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EVALUATING AGRI-FOOD SYSTEMS FOR SUSTAINABLE FOOD SECURITY IN INDIA

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Abstract
Sustainable food security continues to be a significant challenge in India, as agricultural production systems and food supply channels are intricately linked to socio-economic, environmental, and policy implications. This review paper investigates the present condition of agri-food systems in India, with an emphasis on their contribution to the attainment of sustainable food security. It evaluates the impact of unsustainable practices on food production and distribution and explores the primary challenges encountered by Indian agriculture, including climate change, resource constraints, and socio-economic disparities. The paper also emphasises the role of technology in improving the resilience and efficacy of agri-food systems by incorporating innovative sustainable agricultural practices, including agroecology and organic farming. Moreover, the paper advocates for regional level study in Indian context. Furthermore, it evaluates government policies and initiatives that are designed to enhance food security and examines successful case studies from various regions of India. The review concludes with suggestions for the enhancement of agri-food systems in India to guarantee long-term sustainability and food security. The necessity of integrated strategies that encompass policy reforms, technological advancements, and community-based initiatives is underscored.
Keywords: Agri-food systems, Sustainable food security, Agriculture, India,

INTRODUCTION

The sustainability of the agri-food sector, which encompasses agriculture, livestock, and the agri-food industry, is becoming a more important global concern due to the potential detrimental consequences on society, the environment, and the economy [1]. It is vital to reduce environmental degradation while increasing productivity, as the world's population is expected to exceed 9.7 billion by 2050 [2]. In India, many middlemen are involved in the distribution and sale of agricultural products, and the process is extensively regulated by national and state rules governing transportation, storage, and procurement [3, 4].
India's food system exemplifies the problems and opportunities of feeding a diverse population of over 1.4 billion people while balancing national and global concerns about economic development, sustainability, and public health. Because of its diversified farming techniques, rights-based food legislation, and engagement in several food systems with significant socioeconomic and environmental variances, it is an important case study for understanding challenges related to global food system transformation [5]. Until now, India's food policy has primarily focused on three goals: boosting food production, ensuring there is enough food to go around, and promoting trade and employment in rural regions [6, 7]. Policymakers realise that meeting future food demands in a sustainable manner while maintaining nutritional security, dietary diversity, and environmental protection is a long process [8, 9].
There has never been a more essential time to reform India's food system [10-11]. Nutritionally insufficient diets

generate significant levels of malnutrition [12-14], resulting in enormous productivity-related economic losses, even as per capita incomes have increased. Malnutrition is the main cause of disease burden in India, accounting for almost 194 million undernourished individuals, 43.3 million stunted children under five, and a concerning rise in obesity [15]. Because overweight and obese persons are less productive, the agricultural workforce loses 2.34 percent of its GDP [18]. Soil deterioration, chemical runoff, and excessive water withdrawals have all gotten worse as a result of two distorting policies: cereal-intensive agriculture and energy and fertiliser subsidies [19, 20]. Nowadays, just around 5% of freshwater is set aside for conservation efforts [23], with the majority going towards rice and wheat cultivation [21, 22]. The country's nitrogen pollution is among the worst in the world, costing the Indian economy more than $75 billion annually [24, 25]. Rice and animal emissions account for approximately 14% of the total [26, 27]. Concerns regarding inequality and exclusion derive from the fact that 82% of farmers are smallholders, agricultural and non-agricultural farm incomes differ greatly, and agriculture employs more than half of the workforce [28].

Disagreements on sustainability can develop when competing objectives, such as health, the environment, society, or economic growth, are given too much weight [29]. As a result, we need coordinated and systematic activities to assist us progress towards healthier food systems that consider interconnected issues such as health, the environment, and inclusivity [30].

1. RELATED WORKS

Vatta et al. (2024) [31] investigated a number of barriers to ensuring nutritional security for the Indian populace. Sustaining nutritional food security requires overhauling food systems and addressing every facet of the issue. Solutions that can address the particular challenges encountered by various demographic groups and adjust to a variety of geographical settings are required. There should be a mutually reinforcing relationship between food production and environmental sustainability. Crop diversification, aquaculture, domestication of wild fruits, and animal feed improvement are areas where children, women, and indigenous groups stand to benefit the most. It is anticipated that farm income will increase along with improvements in food availability, dietary diversity, and nutritional stability. Strengthening food value chains will benefit farmers by increasing their compensation, reducing food waste, and increasing the amount of food that is accessible, reasonably priced, and socially acceptable. Crop breeding programs should be integrated, research and extension spending should be increased, markets should be expanded, and vulnerable areas should be the main emphasis of any nutritional security plan.

Singh et al. (2024) [32] examined 23 food system indicators in four areas—economics, health, and the environment—using a global food system modelling framework to analyse an assessment of the Indian food system. The food system includes sustainable agriculture, ecological preservation, fair livelihoods, environmental transformations, and nutrient-dense diets. Thirteen out of fourteen indicators, including those related to nutrition and environmental outcomes, show improvement as a result of the synergistic impacts of coordinated actions, which reduce trade-offs among the four components of the food system. Although there has been progress in many environmental and health measures, issues such as rising obesity and nitrogen pollution persist. By measuring the dynamics of India's food system under different conditions, we want to gain a deeper understanding of the trade-offs that arise in many dimensions. The results thus can help policymakers pinpoint crucial interventions and create strategies.

Bhagat et al. (2024) [33] investigated the integrated farming system (IFS). Small- and marginal-farmers can benefit from this all-inclusive farming techniques. The purpose of this approach is to help these farmers achieve food and nutrition security for their family by boosting the farms' profitability, employment, and productivity. By providing a multitude of ecosystem services, the IFS mechanism makes farms more environmentally friendly, sustainable, and climate resilient. Different farming components are used in a methodical way on a single farm in integrated farming systems (IFS). Compared to simpler farms, the productivity, health, biodiversity, and environmental friendliness of the farm are improved when these elements function as a whole. Therefore, this review article is an extensive analysis of the literature on IFS that explores its idea, elements, and requirement while emphasising its potential to profitably and sustainably boost system productivity and employment generation. It also explores the role of different agricultural elements on a single farm in relation to ecosystem services (e.g., reducing greenhouse gas emissions, sequestering carbon, recycling nutrients, improving soil health, and maintaining biodiversity).

Shankar et al. (2024) [34] examined the relationship between digital technology and agri-food systems to guarantee equitable outcomes in various scenarios. From production to consumption, every stage of the agri-food value chain is being impacted by recent technological advancements like blockchain, the Internet of Things (IoT), artificial intelligence (AI), and precision agriculture. These technologies provide real-time data collection, analysis, and decision-making in addition to increasing productivity, optimising resource usage, and lessening environmental impact. Supply chain transparency, enabled by digital platforms, gives smallholder farmers and impoverished communities a sense of agency and promotes accountability and trust among all stakeholders. To fully benefit from digital breakthroughs for sustainable and equitable agri-food systems, cooperation between governments, industrial participants, academic institutions, and civil society will be required. By leveraging the transformative potential of digitalisation through collaborations, information sharing, and capability building, they seeks to build a more just, resilient, and sustainable future for all.

Olawuyi et al. (2024) [35] examined the ways in which IKPs (indigenous knowledge practices) assisted farmers in achieving food security. Data from 349 randomly chosen smallholder farmers were analysed using descriptive statistics, a multivariate probit regression model, and a standardised food insecurity experience scale survey module. A documentary evaluation of the literature and empirical data served as the foundation for the data. 10% more farmers fell into the categories of chronic and moderate food insecurity, accounting for nearly 90% of all farmers experiencing food insecurity. About 86% of farmers strongly and favourably believe that IKPs have a favourable impact on agricultural output. The findings also demonstrated the influence of the following factors on traditional farming practices: age, years of farming experience, crop selection/rotation strategies, frequency of staff visits, household size in relation to dependency ratio, food security status of farmers, and awareness of IKPs. Even with IKPs on staff, most farmers still experience food insecurity. They conclude that smallholder farmers face contemporary difficulties in the agri-food systems and recommends a multi-stakeholder collaboration to assist them in overcoming these challenges by fusing traditional knowledge with cutting-edge scientific techniques.

Kumar et al. (2024) investigated the numerous benefits of implementing circular principles in agriculture, such as the development of sustainable methods, increased resource efficiency, and economic prosperity [36]. The transition to circular agriculture is more challenging than initially due to financial constraints, technological advancements, and regulatory impediments. Policy initiatives significantly facilitate the promotion of circular approaches in the agricultural sector. Governments are responsible for establishing incentives and regulations that motivate agribusinesses and producers to implement circular strategies. Powerful incentives for procuring eco-friendly products and services are subsidies and tax credits, which are forms of financial support. Regions are actively promoting circularity through their mandates for resource repurposing and waste reduction. New markets for recycled agricultural materials may also emerge, and employment opportunities in the circular economy may be generated, provided that legislation is created to promote circular activities.

Sannou et al. (2023) [37] examined 128 scholarly publications about social sustainability in agri-food systems. By carefully examining key indicators, this study seeks to centralise knowledge about social sustainability indicators in the agri-food sector. Guiding empirical research in agri-food systems is its aim. They were categorised into eight groups after 36 markers were found. Several factors that are crucial for decision-making have been examined, such as temporal scale, agri-food system type, level of Theory of Change (ToC), and regional size. At the farm, community/local, and regional levels, as well as the supra-regional level, were where the indicators were found. While indicators are less frequently used in assessments of exclusive food systems, livestock, forests, plantation-based systems, aquaculture, and fisheries, they are primarily used in studies of integrated and cropping systems in the agri-food industry. Activity level indicators are in the forefront of terms of levels along the ToC. Though their average usage has expanded dramatically since the SDGs' launch in 2015, the keywords connected with social sustainability indicators have stayed stable over time. Concerns regarding gender parity, water accessibility, and participation emerged as the most important aspects of the discussion that a word embedding algorithm detected while assessing the social sustainability of agri-food systems. It is evident from the results that decision-making processes can be made more sustainable by incorporating social sustainability indicators.

Uztürk et al. (2022) [38] focused on food security in sustainable agri-food sectors. Agriculture has traditionally been seen as a key sector for developing economies. Food offer that is clean, healthy, and readily available is a dilemma that future farmers will face more and more. Factors including the changing climate, population increase, and urbanization are putting the current agricultural systems in danger. Food security (FS) is a crucial transition area for resilient and sustainable development. As such, the main objective of this paper is to develop a comprehensive assessment approach for determining the key FS enablers in long-term sustainable agri-food supply chains. Literature reviews and expert opinions are used to identify key facilitators for the FS, which are then compiled into an index. The proposed approach relies on fuzzy language metrics. 2-Tuple linguistic (2-TL) model is the recommended model when utilising MCDM technologies. The 2-TL model is an analytical technique grounded on language that can guarantee no information is lost in translation. Finally, to illustrate the usefulness and managerial implications of the proposed technique, an actual case study is used for testing.

El Bilali et al.'s (2021) highlighted the limits of this rapidly developing field of study and its links to sustainability [39]. A Web of Science search in January 2020 turned up 1389 documents; 1289 of those underwent bibliometric and topical analysis. The theme research was organised using the FAO's SAFA (Sustainability Assessment of Food and Agriculture systems) approach, which was based on environmental, economic, social and cultural, policy, and governance issues. The review points out that there has been an exponential increase in the number of publications on AFS. Nonetheless, the study field is biassed towards the north and is dominated by academics and groups from industrialised nations. Additionally, the study demonstrates that while environmental issues are appropriately addressed, political, social, and economic issues are frequently ignored. The authors conclude the paper by outlining future research directions and offering a list of possible topics for an all-encompassing, multidisciplinary strategy to address the intricate (un)sustainability of AFS. It makes the case that research on agri-food systems ought to adopt a more thorough 4-P (people, planet, profit, and policy) framework.

Bisht et al. (2021) [40] demonstrated that the small-scale ecological farming practices of the Uttarakhand highlands can help attain resilience to climate change. The emphasis on diversity production in these approaches broadens the range of climate change responses. Among the many urgent issues concerning the sustainability of traditional hill farming methods and food systems is eco-nutrition. The benefits and drawbacks of integrating four regional marketing campaigns with conventional hill farming are examined in this study. Some of these include developing value chains for regional plant food resources and enhancing market accessibility; tying traditional farming into school meal programs; supporting community-supported organic/biodynamic agriculture (CSA) in a stronger way; and assisting young people in rural areas in finding off-farm employment opportunities. It talks about the necessity to review current agriculture and health policies around food and nutrition, as well as develop cross-sectoral implementation strategies. Results may assist state legislators in setting aside funds for regional farms and a regenerative food system, which should both result in higher profits.

Sharma et al. (2020) [41] indicated that there is much disagreement surrounding grassroots agricultural sustainability in India. This has resulted in protests, discussions, and debates supported by data on social unrest, environmental degradation, and economic fragility. To make a greater impact on environmental sustainability, organisations that advocate for farmers are bringing their agricultural products to market through programs like fair-trade. To identify the most pertinent elements and indicators in each, this research project compares and analyses the sustainability of farmers growing basmati rice under conventional and fair-trade systems. An attempt was made to collect primary data on four aspects of sustainability—economics, environment, society, and governance—by asking basmati rice growers in both conventional and fair-trade systems to self-administer a survey. To evaluate the data, a mix of descriptive statistics, discriminant analysis, and structural equation modelling was employed. The findings demonstrate how much better the fair-trade system does than the traditional system on sustainability metrics, with governance being the key differentiator.

Table 1: Comparative Analysis of Agri-Food Systems for Sustainable Food Security

Author(s) & Year	Focus Area	Key Findings	Challenges Addressed	Recommendations/Implications
Vatta et al. (2024)	Nutritional security in India	Crop diversification, aquaculture, animal feed improvement benefit vulnerable groups; strengthening food value chains	Nutritional instability, environmental sustainability	Integrated crop breeding, increased research and extension, focus on vulnerable areas
Singh et al. (2024)	Assessment of Indian food	13 out of 14 food system indicators	Obesity, nitrogen pollution	Targeted interventions for trade-off reduction, radical systemic change

	system	show improvement through coordinated actions		
Bhagat et al. (2024)	Integrated farming systems (IFS)	IFS enhances farm profitability, productivity, and environmental resilience	Climate change, low farm income	Promote IFS for small-scale farmers, enhance ecosystem services
Shankar et al. (2024)	Digital technology in agri-food systems	Blockchain, AI, IoT, and precision agriculture improve supply chain transparency, efficiency	Data privacy, digital divide, technology literacy	Multi-stakeholder collaboration, capacity building for digital inclusion
Olawuyi et al. (2024)	Indigenous knowledge practices (IKPs) and food security	IKPs improve agricultural output but food insecurity persists among smallholder farmers	Limited access to extension services, dependency ratio issues	Fuse traditional knowledge with modern techniques, strengthen extension services
Kumar et al. (2024)	Circular agriculture	Circular practices improve resource efficiency and sustainability	Financial constraints, regulatory barriers	Policy incentives for circular practices, promote eco-friendly markets
Sannou et al. (2023)	Social sustainability in agri-food systems	36 social sustainability indicators identified, with focus on gender parity and water accessibility	Lack of comprehensive social sustainability metrics	Incorporate social sustainability indicators in decision-making
Uztürk et al. (2022)	Food security in sustainable agri-food systems	Developed a comprehensive assessment approach using MCDM and 2-TL model for FS enablers	Food supply chain risks due to climate change, urbanization	Apply FS enablers in supply chain resilience strategies
El Bilali et al. (2021)	Sustainability assessment of agri-food systems (AFS)	Environmental sustainability dominates AFS research, other areas (social, political) underrepresented	Biased focus on developed nations, limited social/economic research	Adopt a multidisciplinary 4-P framework (people, planet, profit, policy)
Bisht et al. (2021)	Climate resilience in small-scale farming	Small-scale ecological farming builds resilience to climate change	Market access, eco-nutrition gaps	Support CSA initiatives, integrate local food chains into school meal programs
Sharma et al. (2020)	Fair-trade vs conventional agriculture in India	Fair-trade systems outperform conventional systems on sustainability	Economic fragility, environmental degradation	Strengthen fair-trade governance, promote sustainable farming practices

		indicators		

2. CURRENT STATUS OF AGRI-FOOD SYSTEMS IN INDIA

India's agricultural sector is facing numerous ecological challenges, including loss of agrobiodiversity, pollution, diminishing soil fertility and soil carbon pool, and improper land use practices [42–45]. The industry is extremely vulnerable to climate shocks due to its reliance on rainfall, small-scale farming, financial limitations, and heat-stress events brought on by insufficient rainfall [45,46]. Groundwater depletion is a major issue for states with high agricultural productivity, such as Punjab and Haryana [47]. The increased use of agrochemicals, which increased from 17,360 metric tonnes in 2001–02 to 27,375 metric tonnes in 2018–19, is another trend during the past 20 years. Overfertilization not only lowers soil quality but also increases groundwater pollutant concentrations and raises overall food production costs. Therefore, it is essential to safeguard food supplies and the environment by using cutting-edge, ecologically sound farming practices [48]. Government initiatives, policy, and legislation must promote ecosystems and biodiversity at the same time [49].
By implementing preventative measures against emerging infectious diseases (EIDs) such as the current pandemic, the agriculture and food business may contribute to averting future pandemics, conserve the environment, and safeguard public health. In order to assist underprivileged areas and lessen the effects of the COVID-19 issue, social protection programs must be put into place [52]. The Fair Price Shops (FPS) in Kerala started providing pre-made meal kits through the TPDS in conjunction with the PMGKAY. Meals packages contain seventeen components, including premeasured portions of tea, sugar, flour, and other items. The kits prevent hoarding in addition to guaranteeing that all low-income households have access to a sufficient supply of food and lessening crowding at the FPS. Another step was the creation of community kitchens to serve hot meals to health-line employees and migrant workers [53]. Uttar Pradesh's community kitchens were even the first to use geotagging to improve monitoring. In addition to utilising student volunteers and non-governmental organisations, recognising "community kitchens" as a component of CSR (corporate social responsibility) activities may motivate commercial enterprises to become engaged.

A shift to agrarian sustainability, which is accomplished through policies that support plant agrobiodiversity and crop diversification, can enhance both food security and farmers' financial stability [54–56]. At the moment, the majority of farmers prefer to plant wheat and paddy due to the guaranteed price (MSP) that these commodities bring in. MSP is found in maize, sunflower, soyabean, and a few pulses, in addition to jowar and bajra. However, because the government buys the majority of these two commodities, they are also the most likely to benefit farmers. Furthermore, there is a significant gap in the coverage of rice producers under the procurement process. States with the biggest concentration of marginal farmers, such as Uttar Pradesh and Bihar, have the lowest coverage rates, at 3.6% and 1.7%, respectively, while Punjab and Haryana have the highest, at 95% and 70%. Some studies have found that economically vulnerable farmers in India are unable to grow high-value crops such as fruits and vegetables because agricultural markets are not well-organised, smallholder farmers have a more difficult time getting their crops to market, and there are few opportunities to trade these crops [57-59].

Crop diversification choices based on soil characteristics and agro-climatic conditions, as illustrated in Figure 1, help alleviate buffer cereal supplies while also addressing environmental concerns such as depleting water reserves and soil nutrients. Through integrated study and production of underutilised wild species as part of agricultural diversification, it is possible to attain nutritional security and climate resilience [60]. If India aspires to attain food sovereignty and security, it can do it in a variety of ways, including agro-ecological conservation and relying on its rich cultural history and traditional knowledge systems [61-63].

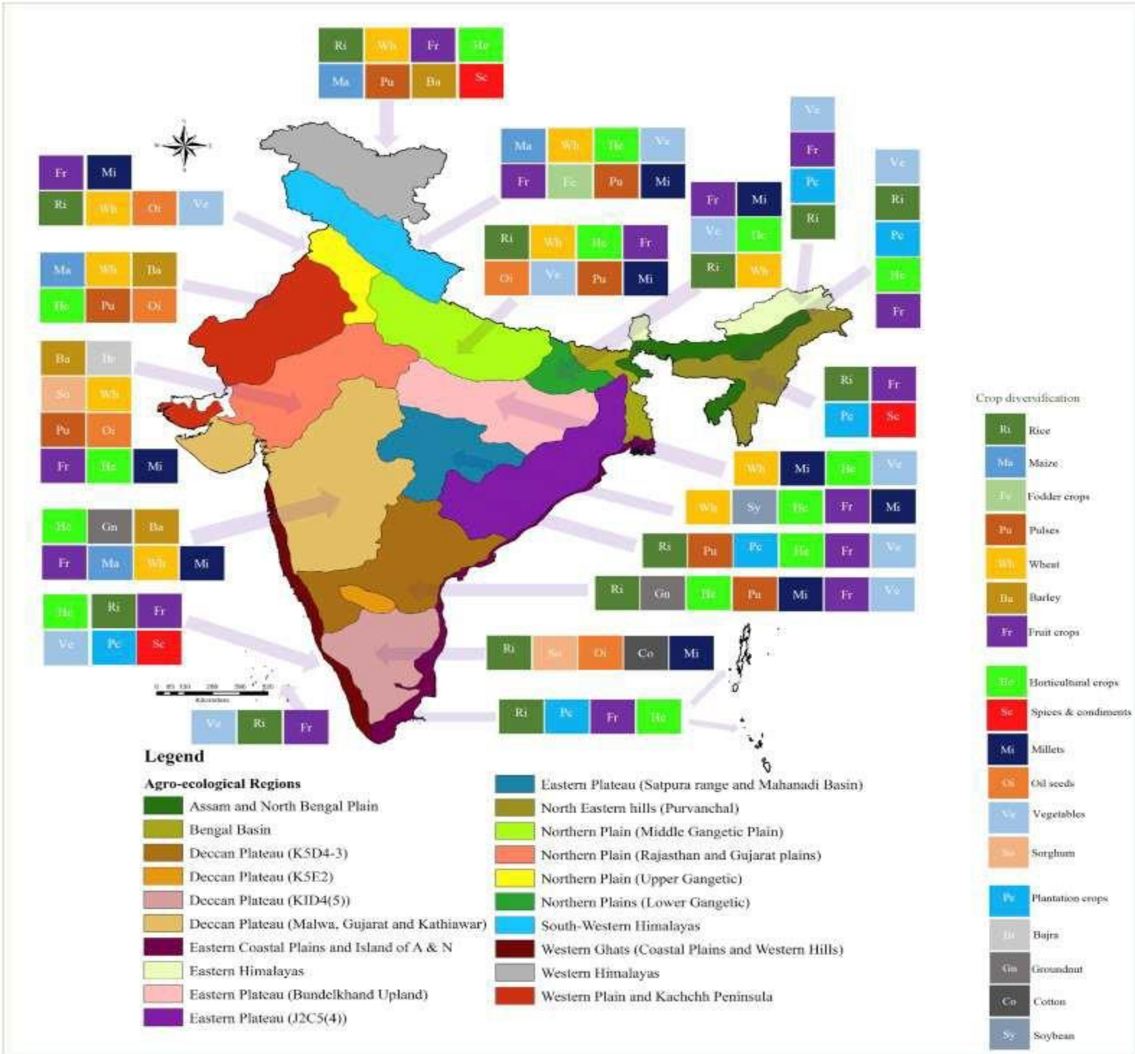

Fig. 1: Existing and Proposed Crop Diversification Patterns for Agro-Ecological Regions of India

The concepts of urban farming, urban gardening, and urban and peri-urban agriculture are all part of the new methods that are crucial to ecological and environmental sustainability. Food security, biodiversity, and job creation are just a few of the many facets of urban sustainability that are significantly improved by these practices, which all involve growing food on urban lands utilising a variety of techniques [64, 65]. Urban agriculture (UA) plays a critical role in building urban resilience by providing food for local communities to eat during times of disruption to external supply chains, like a pandemic-induced lockdown [66]. Langemeyer et al. (2021) acknowledge that urban housing and transport are more lucrative urban market avenues. People's understanding of how food is produced and prepared can be increased through urban agriculture (UA) and community gardens (CGs), which may motivate them to choose more ecologically friendly food choices [67–69]. Growing crops on contaminated or damaged soil can assist achieve numerous sustainability goals, including biofortification and the conservation and regeneration of land resources, as an additional option to tackle food insecurity and the scarcity of arable land [70]. A number of crops have been studied in the field to determine how well they thrive in contaminated soils and how much pollution makes its way into the food they produce. These crops include maize [71], rice [72], bitter gourd [73], and onion [74].

3. ROLE OF AGRI-FOOD SYSTEMS IN SUSTAINABLE FOOD SECURITY

The agriculture industry helps to both increase food availability and achieve food security [75–77]. Although most experts believe that the global food demand will increase over the coming decades, no one is certain how much food production in the agricultural sector will be able to meet this demand. Enhancing the food supply through more effective use of agricultural land and increased agricultural productivity overall seems to be one strategy to end hunger [78]. However, with present agricultural technology and knowledge, emerging countries with low per capita income may find it difficult to meet their food demands in 2020 and beyond. It is obvious that developing countries need to increase their spending in agricultural research and extension programs in order to increase agricultural output per acre of land and per agricultural worker. To the inhabitants of Africa's subcontinent. These results suggest that prioritising investments that will propel African agriculture towards increased productivity while avoiding significant environmental degradation is a good idea. Industrialised nations should transfer technology to developing nations in order to speed up these processes, bridge technological gaps, and get around knowledge barriers.

The aim is to determine the correlations between the undernourishment scale and some features that characterise the agriculture sector in chosen India developing country clusters. It takes into account that various countries have varying capabilities for agricultural production and that agriculture has a considerably higher influence on alleviating poverty and improving food security than other sectors of the economy [79].

4. POLICY AGENDA FOR SUSTAINABLE FOOD SYSTEMS

Policy for sustainable food systems seeks to improve the ecological, social, and economic well-being of rural ecosystems simultaneously. It improves on the ideas of sustainable intensification by incorporating social and human capital components. According to Pretty, "increasing contributions to natural capital and the flow of environmental services while reducing the negative environmental impacts and producing more output from the same area of land" [80] is what she means by sustainable intensification. In light of this, it is equally important to intensify agriculture without making the negative externalities of this output worse. These externalities include, but are not limited to, degraded land and water, rising greenhouse gas levels, and dwindling biodiversity. Policies pertaining to sustainable food systems also place a higher priority on the health of consumers and producers, especially smallholders, taking into account aspects like food safety.

5. PROMOTING FOOD SYSTEM DIVERSIFICATION

The lack of strength in the private sector and the rules and constraints put in place during the green revolution limited the supply of vegetables, nonstaple foods, livestock, aquaculture, and underutilised or neglected plant varieties and breeds despite the rising demand. It would be beneficial to establish a "level policy playing field" that rectifies the historical bias in favour of staple crops in order to increase incentives for diversification of production towards nonstaple foods. The intensification of staple crops was given priority in previous agricultural plans. Now and for the foreseeable future, farmers must adopt a strategy that is "crop neutral," removes distortions, and allows them to respond to market signals when determining which crops to cultivate [81]. Levelling the playing field and investing in cold storage facilities, road infrastructure, and transportation are all necessary for the development of the perishable goods market. Investments in connectivity, especially via mobile phones, and market information systems could result in a significant decrease in the transaction costs for farmers to engage in the market. Policies that support food safety should place a high priority on enhancing traditional markets and safeguarding public health. Not only may food safety laws reduce the number of cases of food poisoning and other illnesses, but they can also incentivise retailers to source their products from traditional marketplaces. Investing in literacy initiatives and giving farmers specific training to enable them to meet the quality and safety standards for high-value crops are two ways to assist smallholders in joining market value chains. Finally, formalised contractual arrangements that depersonalise market transactions, access to funding unrelated to commodities, and institutional investments in properly defining land and asset ownership are all necessary for diversified production systems.

6. MANAGING CLIMATE CHANGE IMPACTS

The need to reduce the effects of climate change and increase productivity is a major barrier to the growth and development of agriculture. Resources must be allocated for research and development of agricultural technologies resistant to heat and drought as well as infrastructure improvements such micro-irrigation systems. It is crucial that smallholders have easy access to these technology[82]. Examples of how agricultural policy design should embrace these practices are in soil conservation, agroforestry for carbon sequestration, and watershed management measures to reduce land degradation and improve water conservation [83]. Not to mention, the expenses associated with welfare due to increasingly frequent extreme events—such as floods and droughts—make the creation of safety net measures, insurance policies, and disaster relief programs necessary.

7. CONCLUSION

In conclusion, the integration of environmentally sound agricultural practices, resilient food supply chains, and equitable resource distribution is essential for the agri-food systems in India to undergo a comprehensive transformation to achieve sustainable food security. It is imperative to confront obstacles such as resource scarcity, climate change, and socio-economic disparities to improve the accessibility and production of food. The sustainability and efficiency of food systems can be considerably enhanced by innovations in agroecology, technology, and policy reforms. Regional level studies to be conducted to further explore the issues of food security in Indian context, wherein the focus should be laid up on agroecological aspects related to food systems. Government initiatives and community-based programs are essential for the scaling of successful models. The key to assuring long-term food security in India will be a holistic approach that involves continuous adaptation and multi-stakeholder participation.

REFERENCES

1. UN (2022) World population prospects 2022. Edited by United Nations. New York, USA.
2. FAO (2017) Towards Zero Hunger 1945–2030. Organización de Las Naciones Unidas Para La Agricultura y La Aliment- ación, Roma, Italia. pp 1–237.
3. AGRICOOP, 2014. Integrated Scheme for Agricultural Marketing, Operational Guidelines. Department of Agriculture Cooperation and Farmers Welfare, Government of India. Available at. http://agricoop.nic.in/sites/default/files/fina_lopguidelines_0.pdf.
4. AGRICOOP, 2018. Annual Report 2017-18. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. Available at. http://agricoop.nic.in/sites/default/files/Krishi%20AR%2020 17-18-1%20for%20web.pdf.
5. Athare, T. R., Pradhan, P., Singh, S. R. K., & Kropp, J. P. (2022). India consists of multiple food systems with scoioeconomic and environmental variations. Plos one, 17(8), e0270342.
6. Narayanan, S., & Gerber, N. (2017). Social safety nets for food and nutrition security in India. Global food security, 15, 65-76.
7. Panda, M. (2023). Evolution of India's policy response to hunger, nutrition, and food security since independence. In Achieving zero hunger in India: Challenges and policies (pp. 21-46). Singapore: Springer Nature Singapore.
8. Pingali, P., & Sunder, N. (2017). Transitioning toward nutrition-sensitive food systems in developing countries. Annual Review of Resource Economics, 9(1), 439-459.
9. Sengupta, P., & Mukhopadhyay, K. (2016). Economic and environmental impact of national food security act of India. Agricultural and Food economics, 4, 1-23.
10. Pingali, P., Aiyar, A., Abraham, M., & Rahman, A. (2019). Transforming food systems for a rising India (p. 368). Springer Nature.
11. Gulati, A., Paroda, R., Puri, S., Narain, D., & Ghanwat, A. (2023). Food system in India. Challenges, performance and promise. Science and innovations for food systems transformation, 813-828.
12. Meenakshi, J. V. (2016). Trends and patterns in the triple burden of malnutrition in India. Agricultural Economics, 47(S1), 115-134.
13. Tak, M., Shankar, B., & Kadiyala, S. (2019). Dietary transition in India: temporal and regional trends, 1993 to 2012. Food and nutrition bulletin, 40(2), 254-270.
14. Ganpule, A., Dubey, M., Pandey, H., Venkateshmurthy, N. S., Green, R., Brown, K. A., ... & Mohan, S. (2023). Snacking behavior and association with metabolic risk factors in adults from north and south India. The Journal of Nutrition, 153(2), 523-531.
15. Swaminathan, S., Hemalatha, R., Pandey, A., Kassebaum, N. J., Laxmaiah, A., Longvah, T., ... & Dandona, L. (2019). The burden of child and maternal malnutrition and trends in its indicators in the states of India: the Global Burden of Disease Study 1990–2017. The Lancet Child & Adolescent Health, 3(12), 855-870.
16. Chaudhary, M., & Sharma, P. (2023). Abdominal obesity in India: analysis of the National Family Health Survey-5 (2019–2021) data. The Lancet Regional Health-Southeast Asia, 14.
17. Venkatrao, M., Nagarathna, R., Majumdar, V., Patil, S. S., Rathi, S., & Nagendra, H. (2020). Prevalence of obesity in India and its neurological implications: a multifactor analysis of a nationwide cross-sectional study. Annals of Neurosciences, 27(3-4), 153-161.
18. Wellesley, L., Eis, J., Marijs, C., Vexler, C., Waites, F., & Benton, T. G. (2020). The business case for investment in nutrition. Chatham House, The Royal Institute of International Affairs.
19. Pingali, P. L. (2012). Green revolution: impacts, limits, and the path ahead. Proceedings of the national academy of sciences, 109(31), 12302-12308.

20. Bijay-Singh, H. M. B., & Aziz, T. (2021). Nitrogen use efficiency in crop production: issues and challenges in South Asia. Nitrogen Assessment: Pakistan as a Case-Study, 127.
21. Kayatz, B., Harris, F., Hillier, J., Adhya, T., Dalin, C., Nayak, D., ... & Dangour, A. D. (2019). “More crop per drop”: Exploring India's cereal water use since 2005. Science of the total environment, 673, 207-217.
22. Singh, V., Stevanović, M., Jha, C. K., Beier, F., Ghosh, R. K., Lotze-Campen, H., & Popp, A. (2023). Assessing policy options for sustainable water use in India’s cereal production system. Environmental Research Letters, 18(9), 094073.
23. Srivathsa, A., Vasudev, D., Nair, T., Chakrabarti, S., Chanchani, P., DeFries, R., ... & Ramakrishnan, U. (2023). Prioritizing India’s landscapes for biodiversity, ecosystem services and human well-being. Nature Sustainability, 6(5), 568-577.
24. Dhar, A. R., Oita, A., & Matsubae, K. (2022). Food nitrogen footprint of the Indian subcontinent toward 2050. Frontiers in Nutrition, 9, 899431.
25. Sutton, M. A., Drewer, J., Moring, A., Adhya, T. K., Ahmed, A., Bhatia, A., ... & Raghuram, N. (2017). The Indian nitrogen challenge in a global perspective. In The Indian Nitrogen Assessment (pp. 9-28). Elsevier.
26. Dawson, B., & Spannagle, M. (2008). United Nations framework convention on climate change (Unfccc). In The complete guide to climate change (pp. 392-403). Routledge.
27. Vetter, S. H., Sapkota, T. B., Hillier, J., Stirling, C. M., Macdiarmid, J. I., Aleksandrowicz, L., ... & Smith, P. (2017). Greenhouse gas emissions from agricultural food production to supply Indian diets: Implications for climate change mitigation. Agriculture, ecosystems & environment, 237, 234-241.
28. Chand, R., & Singh, J. (2023). From green revolution to amrit kaal. National Institution for Transforming India. GoI.
29. Brown, K. A., Venkateshmurthy, N. S., Law, C., Harris, F., Kadiyala, S., Shankar, B., ... & Knai, C. (2021). Moving towards sustainable food systems: A review of Indian food policy budgets. Global Food Security, 28, 100462.
30. Beier, F., Humpenöder, F., Leip, D., Crawford, M., Chen, D., von Jeetze, P., ... & Bodirsky, B. (2023). A food system transformation can enhance global health, environmental conditions and social inclusion.
31. Vatta, K. (2024). Reassessing Agri-Food Systems for Sustaining Nutritional Food Security: Evidence, Imperative and Way Forward. Indian Journal of Agricultural Economics, 79(1).
32. Singh, V., Das, P., Stevanovic, M., Jha, C., Bodirsky, B., Beier, F., ... & Lotze-Campen, H. (2024). An Inclusive agri-food systems transformation pathway for India.
33. Bhagat, R., Walia, S. S., Sharma, K., Singh, R., Singh, G., & Hossain, A. (2024). The integrated farming system is an environmentally friendly and cost-effective approach to the sustainability of agri-food systems in the modern era of the changing climate: A comprehensive review. Food and Energy Security, 13(1), e534.
34. Gowri Shankar, D. V., Neelambaram, B., Repalli, V., Nagpal, P., & Dhote, S. REVOLUTION AGRI-FOOD SYSTEMS: LEVERAGING DIGITAL INNOVATIONS FOR EQUITABLE SUSTAINABILITY AND RESILIENCE.
35. Olawuyi, S. O., Ijila, O. J., Adegbite, A., Olawuyi, T. D., & Farayola, C. O. (2024). Smallholder Farmers' Use of Indigenous Knowledge Practices in Agri-food Systems: Contribution of Food Security Attainment Drive. Research on World Agricultural Economy, 5(2), 45-67.
36. Kumar, R., Sow, S., Dayal, P., & Ranjan, S. Food Security and Sustainability.
37. Sannou, R. O., Kirschke, S., & Günther, E. (2023). Integrating the social perspective into the sustainability assessment of agri-food systems: A review of indicators. Sustainable Production and Consumption, 39, 175-190.
38. Uztürk, D (2022). A Linguistic MCDM Methodology to Investigate Enablers for Food Security in Sustainable Agri-Food Chains.
39. El Bilali, H., Strassner, C., & Ben Hassen, T. (2021). Sustainable agri-food systems: environment, economy, society, and policy. Sustainability, 13(11), 6260.
40. Bisht, I. S. (2021). Agri-food system dynamics of small-holder hill farming communities of Uttarakhand in north-western India: Socio-economic and policy considerations for sustainable development. Agroecology and Sustainable Food Systems, 45(3), 417-449.

41. Sharma, R. K., Abidi, N., & Misra, R. K. (2020). Assessment of agricultural sustainability-a study of farmers growing basmati rice under conventional and fair-trade systems in India. International Journal of Sustainable Agricultural Management and Informatics, 6(1), 1-21.
42. Rao, C. S., Kareemulla, K., Krishnan, P., Murthy, G. R. K., Ramesh, P., Ananthan, P. S., & Joshi, P. K. (2019). Agro-ecosystem based sustainability indicators for climate resilient agriculture in India: A conceptual framework. Ecological Indicators, 105, 621-633.
43. Sarkar, D., Kar, S. K., Chattopadhyay, A., Rakshit, A., Tripathi, V. K., Dubey, P. K., & Abhilash, P. C. (2020). Low input sustainable agriculture: A viable climate-smart option for boosting food production in a warming world. Ecological Indicators, 115, 106412.
44. Bhattacharya, P., Maity, P. P., Mowrer, J., Maity, A., Ray, M., Das, S., ... & Krishnan, P. (2020). Assessment of soil health parameters and application of the sustainability index to fields under conservation agriculture for 3, 6, and 9 years in India. Heliyon, 6(12).
45. Dubey, P. K., Singh, A., Raghubanshi, A., & Abhilash, P. C. (2021). Steering the restoration of degraded agroecosystems during the United Nations Decade on Ecosystem Restoration. Journal of Environmental Management, 280, 111798.
46. Birthal, P. S., & Hazrana, J. (2019). Crop diversification and resilience of agriculture to climatic shocks: Evidence from India. Agricultural systems, 173, 345-354.
47. Suhag, R. (2016). Overview of ground water in India. PRS On Standing Committee On Water Resources, Legislative Research,(February), 12p.
48. Priyadarshini, P., & Abhilash, P. C. (2020). Policy recommendations for enabling transition towards sustainable agriculture in India. Land Use Policy, 96, 104718.
49. McElwee, P., Chiroleu-Assouline, M., Clapp, J., Isenhour, C., Jackson, T., Kelemen, E., ... & Santos, R. (2020). Ensuring a post-COVID economic agenda tackles global biodiversity loss. One Earth, 3(4), 448-461.
50. Sperling, F., Havlik, P., Denis, M., Valin, H., Palazzo, A., Gaupp, F., & Visconti, P. (2020). Transformations within reach: Pathways to a sustainable and resilient world-Resilient Food Systems.
51. Di Marco, M., Baker, M. L., Daszak, P., De Barro, P., Eskew, E. A., Godde, C. M., ... & Ferrier, S. (2020). Sustainable development must account for pandemic risk. Proceedings of the National Academy of Sciences, 117(8), 3888-3892.
52. Hidrobo, M., Kumar, N., Palermo, T., Peterman, A., & Roy, S. (2020). Gender-sensitive social protection: A critical component of the COVID-19 response in low-and middle-income countries. Intl Food Policy Res Inst.
53. Mathieu, I. P. E. S. (2020). COVID-19 and the crisis in food systems: Symptoms, causes, and potential solutions.
54. Leyva, Á., & Lores, A. (2018). Assessing agroecosystem sustainability in Cuba: A new agrobiodiversity index. Elem Sci Anth, 6, 80.
55. Waha, K., Van Wijk, M. T., Fritz, S., See, L., Thornton, P. K., Wichern, J., & Herrero, M. (2018). Agricultural diversification as an important strategy for achieving food security in Africa. Global change biology, 24(8), 3390-3400.
56. Dubey, P. K., Singh, G. S., & Abhilash, P. C. (2020). Adaptive agricultural practices: Building resilience in a changing climate (p. 132). Switzerland: Springer.
57. Negi, D. S., Birthal, P. S., Roy, D., & Khan, M. T. (2018). Farmers' choice of market channels and producer prices in India: Role of transportation and communication networks. Food Policy, 81, 106-121.
58. Birthal, P. S., Negi, D. S., & Hazrana, J. (2019). Trade-off between risk and returns in farmers' choice of crops? Evidence from India. Agricultural Economics Research Review, 32(1), 11-23.
59. Birthal, P. S., Hazrana, J., & Negi, D. S. (2020). Diversification in Indian agriculture towards high value crops: Multilevel determinants and policy implications. Land Use Policy, 91, 104427.
60. Singh, A., Dubey, P. K., Chaurasia, R., Dubey, R. K., Pandey, K. K., Singh, G. S., & Abhilash, P. C. (2019). Domesticating the undomesticated for global food and nutritional security: four steps. Agronomy, 9(9), 491.
61. Bridgewater, P., & Rotherham, I. D. (2019). A critical perspective on the concept of biocultural diversity and its emerging role in nature and heritage conservation. People and Nature, 1(3), 291-304.
62. Priyadarshini, P., & Abhilash, P. C. (2019). Promoting tribal communities and indigenous knowledge as potential solutions for the sustainable development of India. Environmental Development, 32, 100459.

63. Resler, M. L., & Hagolani-Albov, S. E. (2021). Augmenting agroecological urbanism: the intersection of food sovereignty and food democracy. Agroecology and Sustainable Food Systems, 45(3), 320-343.
64. Borysiak, J., Mizgajski, A., & Speak, A. (2017). Floral biodiversity of allotment gardens and its contribution to urban green infrastructure. Urban ecosystems, 20, 323-335.
65. Caputo, S., Schoen, V., Specht, K., Grard, B., Blythe, C., Cohen, N., ... & Poniży, L. (2021). Applying the food-energy-water nexus approach to urban agriculture: From FEW to FEWP (Food-Energy-Water-People). Urban Forestry & Urban Greening, 58, 126934.
66. Langemeyer, J., Madrid-Lopez, C., Beltran, A. M., & Mendez, G. V. (2021). Urban agriculture—A necessary pathway towards urban resilience and global sustainability?. Landscape and Urban Planning, 210, 104055.
67. Mitchell, M., Goldsworthy, N., Roth, A., & Gonzalez-Avram, C. (2019). Unique in-school garden and nutrition intervention improves vegetable preference and food literacy in two independently conducted evaluations (P16-040-19). Current Developments in Nutrition, 3, nzz050-P16.
68. Petrovic, N., Simpson, T., Orlove, B., & Dowd-Uribe, B. (2019). Environmental and social dimensions of community gardens in East Harlem. Landscape and Urban Planning, 183, 36-49.
69. Puigdueta, I., Aguilera, E., Cruz, J. L., Iglesias, A., & Sanz-Cobena, A. (2021). Urban agriculture may change food consumption towards low carbon diets. Global Food Security, 28, 100507.
70. Abhilash, P. C., Tripathi, V., Edrisi, S. A., Dubey, R. K., Bakshi, M., Dubey, P. K., ... & Ebbs, S. D. (2016). Sustainability of crop production from polluted lands. Energy, Ecology and Environment, 1, 54-65.
71. Meers, E., Van Slycken, S., Adriaensen, K., Ruttens, A., Vangronsveld, J., Du Laing, G., ... & Tack, F. M. G. (2010). The use of bio-energy crops (Zea mays) for 'phytoattenuation'of heavy metals on moderately contaminated soils: a field experiment. Chemosphere, 78(1), 35-41.
72. Yu, L., Zhu, J., Huang, Q., Su, D., Jiang, R., & Li, H. (2014). Application of a rotation system to oilseed rape and rice fields in Cd-contaminated agricultural land to ensure food safety. Ecotoxicology and environmental safety, 108, 287-293.
73. Ismail, A., Riaz, M., Akhtar, S., Ismail, T., Amir, M., & Zafar-ul-Hye, M. (2014). Heavy metals in vegetables and respective soils irrigated by canal, municipal waste and tube well waters. Food Additives & Contaminants: Part B, 7(3), 213-219.
74. Stasinos, S., & Zabetakis, I. (2013). The uptake of nickel and chromium from irrigation water by potatoes, carrots and onions. Ecotoxicology and Environmental Safety, 91, 122-128.
75. Otsuka, K. (2013). Food insecurity, income inequality, and the changing comparative advantage in world agriculture. Agricultural Economics, 44(s1), 7-18.
76. Smutka, L., Steininger, M., Maitah, M., & Škubna, O. (2015). The Czech agrarian foreign trade-ten years after the EU accession.
77. Wegren, S. K., & Elvestad, C. (2018). Russia's food self-sufficiency and food security: An assessment. Post-Communist Economies, 30(5), 565-587.
78. Smyth, S. J., Phillips, P. W., & Kerr, W. A. (2015). Food security and the evaluation of risk. Global Food Security, 4, 16-23.
79. Modi, R. (2019). The role of agriculture for food security and poverty reduction in sub-Saharan Africa. The Palgrave handbook of contemporary international political economy, 391-410.
80. Pretty, J. N., Williams, S., & Toulmin, C. (2012). Sustainable intensification: increasing productivity in African food and agricultural systems. Routledge.
81. Sahn, D. E. (Ed.). (2015). The fight against hunger and malnutrition: the role of food, agriculture, and targeted policies. OUP Oxford.
82. Abraham, M., & Pingali, P. (2020). Transforming smallholder agriculture to achieve the SDGs. The role of smallholder farms in food and nutrition security, 173-209.
83. Mulatu, K., & Hunde, D. (2019). Agroforestry: A Supplementary Tool for Biodiversity Conservation and Climate Change Mitigation and Adaptation. system, 9(19).