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Review Article

Sustainable Agriculture: Solution For Climate-Induced Food Insecurity

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Abstract

Climate change is causing fluctuations in temperature and precipitation, posing a challenge to food security in the developing world. The projected increase in food demand due to population growth requires agricultural development. However, intensive agriculture has led to land degradation, water pollution, and greenhouse gas emissions. The challenge is to meet the growing demand for food in an environmentally and socially sustainable way. Climate change threatens agriculture through disruptions to crop production and livestock health. Sustainable agriculture promotes long-term cultivation and efficient resource use and is crucial for food security. Research, education, and technological applications are needed to improve sustainable agriculture. Technology, including traditional and emerging methods, can enhance sustainability in agriculture. Farmers are implementing alternative techniques to reduce chemical fertilizer use. As the population grows, sustainable intensification of agriculture is necessary. Small-scale agriculture can be developed through crop diversity, careful fertilizer application, and soil conservation. Resource conservation technologies are important for long-term agricultural viability. Research should focus on strategies that minimize disruption to natural habitats while increasing the environmental value of agricultural land. Government assistance is needed for poor countries to adopt sustainable agriculture methods.

Keywords: climate change; food security; agricultural development; intensive agriculture; environmental impact; sustainable agriculture

Introduction

Temperature and precipitation fluctuations in agriculture caused by climate change pose a grave threat to food security in developing nations. Given the anticipated global population of 9 billion by 2050, it is probable that food demand will increase at a higher rate than arable land area. To combat food insecurity, agricultural progress is necessary. Highyielding genotypes of staple cereals have been developed since the Green Revolution to combat starvation and encourage the consumption of monotonous meals deficient in bioavailable micronutrients and vitamins (Odeku, 2014). Over 43% of the Earth's land is devoted to agriculture, 87% is utilized for food crops, and 13% is devoted to nonfood crops. As a means of guaranteeing food security on scarce agricultural land, most nations have, at minimum, shifted from extensive to intensive agriculture. Conversely, as the relative growth rate decelerates, the global average yield of the principal food commodities rises linearly. The average agricultural product attains the biophysical yield potential limit, which is influenced by climate, water availability, and soil conditions. Without horizontal expansion (an increase in crop area), it would be challenging to satisfy future food demands if yield growth maintained its current trajectory (Akanwa et al., 2023). Severe environmental repercussions associated with intensive or conventional agricultural production systems

present an imminent threat to both agricultural sustainability and global food security. Intensive crop production has led to enhanced labour productivity and food production. Nevertheless, this progress has often come at the cost of detrimental environmental conditions, including soil degradation resulting from nutrient losses, depletion of freshwater resources, contamination of marine and waterways, and increased greenhouse gas (GHG) emissions. Furthermore, ecological resilience and biodiversity have been negatively impacted by these issues. Agriculture is a significant contributor to climate change—approximately one-third of all greenhouse gas emissions—and a highly vulnerable sector, which can impact food production and global food security (Chiawo and Otiende, 2021). Ensuring or sustaining optimal soil fertility and crop productivity is imperative for enhancing food security while J. Phys. Biomed. Biol. Sci. 2024; Volume, 3: 23 Ajmal et al., (2024) 2 minimizing environmental damage. Achieving a harmonious coexistence between extensive food production and preserving climate-resilient agricultural ecosystems is paramount. Implementing solutions that reduce environmental risk while maintaining food quality and integrity is necessary. A sustainable agricultural sector is essential for food security and is influenced by climate and food supply conditions for pasture and crop production (Saina et al., 2013). In recent decades, several developing nations have encountered difficulties due to urbanization, agricultural decline, fluctuating dietary preferences, and the instability of the global food market. Industrial agriculture significantly threatens agricultural ecological processes that influence food production. Ratified by the United Nations General Assembly in 2015, Sustainable Development Goal (SDG2) "Zero Hunger" aims to tackle worldwide food security and environmental sustainability issues. Adopting environmentally conscious and sustainable agricultural practices has the potential to mitigate malnutrition while concurrently enhancing food security, farmer output, and nutritional variety. The article emphasises the knowledge gap and discusses future research trends concerning implementing sustainable agriculture technologies (Das and Ansari, 2021).

Food Demand

The rising global population and increasing per capita incomes drive crop demand, which is expected to continue for decades. However, agriculture already harms the environment, including habitat fragmentation and land clearing that threaten biodiversity. Meeting the increased food production required to meet this demand may involve land clearing and more intensive use of currently planted lands. Still, the environmental consequences of these approaches are unknown. Additionally, agriculture contributes to greenhouse gas emissions and negatively affects ecosystems. Significant modifications are needed to address these challenges in how food is produced, stored, processed, distributed, and made accessible. However, these modifications will be limited by Earth's limited resources (Gonzalez, 2011). Impact of climate change on food production and consumption: Climate change, a consequence of anthropogenic activities including deforestation, industrial pollution, and greenhouse gas emissions, poses a severe threat to agriculture. Immediate effects include disruptions to crop production systems, livestock health, and trade balance in food and food products. The potential consequences of global climate change on agricultural productivity during the latter part of the twenty-first century could indirectly and directly impact all four facets of food security (Ghosh, 2019). Increased atmospheric CO2 levels and global temperatures will impact plant growth, yields, regional precipitation patterns, water availability, soil erosion, and fertility. Concerning the combined effects of these changes, there is still considerable uncertainty, especially concerning the potential occurrence of drought in tropical regions. The anticipated impact of climate change on agricultural crop productivity is a scarcity of land by 2050. The effects of climate change on agriculture and food production are extensive. They may manifest themselves directly or indirectly via alterations in agroecological conditions, impacts on agricultural product demand, or revenue growth. Land suitability and crop yields will be impacted by the persistent temperature and precipitation fluctuations brought about by greenhouse gas emissions (Amoak et al., 2022). The potential for a self-perpetuating cycle wherein infectious diseases intensify or cause hunger, thereby increasing the vulnerability of affected populations to further infections, reducing labour productivity, heightened poverty, and potentially fatalities, renders climate change and food security significant issues. Sustainable agriculture and its effectiveness Sustainable agriculture promotes long-term cultivation and more effective use of limited resources. It is an environmentally conscious approach to resource management. Governments and other institutions may work with farmers to produce solutions for the world's growing population because regionalization is more practical. Crop rotation, strategic sowing, and organic herbicides and fertilizers are methods used in sustainable agriculture. Biotechnology has no negative consequences for people, animals, or plants (Hossain et al., 2023). A state of balance between inputs like recycled water, fertilizer, and soil and yield is attained by sustainable agriculture. Foods consumed by humans and those produced on a sustainable farm are considered edible. Enhancing agricultural productivity aids in the preservation of plant and animal species. Sustainable agriculture uses the resources found in the land and climate to produce food that protects the environment's fertility for future generations (Khalid et al., 2021). Research, education, and technological applications are necessary for continuous development and improvement of this approach. Numerous parties are involved. These include governmental agencies, farmers, consumers, impact investors, nonprofit organizations, local communities, and organizations promoting sustainable agriculture. Another way to ensure sustainability is to include the corporate sector in creating more sustainable agriculture methods through fundraising and donations. Water recycling is a simple strategy that local producers can use to improve food production while conserving water (Mukwada et al., 2020). Management of Land for Sustainable Agriculture Environmental protection and provisions for a global population expected to surpass nine billion by 2050 are two of the most urgent challenges facing agriculture on an international scale. To mitigate concerns regarding food security, sustainable J. Phys. Biomed. Biol. Sci. 2024; Volume, 3: 23 Ajmal et al., (2024) 3 agriculture methodologies must consider the interplay between environmental and economic factors. Nonetheless, due to unsustainable land management, agricultural land has been lost to desertification, salinization, urbanization, and soil erosion. The fundamental objective of research on sustainable land management is to enhance comprehension of the intricate connections between economic, environmental, and social determinants that impact the management of natural resources and land utilization (Ngachan and Das, 2018). The objectives of environmentally and financially sustainable agriculture are the conservation of soil fertility, increased agricultural output, and stability. Adapted, high-yielding cultivar selection, crop protection techniques, fertilizer and water management tailored to the site and season are all viable management approaches. Because doing so during a single growing cycle is impractical, the effects of these strategies must be assessed on a diverse range of commodities (Khalid and Amjad, 2022). Crop rotation is essential to a comprehensive resource conservation and sustainable agriculture strategy. By utilizing soil's physical, chemical, and biological properties, it is possible to predict the immediate and prolonged consequences of a specific cultivation cycle and its management techniques. Selected crop rotation increases the environmental friendliness of an agricultural system (Okafor et al., 2023). Technologies for Increasing Sustainable Agricultural Sustainability in agriculture refers to an agroecosystem's capacity to maintain a constant production level over a long time. Stability under sitespecific environmental and economic constraints is essential to sustainability and can only be addressed individually. A large part of agriculture's stability and productivity will surely depend on how quickly emerging technologies are developed and innovated (Hutchins and Gehring 1993).

The traditional definition of technology includes developing and applying crop types, pesticides, fertilizers, and agricultural instruments. However, technology includes a range of innovations, including the application of synthetic pesticides, the development of genetically modified crops that improve nutritional efficiency (e.g., yield or calories per yield), and the implementation of farm management strategies that prioritize overall farm productivity over yearly production per hectare (Garcia, 2015). Regarding agriculture, Indian farmers can use a wide range of onfarm management techniques. The importance of these agricultural approaches is especially highlighted in semi-arid regions, where some Indian states have already adopted intensive farming using irrigation water from aquifers and channels (Mutengwa et al., 2023). If these methods are applied consistently, the water requirements of established crops may gradually decline, and the primary productivity of the cultivated area may rise. Indian farmers are gradually implementing alternative techniques, including crop rotation, mulching, organic manure, vermin-culture practices, crop rotation, and biopest management, to reduce their use of chemical fertilizers. In addition to increasing the soil's nutrients, organic manure can help restore the soil's texture and structure and improve its capacity to hold onto moisture. Indian farmers can employ management strategies like mulching to lower soil surface transpiration and improve irrigation water use efficiency (Alotaibi, 2023). Knowledge gaps and future trends By 2050, the world's population will have grown by 25%, putting more pressure on farmers to boost yields and production to ensure enough food for everyone. Climate change worsens this problem by boosting competition for natural resources, greenhouse gas emissions, land degradation, and deforestation. To enhance yields while lowering costs to the environment and the economy, sustainable intensification of agriculture will require multidisciplinary research focusing on the highly efficient use of inputs like energy, water, and nutrients (ÖZEKAN and AKAN, 2023). Sustainable smallscale agriculture is simple to develop through crop diversity, carefully applying fertilizers, and conserving soil with trash and leftovers. Large-scale application of these technologies is made more difficult by the paucity of research on the viability of their deployment in production systems and the evaluation of their environmental impact (Nagoda, 2015). Because so many countries rely on agricultural imports to meet their food needs, research and development goals are significantly impacted by global markets' availability and cost of commodities. Researchers should investigate unique research approaches and technologies that provide improved output with low environmental effects, high resource efficiency, and fewer inputs when applied to a specific crop, soil, and environment (Baptista et al., 2022). By maintaining soil health and production, resource conservation technologies are essential to guaranteeing the long-term viability of agricultural harvests. Intensive agricultural techniques, which involve frequent crop rotations and the degradation of natural ecosystems, have decreased biodiversity (Erezi et al.). Research should be directed towards agricultural strategies that minimize disruption to and conversion of natural habitats while increasing the environmental value of agricultural land. Furthermore, studies on land use patterns in space should maximize trade-offs and synergies between various variables. Government assistance and initiative are needed for poor countries to adopt sustainable agriculture methods.

Conclusion

In conclusion, climate change and the growing global population pose significant food security and agricultural sustainability challenges. The current agricultural practices, such as intensive farming, have J. Phys. Biomed. Biol. Sci. 2024; Volume, 3: 23 Ajmal et al., (2024) 4 led to land degradation, pollution, and biodiversity loss. Sustainable agriculture practices, including crop rotation, organic farming, and resource conservation, are crucial to address these issues. Technology, such as genetically modified crops and farm management strategies, can contribute to sustainability. However, more research is needed to assess these technologies' viability and environmental impact. Additionally, government support is necessary to promote sustainable agriculture in developing countries. A multidisciplinary approach and stakeholder collaboration are essential to ensure long-term food security and environmental preservation.

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