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CLIMATE CHANGE RISKS AND CHALLENGES IN GLOBAL AGRICULTURE

Mirjana Bartula[1*], Snežana Janković[2], Ivan Šekler[1], Dušica Ćirković[3], Slađan Stanković[2], Divna Simić[2], Vera Popović[4]

[1]Metropolitan University Faculty of Appled Ecology Futura, Belgrade, Serbia,
[2]Institute for Science Application in Agriculture, Belgrade, Serbia,
[3]Toplica Academy of Applied Studies, Prokuplje, Serbia,
[4]Institute of Field and Vegetable Crops, Novi Sad, Serbia,
***Corresponding author: mirjana.bartula@futura.edu.rs**

Abstract: Climate change is a major global challenge, with agriculture being highly vulnerable. Rising temperatures, altered precipitation, and extreme weather events threaten crop yields, livestock productivity, and food security. These changes increase risks such as heat stress, droughts, floods, and pest outbreaks. This study analyzes the impacts of climate change on agriculture and highlights adaptive strategies to enhance resilience and sustainability.

Keywords: Climate change, Agriculture, Crop production, Livestock, Food security, Sustainability

INTRODUCTION

Climate change represents one of the most significant challenges facing contemporary society, with profound implications for both natural and socio-economic systems worldwide. According to the Intergovernmental Panel on Climate Change (IPCC), the primary driver of recent climate change is the increase in greenhouse gas concentrations resulting from human activities, particularly the combustion of fossil fuels, land-use change, and intensified industrial and agricultural production (IPCC, 2021). Global mean surface temperature has already risen by approximately 1.1°C above pre-industrial levels, substantially increasing the likelihood of irreversible changes within the climate system.

A defining characteristic of climate change is the clear trend of rising global temperatures, accompanied by alterations in precipitation patterns and an increasing frequency and intensity of extreme weather events. Observational data and climate projections indicate more frequent and severe heatwaves, prolonged droughts, intense rainfall events, floods, and storms across many regions of the world (IPCC, 2022). These climatic changes do not occur uniformly; instead, their magnitude and impacts vary spatially, with certain regions and vulnerable sectors experiencing disproportionately severe effects.

The impacts of climate change extend beyond physical environmental changes, significantly affecting ecosystem functioning and socio-economic stability. Climate-induced stresses contribute to ecosystem degradation, biodiversity loss, and the disruption of essential ecosystem services, including climate regulation, water availability, and soil fertility (Millennium Ecosystem Assessment, 2005; IPBES, 2019). At the same time, climate change poses substantial risks to human well-being by affecting food security, water resources, public health, livelihoods, and economic development. The Food and Agriculture Organization of the United Nations (FAO) emphasizes that climate change exacerbates existing socio-economic inequalities and represents a major obstacle to achieving sustainable development, particularly in rural areas and agriculture-dependent communities (FAO, 2018).

In this global context, understanding the interconnections between climate dynamics and their impacts on natural and socio-economic systems is essential for developing effective mitigation and adaptation strategies. Such understanding forms the foundation for enhancing resilience and sustainability in key sectors, including agriculture, which is among the most climate-sensitive components of the global economy.

MATERIAL AND METHODS

This study employed a literature-based analytical approach to assess the impacts of climate change on agricultural systems and food security, as well as adaptation strategies across different regions. Peer-reviewed articles, reports from the IPCC, FAO, and other international and regional sources were reviewed to examine temperature and precipitation changes, extreme weather events, crop and livestock productivity, pest and disease dynamics, and socio-economic consequences for food availability, access, utilization, and stability. Adaptation measures were analyzed across field-level practices, livestock management, integration of traditional knowledge with technical innovations, and institutional support mechanisms.

RESULTS AND DISCUSSION

Impacts of Climate Change on Agricultural Systems

The analysis indicates that climate change exerts significant and multidimensional impacts on agricultural systems worldwide. Rising average temperatures have been consistently associated with reduced crop yields, particularly for temperature-sensitive crops such as wheat, maize, and rice, especially in tropical and subtropical regions (IPCC, 2022). Heat stress negatively affects plant physiological processes, including photosynthesis and grain filling, while also reducing livestock productivity through decreased feed intake, fertility, and increased mortality rates (Rojas-Downing et al., 2017).

These climate-driven changes in agricultural systems directly translate into broader challenges for food security. Reduced crop yields, livestock productivity losses, and disruptions in cropping patterns compromise the availability and accessibility of food, while increased vulnerability of farming communities threatens both the stability and utilization of food supplies. Understanding these pathways is essential to link the biophysical impacts of climate change with the four interrelated dimensions of food security

Impacts From Climate Change Drivers on the Four Dimensions of Food Security

Climate change affects food security through multiple, interconnected mechanisms that influence the four core dimensions of food security: availability, access, utilisation, and stability. These mechanisms operate through changes in temperature, precipitation patterns, and the frequency and intensity of extreme weather events, with uneven impacts across regions, production systems, and socio-economic groups (FAO, 2018; IPCC, 2022).

Impacts on Food Availability

Climate-induced increases in temperature and the frequency of drought events reduce crop and livestock productivity by intensifying heat stress, degrading soil fertility, and accelerating land degradation. These impacts are particularly severe in countries where a large share of the population depends on agriculture for livelihoods and where food production systems rely heavily on rainfed agriculture and pastoral rangelands (FAO, 2018; Mbow et al., 2019). Reduced yields in these systems directly constrain food availability and increase vulnerability among both rural and urban poor populations. Extreme heat events further affect agricultural production by reducing crop productivity and, when combined with high humidity, significantly lowering agricultural labour capacity and animal performance. Countries and sectors dependent on outdoor manual agricultural labour in hot and humid climates are especially vulnerable to these impacts, as heat stress limits both working hours and labour efficiency (FAO, 2018).

Rising temperatures and changes in precipitation regimes also contribute to the expansion and geographic redistribution of crop and livestock pests and diseases. For example, pastoral communities in East Africa have experienced increased livestock morbidity and mortality due to Rift Valley fever outbreaks during El Niño years, highlighting the link between climate variability and animal health risks (Bebber, 2015; FAO, 2018).

In addition, higher temperatures and drought stress have increased post-harvest losses, particularly through the proliferation of mycotoxins in food and feed. These risks are most pronounced in tropical and subtropical regions where food safety surveillance and storage infrastructure are limited, further undermining food availability and quality (FAO, 2018).

Impacts on Food Access

Climate change affects food access primarily through its impacts on agricultural incomes, food prices, and food distribution systems. Increased droughts, floods, and pest outbreaks reduce agricultural yields and raise production costs, including those associated with water and pest management. As a result, smallholder farmers and pastoralists in low-income regions experience declining incomes and reduced ability to purchase sufficient and diverse foods (Saronga et al., 2016; FAO, 2018; Mbow et al., 2019).

The growing number and intensity of extreme weather events have also been linked to rising food prices and increased price volatility. Higher food prices disproportionately affect low-income consumers, particularly women and girls, often leading to reduced dietary diversity and lower overall food consumption (FAO, 2018; Ilboudo Nebie et al., 2021).

Extreme events such as floods disrupt food storage facilities, transportation networks, and market access, further constraining both physical and economic access to food. These impacts are especially severe in countries dependent on food imports, including Small

Island Developing States, as well as among poor households in flood-prone and saline regions, such as monocropped rice-growing areas in Bangladesh. (FAO, 2018; Algur et al., 2021).

Impacts on Food Utilisation (Food Quality and Safety)

Food utilisation is increasingly affected by climate change through impacts on food safety, nutritional quality, and dietary diversity. Rising temperatures promote the growth of microorganisms and increase contamination risks, including higher levels of mycotoxins in food and feed, particularly in countries with limited food safety monitoring and regulatory capacity (FAO, 2018; Mbow et al., 2019). Climate extremes also influence food affordability and consumption patterns. Fruits and vegetables often become relatively more expensive following climate shocks, making them less accessible compared to calorie-dense but nutrient-poor foods. Urban low-income households and rural households that rely primarily on food purchases are particularly affected, while children in regions such as West Africa face increased risks of reduced dietary diversity and undernutrition due to climate-driven food shortages (Niles et al., 2021).

Impacts on Food Stability

Climate change undermines food system stability by increasing variability in production, incomes, and food supply over time. The rising frequency and severity of droughts and heatwaves lead to recurrent production losses and disruptions to food transport systems, contributing to unstable food supplies, particularly in landlocked and low-income countries reliant on food imports (FAO, 2018; Algur et al., 2021).

Small-scale producers and fishers are especially vulnerable to climate-induced income instability, as droughts, floods, and rising temperatures increase the incidence of pests and diseases and reduce the reliability of agricultural and fisheries-based livelihoods (FAO, 2018). In some temperate regions, reduced frost and snow days may increase food stability by lengthening growing seasons and reducing frost-related crop losses. However, these potential benefits are often offset by heightened risks of pest and pathogen expansion, limiting long-term gains in food security (Ranasinghe et al., 2021).

Adaptive Strategies to Enhance Resilience and Sustainability: Climate Change Adaptation Strategies

Adaptation is widely recognized as the most effective strategy to minimize negative impacts on crop and livestock productivity and to maintain food security (Kamali et al., 2025). Agricultural adaptation involves deliberate actions to anticipate climate risks and modify farming practices, resource management, and infrastructure. The primary aim of adaptation is to increase societal and community resilience to climate-induced shocks (Ricart et al., 2019). Farmers adopt diverse strategies at the field level, including modifying crop areas, changing cropping patterns, adopting drought- or heat-tolerant varieties, adjusting planting calendars, and diversifying crop portfolios (Matewos, 2020). Water management is particularly critical for adaptation. Practices such as deepening wells, enhancing irrigation systems, storing water on-farm, and adopting micro-irrigation techniques help mitigate drought impacts and optimize water use (Srivastav et al., 2021).

In water-stressed regions, farmers often combine traditional knowledge with improved irrigation methods to cope with prolonged dry periods.

Livestock systems are also adapting to climate variability through strategies such as reducing herd sizes, modifying feed composition, providing supplementary feeding, and adjusting grazing schedules (Karimi et al., 2018). These absorptive measures allow farmers to buffer short-term climate shocks while maintaining production stability. Traditional agricultural practices, such as agroforestry, intercropping, crop rotation, cover cropping, organic composting, and integrated crop-livestock systems, remain foundational for adaptation. These approaches form part of Climate-Smart Agriculture (CSA), which combines productivity, adaptation, and mitigation objectives into a single framework (Singh and Singh, 2017). Integration of local knowledge with modern scientific tools enhances adaptive capacity. Indigenous knowledge provides critical insights into climate patterns and resource management, while technical tools, including climate forecasts and decision-support systems, assist farmers in making informed management decisions. In water-scarce areas, households often adopt agronomic adjustments such as reduced cultivation area, shortened irrigation furrows, and optimized fertilizer use to cope with water limitations (Srivastav et al., 2021).

Extension services, among others, influence adaptive capacity and thus play a pivotal role in educating farmers, disseminating climate information, promoting adaptive technologies, and connecting farmers to markets and input suppliers. Incorporating farmers' experiences into policy design enhances the effectiveness of adaptation strategies and reduces vulnerability to climate risks (Acevedo et al., 2020).

Adaptive Strategies for European Agriculture Under Climate Change

Europe is experiencing diverse impacts of climate change on agricultural systems, including rising temperatures, more frequent extreme weather events, altered precipitation patterns, and shifts in seasonal cycles (Hatfield et al., 2020). These changes have already led to yield losses, reduced cultivable area, and declining soil organic matter in several regions (FAO, 2018).

In northern Europe, Finland faces warmer, wetter winters and drier, hotter summers, with more frequent extreme events such as storms and heatwaves. These conditions have extended growing seasons and reduced snow cover but increased the risk of soil degradation (Himanen et al., 2016). Farmers have adopted intercropping systems, under-sowing cereals with perennial grasses, and using diverse forage mixtures to improve soil fertility and quality (Himanen et al., 2016). Similarly, in Scotland, projections indicate hotter, drier summers and wetter winters by 2100, challenging current crop growth while favouring new crop types. Adaptation strategies include rescheduling planting and harvesting, adopting climate-resilient crops, improving soil and pasture management, promoting farmer knowledge-sharing, establishing early warning systems, and optimizing fertiliser use (Jenkins et al., 2023).

Central and southern Europe also face significant challenges. Across the continent, rising temperatures and more frequent droughts have decreased crop yields and productivity, particularly in southern regions. Adaptive strategies commonly implemented include changes in crop rotations, improved irrigation management, and intensified fertiliser use, all aimed at sustaining production under increasingly stressful climatic conditions (De Leo et al., 2023). In France, farmers confront variable temperature, frost, and wind patterns, alongside more frequent heatwaves and droughts. Adaptation practices in French agriculture include cover crops, mulching, agroforestry, crop diversification, and climate-control technologies in tunnels, complemented by efficient irrigation systems (De Leo et al., 2023).

Mediterranean countries are particularly vulnerable. In Italy, recurring droughts, strong winds, floods, and pest pressures have resulted in annual crop losses of 10-40%, with extreme events causing cumulative economic damages of approximately €14 billion between 2009 and 2018. Adaptation measures encompass soil management, innovative breeding, crop protection, water management, digitization, and animal welfare improvements (De Leo et al., 2023). Greece and Cyprus face higher evapotranspiration rates and water scarcity, causing drought stress and reduced crop yields. Farmers respond with regulated irrigation, pruning, grafting, organic mulching, early sowing, intercropping with legumes, and the development of drought- and heat-tolerant crop varieties.

CONCLUSION

Climate change poses significant and multidimensional challenges to agricultural systems and food security worldwide, affecting crop and livestock productivity, pest and disease dynamics, and socio-economic conditions. The impacts are unevenly distributed, with vulnerable regions and communities facing the greatest risks, particularly those reliant on rainfed agriculture and smallholder farming. Effective adaptation requires a combination of field-level practices, traditional knowledge, technical innovations, and institutional support to enhance resilience and sustainability. Integrating these strategies can help safeguard food availability, access, utilization, and stability, ultimately supporting climate-resilient agricultural systems and sustainable development in the face of ongoing climatic changes.

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