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HUMAN DEVELOPMENT, CLIMATE CHANGE, AND FOOD SECURITY IN DEVELOPING COUNTRIES: EVIDENCE FROM A TWO-WAY FIXED EFFECTS MODEL

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Food security remains a critical issue in an era of increasingly evident climate change. In developing countries, food insecurity continues to pose a significant challenge that demands effective policy interventions. This study examines the effects of climate change and human development on food security in developing countries. The analysis employs a two-way fixed-effects model to control for unobserved heterogeneity, using panel data from 93 developing countries over the period 2005–2020. The estimation results reveal that human development is the primary determinant of food security. Higher levels of human development are associated with a lower prevalence of undernourishment. In contrast, climate change, measured by changes in temperature, does not have a statistically significant effect on food security after controlling for country and year fixed effects. These findings underscore the importance of strengthening human development through improvements in education, healthcare, and individual income to enhance food security in developing countries

Keywords: food security, climate change, HDI

1. Introduction

Food security is a crucial issue because it is directly linked to fulfilling the basic human needs required for survival (Pawlak & Kołodziejczak, 2020). Food security is achieved when the entire population has physical and economic access to sufficient, safe, and nutritious food that meets their needs and preferences, enabling them to lead active and healthy lives (FAO, 2025). In developing countries, food security involves not only the availability of food in markets but also the stability of economic access and the protection of vulnerable groups, ensuring they can continue to meet their food needs and maintain productivity (Bloem & Farris, 2022). Nevertheless, achieving food security remains a challenge for many developing countries.

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Food security remains a major development challenge for many developing nations. Despite the global increase in food production, the prevalence of undernutrition remains notably high in several developing countries (Miladinov, 2023). This situation demonstrates that increased food production alone cannot fully guarantee the achievement of food security. Consequently, food security has become a central focus of the global development agenda, specifically under Sustainable Development Goal 2 (SDG 2), Zero Hunger, which aims to eliminate hunger and ensure access to sufficient, safe, and nutritious food for all (FAO, 2024). Furthermore, food security is closely linked to the achievement of other SDGs, such as poverty alleviation and improvements in health and education, given that undernutrition can hinder an individual's physical and cognitive development as well as their social capabilities (Abebaw, 2025).

Various factors influence a country's success in achieving food security, one of which is climate change. Climate change has emerged as a serious threat to global food systems by affecting food production across various regions of the world; developing nations and archipelagic states are particularly vulnerable to its impacts (FAO et al., 2020). This vulnerability arises because climate change disrupts food production systems and the livelihoods of communities dependent on the agricultural sector (Raj et al., 2022). The impacts of climate change include increased soil erosion, pest and disease outbreaks, declining soil fertility, and heightened risks of drought and flooding, all of which directly reduce agricultural productivity. Ultimately, these conditions weaken food production systems, thereby undermining food security at both local and global levels (Farah et al., 2025).

Beyond the challenges posed by climate change, human resource capacity plays a crucial role in determining a country's ability to maintain food security. Higher levels of human development correlate with a greater capacity to maintain food security by improving the ability to adapt to these risks (Dossa & Miassi, 2025). Advancing human development through improvements in health and education strengthens community capacity to achieve sustainable food security (Pérez-Escamilla, 2017). Furthermore, human development supports the adoption of innovations in the food sector, such as the use of high-yielding seeds, modern agricultural technologies, and soil fertility enhancement, which ultimately contribute to improved food security (Yadav et al., 2025).

The impact of climate change on food security remains varied across studies. Some research identifies significant effects; for instance, negative impact of climate change on food security in North and East Africa (Fusco, 2022), while significant increases in temperature reduce agricultural value-added in the MENA region (Razzouki et al., 2025). Additionally, a 1°C rise in temperature reduces global wheat production by up to 6% (Farah et al., 2025). Conversely, other studies report insignificant results. Research indicates that long-term temperature coefficients have no significant effect on food production, suggesting an adaptive capacity within food systems (Azdagaz et al., 2025). Farmer adaptation strategies, such as the use of climate-resilient seed varieties, can

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boost crop yields by up to 25% in semi-arid regions (Abebaw, 2025). Furthermore, farm-level adaptation in the Global South yields direct benefits for smallholder farmers in coping with climate-related pressures (Raj et al., 2022).

Meanwhile, the influence of human development on food security has consistently been found to be significant across various studies. A study found that identified a strong long-term relationship between the Human Development Index (HDI) and food security in Arab countries (Cherif et al., 2024), aligning with another study that found that the HDI has a substantial positive coefficient regarding food productivity (Yadav et al., 2025). Other research found that a very strong correlation between human development and food-energy-water resource security (Tariq & Willis, 2024). Meanwhile, purchasing power and education levels significantly increase the probability of households achieving food security (Ayaviri-Nina et al., 2022), while education significantly enhances the likelihood of household food security (Mutisya et al., 2016).

Several studies have found that Gross Domestic Product (GDP) contributes to food security. A study demonstrated that GDP growth contributes significantly to enhancing food security in Central Asia (Sun & Zhang, 2021). Similarly, another study revealed a strong positive relationship between GDP and agricultural sector performance in the Maghreb region (Mohamed et al., 2024). However, some studies have found that GDP is not always the most dominant factor. It is found that human development has a larger coefficient than GDP per capita in explaining food productivity (Yadav et al., 2025). Consistent with this, it concluded that agricultural productivity plays a more consistent role than GDP in maintaining food price stability (Dardeer & Shaheen, 2025), thereby supporting the achievement of food security.

A review of the literature reveals several reasons for further research into the impact of climate change and human development on food security. Previous studies have yielded mixed results. Some report that climate change, specifically rising temperatures, negatively affects food security by reducing agricultural productivity and food production (Farah et al., 2025; Fusco, 2022; Razzouki et al., 2025). Conversely, other studies indicate that this impact is not always significant, owing to the adaptive capacity of food systems, such as the use of climate-resilient seed varieties, the adoption of agricultural technologies, and other adaptation strategies that mitigate climate change impacts (Abebaw, 2025; Azdagaz et al., 2025; Raj et al., 2022). These inconsistencies stem from variations in the methods and contexts of prior research, including study regions, data periods, and analytical approaches, making the findings difficult to generalize and not necessarily applicable to the context of the present study. Furthermore, most existing studies examine the effect of climate change and human development variables separately, as shown by study of (Ayaviri-Nina et al., 2022; Cherif et al., 2024; Mutisya et al., 2016; Tariq & Willis, 2024; Yadav et al., 2025). Consequently, there remains scope for further research that examines both variables simultaneously within a single model.

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This study aims to examine the effect of temperature change on food security, given that climate change has become a major concern in the context of sustainable development, particularly in developing countries. In addition to investigating the direct effect of temperature change, this study explores the role of human development as a factor that may influence the relationship between climate change and food security. Furthermore, this study provides empirical evidence using a two-way fixed effects model based on a panel of developing countries, allowing for the control of both country-specific heterogeneity and time-specific effects.

In line with these objectives, this study makes several important contributions. First, it employs panel data from 93 developing countries, enabling the findings to capture a broader and more diverse range of socioeconomic and institutional contexts. Second, the study applies a two-way fixed effects model to control for both cross-country heterogeneity and time-specific shocks, thereby producing more accurate and robust estimates. Third, the findings demonstrate that human development is a more robust determinant of food security after accounting for country fixed effects and time fixed effects, highlighting the importance of human development in strengthening food security across developing countries.

2. Methods

This study utilizes secondary panel data covering 93 developing countries over the period from 2005 to 2020. Panel data combines time-series and cross-sectional data, thereby capturing variations across developing countries as well as changes over time. The data were sourced from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT), World Development Indicators (WDI), and the United Nations Development Programme (UNDP).

Table 1 presents the description of the variables used in this study. The dependent variable in this study is the Prevalence of Undernourishment (PoU). This variable indicates the estimated proportion of the population whose routine food consumption is insufficient to meet the energy levels required for a normal, active, and healthy life. This indicator measures progress toward SDG Target 2.1 (Zero Hunger), which aims to end hunger and ensure access for all people, particularly the poor and vulnerable (including infants), to safe, nutritious, and sufficient food throughout the year (FAO, 2026). In addition, Prevalence of Undernourishment (PoU) is also widely employed in cross-country empirical research because it is measured consistently across countries and available for relatively long time periods. Several previous studies have used this indicator to measure food security (Eini-Zinab et al., 2020) (Ghosh & Sahu, 2023).

The independent variables are Temperature Change (representing the change in average annual temperature) and the Human Development Index (HDI). HDI is an indicator of human development reflecting quality of life based on three key dimensions:

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health, education, and a decent standard of living. The study also incorporates control variables consisting of GDP per capita, Urban Population, and Agricultural Land.

Tabel 1: Data Description and Source

Variable Code	Variable Description	Unit of Measurement	Data Source
Food Security	Prevalence of Undernourishment	Percent	World Development Indicators (WDI)
Temp	Temperature Change	Celcius (°C)	Food and Agriculture Organization Corporate Statistical Database (FAOSTAT)
HDI	Human Development Index	Index (0-1)	United Nations Development Programme (UNDP)
GDP	GDP per capita	US\$	World Development Indicators (WDI)
Urban	Urban Population	Percent	World Development Indicators (WDI)
Agriland	Agricultural Land	Percent	World Development Indicators (WDI)

In this study, climate change is measured based on changes in annual temperature as the primary indicator. Other climate variables, such as precipitation or extreme weather events, are not included in the research model. Meanwhile, food security status is measured using the Prevalence of Undernourishment (PoU) indicator.

Furthermore, this study employs a panel data regression model, beginning with the estimation of a pooled Ordinary Least Squares (OLS) model, followed by the Fixed Effects and Random Effects models. The Hausman test results indicate that the Fixed Effects model is the preferred specification. This approach employs Two-Way Fixed Effects (TWFE) to control for country fixed effects which capture time-invariant structural characteristics such as geographic location, and year fixed effects which capture global shocks affecting all countries simultaneously in a given year (Baltagi, 2021; Wooldridge, 2020).

All estimations utilize clustered standard errors at the country level to ensure robustness against heteroskedasticity and autocorrelation within each country, thereby enhancing the reliability of the estimation results. The two-way fixed-effects empirical model of this study can be expressed as follows:

$$PoU_{it} = \beta_0 + \beta_1 Temp_{it} + \beta_2 HDI_{it} + \beta_3 GDP_{it} + \beta_4 Urban_{it} + \beta_5 Agriland_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

Description:

PoU = Prevalence of Undernourishment

Temp = Temperature Change

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<i>HDI</i>	=	Human Development Index
<i>GDP</i>	=	GDP per capita
<i>Urban</i>	=	Urban Population
<i>Agriland</i>	=	Agricultural Land

3. Results and Discussion

This study employs panel data comprising 1,488 observations across 93 developing countries for the period 2005–2020. Table 2 presents descriptive statistics for the dependent and independent variables used in the study. As shown in Table 2, food security, measured by the prevalence of undernourishment, has a mean of 13.64 percent, with significant variation; values range from a minimum of 2.5 percent to a maximum of 49.4 percent, indicating substantial disparities in food security conditions among the developing countries in the sample.

The temperature variable has a mean of 0.98°C with a standard deviation of 0.43, indicating that the variation in temperature change is relatively small. Its values range from −0.48°C to 2.75°C. Meanwhile, the Human Development Index (HDI) has an average value of 0.62 with a standard deviation of 0.12, suggesting relatively low variation in HDI across the sample. The GDP per capita variable has a mean of US\$3,661.77 and a standard deviation of US\$3,490.87, which is close to its mean. This indicates a relatively high degree of income disparity among the countries included in the sample. The Urban and Agricultural Land variables have average values of 50.12% and 40.04%, respectively. Both variables exhibit wide value ranges, reflecting substantial differences in the characteristics of developing countries included in the study.

Table 2. Descriptive Statistics of Variables

Variable	Obs	Mean	Std. dev.	Min	Max
Food Security	1.488	13,64	9,51	2,50	49,40
Temperature	1.488	0,98	0,43	-0,48	2,75
HDI	1.488	0,62	0,12	0,30	0,86
GDP per capita	1.488	3.661,77	3.490,87	290,83	20.032,54
Urban	1.488	50,12	20,98	13,00	95,40
Agricultural Land	1.488	40,04	20,71	0,44	84,74

Source: Author's estimate

This study estimates the Common Effects Model (CEM), Fixed Effects (FE), and Random Effects (RE) models to determine the most appropriate panel data model. Based on the Hausman test (Chi-square = 19.11; $p = 0.0007$), the Fixed Effects model was selected as the best model. Subsequent estimation employs Two-Way Fixed Effects

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(TWFE) with year fixed effects and clustered standard errors at the country level to control for time effects and generate more robust estimates.

Table 3 presents the regression results obtained from the Common Effects Model (CEM), Fixed Effects (FE), and Two-Way Fixed Effects (TWFE) model. The CEM serves as the baseline specification, while the FE model controls for unobserved country-specific heterogeneity. The TWFE model further accounts for both country and year fixed effects, thereby controlling for time-invariant country characteristics and common shocks affecting all countries over time. To improve the reliability of statistical inference, the FE and TWFE estimations employ clustered standard errors at the country level. Overall, the F-statistics indicate that all models are jointly significant at the 1% level. Among the estimated models, the TWFE specification is considered the preferred model because it controls for both cross-country heterogeneity and time-specific effects, providing more robust estimates of the relationship between temperature, human development, GDP per capita, urban population, agricultural land, and food security in developing countries. Therefore, the interpretation of the regression results primarily focuses on the TWFE estimates.

Table 3: Estimation Results

Dependent Variable: Prevalence of Undernourishment						
Variables	CEM		FE		TWFE	
Temperature	-1,8801	**	0,5001	*	-0,1982	
HDI	-38,3680	***	-46,9750	***	-64,1095	***
GDP per capita	-0,0004		-0,0008	**	-0,0006	*
Urban	0,0244		0,1330		0,0369	
Agricultural Land	-0,0085		-0,1338		-0,1592	*
Constant	39,8385	***	43,8004	***	59,8671	***
Country FE	No		Yes		Yes	
Year FE	No		No		Yes	
Clustered SE	No		Yes		Yes	
Observations	1.488		1.488		1.488	
R-squared	0,3466		0,2104 (Within)		0,2399 (Within)	
F Statistic	17.00 (0.0000)		9.46 (0.0000)		5.77 (0.0000)	

Notes: *** p < 0.01, ** p < 0.05, * p < 0.10

Source: Author's estimate

Based on the results presented in Table 4, different results can be observed for the temperature variable across each model specification. In the Common Effects Model (CEM), the temperature variable has a negative effect on food security as measured by the Prevalence of Undernourishment. However, when the Fixed Effects (FE) model,

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which controls for the characteristics of each country, is employed, the temperature variable shows a positive relationship with food security. Meanwhile, in the Two-Way Fixed Effects (TWFE) model, the coefficient of temperature change becomes negative but is not statistically significant. These results indicate that, after controlling for country fixed effects and year fixed effects, temperature change does not have a significant effect on the Prevalence of Undernourishment in developing countries in this study.

These findings indicate that the impact of climate change on the Prevalence of Undernourishment is not fully captured by changes in temperature, but is likely captured by other climate indicators or other development factors. Similar findings have also been reported, indicating that the impact of climate change on food security is influenced not only by changes in temperature, but also by the quality of human resources and environmental factors (Dasgupta & Robinson, 2022). In addition, the impact of temperature change on food security tends to be indirect, but can occur through various pathways, such as food prices, household income, and agricultural productivity (Wheeler & von Braun, 2013).

The Human Development Index (HDI) consistently exhibits a negative and statistically significant coefficient at the 1% significance level across all model specifications, with coefficients of -38.3680 in the Common Effects Model (CEM), -46.9750 in the Fixed Effects (FE) model, and -64.1095 in the Two-Way Fixed Effects (TWFE) model. These findings indicate that an increase in HDI is associated with a reduction in the Prevalence of Undernourishment in developing countries. The negative relationship can be explained by the fact that HDI reflects the quality of human development, which is measured through education, health, and living standards, all of which simultaneously influence food security. Higher levels of education improve people's ability to understand nutritional information. In addition, education plays an important role in enhancing food literacy, promoting healthy lifestyle practices, and improving households' ability to manage and utilize food resources more efficiently. Improved food and nutrition literacy contributes to better dietary quality and household food security (Aisy et al., 2025; Hanbazaza & Alaklabi, 2026; Karomah & Wahyuni, 2025).

The health dimension also plays an important role in improving food security by increasing labor productivity, as individuals with better health conditions tend to have higher productivity and greater earning capacity. Furthermore, the living standards or income dimension directly enhances food access through greater household purchasing power for adequate and nutritious food. Therefore, the effect of HDI on food security is much greater than that of GDP per capita, which captures only the income dimension. Similarly, countries with higher HDI, higher literacy rates, lower under-five mortality rates, and lower income inequality experienced greater reductions in the prevalence of undernourishment than other countries (Eini-Zinab et al., 2020).

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In the Fixed Effects (FE) model, the coefficient of GDP per capita is negative and statistically significant at the 5% significance level, with a coefficient of -0.0008 . Meanwhile, in the Two-Way Fixed Effects (TWFE) model, the coefficient is -0.0006 and remains statistically significant at the 10% significance level. In contrast, the effect is not statistically significant in the Common Effects Model (CEM). These results indicate that an increase in GDP per capita is associated with a reduction in the Prevalence of Undernourishment in developing countries. These findings are consistent with the studies which found that higher GDP per capita reduces the Prevalence of Undernourishment (Ghosh & Sahu, 2023) and (Bogmans, 2024).

From an economic perspective, an increase in GDP per capita reflects the expansion of economic activity accompanied by higher household income, thereby strengthening purchasing power and improving access to food. Nevertheless, the magnitude of the GDP per capita coefficient is smaller than that of the Human Development Index (HDI), indicating that although economic growth remains important, improvements in human development make a more consistent contribution to reducing the prevalence of undernourishment. Furthermore, the benefits of economic growth are not always distributed equally across all segments of society. In countries with high levels of income inequality, a large share of the benefits from economic growth is concentrated among high-income groups, while vulnerable and poor populations that are at greater risk of food insecurity continue to face limited access to adequate and nutritious food. This finding is consistent with the study that analyzed 89 developing countries and found that economic growth has a positive and significant effect on food security, whereas income inequality has a negative effect (Batool & Sheikh, 2024).

The results presented in Table 3 show that the urban population variable does not have a statistically significant effect on food security in developing countries. This finding indicates that an increase in the proportion of the population living in urban areas does not affect food security in developing countries, even though urban areas generally have better infrastructure and public services than rural areas. Nevertheless, urban areas are also characterized by high levels of income inequality and higher living costs. These findings are consistent with the study which found that increasing urbanization does not necessarily improve food security. Furthermore, the effect of urbanization tends to depend on the quality of human resources (Szabo, 2016). Another study also showed that the urban population does not always have a significant effect on food security (Zezza & Tasciotti, 2010).

The Agricultural Land variable in the CEM and FE models shows insignificant results, whereas in the TWFE model the coefficient of Agricultural Land is negative and significant at the 5 percent level, namely -0.1592 . These results indicate that, after controlling for country fixed effects and year fixed effects, an increase in agricultural land has the potential to reduce the Prevalence of Undernourishment in developing countries. Agricultural land reflects a country's food production capacity because land is one of the

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main input factors in the agricultural production function, in addition to labor, capital, and technology. The larger the available agricultural land, the greater the potential for domestic food production, especially cereal commodities that are staple foods in developing countries, thereby strengthening the food security system and reducing dependence on food imports. These findings indicate the importance of the availability of agricultural resources for food security. These results are consistent with the study which found a negative relationship between agricultural land availability and the Prevalence of Undernourishment, where regions with greater agricultural land availability have lower levels of undernourishment (Marselis et al., 2017).

4. Conclusion

Based on the results of the panel data regression analysis, the Human Development Index (HDI) was found to have a significant negative effect on the Prevalence of Undernourishment in developing countries. This finding indicates that human development has a significant effect on food security. In contrast, the temperature change variable did not show a significant effect under the Two-Way Fixed Effects (TWFE) method, which was used to control for country heterogeneity and time shocks.

These findings indicate the importance of investing in education, improving the quality of health services, enhancing the quality of human resources, and integrating human development policies with food security policies. This study has several limitations. First, climate change was measured only by temperature change and did not include precipitation or extreme weather events in the research model. Second, the study was limited to the use of only one food security indicator, namely the Prevalence of Undernourishment. Therefore, future studies are recommended to use more comprehensive climate change indicators, examine the mechanism through which climate change affects food security via agricultural productivity, and employ other food security indicators.

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