International Journal of Research in Engineering, Science and Management
Volume 6, Issue 12, December 2023
https://www.ijresm.com | ISSN (Online): 2581-5792

Determining the Impact of Climate Change and Growth Indicators on Undernourishment Prevalence in Selected ASEAN Countries

Katrice Clare C. Fabian[1*], Eisshi Louisse S. Gomez[2], Marie Antoinette Lukban Rosete[3]
[1,2,3]*Department of Business Economics, College of Commerce and Business Administration, University of Santo Tomas, Manila, Philippines*

***Abstract*: The world remains faced with the problem of food security, complicated by the complex relationship between economic growth indicators and climate change. It is critical to understand as they can develop reliable and appropriate ways of eliminating undernourishment. This study seeks to establish a combined effect of climate change and some economic growth indicator variables on undernourishment in selected Southeast Asian countries. We aim to understand the intricate relations between climate factors and economic signs through detailed scrutiny. The paper uses Ordinary Least Squares (OLS) regression analysis of panel data from selected ASEAN countries (i.e., Malaysia, Indonesia, Philippines, Vietnam, and Thailand) to explore the relationships between precipitation, temperature, Gross Domestic Product, and Gross National Income. These findings will provide a basis for policy recommendations focusing on environmental sustainability and ASEAN cross-border cooperation.**

***Keywords*: climate change, food security, gross domestic product, gross national income, growth indicator, malnutrition, precipitation, prevalence of undernourishment, temperature.**

1. Introduction

The United Nations Food System Summit defines food security as a safe, universal, and available supply of food that is adequate in quantity and quality. This will only mean that for food security to happen, we must successfully address its problem. These measures are being adopted in the country to include environment-friendly policies for organic farming, ensure the availability of education and healthcare facilities, and increase economic growth. In addition, reduced food wastage coupled with green food production and distribution can also facilitate the realization of food security.

Ensuring food safety in fishing and agriculture is important because they are important sources for the provision of food. Ensuring food security in agriculture and fisheries should be an all-inclusive approach incorporating production, supply availability, and food utilization. To address food security, it is essential to employ appropriate farming practices that do not cause landslides, not exploiting the aquifers and using little chemicals in the trees. Farmers enjoy benefits such as access, technological advancement, and more credit, hence improving the production of foodstuffs.

As an important global problem, climate change inflicts significant and permanent damage to Earth and its ecosystems. Land degradation, more intense soil erosion, and drier spells are the long-term impacts of the phenomenon on the tropical fishing sectors. Additionally, the increased number and severity of natural disasters due to climate change threaten food security, human health, and infrastructure. Changes in rainfall amounts will affect the availability of surface waters, such as irrigation or hydropower in river basins.

Climate change has a profound impact on the world's ecosystem, which is one of the significant challenges for combating hunger and malnutrition, especially in agriculture and food security. Eight hundred million people are chronically underfed, while 160 million children under five face stunted growth. Furthermore, there exist half a billion obese individuals, and more than two billion are without critical nutrients for a healthier lifestyle. The number of hungry people in this area was staggering (239.1 million), which showed that production levels had to be raised substantially to supply sufficient food for everyone. Climate change negatively influences productivity in the agricultural sector, which translates into reduced output volumes, high consumer production prices, poor-quality products, and poverty in the region.

For this study, the researchers identified five individual ASEAN countries with which they endeavored to understand how climate change and growth indicators affect food security in the region. The emphasis is put explicitly on measuring the impacts that changes in temperature and precipitation, increases in GDP per capita, and Gross National Income have on undernourishment concerning food security. This is a study that focuses on the problems faced by the communities that are prone to insecurity.

There are several reasons why the relationship between climate change, economic growth indicators, and food security should be examined in ASEAN countries. Given the region's location, geography, and dependence on farming, it is susceptible to the outcomes of global warming. Such information from the research may have a global impact on climatic change growth indicators of food security. Moreover,

*Corresponding author: katriceclare.fabian.comm@ust.edu.ph

it provides valuable data about the country's responsiveness to the effects of climate change and the growth rate related to food safety within the ASEAN nations. These insights could guide policymakers and other development agents in designing appropriate strategies for addressing food insecurity resulting from the combination of growth patterns, climatic changes, and other factors in this region. Finally, this study adds to the corpus of scientific writing about climate change, growth indicators, and food security, targeting five selected ASEAN countries – Malaysia, Vietnam, Philippines, Indonesia, and Thailand. In this way, it fills the gap on climate change, growth parameters, and food safety within the region. Investigating Climate Change, Growth Indicators, and Food Security, among other issues, helps us understand how Climate Change and other growth factors shape Food Security while offering ways of tackling this contemporary global challenge.

2. Literature

A. Food Security

Several reasons may lead to food security issues due to their complicated nature. According to FAO (2013), food security is the state in which every individual always has physical and financial access to a supply of food that is both safe and nourishing and will meet their individual needs and preferences. According to Galang (2022), food security states that availability, accessibility, utilization, and stability. A market that is stable guarantees accessibility, distribution, and administration of food to the economy. Grafton et al. (2015) have indicated that the paradigm of food, fuel, environment, and water will take over thirty years to shift.

This new sustainable food security concept emerged after recognizing that the environmental dimension also has a major influence on food security. It guarantees that from production to consumption, it is socially equitable, sustainable, and commercially viable over the long term, according to Chowdhury et al. (2022). A study by Jacinto, M. R. et al. (2015) stated that it is essential in the future and determines an approach to population planning, for citizens will no longer problematize whether their future generations will have nutritious and enough food to be the source of their strength for body and growth building. Despite all the knowledge, most states still present a major challenge when it comes to food security.

1) Measure of Food Security

Galang (2022) claims that most initiatives in preventing malnutrition and promoting food security rely heavily on agricultural and fishery-based research. However, food security is not only about nutrition but also extends to the availability and utilization of food (Muir, 2013). Nevertheless, a sufficient understanding of the commodity's type, quantity, and quality is vital in assessing food security.FAO adopts one of these frameworks, which addresses availability, access, usage, and stability at the household or national level.

Food availability is the number of food items available to individuals or populations from a specific area within a country (Lancker et al., 2019). This can be measured regarding local production, trade, food relief, and post-harvest losses. Factors affecting agriculture production, transport, marketing channels, trade policies, weather, and natural calamities in that particular location or country. Though there may be an indirect link between increased food quantities and a more secure food supply, attempts to enhance food quantity (Foale et al., 2013; Darling, 2014; Mcclan et al., 2013). This involves the development of improved crop varieties, increased water supply and storage facilities, and appropriate environmental conditions for healthy crops (FAO, 2014).

The most common studies in this domain address causal factors of food availability, as well as, evaluating the efficiency of various tools to enhance it. For example, Qaim and Kouser (2013) asserted that introduction of such new technological inventions as genetically modified organisms (GMOs) into agriculture would lead to higher food output. While these innovations may have its positive effect, some are worried about the adverse effects it may have on human health and the environment. The successful management of the availability dimension is closely related to a wider and deeper comprehension of how provision could be interpreted in relation to numerous contexts.

Fisheries, and agriculture practices are highlighted in the availability dimension. It also entails sustainable farming that is compatible with agroforestry and food conservation. Other authors, like Chowdhury et al. (2022) also considered the effect of climate shocks on production and consumption.

Therefore, the houses deteriorate which denies them of providing good quality foods at low prices. This commonly results in food insecurity (Gholami et al., 2013). These include factors such as food production, distribution processes, and other factors like social norms and preferences. Concepts entailed in the term food security include food access which means that an individual or population is capable of purchasing healthy diets. Such access can include use of cars, buses, availability of adequate meals in the area and lots more. Further, the economic aspect encompasses cost of healthy diets, consumer prices, and share of households not consuming food regularly (Hayes et al. 2022; Gorodeski & Semyonov, 2014).

Using a variety of food sources, including harvested agricultural products and fisheries catch, is part of the usage dimension of food security (Belton et al., 2018; Thilsted et al., 2016). In order to maintain health and wellbeing, utilization focuses on using and absorbing nutrients from the food. It falls into three categories: Food Quality, Food Safety, and Consumption. Indicators such as the Daily Per Capita Protein Supply, the Share of Secure Food Households (HFIAS), and the Food Consumption Score are used to quantify consumption. Indicators related to food safety include the percentage of the population with access to WASH services, power, and clean drinking water (Galang, 2022). Research has emphasized the importance of considering food utilization, including nutritional worth and the capacity to consume it adequately, as a critical aspect of food security (Haileslassie et al., 2014; Poudel & Gopinath, 2021).

According to Jones et al. (2018), the stability dimension of food security is the capacity of people and communities to bear

disruptions and difficulties such as natural disasters, conflict, and market volatility without experiencing a decline in food security. Research characterizes and quantifies food security stability by assessing how resilient households or communities are to a range of shocks and strains. This feature highlights how important it is to take a holistic approach to comprehending and resolving the stability of food security, taking into account elements like income diversification, social capital, and resilience. By taking these characteristics into account, practitioners and policymakers can create more effective interventions to support food security stability and improve community resilience (Vaitla et al., 2017; Lee et al., 2016; McKay et al., 2016).

According to Chinnakonda and Jolly (2013), policy choices on food subsidies and social safety nets are necessary for ensuring an important part of food security: concerns about food availability in urban settings pertain to the issue of urban populations gaining access to affordable, whole foods. Jain and Singh (2021) state that digital technology can improve food stability in the populations living near food deserts or faced with complex transportation options.

2) Undernourishment

The World Bank uses the percentage of the global population experiencing hunger or malnutrition to measure the daily dietary energy required for a healthy, energetic life (Leogrande, 2023). This global public health issue influences the performance levels of affected individuals and negatively influences the economies of various countries. Persistent effects of undernourishment in early life on a child's development and a country's economic advancement are based on clinical but also behavioral and sociological issues; therefore, these questions remain to be answered (Islam, 2021).

Malnutrition is caused by many diseases that include respiratory infections, intestinal parasites, HIV, dysentery, malaria, and diarrhea, with potential risk to one's mental and physical well-being. The same also applies to other behavioral factors like early child nutrition and practices that include breastfeeding, which are capable of causing malnutrition in certain stages of life.

According to Abinaya et al. (2023), the world population is estimated to be above a billion today. However, it will eventually grow to about 8.5 billion by 2030 and over 9.7 billion by the year 2050. Therefore, in the year 2100, the population will be approximately 10.9 billion, which suggests that the increase will pose several challenges, like shelter, nutrition, and growth opportunities. Countries experienced some stability in global hunger between 2014 and 2019. During this time, COVID-19 struck, drastically changing diet and food security. In 2020, worldwide undernourishment increased marginally by a percent, which resulted in almost comparable growth of 9.9 % of its incidence rate for undernutrition. In 2021, hunger signs showed that food insecurity could be a long-term effect due to the pandemic. These encompass globally coordinated measures targeted at alleviating the plight of impoverished people.

The case of Thailand, Philippines, Vietnam, Indonesia, and Malaysia shows similar efforts addressing undernourishment among the population of this area. There have been notable strides in undernourishment reduction in Thailand, whereby many people can afford nutritious diets. The fight against undernourishment still presents problems in the Philippines, wherein the government and nongovernment agencies are doing their part through different programs. The improvements in Vietnam's economy towards food security and malnutrition issues have positively impacted its economy and poverty reduction strategies. In Indonesia, the policy addresses food insecurity and malnutrition among its population in the rural and interior areas. In Malaysia, with its relatively low percentage of undernourished people, there are problems relating to obesity and other health disorders associated with poor diets and life.

B. Climate Change

According to this IPCC assessment in 2014 it was determined that most often global warming is a result of changing climate patterns for many decades and it can be either as a natural cause or because of anthropogenic impact. Climate change can include changes in extremity, impacts on plant growth and biodiversity. A lot of scholars suggest an alternative approach which includes adaptation and mitigating measures and is more all-encompassing than the current one (Adger, et al., 2013). As such, the cut off program is aimed at reducing the emission volume of the outgoing greenhouse gasses into a tolerable level of global warming. However, measures for adaptation are introduced through land use change and infrastructure improvement policies.

A recent IPCC report of 2019 indicates that a majority of evidence suggests anthropogenic forces are main drivers for climate change/global warming with diverse human actions ranging from burning coal, deforestation, and agriculture. Health, and Air Quality are two other investigative components which relate mainly to mitigation measures (West et al., 2013). Some aspects of global warming now require both mitigations and adaptations.

ASEAN countries are becoming more vulnerable to climate-related hazards, constituting an ever-growing issue for the region. Typhoons, drought, floods, and other calamities hit ASEAN member states, causing substantial economic and socio-economic loss (ADB, 2019). According to the IPCC Forecast Report 2014, these countries will face worsened conditions because of higher heat intensities, increased water levels, and changed precipitation patterns. Numerous studies have been conducted on what climate change could mean for SEAN states in specific arenas. Studies have suggested that reduced rainfall and high temperatures would lower yield. This would, in turn, pose a threat to future food security as well as future agricultural production (Pham et al., 2018).

Many of the ASEAN member states have implemented varied approaches and policies to tackle climate change in response to these challenges. The ASEAN Agreement on Pollution, specifically on Transboundary Haze, exemplifies efforts toward solving forest and land-origin cross-border haze. Similarly, the ASEAN Climate Change Initiative aspires to enhance cooperation amongst ASEAN members and upgrade

their resilience in climate change mitigation and adaptation issues.

C. Growth Indicators

While talking about economic development, Nasitowski (2016) describes it as a continued amplification of the production capacity that the country can provide to its people. This notion primarily constitutes the boosting of key macroeconomic measures such as total GDP across an economy in question. Many of these previous studies have attempted to provide empirical proof of the linkage between food security and economic welfare, but most have been conducted in developing countries. The focus is on developing countries because they grow from agri-food production activities. GDP, an index for the market value of labor and production in a given Country over a stipulated time, has always been the standard measurement for economic growth (Manikas et al., 2023). It is stated by Fernandes & Samputra (2022), Although many researchers try to show that there is an association between food security and economic expansion, the underlying reason for this connection still needs to be more cohesive. Specifically, it means we still do not know whether economic growth leads to food security, whether it triggers economic growth, or whether some causal connection exists between them.

D. Precipitation (mm per year) Impact to Prevalence of Undernourishment (% of population)

Agriculture is essential for the economy and food security in the ASEAN region. Precipitation that happens annually affects the production and yield of crops, and if there are any precipitation irregularities, it can affect food security. Several studies by Teng and Wong (2015), Li (2017), and Nguyen (2020) suggest that the impact of changing weather patterns and, consequently, the situation of water shortage and lower production levels in some places has created a severe problem, resulting in scarcity and higher food prices in that region. This means that addressing food security in the ASEAN region requires fully understanding the interactions between climate, agriculture, and water.

One recent study at the Pennsylvania State University reveals that increased food insecurity in the country is attributed to reduced precipitation (Bohn, 2022). As climate change continues and its impacts on the different climates, it is important to have mechanisms whereby the poor will survive amidst food shortages. Several studies like Win et al. (2019) on Myanmar or Adger et al. (2013) on Indonesia have looked into connections between rainfall, climate's fluctuation, extreme climate's effects as well as food security especially in relation

Some possible intermediaries include maize variety resistant to drought, improved extension outreach, more agriculture insurance coverage, promotion of use of water and soil conservation measures, and weather-based transfers. This phenomenon not only affects the issue of food security but physical and mental health, labor efficiency of families, child development, growth, and poverty reduction, etc. UNDRR (2023) also stresses that while IPCC anticipates increasing risks for household food security in developing countries reliant on agriculture, literature reveals very limited studies exploring differences in household food insecurity severity versus occurrence based on climate conditions.

Research carried out on mitigation measures in response to the weather vagaries has also examined means of limiting the impacts of rain on food security. Tinh et al. (2018) proposed climate smart agriculture approaches that included growing crops resistant to drought, water and soil conservation, raising productivity within watershed management systems as ways through which to support farmers' adaptive capacities in enhancing national food security.

Ho_1: Precipitation (mm per year) does not impact Prevalence of undernourishment (% of population)

E. Temperature (mm per year) Impact to Prevalence of Undernourishment (% of population)

Eltholth et al. (2015) research said that temperature changes affect food security in the ASEAN region, which needs to be taken seriously. How people eat due to price changes and declining agricultural output would depend on consumers' adjustments in response to these developments. High temperatures might have an impact on the quantity and quality of crops. This situation will be harmful not only for yielding but also for the nutritive value of food.

The van der Merwe et al. (2022) study showed a positive relationship between undernourishment and temperatures. Hence, increased temperatures lead to higher cases of malnutrition among the populace. High temperatures also lead to slowing down food manufacturing processes and an increased presence of pests, which results in lower worker productivity. This may decrease production and leave the dependents who survive on the agricultural produce insecure regarding their food security. In addition, high temperatures can change the nutrition content in plants, leading to the depletion of essential nutrients that humans should consume.

FAO (2015) said which was later approved by UNDRR (2023) that change in climatic phenomena including temperature and precipitation can lead to reduction of micronutrient produced from plants due various reasons. Such a situation would affect plant growth patterns hence influencing the source's levels of availability as well. Temperature changes can increase health risk to our food by facilitating transmission of disease vectors and organisms within the growing or production environment. There is a direct link between climate change and undernourishment. As such, increased temperatures will result in a number of irregular weather shifts which in turn will lead to frequent environmental disturbances and severe temperatures which will all translate into increase in undernutrition globally.

Economic vulnerability in prices constitutes one pillar where minor shifts from climate shock become huge costs and contribute towards increased price change vulnerability. Adaptation strategies put forth by researchers against temperature impact on the production of food include the use of heat-tolerant crop varieties and agroforestry systems.

Ho_2: Temperature (mm per year) does not impact Prevalence of undernourishment (% of population)

F. Gross Domestic Product (GDP) Per Capita Impact on Prevalence of Undernourishment (% of population)

Abdullah (2023) describes Gross domestic product or GDP as a commonly used indicator describing the per capita output and impacting national capital and well-being. These elements include accessibility, food prices, and income, which are crucial to sustainable economic development (FAO, 2019). To ensure that the economy contributes to sustainable development, policymakers should consider social, governance, and environmental factors.

Several studies, like Fernandes and Samputra (2022), Headey (2013), and Joshi et al. (2016), examine the connection between the incidence of malnutrition and GDP per head. Researchers have shown a high negative interrelationship between the variables, implying that increased GNP translates into fewer undernourished people by simply improving diet for all and increased purchasing power concerning healthy meals (Joshi et al., 2016; Fernandes & It is worth noting that it demonstrates how vital economic growth and increased real incomes play into making poor countries more food secure.

Interestingly, countries with high GDP are improving in food security even though most previous studies concentrated on food development issues within developed countries rather than developing countries producing much food. However, Yaya and others (2020) suggest a massive connection between GDP per capita and the rate of malnourished people, implying an increased rate of malnourished people with an increased GDP per capita. Similarly, Swietlik's (2018) research established a positive relationship between higher GDP and more food security.

Ho_3: Gross Domestic Product (GDP) per capita does not impact Prevalence of undernourishment (% of population)

G. Gross National (GNI), PPP (current international $) Impact on Prevalence of Undernourishment (% of population)

The gross national income is the most critical factor in determining a country's national wealth. According to Song (2019), it is one of the economy's most significant economic performance indicators. It indicates the total worth of all domestic products, including the net incomes earned from other nations. It measures the total or aggregate economic activities of those living in that country. So, it is a summary indicator of gross national welfare. GNI has made the comparison of individual countries economically possible by examining the living standards and development among different states.

Several investigations reveal that greater GNI may boost food security through increased buying ability, agriculture sponsorships, and social protection. Some studies show that countries with significant per capita income levels prioritize agricultural sector development and creating better infrastructure and technology. Consequently, they increase the availability of sufficient food and thus reduce undernourishment occurrences. Secondly, countries with more GNI have higher powers in global trades and food markets, thus affecting food availability and prices, consequently affecting global food safety.

According to Aziz et al. (2021), GDP, GNI, and CPI should be enhanced to ensure that individuals become wealthy and healthy. Nevertheless, revenue disparities, external jolts, and trade tendencies substantially impact food safety outcomes. Therefore, policymakers and researchers must consider how complex GNI impacts nutrition security and develop efficient procedures to ensure every individual can have enough healthy nutrition.

Ho_4: Gross National (GNI) does not impact Prevalence of undernourishment (% of population)

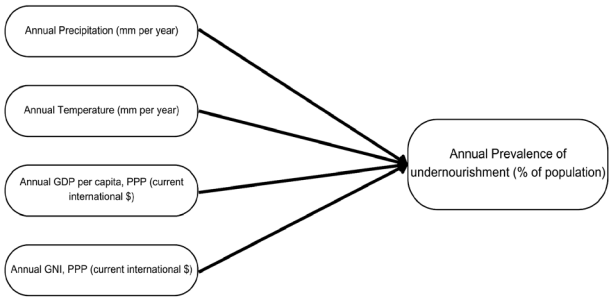

Fig. 1. Framework

3. Method

This study proposes balanced panel data and statistical methods for analyzing how climatic factors affect food security levels in some ASEAN nations like Malaysia, Indonesia, Philippines, Vietnam, and Thailand. The World Bank climate change portal will provide temperature and precipitation data. Moreover, GDP per capita, PPP (current international $), GNI, PPP (current international $), as well as Prevalence of undernourishment (% of population) would be obtained from FAOSTAT, World Development indicator of the World Bank and Our World in data It covers up to 32 years since 1990 to 2022, including variables related to climatically induced events, economic elements that promote growth, and prevalence rates of undernutrition. The primary purpose of this design is to identify the long-term trend patterns and study how various factors affect the particular outcome under consideration.

In this regard, descriptive data analysis methods such as mean/standard deviations are utilized to explore the variances across the variables. Concerning this, multiple regression analysis will be used to determine dependence and independent variables. This will be discussed in the text of the study, along with tables and graphs. Analyzing quantitative data using SPSS and the review will appear within the set.

OLS regression analyses will then be explicitly used to study the effect of climate change on food security in the selected ASEAN countries.

$$PU = \beta_0 + \beta_1 P + \beta_2 T + \beta_3 GDP + \beta_4 GNI + \varepsilon \quad (1)$$

Where, PU is the Annual Prevalence of Undernourishment (% of population), P is the Annual Precipitation (mm per year), T is the Annual Temperature (mm per year), GDP is the Annual GDP per capita, PPP (current international $), and GNI is Annual GNI, PPP (current international $).

4. Results and Discussion

Table 1
Annual Prevalence of Undernourishment (% of the population), Annual Precipitation (mm per year), Annual Temperature (mm per year), Annual GDP per capita, PPP (current international $), and Annual GNI, PPP (current international $) – Summary Statistics

Variable	Mean	Std. Deviation
Prevalence of undernourishment (% of population)	12.225	4.800
Precipitation (mm per year)	2364.468	200.407
Temperature (mm per year)	26.035	0.233
GDP per capita, PPP (current international $)	9402.98	4,178.62
GNI, PPP (current international $)	788,909,090,909.09	449,521,437,450.18

Summary statistics on Annual Prevalence of Undernourishment (% of the population), Annual Precipitation (mm per year), Annual Temperature (mm per year), Annual GDP per capita, PPP (current international $), and Annual GNI, PPP (current international $) is provided in the following table. The table indicates that the mean prevalence of malnutrition among the studied population was 12.225%, with a standard deviation equal to 4.800, which reflects inter-period differences in values. Average annual precipitation is 2364.468 mm with a std of 200.407, which translates to fewer variations relative to the prevalence of undernourishment. It has a mean value of 26.035 degrees Celsius with a relatively small standard deviation of 0.233 in temperature, a stable trend observed between 1990 and 2022.

On economic grounds, with an average nominal GDP per person of 9,402.98 USD (current international dollars adjusted for parity purchasing power), there is a high deviation of 4,178.62 USD, suggesting considerable variations in economic prosperity. Therefore, it has a higher average GNIP at USD 788,909,090,90.09 compared to a more significant standard deviation of $449,521.437.45 million, which signifies significant variation.

Table 2
Ordinary Least Square Multiple Regression Analysis used for the effects of annual precipitation (mm), temperature (mm), GDP per capita, and GNI, PPP

Adjusted R Square	F	df_1	df_2	Durbin-Watson	
0.971	272.815	4	28	1.702	
Model		**Coefficient**	**Std. Error**	**t**	**p**
(Constant)		78.836	25.861	3.048	0.005
Precipitation (mm per year)		-0.001	0.001	-0.823	0.417
Temperature (mm per year)		-1.833	0.943	-1.944	0.062
GDP per capita, PPP (current international $)		-0.005	0.001	-6.644	<0.001
GNI, PPP (current international $)		-0.001	0.000	5.087	<0.001

The results of OLS multiple regression analysis are provided in Table 2, which evaluates the impact of annual average precipitation (in millimeters), temperature (degrees Celsius), and country's GDP per capita (current US dollars adjusted by purchasing power parity. Notably, the adjusted R-squared, indicating the model's fit considering the number of predictors, stands for. A modified R Square value of 0.971 means that 97.1% of the variance associated with undernutrition was caused by precipitation, temperature, GDP per Capita, and GNI as dependent variables.

This analysis uses the Durbin - Watson static to check for autocorrelation in residuals of a regression model. A value near 5 denotes insignificant auto-correlation, meaning self-independent errors. The Durbin-Watson statistic is 1.702, suggesting no considerable autocorrelation in their model's residuals.

The OLS regression model shows a significant negative relationship between the prevalence of undernourishment and climate change impacts (e.g., annual precipitation and temperature) at the level of significance of 10%. In particular, a 0.1% and 183.3% decrease in undernourishment occurs for each additional impact resulting from precipitation and temperature, respectively.

Additionally, it is revealed that the poor development indices such as GDP per capita and GNI have an inverse statistical relationship with widespread hunger. Practically speaking, each additional impact of climate change contributes to a 5% decrease in prevalence undernutrition. Concerning the Growth indicators, GDP and GNI, each increase will result in a 0.5% and 0.1% decrease, respectively. This correlation concurs with studies like that of Lin et al. (2022) and Fernandes & Samputra (2022), which have revealed a close bond among growth indicators. Aziz et al. (2021) argue that such indices as GDP per capita and GNI per capita are essential for an individual's prosperity.

The cumulative evidence indicates lower levels of undernourishment in countries with high GDP and GNI. For instance, scholars such as Headey (2013) and Joshi et al. (2016) argue that higher purchasing power in households results in more buying of quality foods, hence better nutrition. Islam (2021) says higher productivity and national income reduce hunger, improving nutritional status as countries become more prosperous.

Table 3
Annual Prevalence of Undernourishment (% of the population), Annual Precipitation (mm per year), Annual Temperature (mm per year), Annual GDP per capita, PPP (current international $), and Annual GNI, PPP (current international $) – Multicollinearity

Variables	*Collinearity Statistics*	
	Tolerance	**VIF**
Precipitation (mm per year)	0.527	1.898
Temperature (mm per year)	0.425	2.352
GDP per capita, PPP (current international $)	0.003	389.249
GNI, PPP (current international $)	0.003	391.435

Multicollinearity amongst the predictor variables in a regression model is assessed, as shown in Table 3. Predictors become highly correlated in multicollinearity, making them difficult to interpret and making regression analyses less reliable. The table above denotes a degree of collinearity characterized by a VIF value of 1.898 and 2.352 for precipitation (mm per year) and temperature (mm per year). The respective tolerances for these variables are 0.527 and 0.425, which indicate that around 52.7% and 42.5% of these variances remain not subject to the influence of other predictors.

The data results for GDP per capita, PPP (current international $), and GNI, PPP (current international $) point

towards significant problems that derive from multicollinearity. The respective variations for both variables are 0.003 and 0.3%, respectively, implying that only a minute portion (less than 0.3%) of this variance is independent of other predictors. The extremely high VIFs of 389.249 and 391.435 for GDP per capita and GNI show that the multicollinearity problem is severe within the model.

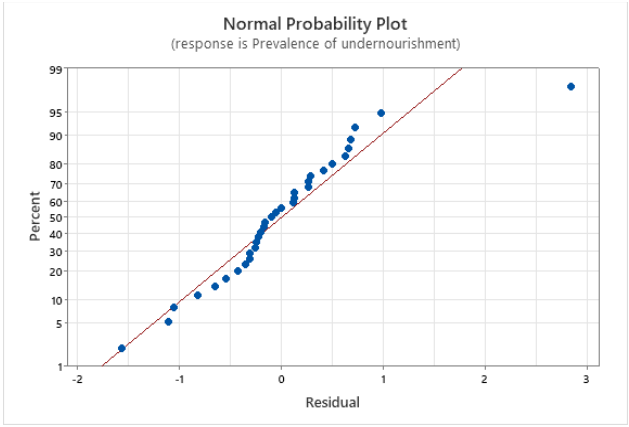

Fig. 2. Normal probability plot of the effects of climate change and growth indicators

Figure 2 shows a normal probability plot showing the effects of Annual Precipitation (mm per year), Annual Temperature (mm per year), Annual GDP per capita, PPP (current international $), and Annual GNI, PPP (current international $). The plot illustrates that the residuals are near the straight line that passes diagonally in order to suggest that they have a pattern of following a normal distribution. The closeness of the data points to the assumed normal distribution in the residual models confirms the overall compliance with the normality requirements.

On a close examination, however, one separated point deviates significantly from what would be normally expected. The anomaly suggests that a problem could be associated with assuming normalcy in that particular observation. This may indicate an instance wherein the residue of some of that specific data point varies from the typical normal frequency distribution.

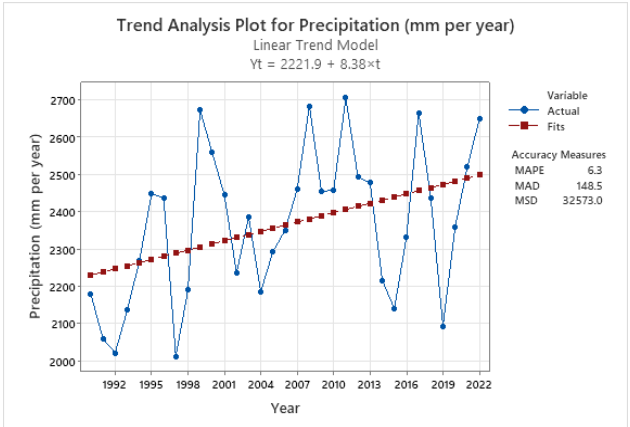

Fig. 3. Precipitation (mm per year) – Trend Analysis Plot

The precipitation trend, as manifested in the Trend Analysis plot in Figure 3 for the period 1990-2022. Despite some variations in the plot, general increasing precipitation is distinguishable. This shows that there has been a continuous increase in yearly precipitation from 1990 to 2020.

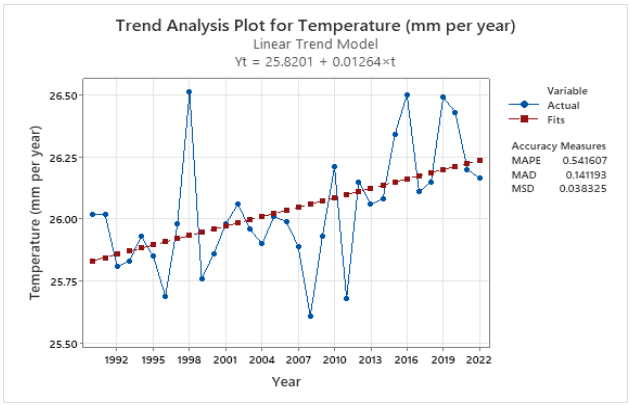

Fig. 4. Temperature (mm per year) – Trend Analysis Plot

The figure shows the annual temperature trend during this period (from 1990 to 2022). Though the plot exhibits some anomalous fluctuations on an annual basis for this period, it is pretty easy to notice that there is an upward tendency overall as well. Thus, it means that the annual temperatures have risen over time.

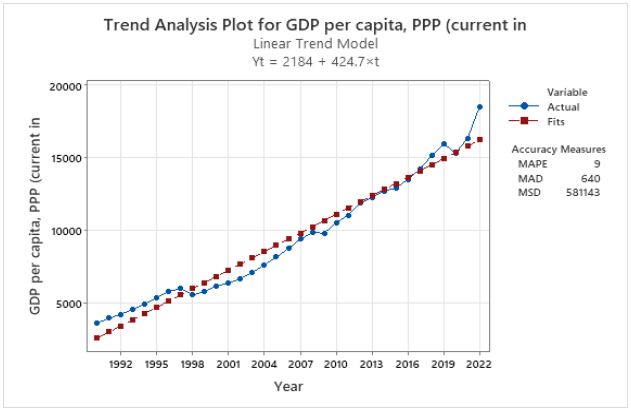

Fig. 5. GDP per capita, PPP (current international $) – Trend Analysis Plot

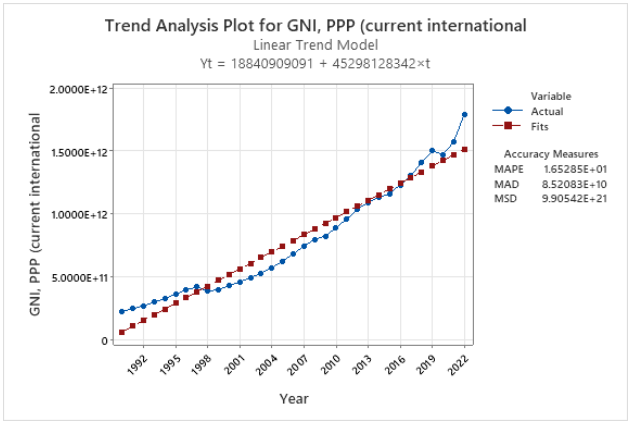

Fig. 6. GNI, PPP (current international $) – Trend Analysis Plot

Figure 5 shows the trend curve for the country's annual GDP

per capita for 1990-2022. The figure shows a straight positive growth for the annual GDP per capita during the review period. This implies a continuous growth of GDP per capita, PPP (current international $), showing good economic progress since 1990.

The trend analysis plot depicting the annual GNI, PPP between 1990 and 2022 is seen in Figure 6. This is depicted by an increasing tendency of the yearly GNI, PPP during the period. The perennial upgrade of GNI, PPP depicts continuous growth in purchasing power parity of the country's gross national income for many years.

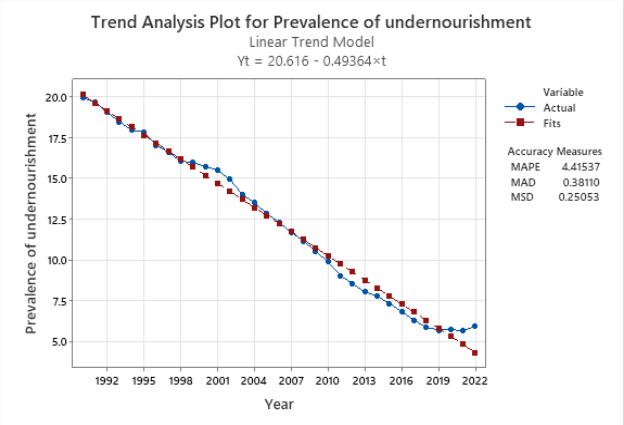

Fig. 7. Prevalence of undernourishment (% of population) – Trend Analysis Plot

The trend analysis plot of the annual prevalence of undernourishment from 1990 to 2022 is seen in Figure 6. It shows that for those years, there has been a decline in the prevalence of undernourishment. The decreasing trend is improving food security as people are less likely to experience malnutrition.

5. Conclusion

This paper aims to investigate how climatic change factors and economic growth markers affect food security by analyzing panel data of five chosen ASEAN member states from 1990 – 2022. Briefly, studies indicate that climate change has an immense effect on undernourishment. Changes in heat and rainfall patterns become vital issues impacting food production, while abnormal weather events such as droughts and floods also negatively impact harvests. Furthermore, altered precipitation constitutes a water shortage from increased temperatures and transpiration. There is strong evidence to the claim that climate change seriously affects the supply of food, its accessibility, use, price, and ultimately quantity. The adverse effects of this impact are even worse in agricultural areas, such as among the poor people in ASEAN states, who may experience additional risks of famine and other food shortages that usually result from climate disturbances.

On the other hand, the undernutrition status is inversely proportional to economic growth indicators like GNP/GGD. Investments in agriculture often coincide with higher indices of Gross National Income (GNI) and Gross Domestic Product (GDP). These positive correlations generally improve food availability through increased crop yields, improved agricultural methods, and enhanced infrastructure. Generally, economic growth entails increased earnings, purchasing capacity, and availability of edibles among people. Higher national per capita incomes, a result of economic progress, enhance easy financial access to enough nourishing foods, which curtails undernourishment levels.

Such a study also has tremendous policy and practice significance to policymakers and interested parties. The recommendations from this are meant to inform the evidence-based policy-making that will address climate effects and sustainable economic development. Strategies promoting sustainable practices and regional collaboration are vital to dealing with undernourishment in the ASEAN region as policy impacts underscore.

References

[1] Abdullah, A. A. (2023). Urban population and co2 emission on GDP per capita: ASEAN countries. Urban Population and CO2 Emission on GDP Per Capita: ASEAN

[2] Abinaya, K. et al. (2023). A Focus on SDG Target for the Prevention of Undernourishment.

[3] Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2013). Successful adaptation to climate change across scales. Global Environmental Change.

[4] Akhi, K., Uddin, M., & Islam, M. (2015). Food Security Assessment of NGO supported and own managed pond fish farmers of two districts in Bangladesh. Journal of the Bangladesh Agricultural University.

[5] Akbari, M.et al. (2022). The evolution of food security: Where are we now, where should we go next? Sustainability.

[6] Alshuniaber, M. A. (2020). Food security management and assessment. EPH - International Journal of Agriculture and Environmental Research.

[7] Angeles-Agdeppa, I. et al. (2021). Moderate and severe level of lppk food insecurity is associated with high calorie-dense food consumption of Filipino households. Journal of Nutrition and Metabolism.

[8] Asian Development Bank. (2019). Climate and Disaster Risk in Southeast Asia: Economic Impacts and the Role of the Private Sector. Retrieved from https://www.adb.org/publications/climate-and-disaster-risk-southeast-asia-economic-impacts-and-role-private-sector

[9] Average precipitation in depth (mm per year). World Bank Open Data. (n.d.). https://data.worldbank.org/indicator/AG.LND.PRCP.MM

[10] Aziz, N., He, J., Raza, A., Sui, H., & Yue, W. (2021). Elucidating the macroeconomic determinants of undernourishment in South Asian countries: Building the framework for action. Frontiers in Public Health, 9.

[11] Barange, M., Merino, G., Blanchard, J. L., Scholtens, J., Harle, J., Allison, E. H., Allen, J. I., Holt, J., & Jennings, S. (2014). Impacts of climate change on marine ecosystem production in societies dependent on fisheries. Nature Climate Change.

[12] Belton, B., Bush, S. R., & Little, D. C. (2018). Not just for the wealthy: Rethinking farmed fish consumption in the Global South. Global Food Security.

[13] Belton, B., & Thilsted, S. H. (2014). Fisheries in transition: Food and nutrition security implications for the global south. Global Food Security.

[14] Béné, C., et al. (2016). Contribution of fisheries and aquaculture to food security and poverty reduction: Assessing the current evidence. World Development, 79, 177-196.

[15] Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., Talsma, E. F., & Khoury, C. K. (2019). When Food Systems meet sustainability – current narratives and implications for actions. World Development.

[16] Beveridge, M. C., Thilsted, S. H., Phillips, M. J., Metian, M., Troell, M., & Hall, S. J. (2013). Meeting the food and nutrition needs of the poor: The role of fish and the opportunities and challenges emerging from the rise of aquaculture. Journal of Fish Biology.

[17] Bohn, K. (2022). Lower than normal rainfall linked with a higher chance of food insecurity. Penn State University.

https://www.psu.edu/news/agricultural-sciences/story/lower-normal-rainfall-linked-higher-chance-food-insecurity/
[18] Chinnakonda, M., & Jolly, C. M. (2013). Food accessibility and food security status among rural households in southern India. Journal of Hunger & Environmental Nutrition, 8(4), 430-440.
[19] Cororaton, C., Inocencio, A., Siriban-Manalang, A. B., & Tiongco, M. (2015). A Conceptual Framework for Estimating the Impact of Climatic Uncertainty and Shocks on Land Use, Food Production, and Poverty in the Philippines. DLSU Business & Economics Review. https://drive.google.com/file/d/1KyyUWGiwIJcoGcZJjw-SYVf10uGeGauL/view?usp=sharing
[20] Chowdhury, Md. M., Rahman, S. M., Amran, M. I., Malik, K., Abubakar, I. R., Aina, Y. A., Rahman, S. M., Khan, M., Muhyedeen, M. A., & Hasan, Md. A. (2022). Climate Change Impacts on Food System Security and Sustainability in Bangladesh.
[21] Darling, E.S. (2014). Assessing the Effect of Marine Reserves on Household Food Security in Kenyan Coral Reef Fishing Communities. PLoS ONE 9(11): e113614.
[22] Desiere, S., Hung, Y., Verbeke, W., & D'Haese, M. (2018). Assessing current and future meat and fish consumption in Sub-Sahara Africa: Learnings from FAO Food Balance Sheets and LSMS household survey data. Global Food Security.
[23] Eltholth, M., Fornace, K., Grace, D., Rushton, J., & Häsler, B. (2015). Characterisation of production, marketing and consumption patterns of farmed tilapia in the Nile delta of Egypt. Food Policy.
[24] Fabinyi, M. et al. (2016). Fish, trade and food security: Moving beyond 'availability' discourse in marine conservation. Human Ecology.
[25] Farmery, A.K. et al. (2021). "Conceptualising value chain research to integrate multiple food system elements," Global Food Security.
[26] FAO. (2015). Food security. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/y4671e/y4671e06.htm
[27] FAO. (2019). The state of food security and nutrition in the world 2019: safeguarding against economic slowdowns and downturns. Rome: FAO.
[28] Fernandes, M., & Samputra, P. L. (2022). Exploring linkages between Food Security and economic growth: A systematic mapping literature review. Potravinarstvo Slovak Journal of Food Sciences.
[29] Foale S. J. et al. (2013). Food security and the coral triangle initiative. Marine Policy.
[30] Food and Agriculture Organization (FAO) of the United Nations. (2020). State of the world's forests 2020 Forestry, biodiversity and people. Food & Agriculture Org.
[31] Galang, I. M. (2022). Is Food Supply Accessible, Affordable, and Stable? The State of Food Security in the Philippines.
[32] GDP per capita (current US$). World Bank Open Data. (n.d.). https://data.worldbank.org/indicator/NY.GDP.PCAP.CD
[33] Gibbens, S. (2021). How fishing is being used to support Food Security, Environment. National Geographic. Available at: https://www.nationalgeographic.com/environment/article/news-fisheries-aquaculture-foodsecurity#:~:text=As%20a%20food%20source%2C%20fish,China%2C%20fish%20consumption%20is%20booming
[34] Gholami, A. et al. (2013). Food Insecurity Status and Associated Factors among Rural Households in North-East of Iran.
[35] Gibson, E. et al. (2021). "Coping or adapting? experiences of food and nutrition insecurity in specialized fishing households in Komodo District, Eastern Indonesia," BMC Public Health.
[36] Gitz, V., Meybeck, A., Lipper, L., Young, C. D., & Braatz, S. (2016). Climate change and food security: risks and responses. Food and Agriculture Organization of the United Nations (FAO).
[37] GNI per capita, PPP (current international $). World Bank Open Data. (n.d.). https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD
[38] Golden, C. D. et al. (2016). Nutrition: Fall in fish catch threatens human health. Nature, 534(7607), 317–320.
[39] Gorodzeisky, A. and Semyonov, M. (2014). "Making a living in two labor markets: Earnings of Filipinos in the global and the domestic economy," Research in Social Stratification and Mobility.
[40] Grafton, R. Q. et al. (2015). Towards Food Security by 2050. Food Security.
[41] Haileslassie, H. A., Girma, M., Tegegne, B. S., & Fekadu, B. (2014). Impact of nutrition education on knowledge and practice of complementary feeding among caregivers of children aged 6-23 months: a randomized controlled study in Addis Ababa. BMC Nutrition, 16(1), 1-9.
[42] Hasegawa, T., Fujimori, S., Takahashi, K., Yokohata, T., & Masui, T. (2016). Economic implications of climate change impacts on human health through undernourishment. Climatic Change.
[43] Hassan, M., Saif, K., Ijaz, M. S., Sarfraz, Z., Sarfraz, A., Robles-Velasco, K., & Cherrez-Ojeda, I. (2023). Mean temperature and drought projections in central Africa: A population-based study of food insecurity, childhood malnutrition and mortality, and infectious disease. International Journal of Environmental Research and Public Health.
[44] Headey, D. D. (2013). Developmental drivers of nutritional change: A cross-country analysis. World Development.
[45] Hussein, F. M. et al. (2018). Household food insecurity access scale and dietary diversity score as a proxy indicator of nutritional status among people living with HIV/AIDS, Bahir Dar, Ethiopia, 2017. PLOS ONE.
[46] Ibe, G. O., & Amikuzuno, J. (2019). Climate change in Sub-Saharan Africa: A menace to agricultural productivity and ecological protection. Journal of Applied Sciences and Environmental Management.
[47] IPCC. (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
[48] IPCC. (2019). Special report on climate change and land — IPCC site. https://www.ipcc.ch/srccl/
[49] Islam, Md. S. (2021). Influence of socioeconomic determinants on undernourishment in South Asia: A panel cointegration analysis. Health Scope.
[50] Jacinto, M. R. et al. (2015). Development and application of the Fisheries Vulnerability Assessment Tool (fish vool) to tuna and sardine sectors in the Philippines. Fisheries Research.
[51] Jain, M., & Singh, R. K. (2021). Digital technologies and food accessibility: A review. Journal of Agribusiness in Developing and Emerging Economies.
[52] Jones, A. D., Ngure, F. M., Pelto, G., & Young, S. L. (2018). What are we assessing when we measure food security? A compendium and review of current metrics. Advances in Nutrition, 4(5), 481-505.
[53] Joshi, P. K., Parappurathu, S., & Kumar, P. (2016). Dynamics of food consumption and nutrient insecurity in India. Proceedings of the Indian National Science Academy.
[54] Kjellstrom, T., & McMichael, A. J. (2013). Climate change threats to population health and well-being: The imperative of protective solutions that will last. Global Health Action.
[55] Lancker, K. et al. (2019). Assessing the contribution of artisanal fisheries to food security: A bio-economic modeling approach. Food Policy.
[56] Lapina, G. F., & Catelo, S. P. (2017). Knowledge and Information Gaps: Implications for Philippine Food Security. Journal of Economics, Management & Agricultural Development.
[57] Lee, G., Nam, K., & Park, C. Y. (2016). Social capital and food security: An empirical analysis of the mediating role of collective action in the highlands of Vietnam. Food Security.
[58] Leogrande, A. (2023). The Undernourishment Worldwide.
[59] Macusi, E. D., Camaso, K. L., Barboza, A., & Macusi, E. S. (2021). Perceived vulnerability and climate change impacts on small-scale fisheries in Davao Gulf, Philippines. Frontiers in Marine Science.
[60] Manikas, I., Ali, B. M., & Sundarakani, B. (2023). A systematic literature review of Indicators Measuring Food Security. Agriculture &; Food Security.
[61] Mbowa, H. S., Asiimwe, S., & Birungi, B. (2022). Drought and food security in Bukomansimbi District, Uganda. Encyclopedia of Information Science and Technology.
[62] McClanahan T., Cinner J., and Allison E. (2013). Managing fisheries for human and food security. Fish and Fisheries.
[63] McKay, S., Velasco, I., & Cakouros, B. (2016). Farm-level strategies to increase resilience to shocks: Insights from a survey of smallholder farmers in Chiang Mai Province, Thailand. Food Security, 8(6), 1163-1178.
[64] Muir, J.F. (2013). "Fish, feeds, and food security," Animal Frontiers.
[65] Muleta, B. W. (2022). Climate Change and Food Security in Sub-Saharan Africa.
[66] Nasitowski, M. (2016). System rynkowy. Podstawy mikro-i makroekonomi. Warszawa: Wydawnictwo Key Text.
[67] Nguyen, T. T. H., & Tran, N. N. (2020). Climate change, food security, and poverty reduction: An analysis of the impact of seasonal rainfall on crop yields in Vietnam. Climate.
[68] Olaganathan, R., & Kar Mun, A. T. (2017). Impact of Aquaculture on the Livelihoods and Food Security of Rural Communities. International Journal of Fisheries and Aquatic Studies.

[69] Olofin, O. P. (2016). New findings on food security, climate change and income growth in West African countries: P-var approach. European Scientific Journal, ESJ.
[70] Pradeepkiran, J. A. (2019). Aquaculture role in global food security with nutritional value: A Review. Translational Animal Science.
[71] Pham, H. V., Chu, T. T., & Hoang, V. T. (2018). Impacts of climate change on agriculture and food security in Southeast Asia. Environmental Science and Pollution Research, https://cirs.qatar.georgetown.edu/event/the-impact-of-climate-change-on-agriculure-in-south-asia/
[72] Poudel, D., & Gopinath, M. (2021). Exploring the disparity in Global Food Security indicators. Global Food Security.
[73] Prevalence of undernourishment (% of population). World Bank Open Data. (n.d.). https://data.worldbank.org/indicator/SN.ITK.DEFC.ZS
[74] Qaim, M., & Kouser, S. (2013). Genetically modified crops and food security.
[75] Rahman, M. M., Alam, M. S., & Sarker, S. (2020). Coping with Climate Change: Adaptation Strategies of Smallholder Farmers in Bangladesh. Journal of Agricultural Extension and Rural Development, 12(9), 1-14.
[76] Rosenzweig, C. et al. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. Proceedings of the National Academy of Sciences, 111(9), 3268–3273.
[77] Schmidt, E., & Tadesse, F. (2019). The impact of Sustainable Land Management on household crop production in the Blue Nile Basin, Ethiopia. Land Degradation & Development, 777–787.
[78] Smith, L. C., & Haddad, L. (2014). Explaining child malnutrition in developing countries: A cross-country analysis. https://core.ac.uk/download/pdf/6289507.pdf
[79] Song, X. (2019). Similarities and differences between GDP and GNI. Understanding Chinese GDP.
[80] Suzuki, A. et al. (2017). Evaluation of factorial validity and reliability of a food behavior checklist for low-income Filipinos. Journal of Nutrition Education and Behavior.
[81] Swietlik, K. (2018). Economic Growth versus the issue of Food Security in Selected Regions and Countries worldwide. https://ageconsearch.umn.edu/nanna/record/276629/files/Swietlik%2C.pdf?withWatermark=0&withMetadata=0&version=1&registerDownload=1
[82] Taniguchi, M., Masuhara, N., & Burnett, K. (2015). Water, energy, and food security in the Asia Pacific region. Journal of Hydrology: Regional Studies.
[83] Teng, P.S., & Wong, C. (2015). Food security in ASEAN: Challenges and initiatives. Food Security.
[84] Tezzo, X., Bush, S. R., Oosterveer, P., & Belton, B. (2020). Food System Perspective on fisheries and aquaculture development in Asia. Agriculture and Human Values.
[85] Tinh, B. H., Quynh, P. T. H., Tuan, N. D., & Van Hop, N. (2018). The potential of climate-smart agriculture in adapting to rainfall variability and improving food security in Vietnam. Agriculture, Ecosystems & Environment, 256, 125-135.
[86] Trinh, T. Q., Rañola, R. F., Camacho, L. D., & Simelton, E. (2018). Determinants of farmers' adaptation to climate change in agricultural production in the Central Region of Vietnam. Land Use Policy, 70, 224–231.
[87] UNDRR. (2023). National Disaster Risk Reduction Strategy 2023-2030 (2nd ed.). The Hashemite Kingdom of Jordan.
[88] Vaitla, B., Chen, Y., Foltz, J., & Gitter, S. (2017). Measuring household food security stability: Evidence from Tanzania and Uganda. Food Policy, 71, 74-87.
[89] Vithanage, H. G., & Dunusinghe, P. M. (2023). The association between Time Poverty and Income Poverty: The case of Sri Lanka. Sri Lanka Journal of Economic Research.
[90] West, J. J., et al. (2013). Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health. Nature Climate Change, 3(10), 885–889.
[91] Win, K. K., Maung, T. M., & Thu, P. M. (2019). Impact of climate variability and extreme weather events on rice production and food security in Myanmar. Climate and Development, 11(3), 199-211.
[92] World Health Organization. (2019). The state of food security and nutrition in the world 2019: Safeguarding against economic slowdowns and downturns (Vol. 2019). Food & Agriculture Org.
[93] Yaya, S., et al. (2020). Does economic growth reduce childhood stunting? A multi country analysis of 89 Demographic and Health Surveys in sub-Saharan Africa. BMJ global health, 5(1), e002042.
[94] Zougmoré, R. B., Partey, S. T., Ouédraogo, M., Torquebiau, E., & Campbell, B. M. (2018). Facing climate variability in sub-Saharan Africa: analysis of climate-smart agriculture opportunities to manage climate-related risks. Cahiers Agricultures. Countries.