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Using the vulnerability index to assess the risk of climate change impacts on agricultural and food security

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ABSTRACT

Climate change is among the most critical global challenges of our time, with far-reaching impacts on human lives and livelihoods. Egypt is particularly vulnerable to climate-related risks that threaten food security. This study aimed to investigate the relationship between hunger and climate risk in Egypt and identify the factors that contribute to vulnerability to climate-related risks. The study applied the Hunger and Climate Vulnerability Index to analyze different indicators, including climate hazards, environment, agriculture, coastal zones, infrastructure, socioeconomic structure, and governance, to assess the susceptibility of Egypt to climatic risks. The findings revealed a significant correlation between hunger and climate risk, with the sensitivity variable exhibiting the most positive association with the occurrence of undernourishment. The study identified vulnerable employment and a lack of forests as the primary factors that determine vulnerability in Egypt.

The study also found no correlation between adaptive capacity and undernourishment. Therefore, measures to improve adaptive capacity, such as improving infrastructure, reducing poverty, and enhancing government effectiveness, could provide the greatest benefits for food security in the face of climate change. This study provides insights into the factors that contribute to climate-related risks to food security in Egypt and highlights that targeted policies are necessary to reduce food insecurity vulnerability.

Key Words:

Climate Change; Vulnerability Index; Food Security; Agriculture; Hunger; Risks, Egypt

1. INTRODUCTION

The phenomenon of climate change has emerged as a significant and pressing global concern, with individuals worldwide experiencing its repercussions in various ways. **[1]**. The agriculture industry is anticipated to be negatively impacted as a result of heightened fluctuations in precipitation, temperature, and the occurrence and strength of extreme weather events. **[2]**. Obvious repercussions include reduced productivity in specific regions and alterations in the geographical distribution of production. Numerous studies conducted across diverse regions and crops have consistently demonstrated a prevalence of adverse effects of climate change on crop yields, outweighing any positive impacts. Climate change directly affects food output through agriculture, forestry, and water resources. **[3]**. Climate change may lead to a rise in the intensity of extreme weather phenomena like droughts, storms, and floods. Consequently, this could heighten the vulnerability of communities already experiencing food insecurity. Increased frequency, severity, or duration of extreme weather events may impact food production, leading to decreased agricultural output in certain regions. This, in turn, can result in higher food costs, limited access to markets, and adverse nutrition consequences. **[4]**. Furthermore, enduring alterations in climate may impact the appropriateness of land for cultivating crops and the viability of rain-fed agriculture in certain regions. Consequently, climate change has the potential to amplify exposure in intricate manners. Climate change may heighten the vulnerability of households experiencing food insecurity. Rain-fed agriculture constitutes the primary kind of farming in the most food-insecure nations. However, the impact of climate change on weather patterns may disrupt the appropriateness of agricultural regions for crop cultivation, thus leading to a decline in crop yields. The presence of water can also impact crop production. Alterations in precipitation patterns due to climate change might influence water availability, therefore intensifying agricultural vulnerabilities. Climate change may modify temperature and soil moisture, which would likely heighten the vulnerability of households experiencing food insecurity. Variations in temperature can impact agriculture by affecting soil and water moisture needs. **[5]**.

Over the course of time, it is becoming more and more apparent in the realm of climate change research regarding the importance of incorporating vulnerability assessment as a means to inform policy development. Nevertheless, a continuous discourse persists regarding the conceptualization and operationalization of vulnerability in both theoretical frameworks and practical applications. Historically, vulnerability analysis has been linked to external factors that have the potential to adversely impact a system's valued attribute, with particular emphasis placed on natural disasters [6]. The vulnerability assessment paradigm has undergone a recent shift, wherein vulnerability is now regarded as an inherent attribute of a system, as conceptualised by the Intergovernmental Panel on Climate Change. Water is in short supply due to rising temperatures. Every nation needs to have food security. One of the most important factors influencing agricultural output is water availability. Within the framework of addressing the difficulties associated with the establishment of a vulnerability assessment approach, the scientific article suggests the implementation of an investigational Hunger and Climate Vulnerability Index. The

UK Met Office Hadley Centre and the UN World Food Programme collaborated on the development of this index. **[7]**.

This study aims to shed light on the agriculture sector and food security in the face of climate change and mitigate its consequences especially in Egypt as one of up to date studies. In order to achieve this, we will run a test using the vulnerability and vulnerability index. The suggested index uses readily available global datasets on different socio-economic and environmental factors. Its goal is to help identify the populations that are most vulnerable to the effects of climate change. Furthermore, it provides useful information for identifying countries particularly prone to climate-related impacts on food security. Our study includes several points, including climate changes and their impact on agriculture, how food security is affected by these changes, the use of vulnerability and vulnerability indexes, and the development of a simple strategy to confront this crisis. This methodology can be duplicated at lower administrative levels to ascertain and assess risks that are specific to the local context. It can also be utilised to track trends in vulnerability, assess the potential efficacy of programmes, and investigate the possible consequences of climate change by incorporating adaptation scenarios and climate projections into the vulnerability index model. The study employed a five-step methodology to construct index of Hunger and Climate Vulnerability. The analysis demonstrates the significant influence of adaptive capacity in assessing vulnerability, surpassing the sole consideration of climate's effect on crop yields. It offers a comprehensive evaluation of vulnerability by incorporating multiple dimensions. Additionally, the research provides a dependable planning instrument for policymakers by delineating an approach for determining how vulnerable food security is to climate-related hazards across different levels of analysis. By integrating scenarios into the vulnerability model, this approach can additionally be employed for vulnerability tracking, evaluating the prospective efficacy of programmes, and examining the probable impacts of climate change. This paper also discusses how various adaptation techniques can lessen sensitivity to climate change and boost food security.

2. METHOD

The concept of vulnerability emerges from the intricate interplay among institutional, socio-economic, and environmental systems, thereby introducing challenges in the evaluation and quantification processes. The Hunger and Climate Vulnerability Index was developed using a five-step approach. (Figure 1).

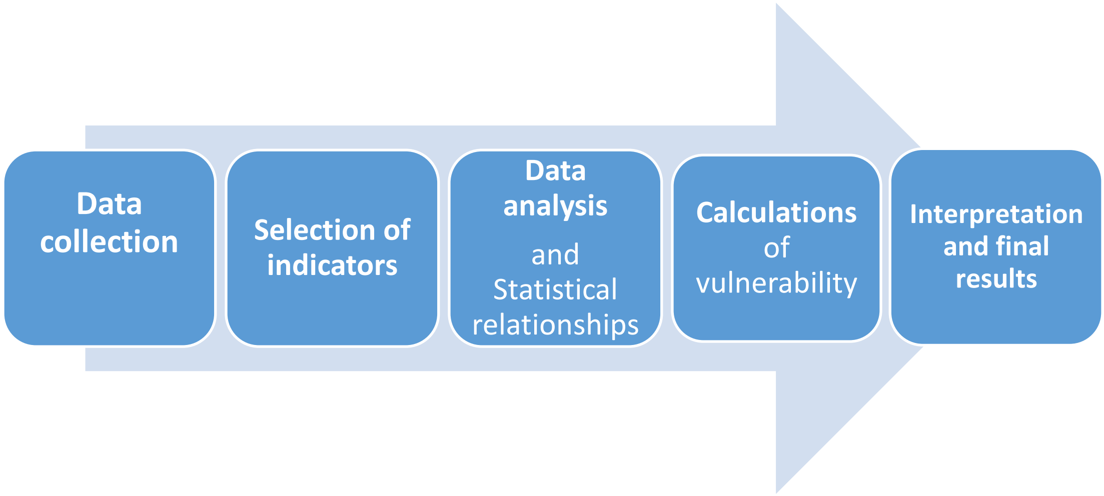

Fig (1): The approach taken in the methodology.

Global databases of the World Bank, the World Resources Institute (WRI), EM-DAT, and UN agencies (FAOSTAT, UNFPA, and the International Monetary Fund) were combed for relevant data. A country's vulnerability or resilience can be measured and characterised by a variety of indicators. Thus, the index is a combination of the variables that summarise overall susceptibility to climate impacts. Subsequently, a statistical study was conducted to ascertain the link between particular variables and undernourishment. Although there are no established global standards for quantifying hunger [8], undernourishment is employed as a substitute for hunger in this context. Undernourishment is the predominant indicator of hunger on a worldwide scale, and it is measured by calculating the ratio of available kilocalories, derived from total crop production, to the population size **[9,10]**. Due to their regular inclusion in national censuses, these metrics constitute the most extensive worldwide dataset on hunger over extended periods **[9,11]**. The primary utility of this assessment lies in evaluating the enduring consequences of malnutrition, as opposed to instances of immediate food insecurity that arise in the aftermath of a food security crisis. In this analysis, the most practical benchmark for quantifying vulnerability was deemed to be undernourishment statistics, due to the availability of global data for this indicator **[12]**. Nevertheless, in future studies, additional food security variables such as diversity of dietary, diet amount, volatility and food price can offer more insights into the connections between climate risk and specific dimensions of food security. Furthermore, the selection of indicators was based on the outcomes of the statistical study. Various indicators were chosen to represent each of the three primary aspects of vulnerability (adaptive capacity, sensitivity, and exposure) **[13]**. If there was no statistically significant correlation between hunger and potential indicator, the indicator was excluded from further evaluation. The indicators were assessed for autocorrelation. In cases where two or more indicators showed a statistically significant link with hunger and were autocorrelated, only the indicator that connected with undernourishment was included in the index. Furthermore, certain metrics were employed to compute the Hunger and Climate Vulnerability Index, following the guidelines provided below. The computation results were shown on a Geographic Information System (ArcMap 9.3) to ascertain the spatial distribution of vulnerability. Subsequently, the results were compared with global-level statistical findings. This index employs a balanced weight methodology, where each component is considered to have an equal contribution to the index, irrespective of the number of indicators within each component [14]. In order to accomplish this, the element's score was divided by the total number of indicators. The weighting algorithm can be modified to accurately represent the perceived significance of particular criteria. For instance, Schlossarek [14] propose engaging in talks with focus groups and seeking expert opinions to ascertain the relative importance of indicators. Due to variations in scales or units, it was imperative to standardise each indicator. To do the conversion, the outcomes were indexed and expressed as a percentage of the maximum value for that specific indicator. [15,16]:

$$\boldsymbol{Indicator\ (standerised)} = \frac{\textbf{Indicator (value)}}{\textbf{Indicator (maximum)}}$$

The component's value was then calculated by adding the indicator values:

$$\boldsymbol{Component\ value} = \frac{\textbf{Indicator 1} + \textbf{Indicator 2} + \cdots \textbf{I}\boldsymbol{ndicator\ n}}{\mathbf{n}}$$

that is, for each component, n is the count of indications. Adaptive capacity hurts the index since it decreases vulnerability. Because of this, we utilise the inverse value (1-x) to represent adaptive capability, which is to say, the absence of it, for the rest of the work. The values of the components are also normalised such that they can only take on a maximum of 1. The index score was calculated by multiplying the obtained normalised values. [15,16]:

$$\textbf{Vulnerability score} = \textbf{Exposure value} \times \textbf{Adaptive capacity value}$$

The index score was likewise standardized, with a maximum value of 1. The computation findings are utilized to quantify the relative susceptibility at the national level. The model's values were categorized into five distinct groups using the quintile method, where each range represents 20% of the maximum vulnerability in a cumulative manner (Table 1).

Table 1: Indicators of vulnerability to climate-related hazards [15,16].

Vulnerability index	<0.2	0.2–0.4	0.4-0.6	0.6–0.8	>0.8
Severity of vulnerability	Very low	Low	Medium	High	Very high

3. RESULTS AND DISCUSSION

While the Hunger and Climate Vulnerability Index may have limits in providing extensive information at a sub-national level, it remains useful for comparison study and gaining insights into the relative significance of various indicators incorporated within the index at the national level [15,16,17]. The statistical association between the selected factors and undernourishment is summarised in Table (2,3). The index includes a comprehensive set of indicators, which can be found in Annex A.

Table 2: The selected indicators value from different original datasets (2010-2021)

Indicator	Value	source
Undernourishment (%)	7.2	FAOSTST
Mortality (per 1000 people)	6.33	EM-DAT
Number of droughts (2010–2020)	NA	CCKP, World Bank Data
Number of floods (2010–2020)	10	CCKP, World Bank Data
Number of storms (2010–2020)	7	CCKP, World Bank Data
Reported economic losses (% of GDP)	6.6	World Bank Data
Mean annual temperature (national)	38	FAOSTST CCKP, World Bank Data
Cereal yield (kg/ cultivated ha)	74185	FAOSTST
Consumer prices (food) index	189.90	FAOSTST
Land under cereal production (ha)	32268	FAOSTST
Net cereal imports as percentage of consumption	45	FAOSTST
Forest area (% of total land)	0.005	FAOSTST
Arable land (ha/ person)	3.077	FAOSTST, World Bank Data
Agricultural rainfed land (% of total agricultural land)	3	FAOSTST, World Bank Data
Food production index	7.7	FAOSTST
Rural population with access to water sources (%)	57.1	FAOSTST, World Bank Data
Urban population with access to water sources (%)	42.9	FAOSTST, World Bank Data
Paved roads (%)	73.7	FAOSTST, EM-DAT , World Bank Data
Government effectiveness	88.8	EM-DAT , World Bank Data
Poverty gap at $2 a day (PPP) (% of total pop)	26.5	FAOSTST, EM-DAT , World Bank Data
Rural population (% of total)	41.1	FAOSTST, EM-DAT , World Bank Data
Vulnerable employment (% of total labour force)	18.13	FAOSTST, EM-DAT , World Bank Data
Decadal population growth (%)	1.67	FAOSTST, EM-DAT , World Bank Data

Table 3: The vulnerability index's components and indicators, as well as the statistical correlations between these indicators and undernourishment

Component	Input Profile	Indicator	Statistical relationship Correlation to hunger (p-value)
Exposure (r = 0.011)	Climate hazard[1,2,3]	Mortality (per 100,000 population)	0.21 (<0.05)
		Reported economic losses per capita (% of GDP)	0.61 (<0.05)
		Number of droughts (2010–2020) (unit)	0.11 (<0.05)
		Number of floods (2010–2020) (unit)	0.15 (<0.05)
		Number of storms (2010–2020) (unit)	0.10 (<0.05)
Sensitivity (r = 0.83)	Environment[3,4]	Forest cover (% of total area)	_0.92 (0.05)
	Agriculture [2,3]	Rainfed agriculture (% of total agriculture)	0.74 (<0.05)
		Cereal crop production (yield/ha)	_0.75 (<0.05)
		Rural area (% of total)	0.89 (0.05)
Adaptive capacity (r = 0.36)	Infrastructure[2,3]	Water access (rural population) (%)	0.40 (<0.05)
		Water access (urban population) (%)	0.51 (0.01)
		Paved roads (% of all roads)	0.45 (0.01)
	Socioeconomic structure[3,4]	Decadal population growth (2010–2020) (%)	0.21 (<0.05)
		Total population below poverty line ($2 per day, PPP) (%)	0.19 (<0.05)
	Governance[3,4]	Vulnerable employment (%)	0.88 (0.01)
		Rural population (%)	0.32 (<0.05)
		Government effectiveness	0.71 (<0.05)

1: IMF, 2: EM-DAT,3: FAOSTST 4: World Bank Data

This particular analysis offers an initial assessment of the factors that contribute to a country's susceptibility to climate-related risks. Figure (2) depicts a vulnerability triangle that visually represents the contributing factors associated with exposure, sensitivity, and adaptive capacity for the country of Egypt, thereby exemplifying a potential application of the index. The diagram illustrates the high sensitivity of Egypt, as evidenced by the fact that 32.18% of the country's agricultural activities rely on rainfall, while a mere 0.005% of its land area is covered by forests [18]. The utilisation of the vulnerability index has the potential to evaluate the prospective influence of a policy, programme, or project through the substitution of the anticipated variable and subsequent recalculation of the index. For instance, in the case of an intervention targeting the enhancement of social protection accessibility, the anticipated percentage can be incorporated into the equation for determining the revised vulnerability score. For instance, in the context of Egypt, a hypothetical reduction of vulnerable employment by 55%, leading to an increase in the availability of social protection, is projected to enhance the overall adaptive capacity by approximately 35 percent. Consequently, this improvement in adaptive capacity is expected to result in a reduction of overall vulnerability by approximately 17%, when compared to the baseline scenario. Nevertheless, accurately quantifying the direct and indirect impacts of policy interventions poses a challenge, necessitating the implementation of a distinct evaluation procedure [16,18].

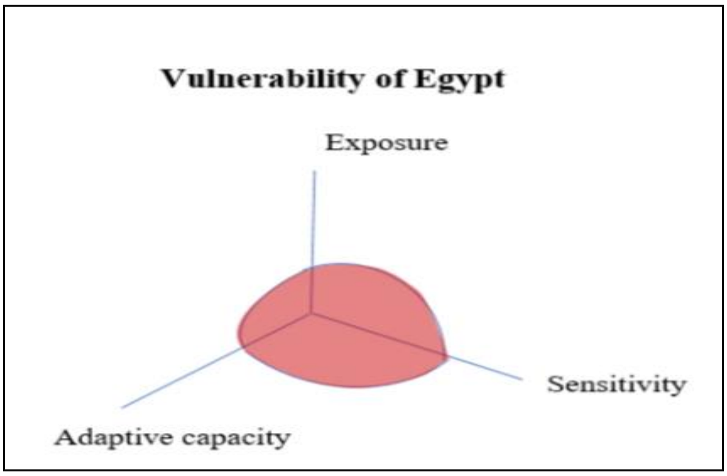

Fig (2): Vulnerability triangle for Egypt

According to the results, vulnerable employment is the main factor that determines vulnerability, which measures the percentage of the workforce lacking formal arrangements and social protection, and the absence of forest resources. This suggests that implementing policies aimed at addressing these factors would result in the greatest reduction in vulnerability. The replication of the index might occur at different time intervals and geographical levels, enabling the provision of comprehensive and thorough understanding of vulnerability within extremely particular circumstances. The index can be developed at both the sub-national and national levels by using a consistent methodology. This methodology involves thoroughly reviewing the existing literature on climate and vulnerability science, gathering relevant national datasets, and applying statistical analysis [16]. It is probable that conducting the study in various national contexts will yield vulnerability indices that deviate from the one currently presented, thereby capturing the significance of indicators specific to each country. Indicators can be allocated weightings by incorporating feedback from communities and, experts, thereby highlighting the importance of specific elements. Therefore, the index can be utilised in policy guidance to identify the primary factors that are contributing to vulnerability. Moreover, the utilisation of the index can serve as a means to assess the influence of climate on a given context. For instance, in the event that a specific climate change scenario predicts a rise in the frequency of droughts within a country, the index can be adjusted accordingly, subsequently allowing for the recalculation of the vulnerability score [18,19]. Within this particular framework, climate models assume a significant role as a crucial component of the index. These models aid in forecasting the anticipated frequency of climate-related incidents, along with the corresponding economic damages and loss of life, across various scenarios. As a result, they help to understand how climate affects vulnerability. Climate research incorporation is crucial for the identification of distinct climate-related occurrences that hold significance across various spatial and temporal dimensions. As additional data becomes accessible, there is an opportunity to improve the local index by including information about developing threats, such as the impact of the melting of glaciers on the flow of rivers. Additionally, the index could be expanded to encompass more comprehensive data on the rise of the sea-level and its consequences on inundation of coasts [20]. The vulnerability index can be enhanced by including anticipated repercussions of changing climates, such as changes in crop productivity, to predict future susceptibilities. Additional analyses could potentially yield insights regarding the regions that are expected to experience the greatest influence from the physical consequences of climate change, such as unpredictable patterns of precipitation. Through the examination of the relationship between projected alterations in precipitation patterns and regions reliant on rain-fed agricultural practises for their productivity, it becomes feasible to discern additional agricultural vulnerabilities associated with climate change. Additional incorporation of climate science is necessary in order to establish a comprehensive approach for informing policymaking [16, 21].

The findings of the index were geographically visualised on a global scale using a Geographical Information System (GIS), as depicted in Figure (3,4). The map clearly illustrates the susceptibility of countries' food security to risks from climate change in comparison to each other. This is based on existing climate and socioeconomic characteristics, as determined through a thorough review of literature and our current findings. It is crucial to understand that the index values should be viewed as relative values rather than absolute values and should be compared within the framework of analysis.

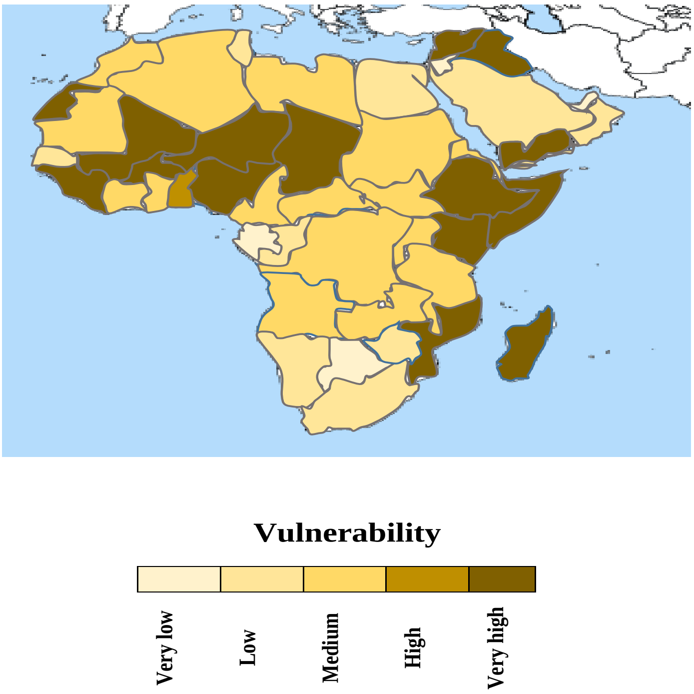

Fig (3): Map displaying susceptibility to hunger and climate change.

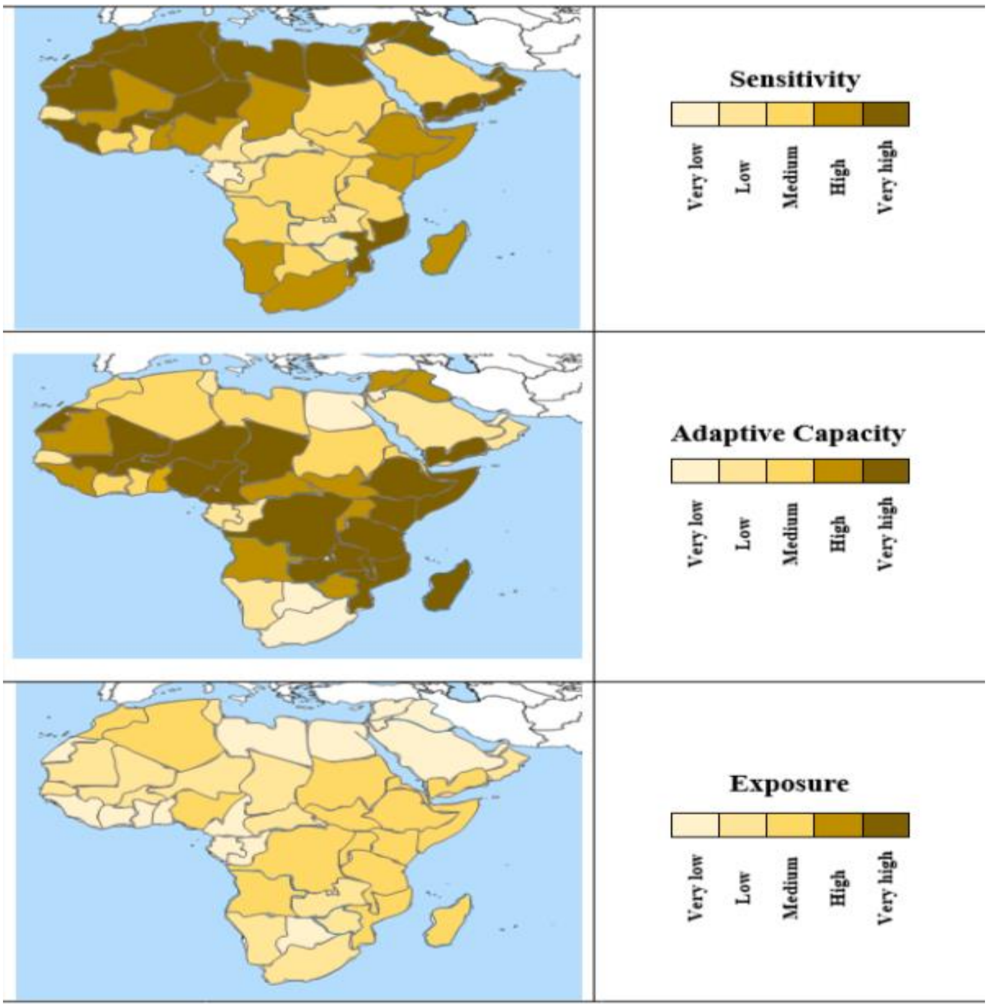

Fig (4): The distribution of the susceptibility components [16], including exposure (very low), adaptive capacity (low), and sensitivity (very high) for Egypt [current study].

According to a statistical study, there is a weak positive correlation ($r = 0.36$, $p < 0.05$) between adaptive capacity and undernourishment. This finding contradicts the results of previous research investigations [22]. Therefore, improving the ability to adapt to changing conditions, especially in terms of efficient administration, infrastructure availability, market access, and poverty eradication, can have the most significant impact on ensuring the provision of sufficient and reliable food supplies in response to the challenges posed by climate change. This study's findings align with previous research that emphasizes the significant impact of related to the social and economic factors and poverty in determining vulnerability to climate change. The sensitivity variable shows a strong positive correlation with undernourishment ($r = 0.83$, $p < 0.05$), indicating that those who are undernourished are more susceptible to the effects of climate change. The intermediate map shows the regional distribution of sensitivity, indicating that the countries with the highest levels of sensitivity are located in Northern Africa and the Middle East, including Egypt. This can be attributed to the scarcity of forested areas, especially in dry regions, and the significant reliance on rainfed agriculture practices. The lowermost map illustrates the distribution of exposure. The variable of exposure shows a minimal connection with undernourishment ($r = 0.011$, $p < 0.05$). The results suggest that countries with larger geographical areas often have higher rates of occurrence and damages caused by disasters, as they have a greater likelihood of being affected. It is worth noting that larger countries with more financial resources are more likely to experience losses due to the higher probability of unfavorable outcomes. However, the relatively low levels of exposure indicate that vulnerability is primarily influenced by sensitivity and adaptive capacity, particularly in nations with elevated levels of undernourishment [23].

Figure (5) demonstrates the existence of regional disparities in both food insecurity and susceptibility to climate-related factors. This remark suggests that there are two important observations that require further empirical examination. The correlation between hunger and climate risk is apparent, since nations with the most severe food insecurity also encounter increased susceptibility to climate-related hazards. Moreover, the occurrence of climate change has the capacity to heighten the susceptibility to food insecurity. Empirical data from several contexts unequivocally demonstrates that climate risk is already exerting a detrimental influence on food security in specific places. In 2011, Eastern Africa encountered droughts that offered a substantial peril to the sustenance of over 9 million people. The droughts were caused by changes in rainfall patterns, leading to negative impacts on the afflicted people. The predictions of inadequate precipitation in particular regions of Somalia, Kenya, and Ethiopia indicate that a significant number of livelihoods may be at risk [24]. An analysis of drought risk in Egypt found a direct relationship between a 0.5 to one-degree Celsius increase in local, seasonal temperature and a decrease in rainfall during the important rainy season. This has resulted in more severe drought episodes in Egypt [25]. If this trend continues, the amount of high-quality farmland would decline, potentially affecting the important locations in Egypt where excess maize is grown, and so posing a risk to food security. The examples provided illustrate the close relationship between fluctuations in climate and the availability of food in countries that are highly vulnerable to negative effects.

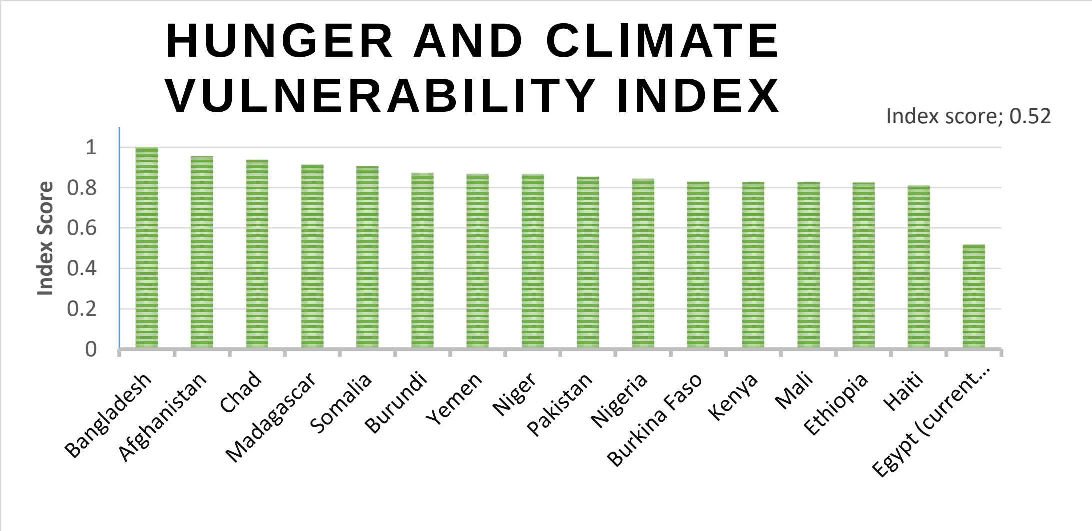

Fig (5): Climate Vulnerability Index.

Assessing regional influences on climatic variability is essential for selecting the optimal level of analysis. According to [26], while studying vulnerabilities at the household level, it is crucial to consider the broader context of economic, environmental, and social dynamics. Regarding the index under consideration, it is noted that the significance of catastrophic incidence data is higher when examined at the regional and national scales, rather than the local scale. Another factor that influences the extent of analysis is the availability of resources needed for data collection, processing, and interpretation. The examples provided illustrate the close relationship between fluctuations in climate and the availability of food in countries that are highly vulnerable to negative effects. Open source data from worldwide datasets was aggregated to create the index that was reported in this study. Subsequent investigations could duplicate this methodology by utilising data gathered explicitly for assessments of climate change vulnerability and food security. Future study might make use of climate models in conjunction with the vulnerability index to guide interventions, provided that reliable climate science is accessible. Thanks to the index's incorporation of climate projections, users may accurately ascertain the relative influence on total risk and evaluate the influence on exposure criteria. Users may be able to execute sensitivity tests by adjusting the other index indicators in future versions of the index that can provide valuable insights for adaptation planning. This feature will enable people to delve into the complexities of climate change amidst uncertainties.

4. CONCLUSION

This study proposes a Hunger and Climate Vulnerability Index to evaluate the extent of national food security vulnerability to climate-related impacts. The method used here is based on a comprehensive examination of existing research and meticulous statistical analysis, which provides a detailed account of the factors that contribute to an increased susceptibility to food insecurity due to global climate change. The use of visual representations such as triangle and spider diagrams helps to convey additional vulnerability information, showing the overall vulnerability profile as well as the relative importance of several indicators of susceptibility. The study is based on multiple spatial and temporal dimensions, which allow for replication of the study by utilizing datasets and climate scenarios that are specific to the context.

Implementing this method is expected to produce diverse vulnerability indices, along with an understanding of the various historical circumstances of countries' adaptive capacity, exposure, and sensitivity. With the progress of research and the availability of data, it is possible to incorporate developing climate-related risks, including melting glaciers and rising sea levels, into a vulnerability assessment. On a worldwide level, this analysis found that adaptive ability and sensitivity are more effective in explaining outcomes than hazard exposure, which implies the existence of two captivating subjects for further investigation.

Firstly, it is worth considering whether the inclusion of more intricate information in a local index duplicates this. Furthermore, it is worth considering whether a basic indicator, implemented repeatedly using a wide array of climate model forecasts, could enable us to accurately measure the significance of the risk and variations in the risk, in comparison to the effectiveness of adaptation strategies, which have thus far proven to be more crucial. This would allow us to precisely assess the specific threat posed by climate change, within a range of uncertainties. Historically, changes in output have been the main focus of assessments of how climate impacts food security, rather than doing comprehensive socioeconomic analyses. The purpose of this index is to expand the range of assessments related to climate change, food security, and vulnerability. Creating smaller versions of the index can offer valuable insights and direction for initiatives that aim to achieve food security and adapt to climate change.

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Data availability: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Appendix A. Qualification of the selected indicators

Component	Indicator	Rationale
Exposure	Mortality rate/(climate disasters)	Climate-related disasters result in fatalities. The higher the death toll from climate threats, the more vulnerable a country is to climate change **[27]**
	GDP losses in %	Climate disasters cause economic damage. To compare impact, adjust losses by GDP. Richer countries suffer more absolute damage. Proportional losses indicate poor climate risk management **[28]**.
	Drought frequency	Insufficient rainfall worsens droughts, causing agriculture losses and food insecurity. Droughts have increased to 12-25% in regions growing important crops since the 1960s. Currently, 700 million people are food insecure due to drought, and this number will rise due to climate change and population growth **[28, 29]**.
	Floods frequency	Climate change can increase floods and rainfall, threatening food security. Floods can damage crops, food stores, farming equipment, and cropland, leading to a loss of food production **[30]** .
	Storms frequency	Tropical cyclones can impact food security and nutrition. They may intensify globally, but regional effects are unclear. High-resolution models predict fewer but more severe cyclones in the future. Cyclones can destroy crops, land, infrastructure, and livelihoods, and can result in loss of life **[31]**.
Sensitivity	Forest	Deforestation affects food security as over 300 million people rely on forests for food. Forests preserve land and water, sustaining agricultural and environmental productivity. They also act as physical barriers and prevent land degradation, guarding against climate-induced disturbances **[32]**.
	Crop Production	Cereal yield is crucial for food security, but climate change can impact it directly and indirectly. It can alter agro-ecological conditions and affect economic growth and income distribution, ultimately affecting agriculture demand. In sub-Saharan Africa, climate change could reduce cropland by 10-20 million hectares for double cropping and 5-10 million hectares for triple cropping due to changes in agroecological conditions and precipitation **[33]**.
Adaptive capacity	Water	Water access is crucial for food security, especially irrigation. Irrigated land is less than 20% of the world's acreage but produces 40-45% of its food. Changing precipitation patterns may increase droughts in sub-Saharan Africa. Clean water is crucial for sanitation and health, especially in urban areas with limited supplies. Poor sanitation worsens diarrhoea and foodborne illness. **[28,29,30]**.
	Roads	The availability of roads is a key factor in ensuring a steady supply of food. By connecting rural and urban regions, boosting land use, and bridging the gap between non-agricultural and agricultural activity, roads boost agricultural production. Investing in roads can open doors to new job opportunities and help people diversify their livelihoods. In the event of a climate-related catastrophe, roads can also serve as escape routes **[34]**.
	Demographic growth	Population growth increases demand for food, requiring higher agricultural productivity **[34,35]**.
	Poverty	Poverty worsens food insecurity and weakens climate resilience, increasing susceptibility to adverse climate impacts **[33,36]**.
	Employment	Rural own-account and family workers lack formal labor arrangements, benefits, and social safety systems, making them vulnerable to climate-related economic swings. Unstable employment is a proxy for social protection demands and correlates with climate change vulnerability **[36]**.
	Rural	Rural areas face food insecurity as 75% of the world's impoverished population lives there and relies on agriculture. Undernourishment is more common among those who rely on subsistence farming due to financial constraints. **[35,36,37]**.

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