Shahid Bahonar University of Kerman
Agricultural Biotechnology Journal
Iranian Biotechnology Society
Print ISSN: 2228-6705 Online ISSN: 2228-6500

Climate change and their implications on agricultural practices for future food safety

M. Thiru Chitrambalam
* Corresponding author. Professor, ISME, ATLAS SkillTech University, Mumbai, India. E-mail: thiru.chitrambalam@atlasuniversity.edu.in

P. Prakash
Assistant Professor, Department of Biotechnology, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India. E-mail: prakash.biotech@sathyabama.ac.in

Suchismita Mohapatra
Assistant Professor, Department of Soil Science & Agricultural Chemistry, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha, India. E-mail: suchismitamohapatra@sao.ac.in

Naveen Kumar Rajendran
Assistant Professor, Department of Aerospace Engineering, Faculty of Engineering and Technology, JAIN (Deemed-to-be University), Ramanagara District, Karnataka - 562112, India. E-mail: r.naveenkumar@jainuniversity.ac.in

Madhu Prakash Srivastava
Associate Professor, Department of Science, Maharishi University of Information Technology, Lucknow, Uttar Pradesh, India. E-mail: madhu.srivastava@muit.in

Saksham Sood
Centre of Research Impact and Outcome, Chitkara University, Rajpura- 140417, Punjab, India. E-mail: saksham.sood.orp@chitkara.edu.in

Jagmeet Sohal
Chitkara Centre for Research and Development, Chitkara University, Himachal Pradesh-174103 India. E-mail: jagmeet.sohal.orp@chitkara.edu.in

Abstract

Objective

Climate change is a serious threat to global agriculture, especially in areas where crop productivity is closely linked to environmental factors such as rainfall and temperature. Although the risk associated with climate change is well recognized, limited empirical research has discovered the effect domestically in rural, agricultural -free fields. This study examines the effect of climate change on domestic food security, identifies large climate voltages and examines socio -economic factors that form adapted reactions from farmers.

Materials and methods
Three decades of climate data (1980-2024) were analyzed to assess temperature and rainfall. A total of 190 Smallholder farmers were selected through simple random samples, and data was collected using structured interviews and focus group discussions to include both quantitative and qualitative insight. Descriptive statistics and analysis of binary logistic region was used to evaluate the relationship between domestic characteristics and food security status.
Results
The findings indicate that irregular rainfall patterns, growing temperatures, multiplied soil erosion, and an upward push in pest and disease outbreaks have adversely affected agricultural productiveness inside the have a look at location. Based on caloric consumption thresholds, 61.5% of the surveyed families had been categorized as food insecure. Statistical evaluation discovered that age, own family size, cultivated land vicinity, and precipitation stages were extensive predictors ($p < 0.04$) of family food security. Notably, 68.9% of the farmers mentioned enforcing adaptive strategies, consisting of crop diversification, adoption of stepped forward crop sorts, livestock rearing, and engagement in alternative profits-producing activities. These adaptive responses reflect developing cognizance and resilience at the network level.
Conclusions
The take a look at emphasizes the significance of enhancing get admission to climate information, strengthening women's involvement in agricultural livelihoods, and enhancing institutional aid for model techniques. Promoting weather-smart agricultural practices and sustainable land management could be critical in addressing the food security challenges associated with ongoing climatic adjustments. The aim of this study is to evaluate the impact of climate change on domestic food security in agricultural societies and identify socio -economic and adaptation factors affecting the flexibility of small farmers.

Keywords: adaptation in agriculture, agricultural practices, food security, household nutrition, smallholder farmers

Paper type: Research paper.

Citation: Chitrambalam, M. T., Prakash, P., Mohapatra, S., Rajendran, N. K., Srivastava, M. P., Sood, S., & Sohal, J. (2026). Climate change and their implications on agricultural practices for future food safety. *Agricultural Biotechnology Journal,* 18(3), 551-570.

Agricultural Biotechnology Journal, 18(3), 551-570. DOI: 10.22103/jab.2026.25120.1690
Received: March 28, 2026. Received in revised form: May 21, 2026.
Accepted: May 22, 2026. Published online: June 30, 2026.
Publisher: Shahid Bahonar University of Kerman & Iranian Biotechnology Society.

Introduction

The impactsof climate change pose a significant danger to attaining the Sustainable Development Goals (SDGs) (Mishra et al., 2024) of eradicating hunger and poverty. Malnutrition, food insecurity, and poverty are widespread. Ten percent of kids aged 5 to 60 months experience severe malnutrition, whereas 22% of the Malian community faces food insecurity. Statistics from 2010 indicate that 65% of the countryside's inhabitants and 52% of those living in cities have a calorie deficit. The annual loss in productivity due to hunger is estimated at 148 million USD, accounting for approximately 4.5% of Mali's GDP. A primary contributor to this dilemma is the poor agricultural climate within the country. Mali is situated in the Sahelian region, noted for its intense and recurrent droughts, unpredictable precipitation, and escalating destruction of the environment. The mean rainfall from 2000 to 2020 was 15% less than that from 1920 to 1980. Since 1980, mean annual temperatures in most regions of Mali have risen by more than 0.7 °C, with average warming rates exceeding 0.3 °C per decade. From 1980 to 2010, the warming over the June-August rainy season exceeded 0.8 °C. Rising temperatures and diminishing rainfall patterns (Yaduvanshi et al., 2021) adversely affect crop production, mainly maize, necessitating greater water availability. This results in reduced total food supply. Agriculture (Muhie, 2022) is among those industries most impacted by global warming (Cho et al., 2023). Many research studies have been undertaken to examine the impacts of climate change on farming (Talić & Mešić, 2022; Thiruvengadam & Akinsorotan, 2022). Climate change may benefit farming in certain location. (Shah & Bansalm, 2023) In lower latitude regions, climate change (Sesana et al., 2021) is anticipated to cause elevated temperatures, diminished precipitation, and a heightened occurrence of severe weather phenomena, including drought and floods. Agriculture that depends on rain will suffer adverse effects (Manickam & Mohan, 2015). The yields of crops (Rezaei et al., 2023) are anticipated to decline. The predominant demographic in this region consists of small-scale farmers who depend on rainfall for survival. Rainfed agriculture (Chen et al., 2024) is the primary farming style, accounting for nearly 90% of the production of cereals. The effects of climate change will heighten the susceptibility of rural people reliant on agriculture based on rainfall, increasing food and nutrition instability (Toha et al., 2025). Tribes in many developing nations have been recognized as the most susceptible to warming temperatures due to numerous stresses and diminished adaptation potential. Farmers (Nor Diana et al., 2022) must adjust to climate change and fluctuation to mitigate its adverse effects on their way of life. Awareness is essential for adaptation, indicating that populations must first recognize and understand the possible impacts of warming temperatures on their survival before implementing effective adaptation solutions (Tunc et al., 2024). Significant community beliefs about climate variation and development have been formed (Ali, 2017). Not all farmers recognize these shifts, and not every view aligns with climate data. Therefore, it is imperative to educate community members, including farmers, of anticipated climate change. The farming sector is thought to be adversely impacted by global warming, resulting in diminished soil moisture, accelerated loss of organic matter from the soil, early grain desiccation, and heightened heat stress. Weather is crucial for cultivating crops and livestock in emerging areas, as farmers predominantly rely on rainfall to grow crops (Bedane et al., 2022). Assuming all other conditions remain unchanged, the impact of climate change is particularly significant on small-scale farmers who rely heavily on farming, resulting in decreased yields and diminished food supply, exacerbating family hunger. Current climatic change-induced events are endangering global nutrition (Mirzabaev et al., 2023). Global environmental shifts and heightened climatic unpredictability necessitate adaptation strategies and methods to mitigate associated dangers. (Kulkarni & Jain, 2023) The escalating effects of warming temperatures and unpredictability compel agriculturally reliant individuals to employ diverse adaptation measures (Spoorthi et al., 2021). This mainly encompasses indigenous expertise and abilities acquired beyond formal education over an extended duration in the countryside. The economy is primarily driven by the subsistence farming sector, which constitutes approximately 41% of the GDP. The agriculture industry, reliant on natural conditions and influenced by the country's geography, terrain, and limited adaptation capacity, renders the nation particularly susceptible to the detrimental impacts of climate change (Alipour et al., 2016). A significant segment of the population has chronic and transient malnutrition that is closely associated with severe, repeated food shortages and famine caused by periodic droughts exacerbated by warming temperatures. Malnutrition trends are seasonal and correlated with rainfall, with hunger trends decreasing following rainfall patterns, rendering the population particularly vulnerable to climate change. In southern Ethiopia, most families without food are located in the central region, typically susceptible to famine and drought. Climate is a crucial determinant of productivity in agriculture, and its alteration impacts many aspects of food security, including food supply, convenience, food use, and the stability of the food system. Climate-related shocks diminish efficiency, obstruct economic advancement, and intensify pre-existing societal and financial problems (Aljeboury et al., 2024). The aim of this study was to investigate the extent to which domestic food security in rural gardeners through climate change, irregularities in rainfall and environmental decline through climate change. It focuses specifically on small farmers who depend on rainfall and find out how social economic properties affect their ability to adapt. By identifying major climate- inspired challenges and assessing locally planned adaptation strategies, the study wants to contribute to the flexibility in terms of climate change and food system.

Materials and methods

Choice of participant agriculturists: Sixty participating farmers were systematically selected from family lists from village leaders across six communities. Each village list comprised 110 homes, from which 11 farmers were chosen. The village had approximately 850 inhabitants, with family lists maintained by village leaders ensuring accuracy and accessibility. Among the 23 female household administrators, 14 were female de facto (divorced, widowed, or never married) and nine were female de jure (family leaders due to their spouses residing in metropolitan centers, locally or in neighboring countries). The chosen 65 farmers were categorized into three income groups based on the hypothesis that their reactions to environmental challenges would differ according to their financial and social standing. The purpose of establishing groupings was elucidated to the farmers, who were invited to propose the criteria for categorizing individuals as "rich," "between," or "poor." The standards were established at the ward level, followed by an agreement among growers in both wards. The primary criteria that producers concurred upon for classifying oneself into the three wealth categories included the ownership of livestock (specifically cattle), the nature of their homestead, the farm equipment they had, and availability of labor. Other agricultural groups have employed these factors in wealth rankings. Once the criteria were established, farmers were asked to classify themselves at the community level. Those with similar characteristics were then grouped into three wealth categories: category A (affluent), category B (middle-income), and category C (impoverished). The number of farmers in the wealthy and intermediate categories was nearly equal, while the impoverished group was the largest. Correspondingly, women comprised 28%, 24%, and 53% of the affluent, intermediate, and impoverished farmers. Farmers aged 40 to 65 predominantly comprised the "wealthy" category. In contrast, almost 50% of those in the low- and middle-income groups were 68 or older. Impoverished farmers often experienced delays in harvesting due to lack of animals and limited access to essential agricultural inputs such as better seeds and fertilizers, which reduced the yield (Mohammadabadi et al., 2024a). This observation was confirmed and valid by an extension through a structured verification process. The supervisor participated in debriefing sessions after initial data analysis and underwent the findings related to delay and resource barriers. This participation was performed using Verification Specialist -select methods, where the observer provided relevant insights on the basis of many years of experience from the region in the region. Their input was triangular with focus group discussion and domestic survey data to confirm the accuracy of the challenges made by peasant -reported challenges. The dividend achievement, which confirmed through this process, is recognized as an important indicator of the economic state of a farmer.

Collecting methodologies and sample dimensions: Out of the 32 kebeles, three were utilized for this research. Three of the kebeles were chosen using straightforward random sampling methods, taking into account likelihood proportional to size. One hundred eighty-five houses were considered for the inquiry and selected using simple random sample techniques. Formulas were employed with an 8% margin of error to represent the study people accurately.

$$m = \frac{M}{1+M(e)^2} = 186 \qquad (1)$$

Where, m represents the sample size, M is the number of homes in the three chosen kebeles, and e signifies the margin of error. The primary information was obtained through the utilization of formatted and semi-structured surveys. The initial survey was conducted in collaboration with development agencies to gather general information about the kebeles and regions. The second phase involved fundamental data gathering, encompassing household data regarding demographic factors such as agricultural and livestock production, availability of food, variations in temperatures and precipitation, and adaptation of methods formulated by the household members. Secondary information was acquired from multiple agricultural agencies at various levels. Data spanning 30 years was obtained from the Meteorological Department to validate the actual occurrence of climate change. Trends in temperatures and precipitation were investigated annually, as well as during the Belgian and Meher seasons. A focus group interview was conducted with seven participants to combine the information gathered from the household poll and weather data. The primary topics addressed included alterations in weather, precipitation, agricultural and animal illnesses (Mohammadabadi et al., 2024b), food security position, and strategies for adaptation formulated in reaction to the climate at both community and family levels (Mohammadabadi et al., 2024c). The group members were chosen from among elders, elected officials, and female leaders to get their perspectives. Key informants were questioned, including specialists from various agencies (food safety, natural management of resources, and growth agents). The objective of comparing the primary triangulated source of knowledge with information acquired from a household poll was to ascertain the impact of warming temperatures on families reliant on natural precipitation, to evaluate the severity of food security issues, and to identify the mitigation measures being implemented at both farm and community levels.

Assessing household food security level: The changing climate impacts the farming, availability, access, quality, usage, and the stability of food systems. It affects every facet of the food chain. Extreme weather-related emergencies are on the rise and diminish the yields of principal crops. Elevated CO_2 concentrations diminish the nutritional quality of crops. The household's nutritional status situation was assessed using the daily calorie intake approach because of its straightforwardness. The classification of households as food secure or insecure was based on the medically suggested consumption of 2250 kcal per adult per day. Families were permitted to report the sort and quantity of food they ingested over the preceding seven days. Food supplies originate from personal creation or are acquired through purchase. All food items ingested were quantified for their caloric content per 110 g basis utilizing the caloric conversion coefficients and nutritional tables manual established by the Healthcare and Nutrition Agency. The calorie consumption of households during the past seven days was split by seven. The energy needs of every family member vary according to age, sex, and other pertinent characteristics. We converted each participant's family members into adult equivalents based on their age and sex, using an adult equivalent conversion factor. We then adjusted the total household calorie consumption to reflect the adult equivalent units for each individual. We used the minimum subsistence requirement value as the threshold to distinguish food-secure households from food-insecure ones. To assess a household's food availability, we calculated the difference between calorie supply and calorie demand.

Data analysis: Parametric and inference statistics and an economic model were employed based on the study's objectives. All statistical analyses were conducted utilizing STATA version 16.0. Descriptive data analysis compared and contrasted various scenarios in the sample units with the required attributes. Descriptive statistical techniques were used to assess the quantitative information, including the distribution of frequencies, mean, maximum, and lowest values, percentages, and standard deviation. To analyze the impact of temperature and rainfall on maize yield, a linear regression approach was applied. The explanatory strength of the model was assessed using the R-squared coefficient, which measures the proportion of yield loss that can be attributed to temperature and precipitation variations.

In the economic logistic regression, household food security was used as the dependent variable, with a binary coding 1 indicating food sufficiency and 0 indicating food insecurity. The logistic regression approach was employed to identify the factors influencing the availability of food at the family level. In calculating a logit approach, the dependent variable must be binary. In this instance, food availability was quantified as a binary variable, assigned a value of 1 for family calorie consumption equal to or over 2250 kcal per day and 0 for intake below 2250 kcal per typical adult per day. Mathematically represented as:

$$P = \frac{\exp(zx)}{1+\exp(zx)} \quad (2)$$

1-P denotes the chance of achieving food security and is expressed as:

$$1 - P = \frac{1}{1+\exp(zx)} \quad (3)$$

Reducing equation 1 by equation 2 and rearranging yields:

$$\frac{P}{1-P} = \frac{1+\exp(zx)}{1+\exp(-zx)} = \exp(zx) \quad (4)$$

Equation 3 represents the odds ratio, which compares the likelihood of a farmer achieving food security to the likelihood of experiencing food insecurity. The logit framework is derived by applying the logarithm to equation (3) in the following manner:

$$L\left(\frac{P}{1-P}\right) = L\left(\exp(b_0) + \sum_{y=0}^{N-1} b_y X_y\right) = L(\exp(zx)) \quad (5)$$

L represents the logarithm of the odds proportion, which is linear in both X and the variable. when the stochastic disruption factor v is incorporated

$$Z_x = b_0 + b_1 X_1 + b_2 X_2 + \cdots + b_N X_N + v \quad (6)$$

Before including variables in the logistic regression model, the Variance-Inflation Factors (VIF) and the Contingency Component (CC) were utilized to assess convergence among continuum and categorical variables accordingly. The trend was established based on the correlation between the two parameters of precipitation and temperature, along with their time resolution. Statistical techniques, including regression and the statistic of correlation (R^2), were employed to assess the importance of the rainfall and temperature trends. The determinants influencing farmers' willingness to embrace adaptation measures were identified using a binary logistic regression approach. Farmers typically employ many tactics, with the selection of a specific approach to mitigate climate change consequences informed by the Utility Maximizing Theory. The idea posits that producers make decisions based on the anticipated benefits they hope to derive within a framework of limitations. Thus, a specific climate change adaptation method will be employed only if the anticipated net advantages associated with its implementation exceed those of non-implementation. Since adaptation choices are inherently binary either adopting or not adopting a strategy the binary logistic regression model was used to determine the factors influencing smallholder farmers' responses to climate change. Let Y represent the binary outcome parameter adaption strategy. Y is defined as outlined in Equation 6: Y is a binary variable equal to 1 if the farmer employs a specific adaptation method, and 0 otherwise- indicating whether or not farmer has adjusted to changing climate conditions. to check for multicollinearity, correlation analysis was conducted among the explanatory (causative) variables before performing the logit regression. Factors exhibiting a strong association (connection value exceeding 0.5) were excluded from the regression analysis. In order to ensure the strength and validity of statistical analysis, a clinical examination was performed. These included variance inflation factors (VIF), rest analysis to assess the generality and symmetry of errors and multicollinearity tests using rest analysis to use model evaluation through R^2 and P-Values. The choice of linear regression was appropriately dependent on the continuous nature of the dependent variable (corn yield), while the logistics regression was used in the food security position as the model -binary results. These methods were chosen for their ability to explain the variation and identify important predictions under cross -sectional examination design of the study.

Results

Demographic profile of participants: An analysis was conducted on the fundamental profiles of household leaders that influence food security and the formulation of adaption measures. 76.8% of the participants were male-headed families, while the remainder were female. The focus group conversation findings indicated that female-headed families were more vulnerable to malnutrition due to a deficiency in productive resources, including land, agricultural inputs such as chemical fertilizers, and drought-resistant improved seeds. A significant portion of respondents (54.6%) were illiterate, which often limits their ability to adopt modern agricultural practices, particularly those aimed at addressing climate challenges. The average age of the family leader was 50.13 years. The mean size of a household was determined to be 6.9. Participants of the Focus Group Discussions indicated that "families with larger family sizes are more food poor than those with smaller family sizes." Land size significantly influences crop production's quantity, timing, and methodology. All those surveyed, irrespective of size, claimed land ownership. The mean land ownership among families was 0.93 hectares. Livestock ownership is a crucial indicator of economic stability in the research area. On average, surveyed families possessed 3.45 Tropical Livestock Units, reflecting their reliance on cattle for food security and agricultural productivity.

Status of family nutrition: Climate change-induced yield reductions significantly affect food supply chains, limiting producers' accessibility to essential food resources. The family food insecurity situation was evaluated based on current intake, specifically a one-week recollection. The questionnaire results indicated that of the 190 homes questioned, 61% ingested less than the minimal level of regular adult calories eaten per day (2250 kcal/day), while 40% ingested between 2250 and 2600 kcal/day, which is recommended for a healthy lifestyle (Figure 1). Figure 2 illustrates that the highest-ever mean temperature has risen at a pace of 0.085 °C during the three decades before 2018. The district's coldest recorded average temperature was 11.95 °C. As illustrated in Figure 2, the district's average lowest temperature has risen by around 0.092 °C each annum during the past three centuries. Meteorological data confirms that both maximum and minimum temperatures have shown a consistent upward trend over the analyzed period (Figure 2). In contrast to rising temperatures, precipitation distribution from 1980 to 2024 has declined rapidly. Figure 3 illustrates that the district's typical precipitation over the past thirty years was 1558.2 mm, which has decreased by 4.12 mm during the same time. The information gathered from the Meteorological Agency indicates that the average coefficient of variations for the research area was 26%, 24.5%, and 17.4% for Belgian, Kiremt, and yearly precipitation, signifying significant precipitation variations from 1980 to 2025. The variability in rainfall amounts was more critical during the belg season than direct.

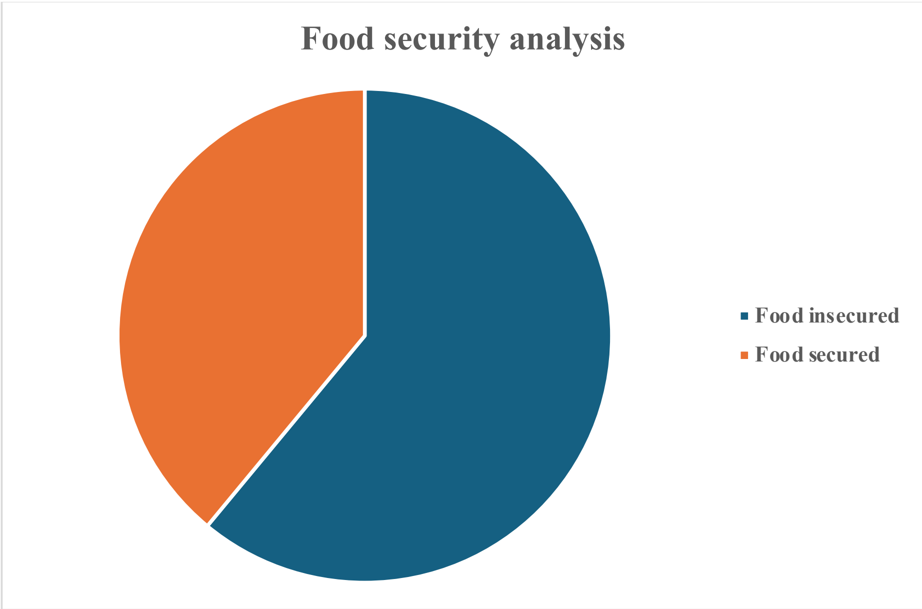

Figure 1. Pie chart of the relationship between family status and levels of food security and insecurity

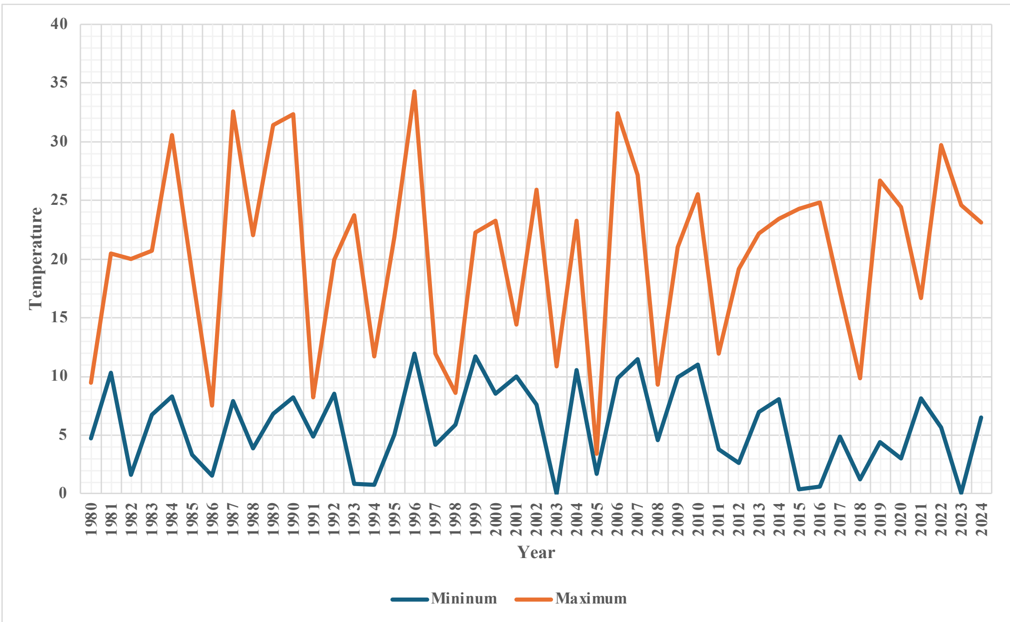

Figure 2. Annual trends in minimum and maximum temperatures from 1980 to 2024, illustrating interannual variability and long-term fluctuations. This temperature analysis provides insight into changing climatic patterns over the observed period

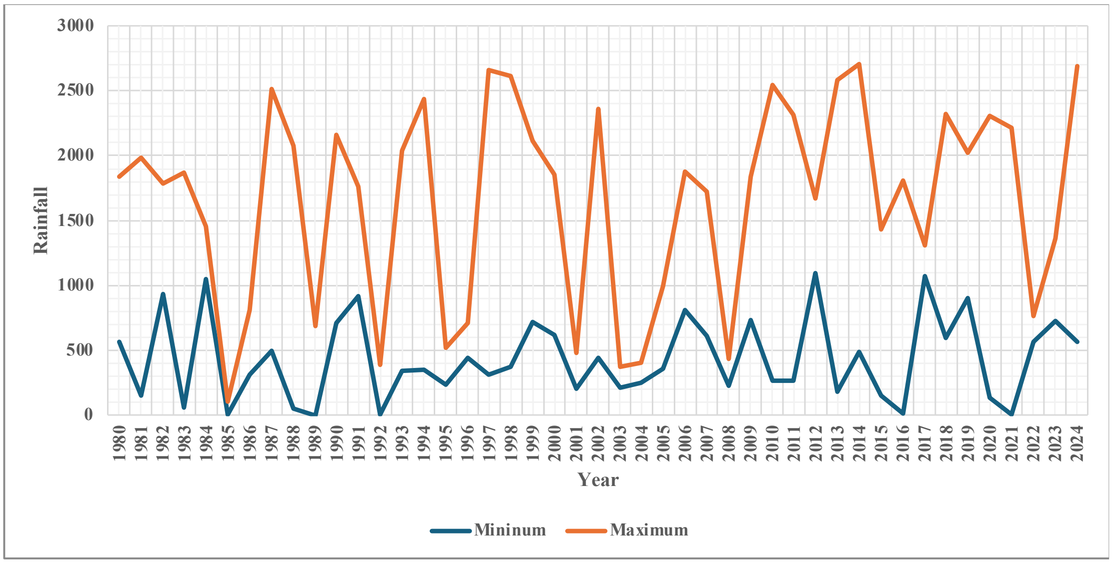

Figure 3. Annual variation in minimum and maximum rainfall from 1980 to 2024. The figure illustrates significant interannual fluctuations in precipitation levels, highlighting trends in extreme rainfall events over the study period

Respondents' perception of environmental change: Regarding farmers' perceptions of climate change, 84.2% observed a reduction in annual rainfall, while 51.6% reported that rainfall occurs later than usual and concludes earlier. 85.1% of those polled noted a significant increase in temperatures. The statistics indicated a proportion of evidence confirming a temperature change.

Domestic source of climate data: Farmers can adjust to environmental changes only if they receive current data. In this context, the respondent obtained climate-related data from multiple places. The primary sources for data included Extension Agents (45.2%), Radio (32.1%), other agricultural producers (22.7%), and Television (4.4%). Only a limited number of individuals possessed visual aids, whereas timely information regarding climate change was predominantly obtained from Development Agencies and radio broadcasts.

Effects of global warming on agricultural yield: The primary crops cultivated in the research region are maize, enset, coffee, and khat. The increases in maize output served as an indicator of the influence of warming temperatures on family nutrition, as it is a primary food crop in the region. Figure 4 demonstrates a strong correlation between yield variations and Rainfall (RF). The descriptive research further substantiates that, while maintaining additional inputs to agriculture stability, the yield of maize fluctuates annually due to climatic change and volatility. The mean yield of maize was 41.20 quintals per hectare from 2008 to 2018, with an average deviation of 43.5 quintals per hectare.

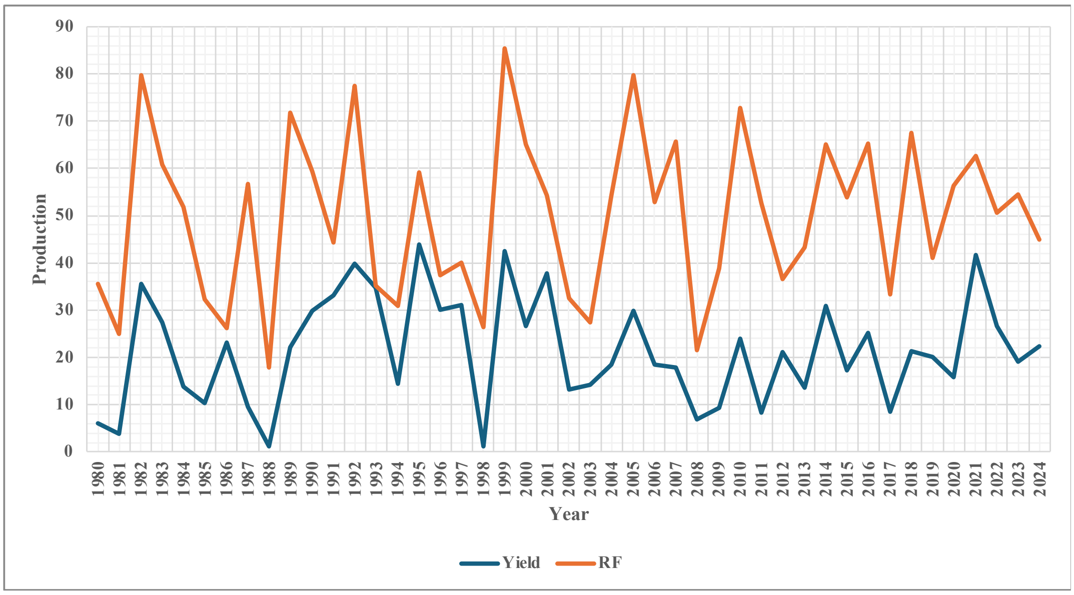

Figure 4. Temporal trends in crop yield and rainfall (RF) from 1980 to 2024. The figure highlights the variability in agricultural production in relation to annual rainfall fluctuations, indicating potential correlations between precipitation patterns and yield outcomes over time

It demonstrates a negative association between the yield of maize and the annual temperature variation. This indicates that a rise in temperature correlates with a drop in maize production. The impact of temperature fluctuations on maize yield is particularly evident in the data from 2010 to 2019. As temperatures increased significantly from 2016 to 2021, corn yield experienced a sharp drop.

Correlation among precipitation, temperatures, and maize yield: The analysis was conducted to ascertain the impact of variations in RF and temperatures on the yield of maize. Controlling for additional factors, the augmentation of rainfall in millimetres has demonstrated beneficial benefits on maize yield from 2005 to 2019. The coefficient from the linear regression model indicates that for every 1 mm increase in precipitation, the mean yield per hectare rises by 2.5 kg. The R^2 value was determined to be 0.72, suggesting that changes in precipitation account for 72% of the variation in maize production. The finding has an essential p-value of less than 2%, as shown in Figure 5. temperature changes, show a negative association with maize yields. The linear regression analysis indicates that for each one-degree increase in temperatures, maize production decreases by 2.37 kg. The p-value shows that the correlation between temperature and output is negligible. The R^2 result indicates that merely 14% of maize production is accounted for by temperature variations.

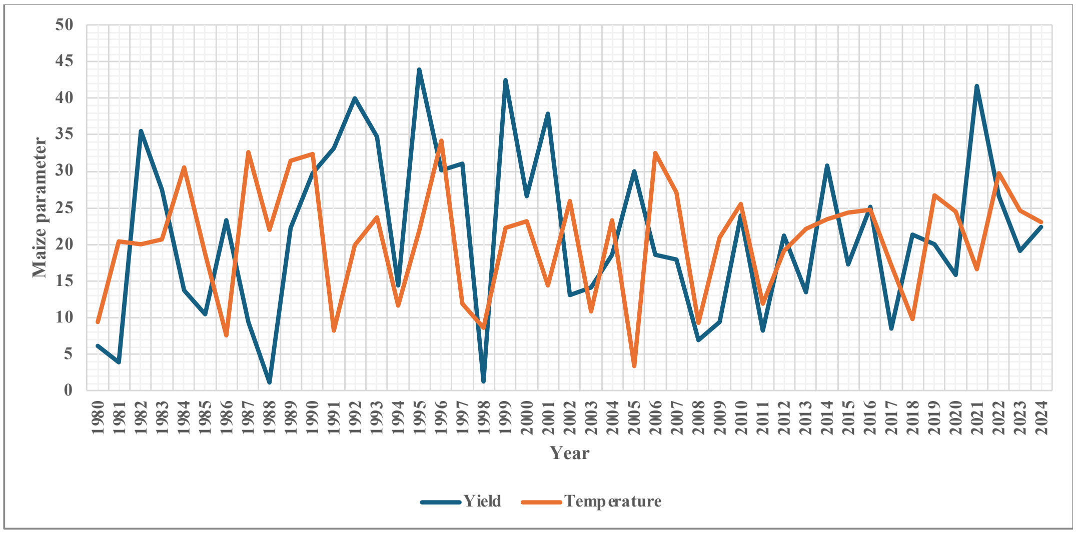

Figure 5. Yearly variation in maize yield and temperature from 1980 to 2024. The figure demonstrates the relationship between temperature fluctuations and maize yield, highlighting the potential impact of climatic conditions on crop performance over the study period

Farming is very susceptible to warming temperatures for three primary reasons: (i) around 80% of the country's population relies on agriculture based on rainwater, (ii) it is an impoverished nation, and (iii) it possesses diverse geographical regions that experience varying degrees of climate effect. The increase in warmth and variability in precipitation creates numerous challenges for those residing in places already afflicted by drought, which are experiencing diminishing rainfall.

Adaptation strategies for climate change: Farmers have adapted to the shifting climate. 68% of those surveyed have employed conserving water and soil to mitigate climate change's effects. The outcomes of the focus group meeting showed that all farmers in the region are required to engage in the conservation of soil and water on both individual and common land.

Examination of factors influencing family food security: The computed household accessible energy was contrasted to the minimal subsistence need of 2250 kcal per adult person daily. The findings indicated that, from the 190 sampled families, 118 consumed less than the suggested caloric intake of 2250 kcal, while 41% of the respondents exceeded the minimal needs. The pertinent factors are examined separately as follows. Family size exhibits a significant difference at the 10% likelihood threshold and negatively correlates with family food availability. The negative coefficient of the model output signifies the likelihood of food insecurity associated with a rise in the number of children. The odds ratio indicates the probability of a household achieving food security diminishes by a factor of 0.42 with each additional member, assuming all other variables remain constant. As the age of the parent or guardian rises, one gains more excellent expertise, enhancing the ability to leverage these insights effectively (Frelat et al., 2016). This variable strongly and positively influences nutritional level at a 6% probability level. The extent of cultivated earth: the primary source of household sustenance in the research area was personal production, with restricted access to alternative sources of income. Households with extensive landholdings exhibit superior production capabilities, enhancing their food security prospects. The odds ratio for farm size reveals that, holding other factors equal, the food security position of the farmer improves by a factor of 40.13 with each additional hectare of farm size.

Alteration in precipitation: those polled indicated a slight increase in rainfall. Farmers believed that food security improves with more rainfall. Food availability in the area has risen by 143.3% due to improved rainfall for families. The topic of the discussion in groups indicated that, even within identical kebele governments, how much rain falls is influenced by terrain, resulting in varying impacts on populations (Hubertus et al., 2023). The findings from this study suggest that women dominated families are weaker for food security due to limited access to large productive resources such as land, fertilizer and better seeds. This corresponds to research indicating that gender -based inequalities in access to agricultural entrances affect the nutrition results and affect the flexibility of climate shock. The high illiteracy between respondents (54.6%) limits their ability to use modern agricultural technologies and explain information related to climate, a challenge that is widely noted in similar studies. Education is often cited as an important possible way, more likely to use better agricultural practices with literary farmers and use climate information effectively. Climate data indicated rising temperature and decrease in rainfall, trends in line with broad regional and global climate change patterns. Farmers' belief in these changes - especially the delay and early expiry and increase in temperature - mixed with real meteorological data, which confirms the validity of local knowledge in climate risk assessment. The relationship between rainfall and corn yield was strong and positive, while rising temperatures adversely affected corn productivity. These findings match other studies that have identified temperature, and grow as a significant crop barrier, especially in rainfall systems. On the other hand, better rainfall is to increase agricultural production, and strengthen the importance of stable climatic conditions for food security. Domestic size was negatively associated with the availability of food, and strengthened the previous comments that large families are receptive to food security due to limited distribution of resources per capita to large families. Meanwhile, the old domestic major was associated with better food security, which is probably due to improvement in accumulated agricultural experiences and decision -making ability. Access to climate information was primarily through expansion agents and radio, which highlights the importance of available, timely and located communication channels to facilitate adaptation. These findings are in line with previous studies, and emphasize the important role of information proliferation in climate flexibility. When it comes to adaptation strategies, a large part of the homes (68%) reported using soil and water conservation methods. This broad use suggests a strong awareness of the importance of natural resource management to maintain productivity under variable climatic conditions. Such practice has usually been seen as the necessary coping mechanism in other areas. Finally, regression analysis showed that large country size and better rainfall significantly improved food security, while an increase in domestic size had a negative impact. These results correspond to previous findings that highlight land access and climate stability in the form of the core determinants of food security in rural agrarian communities.

Thematical analysis

Gender and socio-economic inequality in agricultural vulnerability: Theme summary: Domestic structure and gender roles Average access to productive resources, which in turn affects food security and adaptation strategies, Proof: 76.8% of the houses were male -oriented; Women -oriented families lacked access to land, fertilizer and better seeds. 54.6% of those surveyed were illiterate and limited their ability to use modern practice, and Implication: Gender inequality and educational deficit reduce adaptability. Women -dominated and illiterate families are exposed to the risk of food security and climate dress, which requires targeted support in intervention and capacity.

Climate change trends and local perceptions: Theme summary: Local meteorological trends show a steady increase in temperature and a decrease in rainfall, which is consistent with perceptions of the environmental changes to the farmers, Proof: The temperature increased ~ 0.085-0.092 ° C annually (1980-2024). High variability rainfall fell (Belg: 26%, Kiremt: 24.5%). 84.2% of farmers saw a decline in rain; 85.1% raised attention to rising temperatures, and Implication: The convergence of scientific and local data confirms the validity of social experiences and supports the integration of indigenous knowledge into the climate response.

Food security and nutritional stress: Theme summary: Climate -spared return reduction has direct results on calorie intake and domestic food security, Proof: 61% of families consumed <2250 kcal/day; Only 40% of the recommended intake was found. Larger family sizes are correlated with high food safety (Aud ratio: 0.42 per extra member), and Implication: Nutrition deteriorates during climate dress, especially in large homes. Intervention strategies should address both food and nutritional quality for domestic size.

Agricultural dividend sensitivity to climate variables: Theme summary: The corn outfit is very sensitive to rainfall and temperature races and downs, Proof: The average of the corn yield was 41.2 quinals/hectares, but was raised annually. The rain showed a strong positive correlation with the yield (R G = 0.72; +2.5 kg/mm). There was a slight negative correlation in temperature (R G = 0.14; 0.32.37 kg/° C), and Implication: Precipitation variability is a significantly limited factor in agricultural productivity. Water management and strengthening of irrigation systems can reduce this risk.

Adaptation practices and sources of information: Theme summary: Farmers take steps to optimize, but are forced by reliable climate information and limited access to infrastructure, Proof: 68% practiced soil and water conservation. Climate data source: Extension agent (45.2%), radio (32.1%), peers (22.7%). Low dependence on TV or visual equipment (4.4%), and Implication: Adaptation is widespread, but low technology and knowledge. In order to increase flexibility, it is necessary to expand access to local and available climate services on time.

Structural driver for food security: Theme summary: Land ownership, age of domestic leader and precipitation patterns affect domestic food safety levels to a large extent, Proof: Large landhold (meaning: 0.93 hectares) Improvement of food security (Auds ratio: 40.13 per hectare). Old domestic major associated with better food results. The availability of food increased by 143.3%in increased rainfall, and Implication: Manufacturer of food security is closely associated with property and access to environmental conditions. Land improvement, access to credit and weather -affecting insurance can be transformative in these settings. Government models undergo standard clinical probes to confirm the reliability of the results. Low VIF values indicated the absence of multiple culture among predictions. The remains were almost generally distributed and supported the belief in linear regression. High R^2, value (0.72) for rain -producing models indicate strong explanatory power, while the logistical regression model showed statistically significant relationships between large predictions (eg domestic size, landhold) and food security positions. The choice of these statistical techniques was in accordance with the data and goals of the study, which enables a good understanding of how climate and demographic factors interact to influence the agricultural results.

Conclusion: At present, climate change is a pressing reality, significantly impacting the food security of families in the study region, necessitating the development of adaption methods in reaction. The district's national weather information from the past thirty years confirmed variations in annual precipitation and temperatures. The ratio of rainfall variation indicated significant variability throughout the primary farming season in the region. Demographic characteristics, including age, family size, and financial variables such as agricultural land and annual revenue, influence producers' food security levels. Producers in the district have created strategies for adaptation primarily focused on utilizing enhanced agricultural and livestock output, altering planting and harvesting schedules, implementing soil and water conservation methods, employing irrigation, and diversifying revenue sources. Improving land management systems, providing timely climate data, diversifying sources of income, and implementing superior crop varieties are critical adaptation tactics that must be considered to mitigate food security dangers in the context of warming temperatures. It is imperative to disseminate climate data, educate families on various adaptation measures, and enhance women's household engagement in revenue-generating endeavors, as these are the most crucial strategies.

Author Contributions

All authors have equal contributions.

Acknowledgments

We acknowledge the ATLAS SkillTech University, Sathyabama Institute of Science and Technology, Siksha 'O' Anusandhan (Deemed to be University), Maharishi University of Information Technology, and Chitkara University. The institutional contributions played a significant role in facilitating the successful completion of this study.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability Statement

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Ethical Considerations

This study did not involve any human or animal participants and therefore did not require ethical approval.

Conflict of interest

The authors declare no conflict of interest.

References

Ali, Z. (2017). Evolution of Complexity of Algorithms. *International Academic Journal of Innovative Research, 4*(1), 1-13.

Alipour, A., Hashemi, S. M., Shokri, S. B. S., & Sadeghi, S. H. (2016). Evaluating the water quality in the agriculture part of the Hamoun Hirmand basin. *International Academic Journal of Science and Engineering, 3*(2), 80-86.

Aljeboury, G. H., Dawood, A. T., Khalaf, R. A., Algafari, R. N., Ramadhan, R. S., & Talib, S. S. (2024). Isolation of a Novel Bacterium Isolate Capable of Utilizing Crude Oil and Diesel Oil Spills as a Biological Bioremediation Agent. *Frontiers in Bioscience-Elite*, *16*(4), 31. https://doi.org/10.31083/j.fbe1604031

Bedane, H. R., Beketie, K. T., Fantahun, E. E., Feyisa, G. L., & Anose, F. A. (2022). The impact of rainfall variability and crop production on vertisols in the central highlands of Ethiopia. *Environmental Systems Research, 11*(1), 26. https://doi.org/10.1186/s40068-022-00275-3

Chen, X., Wang, L., Cao, Q., Sun, J., Niu, Z., Yang, L., & Jiang, W. (2024). Response of global agricultural productivity anomalies to drought stress in irrigated and rainfed agriculture. *Science China Earth Sciences*, *67*(11), 3579-3593. https://doi.org/10.1007/s11430-023-1328-2

Cho, H. H., Strezov, V., & Evans, T. J. (2023). A review on global warming potential, challenges and opportunities of renewable hydrogen production technologies. *Sustainable Materials and Technologies, 35,* e00567. https://doi.org/10.1016/j.susmat.2023.e00567

Frelat, R., Lopez-Ridaura, S., Giller, K. E., Herrero, M., Douxchamps, S., Djurfeldt, A. A., Erenstein, O., Henderson, B., Kassie, M., Paul, B. K., Rigolot, C., Ritzema, R. S., Rodriguez, D., van Asten, P. J. A., & van Wijk, M. T. (2016). Drivers of household food availability in sub-Saharan Africa based on big data from small farms. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(2), 458-463. https://doi.org/10.1073/pnas.1518384112

Hubertus, L., Groth, J., Teucher, M., & Hermans, K. (2023). Rainfall changes perceived by farmers and captured by meteorological data: two sides to every story. *Regional Environmental Change*, *23*(2), 75. https://doi.org/10.1007/s10113-023-02064-9.

Kulkarni, P., & Jain, V. (2023). Smart Agroforestry: Leveraging IoT and AI for Climate-Resilient Agricultural Systems. *International Journal of SDG's Prospects and Breakthroughs, 1*(1), 15-17

Manickam, D., & Mohan, C. (2015). Design and Fabrication of Diminutive Aerogenerator. *International Journal of Advances in Engineering and Emerging Technology, 6*(3), 167-177.

Mirzabaev, A., Kerr, R. B., Hasegawa, T., Pradhan, P., Wreford, A., von der Pahlen, M. C. T., & Gurney-Smith, H. (2023). Severe climate change risks to food security and nutrition. *Climate Risk Management, 39,* 100473. https://doi.org/10.1016/j.crm.2022.100473

Mishra, M., Desul, S., Santos, C. A. G., Mishra, S. K., Kamal, A. H. M., Goswami, S., Kalumba, A. M., Biswal, R., Silva, R. M. D., Santos, C. A. C. D., & Baral, K. (2024). A bibliometric analysis of sustainable development goals (SDGs): a review of progress, challenges, and opportunities. *Environment, development and sustainability, 26*(5), 11101-11143. https://doi.org/10.1007/s10668-023-03225-w.

Mohammadabadi, M., Akhtarpoor, A., Khezri, A., Babenko, O., Stavetska, R. V., Tytarenko, I., Ievstafiieva, Y., Buchkovska, V., Slynko, V., & Afanasenko, V. (2024a). The role and diverse applications of machine learning in genetics, breeding, and biotechnology of livestock and poultry. *Agricultural Biotechnology Journal*, *16*(4), 413-442. https://doi.org/10.22103/jab.2025.24662.1644.

Mohammadabadi, M., Babenko Ivanivna, O., Borshch, O., Kalashnyk, O., Ievstafiieva, Y., & Buchkovska, V. (2024c). Measuring the relative expression pattern of the UCP2 gene in different tissues of the Raini Cashmere goat. *Agricultural Biotechnology Journal*, *16*(3), 317-332. https://doi.org/10.22103/jab.2024.24337.1627

Mohammadabadi, M., Kheyrodin, H., Afanasenko, V., Babenko Ivanivna, O., Klopenko, N., Kalashnyk, O., Ievstafiieva, Y., & Buchkovska, V. (2024b). The role of artificial intelligence in genomics. *Agricultural Biotechnology Journal, 16*(2), 195-279. https://doi.org/10.22103/jab.2024.23558.1575

Muhie, S. H. (2022). Novel approaches and practices to sustainable agriculture. *Journal of Agriculture and Food Research*, *10*, 100446. https://doi.org/10.1016/j.jafr.2022.100446

Nor Diana, M. I., Zulkepli, N. A., Siwar, C., & Zainol, M. R. (2022). Farmers' adaptation strategies to climate change in Southeast Asia: A systematic literature review. *Sustainability, 14*(6), 3639. https://doi.org/10.3390/su14063639

Rezaei, E. E., Webber, H., Asseng, S., Boote, K., Durand, J. L., Ewert, F., Martre, P., & MacCarthy, D. S. (2023). Climate change impacts on crop yields. *Nature reviews earth & environment, 4*(12), 831-846. https://doi.org/10.1038/s43017-023-00491-0

Sesana, E., Gagnon, A. S., Ciantelli, C., Cassar, J., & Hughes, J. J. (2021). Climate change impacts on cultural heritage: A literature review. *Wiley Interdisciplinary Reviews: Climate Change*, *12*(4), e710. https://doi.org/10.1002/wcc.710

Shah, V., & Bansalm, T. (2023). Multidisciplinary Approaches to Climate Change Monitoring Using Cloud-based Environmental Data Systems. In *Cloud-Driven Policy Systems* (pp. 25-31). Periodic Series in Multidisciplinary Studies.

Spoorthi, A., Sunil, T., & Kurian, M. (2021). Implementation of Lora based Autonomous Agriculture Robot. *International Journal of communication and computer Technologies*, *9*, 34-39.

Talić, Z., & Mešić, M. (2022). Landslide Remediation on Location of Transmission Line POLE SM 134 ON DV 110 kV TS TUZLA C. - TS DUBRAVE. *Archives for Technical Sciences, 1*(26), 33-42. https://doi.org/10.7251/afts.2022.1426.033T.

Thiruvengadam, V., & Akinsorotan, A. M. (2022). Comparative and regression analysis of Nile tilapia, Oreochromis niloticus (Linnaeus, 1758) (Family: Chchlidae) from Bugungu, Eastern region, Republic of Uganda, East Africa (0 23'31.92" N 33 13'51.95" E). *International Journal of Environmental Research and Education*, *3*(1), 73-78.

Toha, A., Ahmad, H., & Lee, X. (2025). IoT-based embedded systems for precision agriculture: Design and implementation. *SCCTS Journal of Embedded Systems Design and Applications, 2*(2), 21-29.

Tunc, A., Turan, F., & Ergenler, A. (2024). Genotoxic Damage in Rainbow Trout Oncorhynchus Mykiss Exposed to Transport Stress. *Natural and Engineering Sciences, 9*(2), 270-279. https://doi.org/10.28978/nesciences.1506001.

Yaduvanshi, A., Nkemelang, T., Bendapudi, R., & New, M. (2021). Temperature and rainfall extremes change under current and future global warming levels across Indian climate zones. *Weather and Climate Extremes*, *31*, 100291. https://doi.org/10.1016/j.wace.2020.100291

مجله بیوتکنولوژی کشاورزی
انجمن بیوتکنولوژی ایران
دانشگاه شهید باهنر کرمان
شاپا چاپی: ۶۷۰۵-۲۲۲۸   شاپا الکترونیکی: ۶۵۰۰-۲۲۲۸

تغییرات اقلیمی و پیامدهای آن بر شیوه‌های کشاورزی برای امنیت غذایی آینده

م. تیرو چیترامبالام

نویسنده مسئول. استاد، ISME، دانشگاه مهارت‌محور ATLAS SkillTech، بمبئی، هند. ایمیل: thiru.chitrambalam@atlasuniversity.edu.in

پ. پراکاش

استادیار، گروه بیوتکنولوژی، مؤسسه علوم و فناوری ساتیاباما، چنای، تامیل نادو، هند. ایمیل: prakash.biotech@sathyabama.ac.in

سوچیسمیتا موهاپاترا

استادیار، گروه علوم خاک و شیمی کشاورزی، دانشکده علوم کشاورزی، دانشگاه Siksha 'O' Anusandhan، بوبانسوار، اودیسا، هند. ایمیل: suchismitamohapatra@sao.ac.in

ناوین کومار راجندران

استادیار، گروه مهندسی هوافضا، دانشکده مهندسی و فناوری، دانشگاه JAIN، ناحیه راماناگارا، کارناتاکا ۵۶۲۱۱۲، هند. ایمیل: r.naveenkumar@jainuniversity.ac.in

مادهو پراکاش سریواستاوا

دانشیار، گروه علوم، دانشگاه فناوری اطلاعات ماهاریشی، لکهنو، اوتار پرادش، هند. ایمیل: madhu.srivastava@muit.in

سکشام سود

مرکز پژوهش، تأثیر و دستاورد، دانشگاه چیتکارا، راجپورا، ۱۴۰۴۱۷، پنجاب، هند. ایمیل: saksham.sood.orp@chitkara.edu.in

جگمیت سوهال

مرکز پژوهش و توسعه چیتکارا، دانشگاه چیتکارا، هیماچال پرادش ۱۷۴۱۰۳، هند. ایمیل: jagmeet.sohal.orp@chitkara.edu.in

تاریخ دریافت: ۱۴۰۵/۰۱/۰۷   تاریخ دریافت فایل اصلاح شده نهایی: ۱۴۰۵/۰۲/۳۱   تاریخ پذیرش: ۱۴۰۵/۰۳/۰۱

چکیده

هدف: تغییرات اقلیمی تهدیدی جدی برای کشاورزی جهانی به شمار می‌رود، به‌ویژه در مناطقی که بهره‌وری محصولات کشاورزی به عوامل محیطی مانند بارندگی و دما وابستگی زیادی دارد. با وجود اینکه خطرات ناشی از تغییرات اقلیمی به‌خوبی شناخته شده‌اند،

پژوهش‌های تجربی محدودی اثرات آن را در جوامع روستایی و مناطق کشاورزی بررسی کرده‌اند. این مطالعه به بررسی تأثیر تغییرات اقلیمی بر امنیت غذایی خانوارها، شناسایی تنش‌های اقلیمی عمده و بررسی عوامل اجتماعی ـ اقتصادی مؤثر بر واکنش‌های سازگارانه کشاورزان می‌پردازد.

مواد و روش‌ها: داده‌های اقلیمی مربوط به سه دهه (۱۹۸۰ تا ۲۰۲۴) برای ارزیابی دما و بارندگی تحلیل شدند. تعداد ۱۹۰ کشاورز خرده‌مالک از طریق نمونه‌گیری تصادفی ساده انتخاب شدند و داده‌ها با استفاده از مصاحبه‌های ساختاریافته و بحث‌های گروهی متمرکز گردآوری شد تا بینش‌های کمی و کیفی فراهم گردد. برای ارزیابی رابطه بین ویژگی‌های خانوار و وضعیت امنیت غذایی، از آمار توصیفی و تحلیل رگرسیون لجستیک دوجمله‌ای استفاده شد.

نتایج: یافته‌ها نشان داد که الگوهای نامنظم بارندگی، افزایش دما، تشدید فرسایش خاک و افزایش شیوع آفات و بیماری‌ها، بهره‌وری کشاورزی را در منطقه مورد مطالعه تحت تأثیر منفی قرار داده‌اند. بر اساس آستانه‌های مصرف کالری، ۶۱/۵٪ از خانوارهای مورد بررسی در گروه ناامن غذایی قرار گرفتند. تحلیل آماری نشان داد که سن، اندازه خانواده، مساحت زمین زیر کشت و میزان بارندگی از پیش‌بینی‌کننده‌های مهم امنیت غذایی خانوار بودند ($p < 0.04$). همچنین، ۶۸/۹٪ از کشاورزان اجرای راهبردهای سازگاری مانند تنوع‌بخشی به محصولات، استفاده از ارقام بهبودیافته، پرورش دام و مشارکت در فعالیت‌های درآمدزای جایگزین را گزارش کردند. این واکنش‌های سازگارانه بیانگر افزایش آگاهی و تاب‌آوری در سطح جامعه است.

نتیجه‌گیری: این مطالعه بر اهمیت بهبود دسترسی به اطلاعات اقلیمی، تقویت مشارکت زنان در فعالیت‌های کشاورزی و ارتقای حمایت‌های نهادی برای راهبردهای سازگاری تأکید می‌کند. ترویج کشاورزی هوشمند اقلیمی و مدیریت پایدار زمین می‌تواند نقش کلیدی در مقابله با چالش‌های امنیت غذایی ناشی از تغییرات اقلیمی ایفا کند. هدف این پژوهش ارزیابی تأثیر تغییرات اقلیمی بر امنیت غذایی خانوارها در جوامع کشاورزی و شناسایی عوامل اجتماعی ـ اقتصادی و سازگاری مؤثر بر انعطاف‌پذیری کشاورزان خرده‌مالک بود.

کلمات کلیدی: امنیت غذایی، تغذیه خانوار، سازگاری در کشاورزی، شیوه‌های کشاورزی، کشاورزان خرده‌مالک

نوع مقاله: پژوهشی.

استناد: م. تیرو چیترامبالام، پ. پراکاش، سوچیسمیتا موهاپاترا، ناوین کومار راجندران، مادهو پراکاش سریواستاوا، سکشام سود، جگمیت سوهال (۱۴۰۵). تغییرات اقلیمی و پیامدهای آن بر شیوه‌های کشاورزی برای امنیت غذایی آینده. *مجله بیوتکنولوژی کشاورزی*، ۱۸(۳)، ۵۵۱-۵۷۰.

Publisher: Shahid Bahonar University of Kerman & Iranian Biotechnology Society.