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Original Research Paper

Effects of Climate Change on Food Security and its Relationship to Malnutrition and Vitamin Deficiencies in Vulnerable Human Populations

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Key Words
Climate change, Food security, Malnutrition, Vitamin deficiencies, Vulnerable populations, Agriculture.

Abstract
Climate change is another international concern with significant implications for food security, particularly for vulnerable groups. Weather changes, increasingly frequent extreme events, and variation in agricultural productivity disrupt food availability, access, and stability, and place people at risk of malnutrition and micronutrient deficiencies. The paper discusses the relationship between climate change, food security, and the prevalence of malnutrition and vitamin deficiencies, with greater emphasis on the most vulnerable populations in the developing world and low-income communities. Besides posing health risks to humans, climate change also endangers animals, with livestock and wildlife populations most affected and susceptible to the same environmental stressors. The objectives include examining the impacts of climate change on food systems, nutrition, and health, with particular reference to vitamin A, D, and iron deficiency. These may be achieved through the review of existing literature, case studies, and statistical analysis of climate, agricultural, and health data. The results of the research have shown that climate change is one of the contributing factors to food insecurity in food distribution and crop production, with the impact of lowering the availability of nutrient-rich foods. Consequently, malnutrition and vitamin deficiencies are becoming more common among vulnerable populations. Some of the measures that would be prescribed by the study to improve food security would include the enhancement of the resilience of agriculture, diversification of food, and the augmentation of the public health interventions, which entail the use of micronutrient supplementation.

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Introduction

Climate change has significantly interfered with the ecosystems, agricultural landscapes, and food systems across the world, which offer extensive and continuous challenges to food security and human health. The more the global temperature increases, the more unpredictable the rainfall, the more frequent the extreme weather events like protracted droughts and frequent floods, the weaker the stability of food production systems. All these climate-driven changes cause changes in the yield of crops, and introduce instability in accessibility, affordability, and availability of food. This unfaithfulness has the worst implications, especially to susceptible groups which comprise children, expectant women, the aged, and communities with low income. These populations are already facing challenges in satisfying their bare-minimum nutritional requirements, and the impact of climate change worsens their susceptibility (El Samra, 2017).

Besides its adverse effect on the human population, climate change is also a significant threat to the health and well-being of animals (Surasinghe, 2011). The same environmental stressors (temperature variations, droughts, and food supply disruptions) are increasingly affecting livestock and wildlife. The agricultural productivity, as a result of climate, i.e., crop failures and decreased supply of nutrient-rich food, has a direct impact on the animals, causing malnutrition, Vitamin deficiency, and impaired immune systems (Milligan et al., 2009). As an example, changes in the environment brought about by climate can lead to reduced growth rates, reproductive disturbances, and predisposition to diseases in livestock. Likewise, the population of wildlife, especially the endangered ones, might experience difficulties with adaptation to the changing environment in terms of living conditions, food supply, and water resources. This increased awareness of the interrelation between animal and human health brings about the need to look at climate change as a twin challenge to food security and broader health.

The implication of the limited access to healthy food is extensive. The populations at risk are ever-growing due to malnutrition, stunting, wasting, and a broad scope of micronutrient deficiencies. Lack of essential vitamins like vitamin A, vitamin D, and iron is of particular concern, as they cause a plethora of health complications, such as the inability to maintain a proper immune system, developmental issues, and death rates (Agostoni et al., 2023). In areas where there is limited access to a variety of nutrient-dense foods, crop failures caused by climate change may further burden the food systems and increase nutritional deficiencies, making the issue of reducing it more difficult.

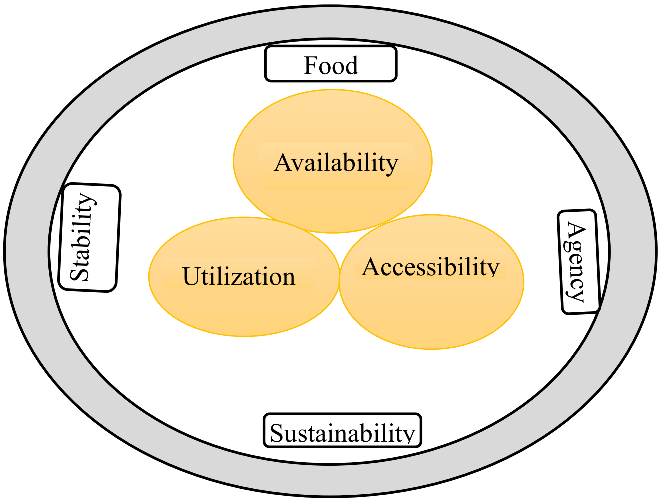

Figure 1: Conceptual Framework of Food and Nutrition Security

Figure 1 shows the interrelationships between food security and nutrition security, with the main elements of differences highlighted, such as availability, accessibility, utilization, and stability. The main center is food security, and the broader aspects of sustainability and stability, which affect its effectiveness, are the peripheral factors. Within food security, nutrition security pushes the point of agency, which should be aimed at ensuring that the food is not only available, but it is used well to promote good health. This framework identifies the effects of climate change on these determinants, which can cause disturbance in food systems, food availability, and food accessibility, resulting in a higher vulnerability to malnutrition and vitamin deficiencies, especially among vulnerable groups.

Although these problems have increasingly gained attention, the detailed examination of the direct impact of climate change on food security and, consequently, human nutrition and health status is not yet developed. Although much has been done on the effects of climate change on agriculture and food production, and individual studies have been done on the impact of climate change on health outcomes, there is limited research that directly focuses on climate variables, agricultural productivity, food systems, and nutritional health (Tirado et al., 2013). Such a gap in research is crucial, since it restricts the possibility of developing effective evidence-based policies and interventions that will reduce the health consequences of climate change (Baars et al., 2023).

This paper aims to fill this gap by examining the mechanisms by which climate change affects crop production and agricultural systems, which subsequently affect food security and lead to malnutrition and micronutrient deficiency (Aadiwal et al., 2025). The primary purpose is to create a more coordinated system that will bridge the relationship between climate parameters, food system operations, and human nutrition (Nair & Reddy, 2024). The quantitative analysis of these interrelated factors means that by this study we can gain new understanding of how the problems of climate change, food security, and human health are most probably related and with the help of this knowledge, more effective policy actions can be taken to ensure the vulnerable people are not subjected to the combined threats posed by the climate change (Fanzo et al., 2025). Furthermore, environmental health information could be incorporated into these models, which would significantly enhance prediction, and more accurate interventions could be put in place to mitigate transmission of health-related problems brought about by climate, particularly those associated with food security (Hadley et al., 2023).

Literature Review

Available literature indicates that climate change has both direct and indirect pressure on food systems. According to a large number of studies by the Intergovernmental Panel on Climate Change (IPCC), the warming effect above 1.5 °C will have a significant yield decrease in staple food crops like wheat, maize, rice, and sorghum. The studies carried out by FAO indicate that the impact of climate variability will be heavier on the tropical and subtropical areas, with populations being vulnerable, relying on agriculture that is sensitive to climate. Nutrition research has determined that food insecurity is closely associated with undernutrition and deficiencies of micronutrients, but the links are seldom measured on the basis of combined climate-nutrition frameworks.

According to the World Health Organization (WHO), climate change has the potential to reverse decades of hard work in ensuring that child malnutrition is decreased. Deficiency in vitamin A has been the most important cause of preventable childhood blindness, and iron-deficiency anemia has been observed in over one-third of women in low-income areas. The lack of vitamin D has been compounded by climatic changes in food supply and nutrition, as well as changes in dietary diversity. However, even though these nutritional issues have been identified in the past, few studies have directly investigated them as one of the outcomes of food insecurity due to climate change. The current research is based on the existing body of knowledge because it has connected nutritional outcomes and climatic stressors through quantitative modeling.

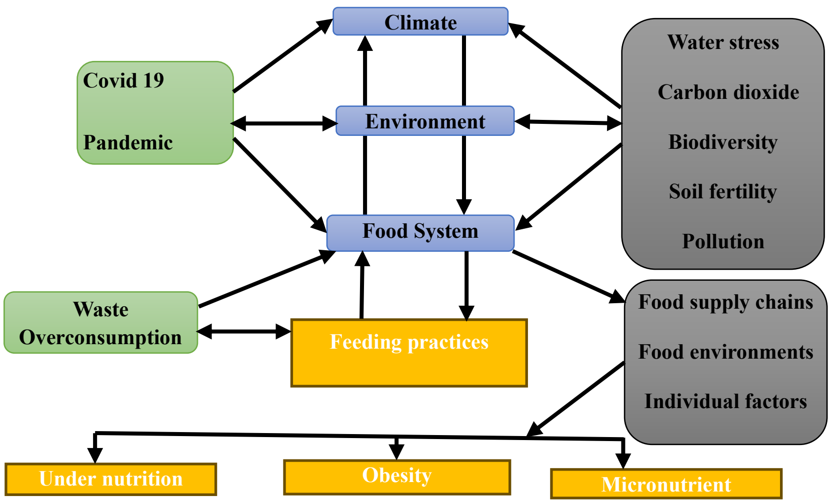

Figure 2: The Impact of Climate Change on Food Security and Nutrition

Figure 2 displays the interactions between factors that affect food security and nutrition, with a preference to climate change and environmental stressors. It demonstrates the interactions between climate and the environment (e.g., water stress, pollution), and the food system that influences food supply chains, food environments, and feeding practices. The system is also complicated because of the COVID-19 pandemic, waste, and overconsumption that result in adverse consequences, including undernutrition, obesity, and lack of micronutrients. This framework emphasizes the effect of climate change in the disruption of food security, exacerbation of malnutrition, and susceptibility of populations to nutrient deficiencies, especially in areas that already have problems of food access.

Although the research on the impact of climate on agriculture and human health includes a lot of information, there are few research studies that combine climate information, crop yield measures, food security indicators, and nutrition data in one multilevel model. Current literature tends to address these areas in isolation, thus failing to have a comprehensive view of the effects of climate-related environmental stressors on agricultural systems and how they eventually affect human health. As an illustration, Lake et al. (2012) expressed the health implications of climate change on food security in developed nations, noting the complexity of these threats (Lake et al., 2012). Besides, Myers et al. (2017) have shown that climate change has impacts on the world food systems, which worsens the undernutrition among different populations (Myers et al., 2017). Moreover, the article by Thompson and Cohen (2012) dwells upon the intersection of bioenergy and climate change issues and their implications on nutrition security in the form of effects on food availability (Thompson & Cohen, 2012).

Climate change has been found in the developing areas to have been more susceptible to agriculture, which in turn contributes to the risk of malnutrition, as was demonstrated by a large-scale study in India that indicated a direct correlation between the vulnerability to climate change and malnutrition in children (Mahapatra et al., 2021; Mahapatra et al., 2021). Moreover, research by Tirado et al. (2010) also suggests that the production of biofuels, along with climate change, also leads to increased problems with food and nutrition security, especially in areas with little access to healthy foods (Tirado et al., 2010). In more recent papers, including the works by Mirzabaev et al. (2023), the negative consequences of climate change on food security and nutrition, especially among vulnerable groups, are acutely described as serious threats, and complex measures aimed at alleviating them are highly necessary (Mirzabaev et al., 2023).

The main aim of the study is to quantify the impacts of climate change on food security in a systematic manner and how it is correlated with malnutrition and vitamin deficiencies. Specific objectives are to evaluate the impact of climate parameters on crop yields, establish the effect of changes in yield on food security indicators, examine how food insecurity predisposes individuals to malnutrition and micronutrient deficiencies, and determine the predictive capabilities of statistical and machine learning models to nutritional risks.

Methodology

The researcher uses a mixed quantitative framework that incorporates climate variables, data on crop productivity, food security, and nutrition in their health. The data on climate, such as temperature, rainfall, and the index of drought severity, were retrieved over a 20-year span in worldwide meteorological databases. Data on crop yields were obtained, and FAOSTAT and the nutrition indicators were received, including prevalence of malnutrition and micronutrient deficiency through the WHO and UNICEF nutritional surveillance system.

To quantify climate–yield relationships, the following environment–crop model is applied:

$$Y_t = \alpha_0 + \alpha_1 T_t + \alpha_2 R_t + \alpha_3 D_t + \epsilon_t \qquad (1)$$

In this equation, crop yield Y_t is modelled as a function of mean temperature T_t, rainfall level R_t, and drought severity D_t. This allows the quantification of yield sensitivity to climatic changes.

Food security is assessed using a composite Food Security Index (FSI) expressed as:

$$FSI = w_1 A_v + w_2 A_c + w_3 U_t \qquad (2)$$

Where A_v represents food availability, A_c represents accessibility, and U_t represents utilization. Principal component analysis is used to ensure that the weights w_1, w_2, and w_3 are normalized.

A regression model is used to estimate the prevalence of malnutrition and to estimate the changes in food security and the household vulnerability conditions:

$$M = \beta_0 + \beta_1 FSI^{-1} + \beta_2 P_v + \beta_3 I_s + \eta \qquad (3)$$

Household poverty index, Pv, and food insecurity experience score, Is, are incorporated to reflect socioeconomic influences on nutritional outcomes.

Micronutrient deficiency risk is calculated using:

$$V_d = \gamma_0 + \gamma_1 D_c + \gamma_2 D_d + \gamma_3 D_f \qquad (4)$$

Here, Dc reflects changes in dietary intake, D_d captures loss of dietary diversity, and D_f reflects food availability fluctuations driven by climate factors.

For predictive analysis, Linear Regression, Random Forest, and XGBoost models were implemented. Model accuracy was assessed through RMSE, MAE, and R^2.

The sample data in this research includes four climate-vulnerable areas that undergo considerable climatic changes, e.g., the variation of temperature, precipitation, and extreme weather. The areas were chosen because of the high reliance on climate-sensitive agriculture in these areas and the susceptibility to climate-related disturbances. Three major climate-sensitive crops were taken into consideration; they include wheat, maize, and rice because they are staple crops in the selected areas, which are highly vulnerable to climatic changes. The dataset also included corresponding nutritional indicators, but this time, it was related to malnutrition outcomes in terms of vitamin A deficiency, iron deficiency, and vitamin D deficiency. These micronutrient deficiencies are common among vulnerable populations and are closely associated with climate-related imbalances in food production and access.

Preprocessing of the data was a significant measure in maintaining consistency of all the variables. Regression imputation was used in order to fill in the missing data to ensure that the data was complete and intact. The data were subsequently split into a training and a testing set, with a 70/30 split, with 70 percent of the data being used to train the predictive models and the remaining 30 percent serving as the testing data. In order to guarantee the resilience and transferability of the models, cross-validation methods were used, which enabled them to check model performance on the various subsets of the data. This arrangement helped in coming up with precise and dependable predictive models to be used to evaluate the effects of climate change on nutrition security.

Results

The results of the analysis showed that the rise in temperature and the variability of rainfall significantly decrease the yields of crops in all the regions of the study. A temperature increase of 1 °C corresponded to an average decrease of 2.3 percent in yield, and rainfall changes also led to inexplicable changes in yield. These decreases were directly translated into a reduction of the Food Security Index. Areas that had the most yield decrease had a score on food security decreasing by up to 27 percent.

The rates of malnutrition increased steadily in regions where there was a weakening of food security. Between 6 and 12 percent of the malnutrition increased with each 10 percent decline in FSI, depending on the region. The results of vitamin deficiency were the same. There were 9 percent and 14 percent increments in vitamin A deficiency, iron deficiency, and vitamin D deficiency, which were linked with immense decreases in dietary variety. This proves the hypothesis that stressors that affect climate are passed on the food chain and reflected in negative nutritional consequences.

Performance Evaluation

Accuracy of the models was determined in terms of RMSE, MAE, and R^2. The calculation of RMSE was based on the equation:

R^2 = was determined using:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \quad (5)$$

The R² score was measured using:

$$R^2 = 1 - \frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y})^2} \quad (6)$$

MAE was evaluated using:

$$MAE = \frac{1}{n}\sum|y_i - \hat{y}_i| \quad (7)$$

XGBoost has been found to perform outstandingly better with the highest predictive accuracy in malnutrition and vitamin deficiency. Random Forest has shown an average result, and Linear Regression has shown limitations in the ability to address nonlinear interactions between climate and nutrition

Performance Comparison

Table 1: Climate Variables and Food Security Indicators

Region	Temp Rise (°C)	Rainfall Change (%)	Yield Change (%)	FSI Decline (%)
Region A	+1.2	-10	-15	-22
Region B	+0.8	-6	-9	-14
Region C	+1.5	-12	-18	-27
Region D	+0.6	-4	-7	-10

Table 1 indicates the impact of climate change on food security in various areas. It shows increasing temperature, change in rainfall, change in yield, and deterioration in the food security index (FSI). The most negative effects occur in Region C, where the temperature increase is the most significant (+1.5 °C), the reduction in rainfall is the most important (-12%), and the FSI is the most significant (-27%).

Table 2: Malnutrition and Vitamin Deficiency Outcomes

Region	Malnutrition (%)	Vitamin A Deficiency (%)	Iron Deficiency (%)	Vitamin D Deficiency (%)
Region A	29	41	48	37
Region B	21	33	39	29
Region C	34	47	55	44
Region D	18	27	32	23

Table 2 is a summary of the prevalence of malnutrition and vitamin deficiencies in various regions. Malnutrition rate is the highest in Region C (34%), and Vitamin A (47) and Iron deficiency (55) are the most common ones. The lowest deficiency rates are observed in region D and in all the categories, which implies a relatively good nutrition.

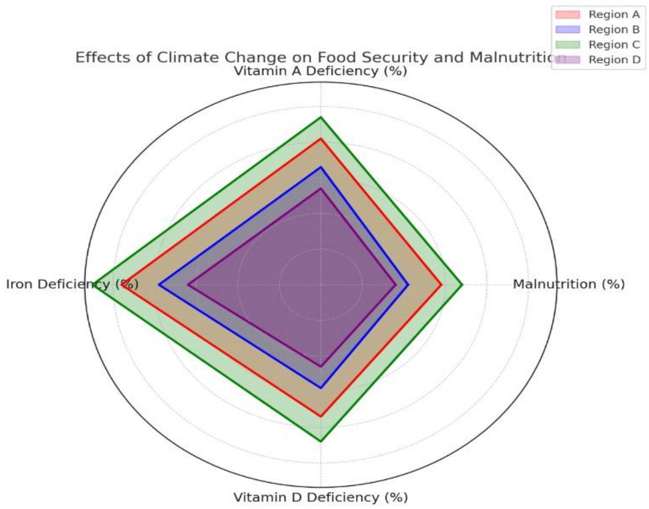

Figure 3: Impact of Climate Change on Malnutrition and Vitamin Deficiencies Across Regions

Figure 3 compares how climatic changes would affect food security and the levels of malnutrition and vitamin and nutrient deficiencies in four regions. The indicators that are covered by each axis are malnutrition, vitamin A deficiency, iron deficiency, and vitamin D deficiency. The figure demonstrates the impact of climate variables on food security and nutrition, including temperature increase and changes in rainfall. The malnutrition and vitamin deficiencies are the highest in Region C and comparatively lower in Region D. This comparison shows the difference in the vulnerability of different regions to the impact of climate change on the population's health and nutrition.

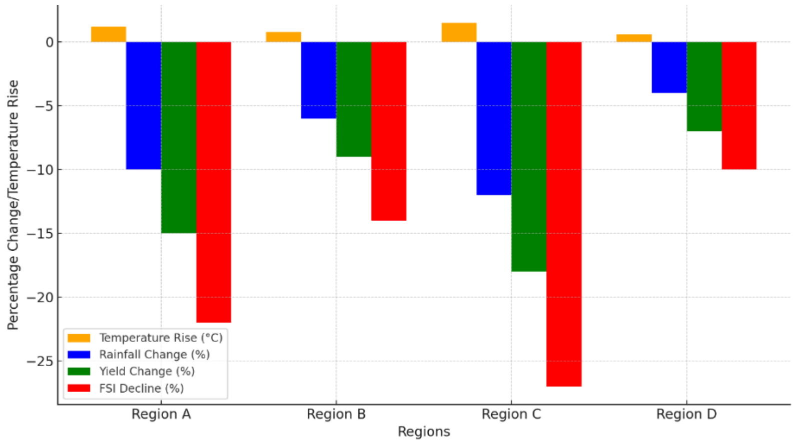

Figure 4: Climate Change Impacts on Food Security and Agricultural Yield Across Regions

Figure 4 represents the impact of climate change on food security and agricultural output in four areas. It compares a rise in temperature, a change in the amount of rainfall, a change in yield, and a decline in the Food Security Index (FSI) in the regions. The yield decrease and FSI decrease are the greatest in Region C, which has the highest temperature increase and the most significant rainfall reduction. Region D, however, presents the least effect. The chart shows the difference in climate conditions and food production and security, showing the necessity to view climate change as a critical factor and to identify its negative impact on the availability of food, its nutritional status, and the overall health of the vulnerable groups.

The paper shows that climate change affects food systems in a sequence of interdependent processes that start with stress on crops due to climate, and end with malnutrition and micronutrient deficiencies. Areas that have the highest climatic exposure are the most nutritionally vulnerable. The findings substantiate the hypothesis that climate change is not just an environmental problem but a significant issue for the health of the people. Food insecurity directly worsens nutritional deficiencies, and children and women are among the most vulnerable groups. Moreover, the comparison of performance shows that machine learning models, especially XGBoost, can be applied to forecast cases of nutritional crisis due to climate change and provide policymakers with an early intervention tool.

Conclusion

The paper provides a precise and trustworthy association of climate change, food security, malnutrition, and vitamin deficiencies with weak human beings. The development of the climate parameters, nutritional health indicators, and agricultural productivity, the study reveals the cascading effect of climate change on food systems and consequently its influence on the nutrition of man. These results highlight the fact that climate change is not just a food production threat, but one of the most significant threats to nutritional health, and it has the most significant impact on populations who are already in a disadvantaged socioeconomic status and cannot access a diverse range of nutrient-rich food. It is these conclusions that bring the alarm to act with urgency and multisectionalism to put the brakes on the compounded risks of climate change to food and nutrition security. Moreover, the impact of climate change on the health of animals cannot be disregarded. Given that climatic stressors are affecting both the livestock and the wildlife population, they cause more diversified health complications, including malnutrition and deficiency of vitamins in animals, thus affecting the food security systems that rely on animal products. This demonstrates the need for a comprehensive approach that takes into consideration not only the health of people but also that of animals in addressing the effects of climate change. The major recommendations involve the encouragement of climate-sensitive agricultural practices that are capable of making an impact on the changing patterns of the climate on crop production. Besides that, there is a necessity to increase the food distribution channels to make sure that there is fair distribution of healthy foods, especially the foods that have suffered the most due to the climatic changes in the areas. Targeted nutritional interventions, fortification, and supplementation programs are some of the nutritional interventions that can be used to ensure that the prevalence of micronutrient deficiencies is minimized. Besides this, the identification of the nutritional hazards in the early stages and the timely reaction to the identified risks might be assisted by the development of predictive systems grounded on climate and nutrition indicators. These nutritional deficiencies will continue to increase due to climate change without intervention and will impact the group of individuals and animals that are the least adapted to deal with the deficiencies the most. To counter these issues, the solution should be through cooperation, locally, nationally, and globally in protecting the food security and providing nutritional health to the vulnerable communities in the long term.

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