Reconfiguring Food Systems for Food Security- Synergies among Productivity Enhancement, Supply Chain Efficiency and Farmer Income Growth: A Review

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ABSTRACT

Ensuring food security continues to be a major global challenge, driven by rapid population growth, climate change, declining natural resources and socio-economic disparities that affect sustainable food production and access. Recent reports suggest that over 733 million people suffered from undernourishment in 2023, highlighting the urgent requirement for resilient and sustainable agri-food systems. This review evaluates crop yield optimization and post-harvest loss reduction as two complementary strategies for strengthening food security at global and national levels, with particular reference to India. It examines recent developments in sustainable agronomic practices, improved crop genotypes, precision agriculture, integrated nutrient and water management, diversified farming systems and climate-resilient technologies that enhance productivity while maintaining ecological balance. The review also examines the magnitude and underlying causes of post-harvest losses, while highlighting improved storage, processing and distribution strategies that can increase food availability and affordability. A systems-based approach integrating technological innovation, sustainable resource management and policy support is essential for long-term food and nutritional security.

Key words: Climate resilience, Crop yield optimization, Food security, Post-harvest loss reduction, Sustainable agriculture.

Food security is regarded as one of the most critical developmental challenges in the modern world. It exists when all individuals, at all times, have physical, social and economic access to adequate, safe and nutritious food that fulfils their dietary requirements and food preferences for maintaining an active and healthy life Food and Agriculture Organization (FAO, 2002). The seriousness of this challenge is increasing as the global population is expected to reach 9.7 billion by 2050, demanding nearly a 60-70% rise in agricultural production over current levels Food and Agriculture Organization (FAO, 2009). However, the ability of global agri-food systems to satisfy this growing demand is being progressively limited by climate change, degradation of land and water resources, declining soil fertility, loss of biodiversity and widening socio-economic inequalities (Saleem *et al*., 2024).

Recent global assessments indicate that hunger and food insecurity have remained persistently high in the post-pandemic period. In 2023, nearly 733 million people across the world suffered from undernourishment, accounting for about 9.1% of the world population, with Africa recording the highest prevalence and Asia contributing the largest absolute number of affected people (FAO, 2024). At the same time, the world is confronting a dual burden of increasing obesity, micronutrient malnutrition and diet-related non-communicable diseases, emphasizing the necessity for food systems that provide not only adequate caloric intake but also improved nutritional quality and dietary diversity (FAO, 2024). These challenges are further compounded by increasing frequency of extreme weather events, such as droughts, floods and heat waves, which disrupt crop production, destabilize food supply chains and intensify vulnerability among smallholder farmers.

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Agriculture remains the backbone of food security, particularly in developing economies. It provides livelihoods for nearly 40% of the global workforce and contributes approximately one-quarter of global economic output (World Bank, 2025). In India, agriculture serves as the primary source of livelihood for more than half of the population and plays a vital role in maintaining national food and nutritional security. Despite substantial progress in foodgrain production since the green revolution, India continues to face serious challenges related to malnutrition, hunger and dietary imbalance. India ranks

111th among 125 countries in the Global Hunger Index, reflecting a serious level of hunger in the country, with pronounced regional disparities in food availability, child nutrition and access to affordable healthy diets (Concern Worldwide and Welthungerhilfe, 2024; NITI Aayog, 2024).

Ensuring future food security requires more than merely expanding cultivated area. Expansion of agriculture into fragile ecosystems has already led to severe environmental costs, including deforestation, emission of greenhouse gases and decline in ecosystem services. Therefore, sustainable intensification producing more food from existing land while minimizing environmental damage has emerged as a key approach to addressing the increasing demand for food (Foley *et al*., 2011). In this context, crop yield optimization through improved varieties, efficient resource management, precision agriculture and diversified farming systems offers significant potential to increase production while conserving natural resources.

Post-harvest losses continue to be a significant challenge to food security, with almost one-third of the world's food production being lost throughout the supply chain, particularly in developing nations where storage, processing, transportation and market infrastructure are insufficient (FAO, 2011; FAO, 2019; Mutungi *et al*., 2023; Nath *et al*., 2024).

These losses represent not only wasted food but also squandered land, water, energy and labour resources. Reducing post-harvest losses, therefore, is equivalent to expanding food supply without further stressing natural ecosystems.

This review critically examines the dual strategy of crop yield optimization and post-harvest loss reduction as an integrated pathway for achieving sustainable food security. It synthesizes current scientific evidence on agronomic innovations, sustainable farming practices, advanced post-harvest technologies and supportive policy frameworks, with particular emphasis on the Indian context. By integrating productivity enhancement with efficient food system management, this review proposes a comprehensive framework for building resilient, climate-smart and nutrition-sensitive agri-food systems capable of meeting present and future food security challenges.

Conceptual framework and dimensions of food security

Food security is a broad and multidimensional concept that goes beyond mere food availability. According to the Food and Agriculture Organization, food security is achieved only when all people continuously have sufficient availability, access, utilization and stability of food (FAO, 2008). These four interconnected dimensions shown Fig 1, form the basic framework for understanding food security at the global, national, household and individual levels.

Shakeel *et al.* (2012) highlighted that the assessment of food security often lacks precision, which affects the understanding of food availability within a specific timeframe and location for the population's consumption. This availability is determined by either local agricultural output or imports from regions with excess supply. Food availability denotes the actual existence of food within a particular region and time period, either through domestic agricultural production or related sectors, while taking into account available technologies, stock levels and both domestic and international trade, including commercial imports and food aid. This dimension primarily focuses on food production (ADB, 2012). Food accessibility refers to the ability of individuals to obtain adequate food through production, stored reserves, purchases, gifts, borrowing and assistance programmes. It is strongly associated with people's capacity to access food by producing it themselves, purchasing it, or receiving it through transfers. Therefore, this component of food security is closely linked with the economic strength of the population to afford sufficient food for survival. Food stability represents the regular and sustained availability of food within domestic markets, thereby supporting nutritional security. It also considers the impact of natural disasters such as floods and droughts

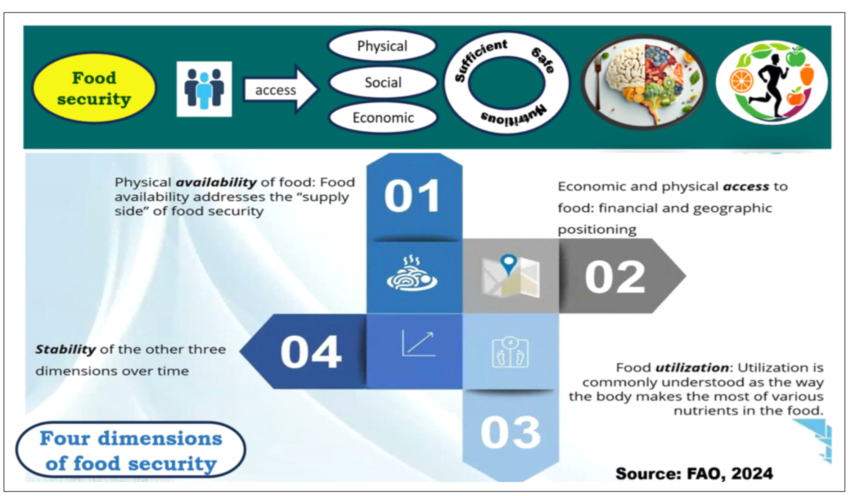

Fig 1: Dimensions of food security.

on agricultural production, with emphasis on ensuring a continuous balance between food supply and demand for food grains. Food utilization emphasizes proper food safety, preservation of nutrients during processing and cooking and the overall health and sanitation conditions of the population Food and Agriculture Organization (FAO, 2009).

Nutritional security and dietary requirements

Food security is inseparable from nutritional security. A balanced diet must provide adequate energy, protein, fats, carbohydrates, vitamins and minerals to sustain human health. As reported by the ICMR, (2024) diversified diets including cereals, pulses, vegetables, fruits, dairy, nuts and oils are essential for meeting daily nutrient requirements. Promotion of nutrient-rich crops such as millets, pulses and horticultural produce not only improves dietary quality but also strengthens farm income and resilience.

Global and indian scenario of food and nutrition security

Global food and nutrition security

Although considerable advancements have been achieved in agricultural production during the last five decades, global food and nutritional security continue to remain vulnerable. Recent estimates indicate that global hunger has stagnated at alarmingly high levelsIn 2023, nearly 733 million people across the globe suffered from undernourishment, accounting for about 9.1% of the world's population, which was an increase of 152 million people compared to 2019 (FAO, 2024). The impact of hunger is not evenly distributed, as Asia contributes the highest absolute number of undernourished individuals, whereas Africa exhibits the greatest prevalence of hunger. Additionally, women consistently experience higher levels of moderate to severe food insecurity than men across all regions, reflecting persistent gender inequalities in access to resources and nutrition (FAO, 2024).

Beyond calorie insufficiency, the global food system faces an escalating nutrition crisis. More than one in four adults in the Americas, Europe and Oceania were classified as obese in 2022, while micronutrient deficiencies continue to affect billions of people worldwide. These trends reveal a shift toward unhealthy, energy-dense but nutrient-poor diets, further complicating efforts to achieve comprehensive food and nutrition security (FAO, 2024). Meanwhile, climate change, conflict, economic instability and supply chain disruptions have intensified vulnerability across food systems, particularly in low-income and conflict-affected countries.

Sustainability challenges in global agriculture

The global agricultural sector has expanded substantially in economic terms, with real agricultural value reaching USD 3.8 trillion in 2022 an 89% increase since 2000 (FAO, 2024). Worldwide crop production reached 9.6 billion tonnes in 2022, mainly supported by major staple crops including rice, wheat, maize and sugarcane. However, this growth has been accompanied by intensifying environmental pressures. Fertilizer use increased by 37% between 2000 and 2022, pesticide use by 70% and greenhouse gas emissions from agrifood systems rose by 10% during the same period, with livestock accounting for more than half of farm-gate emissions (FAO, 2024). These trends pose serious risks to the long-term sustainability of food production and emphasize the urgent need to shift toward climate-smart and resource-efficient farming systems.

Indian food and nutrition security landscape

India presents a complex food security paradox, as it is among the world's leading producers of food grains while still facing extensive hunger and malnutrition. India ranks 105th among 121 countries in the Global Hunger Index, with a score of 27.3, reflecting a serious hunger condition in the country. Around 13.7% of the population continues to suffer from undernourishment, while 35.5% of children below five years are stunted, 18.7% are affected by wasting and more than half of pregnant women suffer from anaemia (IFPRI, 2024; NITI Aayog, 2024).

Economic access to nutritious food remains a major barrier. The estimated cost of maintaining a healthy diet in India is around ₹ 310 per day, yet nearly three-fourths of the population are unable to afford this level of expenditure. Food inflation has further intensified household vulnerability, rising from 7.5% to 8.4% in 2025 (NITI Aayog, 2024). Significant interstate disparities persist, with states such as Kerala, Punjab and Mizoram performing relatively better in hunger reduction, while Bihar, Jharkhand, Madhya Pradesh and Uttar Pradesh exhibit severe nutritional deficits.

Production trends and future demand

India's total foodgrain production reached 276 million tonnes in 2019-20, exceeding domestic demand and generating surpluses in rice and wheat. However, future projections indicate rising demand driven by population growth, dietary diversification and urbanization. Foodgrain demand is projected to reach 326-334 million tonnes by 2030-31 and 402-437 million tonnes by 2047-48. Pulses and nutri-cereals remain in deficit, with production failing to keep pace with demand growth, emphasizing the need for strategic crop diversification and yield enhancement.

Agriculture and food security

Fig 2 illustrates that poverty is influenced by a combination of climatic factors, socio-economic variables, and demographic/infrastructural conditions, which directly affect agricultural productivity and food security. Higher agricultural productivity and improved food security through enhanced availability, accessibility, utilization, and stability of food contribute to poverty reduction, while adverse climatic conditions and poor infrastructure can exacerbate food insecurity and poverty. This highlights the interconnected role of agricultural development and food security in improving rural livelihoods and reducing poverty (Kumar and Sharma, 2013). Agriculture plays a crucial role in ensuring food security, especially in developing countries where it serves as a major source of food and livelihood for a large section of the population. In India, agriculture ss food and nutritional security, contributing significantly to the GDP and rural employment. Globally, agriculture contributes substantially to economic output and employment, with about one-fourth of the economic output and 40% of the workforce engaged in agricultural activities. The sector's significance is highlighted by its provision of food and livelihood, especially in countries like India where over half the population depends on agriculture either directly or indirectly (Gulati and Juneja, 2022; Sirilakshmi *et al*., 2025).

The Indian agricultural sector has experienced significant structural transformation over the years, recording an average annual growth rate of 3.2% between 1980-81 and 2019-20. It supports nearly 1.38 billion people and contributes around 16.5% to the national GDP. In spite of challenges such as shrinking landholdings, climate variability and limited natural resources, agriculture continues to serve as the foundation of food and nutritional security in India (Singh *et al*., 2024; Sirilakshmi *et al*., 2025).

Hence, agriculture's centrality to economic output, employment and food security is well established globally and especially in developing countries like India where its performance directly affects national food security outcomes (Manogna and Mishra, 2022).

Role of agriculture in achieving food security

Agriculture remains the cornerstone of food security, especially in developing economies where it provides both sustenance and livelihoods for a large proportion of the population. Globally, agriculture contributes nearly one-fourth of economic output and employs about 40% of the workforce (World Bank, 2025). In countries like India, agriculture supports more than half of the population either directly or indirectly, making its performance central to national food and nutritional security.

Enhancing food production

Food production forms the foundation of food security, as it directly influences food availability (Swaminathan and Bhavani, 2013). Increasing food production is essential for ensuring food security for the rapidly growing global population, particularly under conditions of climate variability and declining natural resources Food and Agriculture Organization (FAO, 2017). Global food demand is expected to rise by nearly 50% by 2050, necessitating major improvements in productivity from the existing agricultural land base (Tilman *et al*., 2011). In India, food grain production increased remarkably from 50.8 million tonnes in 1950-51 to over 315 million tonnes in 2022-23. This growth has mainly been supported by advancements in agricultural technologies, including the development of high-yielding and climate-resilient seed varieties with improved resistance to pests and enhanced nutritional quality such as higher mineral, vitamin and protein content. Additional progress in irrigation practices, fertilizer use and pesticide management has also contributed to obtaining higher productivity and better economic returns with comparatively lower resource inputs.

Innovations in agriculture may extend beyond increasing productivity to include cost reduction, promotion of sustainable farming systems and strengthening resilience against climate change. Such innovations are not confined only to production technologies, but also include institutional mechanisms that support effective policy implementation, improved storage and logistics systems to minimize post-harvest losses and efficient marketing strategies that enhance the value of agricultural goods and services. Consequently, innovations can influence the entire agri-value chain of food, feed and fibre, extending from farm to consumer, or more appropriately in a demand-oriented approach, from "plate to plough" (Gulati and Juneja, 2018).

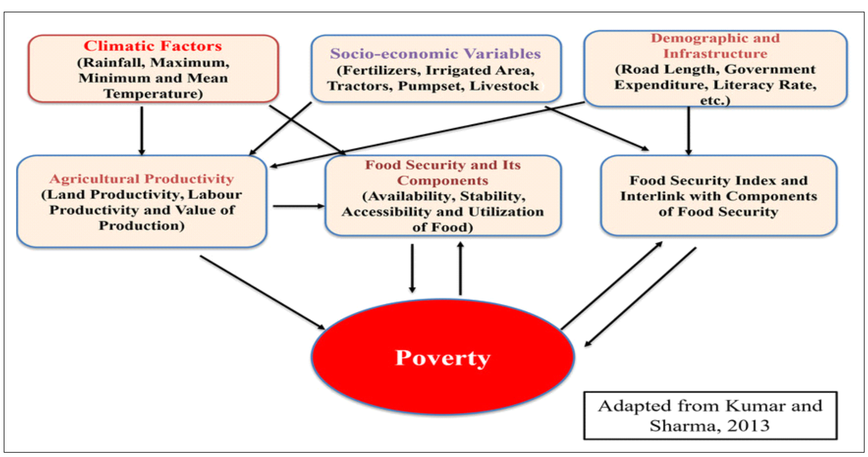

Fig 2: Interrelationship among climatic and non-climatic factors affecting agriculture, food security and poverty.

Advancements in farming practices can improve productivity while simultaneously lowering production costs and supporting sustainable agriculture. The adoption of improved crop varieties, expansion of irrigation facilities and balanced fertilizer use have significantly contributed to agricultural growth. However, declining factor productivity and deterioration of soil health have created a need for sustainable intensification of agriculture (Bhattacharyya *et al*., 2015; Lal, 2015). Conservation agriculture practices such as minimum tillage, crop residue retention and crop rotation have been reported to improve soil organic carbon content, increase water-use efficiency and stabilize crop yields under climatic stress conditions (Jat *et al*., 2020).

A study conducted by Jat *et al*. (2021) on conservation agriculture practices aimed at addressing declining productivity, poor soil health, climate change, farm profitability and sustainability revealed that permanent beds with residue retention (PB+R) increased mustard seed yield by 15.4% and system grain yield by 10.6%. The practice also reduced carbon input by 17% and carbon footprint by 25%, while enhancing carbon output by 12%, carbon net return by 21%, carbon efficiency by 47% and carbon sustainability by 47% in comparison with conventional tillage without residue retention (CT-R). Furthermore, incorporation of legumes into conservation agriculture-based diversified systems significantly improved system productivity (+9.60%), profitability (+24%), protein yield (+18%) and water productivity (+276%) over the traditional rice-wheat system, thereby contributing to food, nutritional and economic security of smallholder farmers (Meena *et al*., 2026).

The development and adoption of climate-resilient crop varieties tolerant to drought, heat and salinity are considered essential for sustaining agricultural productivity in vulnerable regions (Cairns *et al*., 2013; Ray *et al*., 2013). A drought-tolerant groundnut variety, ICGV 91114, developed by International Crops Research Institute for the Semi-Arid Tropics, proved to be a suitable alternative to TMV 2 in farmer-participatory varietal selection trials. At the farm level, adoption of ICGV 91114 resulted in a 23% increase in pod yield, reduced yield variability by 30% and generated 36% higher net income compared to TMV 2. Its adoption over 35% of the 0.8 million hectares under groundnut cultivation in Anantapur by 2020-21 was estimated to generate an annual surplus of ₹ 694 million, of which 65% resulted from increased yield and 35% from reduced yield fluctuations (Birthal *et al*., 2011).

Global mean temperature has been estimated to increase by 0.3°C per decade, which may reduce wheat yields in South Asia by nearly 50% by 2050. To address this challenge, coordinated efforts were undertaken and wheat genotypes such as HW 2045, RAJ 3765, RAJ 4101, WH 1021, Lok 54, HW 2004, RAJ 4250, GW 432 and HD 3095 were identified as having low heat sensitivity indices under multi-location heat tolerance trials. These genotypes are considered promising sources for improving heat stress tolerance in wheat (Mishra *et al*., 2025).

Integrated nutrient management (INM) has also been recognized as an effective approach for improving nutrient-use efficiency, sustaining long-term soil fertility and minimizing environmental impacts (Vanlauwe *et al*., 2010). Sonune *et al*. (2021) reported that the adoption of minimum tillage together with integrated nutrient management practices involving 50% nitrogen through farmyard manure and the remaining recommended dose through chemical fertilizers helped sustain cotton productivity, improve net returns and benefit-cost ratio and maintain soil quality. Similarly, a field experiment on intercropping and integrated nutrient management demonstrated that the oat + grasspea (3:3) intercropping system combined with 75% nitrogen through urea and 25% nitrogen through vermicompost achieved significantly higher system productivity (18.77 q ha^{-1}), greater profitability (net return: US$ 430.4 ha^{-1}; benefit-cost ratio: 1.71) and improved energy indices, including higher energy output, net energy gain, energy ratio and energy profitability (Biswas *et al*., 2024). Yadav *et al*. (2017) demonstrated that conservation agriculture practices, particularly zero tillage and permanent bed, increased maize grain yield by 7.7-14.2% and stover yield by 7.4-13.0% compared with conventional tillage. Arumugam *et al*. (2025) reported that the integrated application of fish pond silt from a duck-dropping-fed pond (5 t ha^{-1}), vermicompost (5 t ha^{-1}) and 100% recommended NPK significantly improved maize productivity, recording the highest grain yield (8293 kg ha^{-1}) and stover yield (11,974 kg ha^{-1}), which were 116% and 132% higher, respectively, than the unfertilized control. Nalabolu *et al*. (2025) reported that subsoiling combined with furrow diking significantly improved groundnut productivity, energy efficiency and carbon sustainability under semi-arid conditions, recording the highest pod yield (3612 kg ha^{-1}), haulm yield (2420 kg ha^{-1}) and net energy return (40,286 MJ ha^{-1}), while reducing carbon intensity from 5.70 to 2.32 kg CO_2-eq kg^{-1} compared with the control.

Strengthening food distribution systems

Efficient food distribution systems are crucial for converting higher agricultural production into better food availability and accessibility. At the global level, nearly 14% of the food produced is lost between harvest and retail stages because of inefficiencies in storage, transportation and processing systems (Gustavsson *et al*., 2011; FAO, 2019). In India, post-harvest losses in cereals, pulses, fruits and vegetables are estimated to range between 4% and 16%, mainly due to inadequate infrastructure facilities and inefficient supply chain management (ICAR, 2016). The development of scientific storage facilities, cold chain infrastructure and refrigerated transport significantly reduces quantitative and qualitative losses of perishable commodities (Kader, 2005). Strengthening decentralized procurement and the Public Distribution System improves food access for economically vulnerable populations (Khera, 2011). Digital agricultural marketing platforms such as the electronic National Agriculture Market enhance price discovery and reduce market fragmentation (Chand, 2017). Farmer producer organizations play a key role in aggregation, grading, processing and direct marketing, thereby improving supply chain efficiency and farmers' share in the consumer price (NABARD, 2020).

Promoting agricultural innovation

Agricultural innovation is a major driver of productivity growth, resource-use efficiency and climate resilience (World Bank, 2019). Recent developments in molecular breeding, genomics and biotechnology have significantly accelerated the creation of high-yielding and stress-tolerant crop varieties (Tester and Langridge, 2010; Varshney *et al*., 2021). Climate-smart agriculture combines productivity improvement with adaptation and mitigation measures, thereby promoting the long-term sustainability of farming systems (Lipper *et al*., 2014). In addition, digital agriculture technologies such as artificial intelligence, the Internet of Things (IoT) and remote sensing facilitate real-time crop monitoring and support better farm-level decision-making (Wolfert *et al*., 2017; Mittal and Mehar, 2016).

Efficient agricultural extension systems play an important role in the rapid dissemination and adoption of improved technologies among small and marginal farmers (Anderson and Feder, 2007). Public-private partnerships further strengthen agricultural innovation systems by enhancing investments in agricultural research and development. The rapid growth of agri-tech start-ups has also improved farmers' access to quality inputs, advisory services and market connectivity.

Sapkota *et al*. (2014) conducted on-farm experiments in seven districts of Haryana to assess the performance of Nutrient Expert (NE) and NE + Green Seeker-based nutrient management practices in comparison with farmers' practices and state recommendations for wheat cultivation. On average, NE-based strategies increased grain yield and biomass yield by 14% and 9%, respectively, over farmers' practices and by 5% and 3%, respectively, compared with state recommendations. Furthermore, the use of tractor-mounted GPS-enabled machinery, drones and soil sensors has enabled the preparation of precise planting maps, resulting in an estimated 5-10% increase in crop productivity.

Encouraging crop and livelihood diversification

Crop diversification strengthens farm resilience, improves soil health and contributes significantly to nutritional security (Lin, 2011; Birthal *et al*., 2015). Diversified cropping systems also enhance nutrient cycling, disrupt pest and disease cycles and improve overall farm productivity (Altieri *et al*., 2015). The promotion of pulses, oilseeds, fruits, vegetables and nutri-cereals such as millets helps address both income and nutritional challenges in India (Chivenge *et al*., 2015; GOI, 2023). Millets are particularly important due to their low water requirement, high climate resilience and superior micronutrient content (Sarmah and Bora, 2025). The development of efficient processing technologies, especially for small-scale enterprises, will play a vital role in promoting the wider adoption and utilization of millets in diverse food products. Integrating millets into sustainable food systems and climate-smart agricultural practices is essential for improving food security as well as environmental sustainability (Sharma *et al*., 2025).

Integrated farming systems combining crops, livestock, fisheries and agroforestry enhance resource recycling and provide multiple income streams to farm households (Herrero *et al*., 2010; Devi *et al*., 2017). Fatima *et al*. (2021) revealed that the total value of the commodities produced on the farm was highest (Rs. 959000) in the case of crop +dairy + fishery + poultry + duckery + apiary + boundary plantation + biogas unit + vermicompost IFS model of 1 ha area and was significantly at par with the crop + dairy + fishery + poultry + duckery model (₹ 941000) which were superior to Rice-wheat system (₹ 199000) and family savings in the above models were ₹ 180000, ₹ 214000 and ₹ 33000, respectively at IARI, New Delhi. Bhargavi and Behera (2020) at IARI, New Delhi reported that the IFS model (crops + dairy + fishery + duckery + poultry + biogas plant + agroforestry) has obtained a system productivity of 56.63 t ha^{-1} yr^{-1} which is 5.5 times higher compared to conventional rice-wheat system which obtained a system productivity of 9.86 t ha^{-1} yr^{-1} wheat equivalent yield and it was mainly due to inclusion of high-value crops like vegetables, flowers and fodder crops and livestock components, that could enhance the economic condition of marginal farmers owing to higher price and volume of their main and by-products. Agroforestry systems improve carbon sequestration, biodiversity conservation and long-term productivity (Jose, 2009). Livelihood diversification through non-farm employment reduces income variability and enhances household resilience to agricultural shocks (Ellis, 2000). Paudel *et al*. (2025) reported that agroforestry has the potential to increase crop yields by 25-80%, enhance dietary diversity by 22-25% and improve soil organic carbon content by 20%. From an economic perspective, agroforestry also promotes income diversification and higher financial returns, with household income increasing by 30-50%, agroforestry contributing 15-30% to total household income and benefit-cost ratios exceeding 2, there by demonstrating its strong economic viability.

Expanding market access and farmer incomes

Improved market access is essential for translating productivity gains into higher farmer incomes and rural prosperity (Barrett, 2008). Participation in structured markets and modern value chains enhances price realization and reduces transaction costs for smallholders (Shiferaw *et al*., 2008). Development of rural roads, storage facilities and market infrastructure significantly improves market participation and reduces post-harvest losses (World Bank, 2008). FPO, contract farming and cooperative marketing strengthen farmers' bargaining power and ensure better price realization (Bellemare and Lim, 2018; Singh, 2012). Access to real-time market information

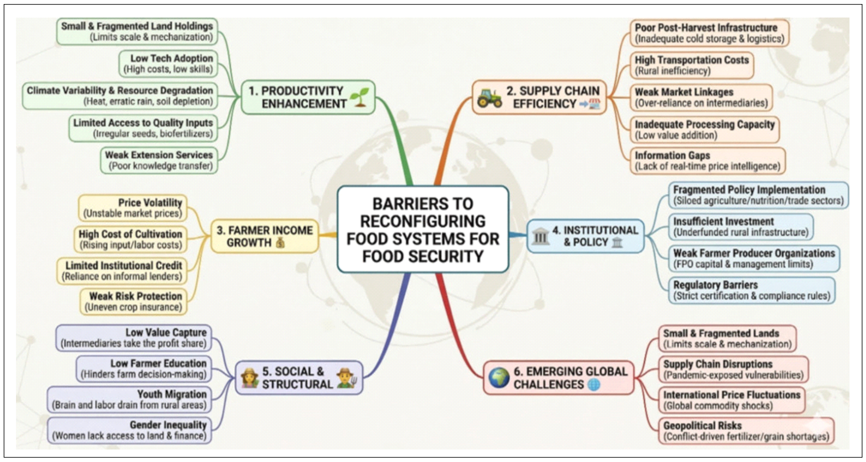

Fig 3: Barriers to reconfiguring food systems for food security.

through mobile-based platforms improves farmers' marketing decisions and income stability (Fafchamps and Minten, 2012). Institutional credit and financial inclusion help farmers adopt productivity-enhancing technologies and lessen their reliance on informal and often costly sources of finance (Binswanger-Mkhize, 2012). Value addition through grading, processing, packaging, branding and direct marketing significantly enhances farm income and generates rural employment opportunities (Birthal *et al*., 2015). Government initiatives such as the minimum support price, PM-FPO scheme and agricultural export promotion policies further strengthen market access and income security (Government of India, 2023).

Constraints and barriers in reconfiguring food systems for food security

Fig 3 illustrates the key constraints and barriers that hinder the reconfiguration of food systems toward achieving food security, including economic limitations, institutional weaknesses, technical gaps and socio-cultural challenges. These interconnected obstacles span multiple dimensions-social, economic, technical, environmental and institutional-making food system transformation complex and requiring coordinated, multi-stakeholder solutions to address them effectively.

CONCLUSION

The implementation of sustainable agroecological practices has significantly strengthened food security. Practices including crop diversification, organic farming, integrated nutrient management, conservation agriculture and precision farming have improved resource-use efficiency, minimized soil degradation and helped address water scarcity, thereby enhancing crop productivity. Furthermore, biofortification and balanced fertilization have improved food quality and nutritional value, tackling hidden hunger and malnutrition. Advanced post-harvest technologies and machinery have minimized losses, thereby increasing farmers' income and food security. The integration of scientific innovations, government policy interventions and active farmer participation has made agriculture more adaptive and resilient to climate change, resulting in a sustainable, nutritious and stable food supply while safeguarding the long-term viability of agricultural systems.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

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