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Review

Vital Crisis, Causes, Problems and Solutions for Sustainable Agriculture

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Abstract

Global agricultural systems face a deep-seated sustainability crisis due to the combined dynamics of environmental degradation, resource depletion, socio-economic instability, and institutional constraints. Growing demand to increase food production under climate variability, soil health decline, water shortage, and land-use competition has exacerbated vulnerability in both natural ecosystems and farming communities. This article systematically explores the root causes behind the crucial crisis in sustainable agriculture: yield stagnation, nitrogen dependency, land demand expansion, dietary transition, food loss and waste, inequitable distribution of food, and the eventual externalization of environmental costs. Special emphasis is put on emerging challenges in agrarian economies in developing countries, where farmer distress and production risks are compounded by climate change, market volatility, and policy inefficiency. Conceptual frameworks, along with empirical evidence, are used for assessing multi-dimensional management options: agroecological intensification, soil and nutrient stewardship, biodiversity-based land management, climate-resilient water usage, and food system transformation. The analysis underscores that transiting towards sustainable agriculture necessitates coordination in three main areas of intervention: production, consumption, and governance. Strengthening institutional support, aligning policies with ecological limits, and resource-efficient farming systems are all critical options for a long-term food security, environmental sustainability, and socio-economic resilience.

Keywords: Sustainable Agriculture, Climate Resilience, Agroecological Intensification, Food System Transformation and Resource-Efficient Farming.

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Introduction

The largest industry in the world is agriculture. It produces more than $1.3 trillion worth of food annually and employs over a billion people. Approximately half of the Earth's livable land is made up of pasture and cropland, which serve as both food and habitat for numerous species.

Critical habitats can be preserved and restored, watersheds can be protected and soil and water quality can be enhanced when agricultural operations are managed sustainably. However, unsustainable behaviors have detrimental effects on both the environment and people. Sustainable resource management is becoming more and more important. As the world's population increases, so does the need for agricultural products. One of the most crucial areas for conservation worldwide is agriculture because of its close relationships to human communities, the global economy and biodiversity.

What is the vital crisis, causes and problems for sustainable agriculture?

The shift from conventional to organic, greener or more sustainable agriculture is expected to provide a number of closely related major difficulties. Some of those crises were identified. Among all the possible challenges we highlight the following:

Maintaining yields: Following the 2007 and 2008 agricultural commodity price inflation, the idea of "food security" emerged as a pressing geopolitical concern once more. Two important ideas from the FAO Rome Summit on World Food Security were emphasized: in order to feed the world's nine billion inhabitants, food production must quadruple by 2050 and rise by 50% by 2030 (Maye and Kirwan, 2013). Despite the fact that this number was subsequently adjusted to 70%, there was a lot of uncertainty and assumption surrounding the estimations (Tomlinson, 2013). This problem is connected to many of the solutions that have been explored. For example, organic farming has a direct impact on soil health, biodiversity, and food safety.

Nitrogen requirements: The use of inorganic fertilizers is one of the primary barriers to organic agriculture, making it difficult to provide an appropriate supply of nitrogen (Muller *et al.*, 2017). In order to make up for this, legume rotations are frequently utilized for biological nitrogen fixation, which supplies nitrogen for the growth of non-legume crops either in situ or through imported manure. This suggests that there is less space available for the primary crops, which lowers organic agriculture's overall productivity in comparison to conventional agriculture.

Land demand: More land is required to produce the same quantity of yield if we believe that organic agriculture yields less (Muller *et al.*, 2017). Considering the legume rotations for N in order to achieve the same yield as with traditional agriculture, fixation requires 1.6 units of more area for every unit of conventional land (Connor, 2018). However, increasing arable land is not a practical way to lessen conventional agriculture's negative environmental effects. Changes in land use to increase agricultural land, such as turning wetlands, grasslands, or forests into arable land, result in the loss of ecosystem services (biodiversity, water control, sequestered carbon in soil and plants, etc.) as well as products (timber, fiber, energy, etc.). Considering the numerous environmental obstacles and problems (such as the growing competition for land from other human activities, the significance of the ecological functions of unfarmed land, expanding agricultural land is not viewed as an ecologically sound or practical solution due to the deterioration of large regions caused by unsustainable land management methods and the detrimental effects of agriculture on biodiversity (Bernard and Lux, 2017). More land could be set aside for organic agriculture for human consumption if the production and consumption of animal products were decreased along with the amount of food-competing feed from arable land. Therefore, a well-designed food system with more area devoted to organic agriculture, fewer animals and their food consumption, and less food waste must be addressed in order to feed the world's population in a sustainable manner by 2050 (Muller *et al.*, 2017). This challenge relates to efforts to reduce waste, produce food sustainably, and maintain land in a healthy natural state.

Dietary Changes: A method for more sustainable food systems based on the rational use of natural resources, decreased environmental consequences, and protection of human health is to lower the average demand for animal products worldwide and their proportion in human diets (Muller *et al.*, 2017). But dietary adjustments are insufficient to sustainable food systems. To maintain food systems within the limits of the planet, efforts must be made to reduce food waste and losses as well as adjustments to crop production and livestock (Westhoek *et al.*, 2021). A promising component of the solution for more sustainable agricultural output, food supply, and consumption is organic agriculture in conjunction with fewer animals used in livestock production and less food-competing feed requirements. Except for Cyprus, Finland, Ireland, Slovenia, Spain, and Iceland, the majority of European nations saw a significant decline in cattle between 1990 and 2019 (average of −28%) (Environmental Agency of Europe, 2021). According to model estimates, if relatively modest diets are adopted, organic agriculture could likely feed the world's 9.2 billion people by 2050 b Additionally, as eating and production are related, agriculture must be nutrition sensitive, not just concentrate on a small number of species, and address nutritional deficiencies in order to combat obesity and hunger. (Pretty and Bharucha, 2014). Because producing fruits and vegetables requires less land and more inputs, high-quality meals result in less farmland waste but more agricultural inputs in the form of water, fertilizer, and pesticides (Conrad *et al.*, 2018). This suggests that the association between high-quality meals and more effective use of agricultural inputs needs to be reversed. As previously mentioned, legumes can aid in this situation by supplying N to soils and guaranteeing a diet high in protein **(**Cusworth *et al.*, 2021). Action areas are connected to this challenge.

Food waste: There are several causes that relate to food waste in relation to the food industry like processing problems and also lack of appropriate planning. Food consumption patterns also play a key role for sustainable agriculture with regard to food wastage. According to (Conrad *et al.* 2018), the average US consumer produces a food waste equivalent to 30% of the calories available for consumption per day, a quarter of the daily food available for consumption, and 7% of annual cropland. Of the approximately one-third of the food produced globally that is not consumed, about 14% corresponds to postharvest loss. This is a practice mainly used in relatively rich countries to control market prices and prevent prices from falling below production costs. This practice has a high environmental impact because of the depletion of natural resources, which finally do not contribute to the market, often produced unsustainably using large amounts of water, nutrients, and agrochemicals. According to the United Nations Environment Programme, in 2021 a recent study estimated that 931 million of tonnes of food waste were produced in 2019 globally, of which 61% came from households, 26% from food services and 13% from retail.

Distribution and access to food: Apart from production, distribution and access to food are two key aspects to feed the world population. This to give people a broader understanding of solutions to prevent hunger, although it is not widely recognized, food is not included in the framing of food security, but this will be specific to the production side (Tomlinson, 2013). (Beckman *et al.* (2020) have forecasted that there will be people more compared to no adoption scenarios) following the adoption of agricultural input reductions proposed in the F2F strategy owing to higher commodity prices and reduced income reduction of trade), especially in Africa. However, this analysis only takes into account reductions in agricultural inputs, disregarding other measures to incentivize better food distribution and changing patterns of consumption that can lead to less food insecurity and more jobs and income. This issue is connected to the action areas.

Externalities: The threat of externalizing the damages caused by extensive agricultural practices to various countries is arguably the greatest threat associated with agricultural practices that are linked to the Green Deal, as cited by (Fuchs *et al.,* 2020). According to the authors, the EU member state is putting itself at a great threat of externalizing ecological damages to other countries, while taking the credit for green policies at home. For example, (Fuchs *et al.,* 2020) describes a situation where, unlike in the European Union, pesticide and herbicide use, and deforestation are more common in several countries outside the EU that supply oilseeds to the region. The EU recognizes the risk of externalities in the F2F strategy, in recognition of an appropriate accompanying EU food system that and the implementation of the necessary policies to enhance the raising of standards regarding the environment and social productions, which must be avoided.

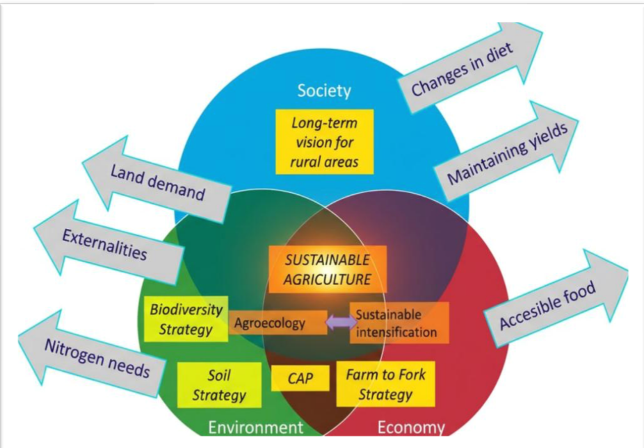

Fig 2. Conceptual framework illustrating the vital crisis in sustainable agriculture

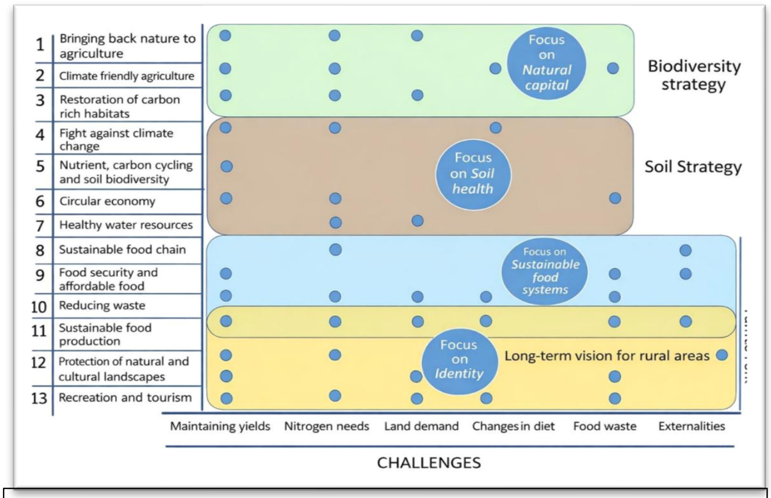

Fig 3. Overview of the relation between the main identified crisis and the 13 action areas of the four studied strategies.

Climate Change and Environmental Degradation: Climate change is a major problem confronting Indian agricultural activities presently. Harmering weather, increasing temperatures, and weather disturbances are causing havoc with the yield of crops and agricultural produce. An unsteady season for growth, pest infestations, and diseases are plaguing the minds of agricultural workers, devoted to the produce of this earth. Additionally, environmental degradation leads to the exacerbation of climate change, affecting agricultural activities adversely. Deforestation, or the clearing of forests, soil erosion, or the wearing away of soil, as well as the depletion, or the reduction in quantity, of natural resources, negatively influence the already vulnerable agricultural ecosystem negatively, owing to the improper unregulated use of fertilizers and pesticides.

Water scarcity and Irrigation Challenges: Water scarcity is the major problem Indian agriculture is facing today, coupled with deteriorating levels of groundwater and inefficient methods of irrigation. Due to the over-exploitation of underground water reserves without the appropriate infrastructure being developed for water management, large-scale water scarcity in farming areas has occurred. Most of the conventional irrigation techniques, like flood irrigation, are either not operational or very ineffective and inefficient. Due to this, equitable distribution of water is highly unequal, and the water-use efficiency remains abysmally low. The extensive area under coarse cereals cultivation further exacerbates the pressure on the already strained water resource base, aggravating the situation of water scarcity.

Market fluctuations and Price Volatility: There exist major challenges that Indian farmers face in the form of market fluctuations and price volatility, which have a direct bearing on the economic sustainability of the Indian farming sector. The volatility in the prices of commodities, coupled with the lack of adequate infrastructure in the markets and inefficient supply chains, makes the Indian farming sector more susceptible to challenges. In addition, the lack of transparent mechanisms in the determination of the prices of goods and the involvement of intermediaries in the markets pose greater challenges to the Indian farming sector. There exists the challenge of distortions in the market, as evidenced by the act of price manipulation and the act of hoarding the products of the Indian farming sector.

Policy Inadequacies and Institutional Reforms: The expansion and development of the Indian agricultural industry are restricted because of policy inadequacies and institutional barriers. The execution of effective crisis management techniques and agricultural innovation and modernization face challenges in consideration of outdated agricultural policies, bureaucratic inefficiencies, and fragmented government structures. Also, inadequate and insignificant changes in land reforms and accessibility of institutionalized credit facilities limit the potential of Indian farmers to effectively invest in modern agricultural technologies and adopt sustainable agriculture. The lack of changes and opposition to institutionalized reforms are responsible for sustaining the status quo and increasing the problems and challenges faced by Indian agriculture.

Management Strategies and Solutions for Sustainable Agriculture

Addressing the vital crisis in sustainable agriculture requires an integrated and multi-dimensional management approach that simultaneously considers societal needs, environmental protection and economic viability, as illustrated in the conceptual framework (Fig. 2). The solutions must focus on reducing negative externalities, improving resource-use efficiency and ensuring food security under changing climatic and socio-economic conditions.

Adoption of Agroecological Practices: Agroecology represents a key management strategy to overcome the environmental and productivity-related crisis in agriculture. Practices such as crop diversification, intercropping, crop rotation, use of legumes for biological nitrogen fixation, integrated pest management and organic amendments improve soil health, enhance biodiversity and reduce dependence on synthetic inputs. By strengthening natural ecosystem processes, agroecology helps maintain yields while minimizing environmental degradation.

Sustainable Intensification: Sustainable intensification aims to increase agricultural productivity on existing farmland while reducing environmental impacts. This strategy focuses on improving nutrient-use efficiency, precision farming, climate-resilient crop varieties and optimized water management. Sustainable intensification addresses the challenge of maintaining yields without expanding agricultural land, thereby preventing deforestation and loss of ecosystem services.

Soil Health and Nutrient Management Strategies: Improving soil health is central to sustainable agriculture. Soil management strategies include conservation tillage, organic matter recycling, balanced fertilization and site-specific nutrient management. Efficient nitrogen management through legume-based systems and integrated nutrient management reduces nitrogen losses, greenhouse gas emissions and water pollution, while maintaining soil fertility and crop productivity.

Biodiversity Conservation and Land Management: The Biodiversity Strategy plays a crucial role in managing the crisis caused by land demand and ecosystem degradation. Conserving semi-natural habitats, promoting agroforestry systems and protecting unfarmed land enhance ecosystem services such as pollination, pest regulation and carbon sequestration. Sustainable land-use planning prevents the conversion of forests, wetlands and grasslands into agricultural land.

Sustainable Food Systems and Dietary Shifts: Changes in diet and food consumption patterns are essential components of sustainable agriculture management. Reducing the consumption of animal-based products, promoting plant-based diets and increasing the use of legumes contribute to lower land, water and nitrogen requirements. Nutrition-sensitive agriculture ensures dietary diversity while reducing pressure on natural resources.

Reduction of Food Waste and Losses: Food waste reduction is a cost-effective solution to improve food availability without increasing production. Improving post-harvest storage, transportation, processing infrastructure and consumer awareness can significantly reduce food losses. Efficient food systems ensure better utilization of resources used in food production and reduce environmental externalities.

Improved Distribution, Access and Market Stability: Ensuring equitable food distribution and access is as important as increasing production. Strengthening supply chains, improving market infrastructure, reducing price volatility and minimizing the role of intermediaries enhance farmers' income security. Policies supporting fair trade, local food systems and rural livelihoods improve economic sustainability.

Climate-Resilient and Water-Smart Agriculture: Climate-smart agricultural practices such as drought-tolerant crop varieties, water-efficient irrigation methods (drip and sprinkler irrigation), rainwater harvesting and groundwater regulation help address climate change and water scarcity challenges. Efficient water management increases water-use efficiency and resilience to climatic variability.

Policy Support and Institutional Reforms: Effective implementation of sustainable agriculture requires strong policy frameworks and institutional support. Strategies such as the Farm to Fork Strategy, Soil Strategy, Biodiversity Strategy and Common Agricultural Policy provide incentives for environmentally friendly practices while supporting farmers economically. Institutional reforms, access to credit, extension services and technology adoption are critical for large-scale transition towards sustainability.

Fig.4 : Multi-dimensional management strategies addressing the vital crisis in sustainable agriculture

Conclusion

The vital crisis in sustainable agriculture encompasses the interrelationship between declining soil quality, inefficient nutrient and water utilization patterns, increased demand for arable land, changes in climatic patterns, and socio-economic factors. Concerns around nitrogen reliance, declining productivity in organic and conventional low-intensity systems, food losses, dietary pressure, and equitable food distribution add to the area of pressure on already stressed agricultural and natural resource systems. From the above discussion, it is made apparent that production-oriented strategies are not sufficient in achieving a more sustainable agriculture. Alternatively, integrated approach strategies encompassing agro-ecology, sustainable intensification techniques, soil and nutrient management practices, biodiversity conservation efforts, climatic and water-relate efficiencies in agriculture, and food system transformations are essential in producing a holistic and sustainable agriculture.

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