boutin & Smith, 2016). Owusu et al. (2021) and Amekudzi et al. (2015) proposed that extreme weather conditions can reduce the amount of acceptable arable land in Africa, hence affecting food production in the region. Further, Affoh et al. (2022) also argued that rainfall had an important beneficial impact on the availability, accessibility, and use of food, while temperature and CO<sub>2</sub> emissions increased food supply and affordability but had no effect on food usage.

Based on the previous studies, we concluded that rising temperatures and shifting patterns of rainfall had an extensive effect on the growing of food. According to the literary work, climatic factors such as precipitation, temperatures, CO<sub>2</sub>, and extreme weather conditions have adverse impacts on the availability of food. It was additionally found that environmental degradation has had an effect on the availability of food and its use, but this was not thoroughly investigated due to its complex nature.

## Methodology

### Model Specification

This study used average temperature and average rainfall (climatic variables) with other independent Variables (population growth, cultivated land under cereal production, and GDP per capita) to estimate the impact of climate change on food security. Thus, the nation's food safety functional form is stated as follows:

$$FOSE = f(CULA, POP, GDP_{PC}, AMTEMP, AMRAIN) \quad (1)$$

FOSE stands for food security. Cereal availability is used as a proxy for FOSE in many studies.

CULA is the cultivated area under Cereal production, POP is population growth, GDP<sub>pc</sub> is GDP per capita, AMTEMP is annual mean temperature, and AMRAIN is annual mean rainfall. To evaluate the impacts of climate change on food security, an econometric model of climatic variables (average temperature and average rainfall) and non-climatic variables is estimated. Food production is influenced by both types of factors (climatic & non-climatic) (Alvi & Jamil, 2018; Di Falco, 2014). The regression equation can be written as follows:

$$FOSE_{it} = \Omega + \gamma_1 CULA_{it} + \gamma_2 POP_{it} + \gamma_3 AMTEMP_{it} + \gamma_4 AMRAIN_{it} + \gamma_5 GDP_{pc_{it}} + \epsilon_{it} \quad (2)$$

### Data characteristics

We used an annual panel dataset on SAARC countries from 1973 to 2021, and we selected this region because it is a region of the most populous and most food-insecure nations. The countries of the region are Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka. The overview of the variables utilized in this present investigation is indicated as, Cereal production is used as a proxy of Food security, and its data was extracted from the World Development Indicators. The unit for measurement of Cereal Production (CP) is metric tons (Byrnes & Bumb, 2017; Smith & Haddad, 2001; Bezuneh & Yiheyis, 2009). Cereal Production Area (CPA) is used as a proxy for land under cereal production in hectares. The data for the CPA, Population Growth in annual percentage form, and GDP Per capita in current US\$ were also extracted from the World Bank (WDI). While the data for the climatic variable (average temperature) and Average rainfall, which shows the amount of precipitation in millimeters, is extracted from Trending Economics.

### Estimation strategies

The purpose of this research is to use advanced panel data methods such as the ADF Fisher Chi-square Test, the Johansen System Co-integration Test, the Housman Test, and the Random Effect Model to determine how climate change is influencing food security in SAARC countries.

Panel unit root tests

The study employed the unit root test to assess the variables' stationary qualities (Maddala & Wu, 1999; Choi, 2001; Levin et al., 2002; Im et al., 2003). This test ensures that the autoregressive coefficients are homogeneous and suggests whether or not the unit root problem is present. Panel unit root ADF-Fisher Chi-square test is used to check stationarity. While the random effects technique is used for evaluating a model. The general form of the ADF test is:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_t - 1 \sum_{k=1}^{m_i} \beta_{ik} \Delta Y_t - i + \mu t \tag{3}$$

Panel Co-Integration Technique

The study employed co integration procedure to determine the existence of a long-term relationship between food security, climatic variables, population growth, cultivated area, and GDP per capita. The main rule of co-integration testing is to examine the reliability of variables when the combinations of variables diverge considerably (Abadir & Taylor, 1999). The expressions below are null & alternative hypotheses for the testing of a panel co-integration technique:

$$H_0: \text{no co integration} \qquad H_1: \text{co integration}$$

More precisely, the null hypothesis shows that there is no co-integration exists. In contrast, the alternative hypothesis proposed that there is evidence of co-integration.

**Results and Discussions**

**Correlation matrix**

The correlation matrix depicts the relationship between the variables involved in the study. The correlation coefficient is between -1 and 1. Table 2 shows the results of the correlation matrix.

Table 2. Correlation matrix.

Correlation matrix	Cereal production	GDP Per Capita	Per Land under cereal production	Population growth	Mean annual temperature	Mean annual rainfall
Cereal production	1.0000					
GDP Per Capita	-0.1185	1.0000				
Land under cereal production	0.9402	-0.1479	1.0000			
Population growth				1.0000		
Mean annual temperature	-0.0259	-0.0320	-0.0244	0.2663	1.0000	
Mean annual rainfall	0.2847	0.2856	-0.1248	0.0571	0.2726	1.0000
	-0.0864	0.2384		0.0175		

Source: Author's own calculations.

Cereal production correlates positively with cereal production land and mean yearly temperature. Cereal outputs, on the other hand, have a negative relationship with GDP per capita, population increase, and mean annual rainfall. There is no trouble with perfect multicollinearity.

### Panel Unit Root Test Results

The ADF Fisher- chi square test results are shown in Table 3.

Table 3. ADF Fisher-Chi square test results.

Variables	Statistical value	probability	Difference level
Cereal production	382.744	0.0000	1st difference
GDP Per Capita	392.254	0.0000	1st difference
Land under cereal production	278.644	0.0000	At level
Population growth	48.9394	0.0000	At level
Mean annual temperature	48.4114	0.0000	At level
Mean annual rainfall	79.1407	0.0000	At level

Source: Author's own calculations.

ADF Fisher-Chi square test is applied to check the stationarity of the data. Cereal production and GDP Per Capita are stationary at the first difference. Land under cereal production, Mean annual rainfall, Mean annual temperature, and population growth are all stationary at a level. So there is mixed order in the variables.

#### 4.3 Johansen System Co-integration Test

H<sub>0</sub>: No Co-integration

H<sub>1</sub>: Co-integration exists

Johansen co-integration test is used to analyze the relationship between different variables and to identify more than one co-integrating relationship. The Johansen Co-integration test results are shown in Table 4.

Table 4. Johansen System Co-integration test results.

Hypothesize No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-Eigen test)	Prob.	Hypothesize No. of CE(s)
None	128.9	0.0000	62.48	0.0000	None
At most 1	46.72	0.0000	22.06	0.0077	At most 1
At most 2	30.48	0.0066	17.46	0.2326	At most 2
At most 3	19.67	0.1411	16.98	0.2572	At most 3
At most 4	10.11	0.7540	10.10	0.7552	At most 4
At most 5	11.43	0.7540	11.43	0.6520	At most 5

Source: Author's own calculations.

According to the Fisher stat (from trace test) at none value is 128.9 and p-value less than 0.05, at most 1 & 2 p-value is again less than 0.5, so it means three equations are co-integrating. In at most 3, 4 & 5, the p-value is greater than 0.05, so these equations are not co-integrating. From the max-Eigen test p-value at none and at most 1 is less than 0.05, so there are 2 equations that are co-integrating. As the p-value of trace statistics and max-Eigen of 'None' and 'At most 1' is less than 0.5, this confirms the rejection of the null hypothesis and shows the existence of co-integration.

### Hausman Diagnostic Test

H<sub>0</sub>: random effect model is suitable

H<sub>1</sub>: The random effect model is not suitable

Table 5. Hausman Test (Dependent variable: Cereal Production)

Test Summary	Results
Chi-Sq- Statistics	. 3.735878
Probability value	0.5880

Note: The three asterisks \*\*\* & \*\*\* reveal the significance level at 1%, 5% & 10%.

The above outcomes in Table 5 are to check whether the random effect model is an appropriate technique or the fixed effect model. The Chi statistic is 3.735878, and the P-value is 0.5880, which is greater than 0.05, and on the basis of these results, we are accepting  $H_0$  and recommend applying the random effect model, which is proven to be more appropriate than the fixed effect model.

Table 6. Random effect model.

Variables	Coefficients/ t-statistics
GDP <sub>PC</sub>	3509406 (2.0760)
LUCP	11863018 (9.0217)
MAT	2678945 (3.3498)
PG	-8.2205 (0.032)
MAR	-318.4783 (0.2005)
CONSTANT	-2.0608
R <sup>2</sup>	0.185

Source: Author's own calculations.

Table 6 shows the results of the random effect model. The predicted signs of the independent variable's coefficients have materialized, and they are also determined to be statistically significant at the 1% or 5% level. It appears that the hypotheses that were intended to be examined have been proven. Not only does land under cereal cultivation contribute positively to output, but so do GDP per capita and mean average temperature. Cereal production is negatively correlated with both population expansion and mean average rainfall. Additionally, the interaction term is positive and statistically significant, suggesting that the two variables are beneficial to one another. R-squared values prove the model fits the data well.

## Conclusions and Policy Implications

Food security is a broader area, and after narrowing down to a single dimension, the availability of cereal production as proxy of food security. The Panel data is used from 1973 to 2021 for the SAARC countries. First of all ADF Fisher chi-square test is used to check the stationarity of data. ADF unit root test indicates that there are mixed results; some variables are stationary at the level, while some are at the first difference. Johansen Co-integration test confirmed the long-run relationship. P-value in the Housman test confirmed that

the Random effect model is appropriate to apply. LUCP, GDP per capita, and MAT have a positive relationship. If land under cereal production increases, then automatically cereal production in the form of availability also increases, which means there is a direct relationship between cereal production and these variables. Population growth and MAR have a negative relationship; as PG and MAR increase, cereal production decreases. When the population increases, they demand more food to fulfill its basic need for food, which creates a shortage of food due to insufficient production, so the issue of food security becomes severe. Facing these issues, the governments may construct new dams to store water, which will also aid in flood control, specifically in developing nations. That floodwater may be utilized in the areas where it has fruitful outcomes. When a specific area of cultivated land is allocated for Cereal production cultivation then farmers may grow more cereal. This increasing area of cultivation may boost the output level and cereal availability, which may help to sort out the main issue of food insecurity. Further, the governments of the studied nations might take some steps to create equivalence between food resources and population growth.

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