



Review paper

Organic Farming in India: Principles, Practices, Environmental Implications, Current Scenario, and Future Perspectives

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ABSTRACT

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Agriculture plays a central role in India's economy and rural livelihoods. Yet, the long-term reliance on intensive chemical inputs following the Green Revolution has raised concerns regarding soil degradation, environmental sustainability, and food safety. In this context, organic farming has emerged as an alternative agricultural approach that emphasizes ecological balance, resource recycling, and reduced dependence on synthetic inputs. This review examines the conceptual foundations, principles, and practices associated with organic farming while highlighting its relevance in the Indian agricultural context. The study also reviews the current status of organic farming in India, the environmental and nutritional implications of organic food production, and the growing consumer interest in organically produced commodities. Government initiatives and policy interventions aimed at promoting organic agriculture are also discussed as important drivers for sectoral growth.



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1. Introduction

The majority of Indians reside in areas that either directly or indirectly rely on the agricultural industry for their livelihood, making the country primarily an agricultural one (Yadav & Anand, 2019). Not only is agriculture the foundation of India's economy (Gugalia, 2021), but it also plays a significant role in rural development and job creation. The Green Revolution represented a structural shift in

agricultural production systems, resulting in a substantial rise in crop productivity. This transformation was driven by multiple interrelated interventions, including the expansion of cultivated land, the adoption of double-cropping systems to maximize land-use efficiency, and the introduction of high-yielding varieties (HYVs) of seeds. The strategy was further supported by the intensive application of synthetic fertilizers and chemical pesticides, the development of assured irrigation infrastructure, and

the modernization of farm machinery along with improved crop management and protection practices (John & Babu, 2021). In January 2016, the Government of India introduced the Pradhan Mantri Fasal Bima Yojana (PMFBY) to strengthen agricultural risk management. The scheme provides financial protection to farmers against crop losses due to natural calamities, pests, and diseases, thereby stabilizing farm incomes and promoting sustainable and resilient agricultural development (Layaraja M & Layaraja C, 2020).

The earliest organized initiatives aimed at promoting organic crop production in India were initiated in Madhya Pradesh. At present, states such as Maharashtra and Madhya Pradesh are recognized for the cultivation of organically grown fruits, including mango, pineapple, banana, and papaya. In addition, several states—namely Haryana, Punjab, Madhya Pradesh, Maharashtra, and Uttar Pradesh—are engaged in the production of organically cultivated cereals such as wheat, maize, and sorghum. Among these, Madhya Pradesh holds a distinctive position in the large-scale production of organic oilseeds, contributing significantly to the country's organic agricultural output (Kulhade et al., 2016). According to the Annual Report of the Ministry of Agriculture and Farmers' Welfare (2021–2022), India's food grain production was projected at approximately 308.65 million tons from an estimated 129.34 million hectares (1,293.43 lakh hectares) of cultivated area, reflecting the long-term productivity gains associated with these technological and institutional interventions.

2. Current Scenario of Organic Farming in India

Organic agriculture in India, although historically embedded in traditional farming systems, has gained formal structure and regulatory support in recent years. Earlier farming practices were largely dependent on ecological processes and the recycling of crop residues, livestock waste, and other organic materials, which sustained soil fertility and productivity (Varghese T. S., 2003). Under current certification requirements, farmland must undergo a three-year transition period before it qualifies for certified organic production, allowing both soil health and management practices to align with prescribed standards.

India has become an important participant in the global organic sector. Around 1.49 million hectares are reported under organic certification, with approximately 1.70 million metric tons of certified organic output recorded in 2015–16 (World of Organic Agriculture – Figures & Emerging Trends, 2018). In 2018, the country ranked first in terms of the number of organic producers and ninth worldwide in total organic area. It also holds the eleventh position globally in organic export earnings.

The sector operates under the National Programme for Organic Production (NPOP), which provides a framework for standards, accreditation, and certification.

Nearly 1.78 million hectares are currently managed organically, producing a wide range of commodities such as oilseeds, cereals, pulses, cotton, sugarcane, medicinal plants, tea, coffee, fruits, and vegetables. Rajasthan, Uttar Pradesh, Maharashtra, Karnataka, and Madhya Pradesh are among the leading states. In crop protection, emphasis is placed on botanical formulations and microbial biocontrol agents as environmentally compatible alternatives to chemical pesticides (Arancon et al., 2003).

3. Core Elements of Organic Farming Systems

Organic farming is built upon several interrelated components that collectively sustain soil health and crop productivity. Key elements include biological nitrogen fixation, systematic crop rotation, incorporation of crop residues, application of biopesticides, and the use of biogas slurry as an organic nutrient source. Vermicomposting also constitutes a central practice in organic systems, as it enhances soil structure, microbial activity, and nutrient availability, thereby supporting sustainable crop growth (Akhtar & Siddiqui, 2009). The principal components of organic farming are outlined below:

3.1 Recycling and Management of Crop Residues

India possesses substantial potential for recycling crop residues, including cereal straw and pulse by-products, within organic farming frameworks. These residues—comprising stalks, stems, leaves, and seed pods—serve as valuable sources of organic matter and nutrients. When incorporated into the soil, particularly in combination with beneficial fungal inoculants, they contribute to improved soil physico-chemical properties and enhanced crop productivity (Santhoshkumar et al., 2017).

3.2 Planned Crop Rotation for Soil and Pest Management

Sustainable farming requires the systematic rotation of crops on the same field across successive seasons to preserve soil fertility and regulate pests, weeds, and diseases. Rotational planning disrupts pest life cycles and reduces the build-up of soil-borne pathogens while improving nutrient balance. The inclusion of leguminous crops in rotation is particularly beneficial, as they enhance soil nitrogen levels through biological fixation, thereby contributing to long-term soil productivity (Santhoshkumar et al., 2017; Akhtar and Siddiqui, 2009).

3.3 Organic Manures as Natural Nutrient Sources

Organic manures originate from plant residues, animal wastes, poultry litter, and other biodegradable materials. After proper decomposition, they are applied in organic systems to ensure they are free from pathogens and weed seeds. They improve crop growth by enhancing humic substance uptake and stimulating soil microbial activity, which supports the gradual release of essential macro- and micronutrients, thereby sustaining soil fertility and productivity (Santhoshkumar et al., 2017; Koner and Laha, 2021).

Animal manure is widely applied to grasslands and cultivated fields as a natural source of nutrients. With the projected growth of the livestock sector, particularly in developing countries, the availability of animal waste is expected to increase in the coming decades. Beyond its fertilizing value, livestock manure has also been examined for its potential role in mitigating soil contamination. Studies indicate that its application can assist in reducing the toxicity of soils affected by heavy metals, functioning as a supportive approach to phytoremediation strategies (Mariappan & Zhou, 2019).

Bird manure is a nutrient-rich organic fertilizer, with uric acid serving as its primary nitrogen source. Seabird guano generally contains 8–21% nitrogen by weight, mainly in the form of uric acid, along with smaller amounts of protein, ammonia, and nitrates. Owing to its high nutrient concentration, particularly its contribution to nitrate (NO_3^-) and ammonium (NH_4^+) in soil, it is widely recognized for enhancing soil fertility (Mariappan and Zhou, 2019).

3.4 Organic Waste Resources in Sustainable Agriculture

The term “waste” refers to materials or by-products that are no longer used for their original purpose. Unlike residues generated within natural ecosystems—such as carbon dioxide or decomposed organic matter—many wastes arising from human activities are more persistent and degrade slowly. Broadly, waste materials relevant to agriculture can be categorized into industrial waste and municipal or sewage waste.

Certain industrial by-products, including spent biomass and coir pith, can be processed and utilized as organic amendments. Similarly, properly treated municipal and sewage wastes represent significant sources of organic matter and nutrients for soil application, contributing to nutrient recycling within agricultural systems (Santhoshkumar et al., 2017; Rai et al., 2021).

3.5 Nutrient Potential of Urine as an Organic Input

Urine is a nutrient-rich liquid containing essential macronutrients required for plant growth, particularly nitrogen (N), phosphorus (P), and potassium (K). Human urine, although often overlooked, represents a valuable resource in nutrient recycling systems. In addition to N, P, and K, it also contains secondary nutrients such as sulfur (S), calcium (Ca), and magnesium (Mg), which contribute to balanced plant nutrition.

Increasing attention is being directed toward the controlled use of treated human urine in agriculture, recognizing its potential as a sustainable and efficient nutrient source within organic farming systems (Mohammadi & Sohrabi, 2012).

3.6 Biofertilizers and Nitrogen-Fixing Microorganisms

Biofertilizers such as arbuscular mycorrhizal fungi can be used in organic farming to enhance nutrient uptake and soil fertility to improve plant growth and development in various ways, like abiotic stress conditions (Khan et al., 2024a; Khan et al., 2025; Dubey et al., 2026). Soil microorganisms can also be used in organic farming as a biofertilizer and soil fertility for better crop production (Khan & Singh 2024; Khan & Singh 2026). Plant growth-promoting rhizobacteria (PGPR) can also be used to enhance nutrient availability and soil fertility to improve plant growth and development in sustainable agriculture (Singh et al., 2025; Khan et al., 2024b).

These include nitrogen-fixing and phosphate-solubilizing microbes applied to seeds or soil to improve nutrient uptake through natural biological processes (Mohammadi and Sohrabi, 2012). They are broadly classified into symbiotic and asymbiotic nitrogen fixers. In symbiotic fixation, *Rhizobium* forms nodules on the roots of leguminous crops and converts atmospheric nitrogen into plant-available forms (Kulhade et al., 2016; Mohammadi & Sohrabi, 2012). Phosphate-solubilizing microbes further improve nutrient efficiency. Asymbiotic nitrogen fixation is carried out by free-living organisms such as *Azotobacter*, blue-green algae (BGA), *Azolla*, *Azospirillum*, and mycorrhizae. *Azolla* is commonly used in rice cultivation in several Asian countries, while *Azospirillum* benefits cereals and millets by colonizing the root zone and enhancing nitrogen availability (Singh R. et al., 2019).

3.7 Vermicomposting and Soil Nutrient Enhancement

Vermicomposting is a biological process in which earthworms decompose organic materials into a stabilized, humus-like product known as vermicompost (Mariappan & Zhou, 2019). The

practice of rearing earthworms for this purpose is termed “vermiculture.” During decomposition, earthworms consume organic residues and excrete nutrient-rich castings that contain appreciable amounts of nitrates and essential minerals such as phosphorus, magnesium, calcium, and potassium. Application of vermicompost has been shown to improve soil quality by increasing total organic carbon and enhancing the availability of nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), zinc (Zn), and manganese (Mn), thereby supporting improved plant growth compared to untreated soils (Mohammadi and Sohrabi, 2012).

3.8 Role of Biopesticides in Ecological Crop Protection

Biopesticides are pest control agents derived from natural sources such as plants, microorganisms, animals, and certain minerals (Wani et al., 2017). These substances exert their effects through biological mechanisms that influence the growth, reproduction, or metabolic functions of insects, fungi, nematodes, and other target organisms. Many biopesticides are plant-based and contain bioactive compounds such as alkaloids, phenolics, and other

secondary metabolites that possess protective properties. Owing to their natural origin and relatively lower environmental impact, they are widely integrated into organic farming systems as sustainable alternatives to synthetic pesticides (Santhoshkumar et al., 2017).

3.9 Plant Nutrition through Organic Inputs

The availability of nitrogen (N), phosphorus (P), and potassium (K) from organic sources is estimated based on their total nutrient content, though their release is generally slower than that of mineral fertilizers. Combining organic amendments with chemical fertilizers can enhance soil quality and maintain long-term crop productivity. While continuous use of inorganic NPK fertilizers may reduce soil pH, organic inputs tend to stabilize or improve it. Beyond supplying primary nutrients, organic materials also mobilize bound phosphates, micronutrients, and nutrients released from decomposed residues, thereby supporting balanced plant nutrition (Kumar et al., 2019). Core components of organic farming and their functional roles in soil and crop management are mentioned in Table 1.

Table 1 Core Components of Organic Farming and Their Functional Roles in Soil and Crop Management

Component of Organic Farming	Functions and Agricultural Significance	References
Crop Rotation	(i) Suppresses weed growth and reduces the incidence of crop diseases. (ii) Maintains and improves soil fertility over successive cropping cycles. (iii) Enhances soil structure and stability. (iv) Supports balanced biotic–abiotic interactions within the soil ecosystem. (v) Minimizes risks of soil and water contamination.	Kumar et al., 2019
Organic Manure	(i) Serves as a natural source of nitrogen and other essential nutrients for crops. (ii) Improves soil structure, fertility, and moisture retention capacity. (iii) Provides essential macro- and micronutrients required for plant growth.	Bullock DG, 1992
Biofertilizers	(i) Contribute to the regulation and improvement of soil nutrient balance. (ii) Facilitate the transformation of insoluble phosphates into plant-available forms. (iii) The indirect method of PGPR can also help in nutrient uptake for better growth of plants.	Han et al., 2016; Khan and Singh 2025
Organic Matter and Crop Residues	(i) Help to regulate soil temperature and moisture conditions. (ii) Promote mineralization processes that release nutrients for plant uptake. (iii) Supply carbon sources that stimulate beneficial soil microbial activity.	Mishra et al., 2013

4. Rationale for Promoting Organic Agriculture

The Green Revolution significantly increased agricultural productivity through the intensive use of irrigation, machinery, fertilizers, and pesticides (Reddy, 2010). Although these interventions strengthened food security, their prolonged and excessive application has generated serious environmental and public health concerns (Kaswan et al., 2012). Over the past four decades, indiscriminate use of agrochemicals and intensive farming practices have contributed to soil degradation, declining groundwater levels, salinization, biodiversity loss, contamination of food products, and rising cultivation

costs. Residual pesticides in food chains have been associated with various health disorders. At the same time, the accumulation of heavy metals such as cadmium (Cd), lead (Pb), and arsenic (As) in soils poses additional risks, and these risks are tackled by using rhizospheric bacteria in organic agriculture to reduce the toxicity of heavy metals (Bhattacharyya, 2004; Xavier et al., 2004; Khan et al., 2026).

Monocropping, excessive tillage, and erosion of indigenous crop varieties have further weakened agroecosystem resilience, particularly in semi-arid regions where traditional crops like millets once thrived (John & Babu, 2021). In this context, organic farming is increasingly viewed as a sustainable

alternative that can restore soil health, preserve biodiversity, and safeguard human well-being while ensuring long-term agricultural stability.

4.1 Organic Food Safety and Health Benefits

The rising demand for organic food is largely influenced by consumer concerns regarding food safety, quality, and environmental sustainability (Pell, 1997; Singh et al., 2022). Although organic farming may produce lower yields, it minimizes the use of synthetic pesticides and fertilizers. Studies have reported higher levels of organophosphate pesticide metabolites in individuals consuming conventionally grown foods compared to those following organic diets (Curl et al., 2003; Lu et al., 2006).

Organic food production follows strict certification standards that restrict agrochemical use (Teixeira et al., 2022; FAO, 2021). In India, regulation is ensured under the Food Safety and Standards (Organic Foods) Regulations, 2017, which set limits for contaminants and residues (Food Safety and Standards Authority of India, 2017). Research also indicates that short-term consumption of organic diets can significantly reduce pesticide exposure in both adults and children (Oates et al., 2014; Bradman et al., 2015).

4.2 Nutritional Attributes of Organic Foods

Studies comparing organic and conventional crops report variable results regarding nutritional quality. Some evidence indicates higher levels of minerals such as iron and magnesium in organically grown crops (Rembialkowska, 2007), including increased iron content in organic aromatic rice (Saha et al., 2007). Organically produced wheat has also shown higher concentrations of micronutrients such as Fe, Zn, Ca, Mg, and Mn in certain studies (Cioel et al., 2012), although other research found no major differences in protein, amino acid composition, or mineral content (Mäder et al., 2007).

Organic crops may also contain higher lysine levels in wheat and greater vitamin C content in some vegetables such as potatoes (Fischer & Richter, 1986; Kolbe et al., 1995). However, some traits, including fatty acid composition in oats, appear largely unaffected by the cultivation system (Capouchová et al., 2021). Overall, nutritional differences vary among crops, indicating the need for further research.

4.3 Environmental Benefits of Organic Farming

Organic farming is considered environmentally sustainable as it avoids synthetic pesticides and fertilizers, thereby reducing soil and water contamination and protecting biodiversity (Oquist et al., 2007; Alföldi et al., 2002). Organic systems improve soil structure, water retention, and ecological

stability while supporting diverse plant, insect, and microbial communities (Pimentel et al., 2005; Lynch et al., 2012).

Practices such as crop rotation, organic manure application, and biological nitrogen fixation enhance soil organic carbon, reduce nutrient leaching, and improve soil fertility (Griffiths et al., 2010; Mondelaers et al., 2009). Long-term studies further show that organic management increases soil carbon, nutrient availability, and microbial activity, contributing to a more sustainable and resilient agroecosystem (Yadav et al., 2009; Singh et al., 2019; Panwar et al., 2022).

4.4 Organic Approaches to Managing Crop Pests and Diseases

In organic agriculture, pest and disease management relies on preventive and ecological strategies rather than synthetic chemicals. Key approaches include cultural practices such as crop rotation, maintenance of soil health, and the use of resistant crop varieties. Habitat management techniques, including shelterbelts and hedgerows, are employed to encourage natural predators. Biological control through the release of parasitoids and microbial agents is also widely practiced. In addition, plant-based formulations, mineral oils, traditional preparations such as Panchagavya and Dasagavya, pheromone traps, and approved organic pesticides are used as part of an integrated organic protection strategy.

5. Constraints in Organic Farming Systems

5.1 Lower Crop Productivity

One of the commonly reported limitations of organic farming is comparatively lower crop yield, particularly during the initial transition period from conventional to organic management. Nutrient supply from organic inputs is generally slower and less immediately available to plants, which can temporarily restrict crop productivity. Although yields may gradually stabilize as soil fertility improves over time, complete reliance on organic nutrient sources may pose challenges in meeting large-scale food production demands (Muscanescu, 2013).

5.2 Higher Production and Market Costs

One of the major constraints of organic farming is the comparatively higher cost of production. Crops cultivated without synthetic pesticides are often more susceptible to pest and disease attacks, which can result in yield losses. In addition, organic farming systems are typically more labor-intensive, and inputs such as organic feed are generally more expensive

than conventional alternatives (Muscanescu, 2013; Sharma & Bhatt, 2022). These increased production costs are usually transferred to consumers, making organic foods more expensive than conventionally produced products. Although some consumers are willing to pay premium prices for organic foods, demand may decline during periods of economic hardship. Furthermore, large institutional buyers such as hotels, restaurants, airlines, and cafés that could regularly purchase high-priced organic products remain relatively limited (Muscanescu, 2013).

5.3 Limited Technical Awareness and Skill Gaps

The effectiveness of organic farming systems is highly dependent on the farmer's technical knowledge, practical skills, and management capacity. In many cases, inadequate awareness of improved composting techniques, including scientific compost preparation and vermicomposting methods, limits the quality and efficiency of organic inputs. Insufficient understanding at both preparation and application stages often results in suboptimal nutrient management, thereby affecting crop performance and overall productivity (Akhtar & Siddiqui, 2009).

5.4 Limited Availability and Market Supply

One of the major challenges in organic farming is the inadequate supply of organic products to meet the growing market demand. In many regions, particularly in India, limited production capacity and insufficient diversity of organic products restrict the expansion of the domestic organic market. This imbalance between demand and supply remains a significant constraint for the development of the organic farming sector (Wani et al., 2017).

5.5 Increasing Cost of Organic Inputs

The rising cost of organic inputs has become a significant constraint in organic farming. Materials such as neem cake, groundnut cake, farmyard manure, cow dung, and earthworms used for vermicomposting are becoming increasingly expensive due to limited availability. This scarcity contributes to higher production costs in organic agriculture. In contrast, chemical fertilizers are often more readily accessible and easier for farmers to procure when they have sufficient purchasing power (Wani et al., 2017).

6. Government Initiatives Supporting Organic Agriculture in India

The Government of India has introduced several programs to promote organic farming, improve domestic supply, and expand export potential, particularly from the northeastern region. These

initiatives focus on farmer awareness, post-harvest infrastructure, certification, marketing support, and premium pricing of organic products, thereby encouraging wider adoption of organic practices (Layaraja M & Layaraja C, 2020).

6.1 Paramparagat Krishi Vikas Yojana (PKVY)

Launched in 2015 under the National Mission for Sustainable Agriculture, PKVY promotes organic farming through cluster development, farmer training, certification, and marketing support (Layaraja M & Layaraja C, 2020).

6.2 One District One Product (ODOP)

Initiated by the Uttar Pradesh government on 24 January 2018, this program promotes district-specific traditional products to generate employment and enhance market visibility (Layaraja M & Layaraja C, 2020).

6.3 Mission Organic Value Chain Development for North Eastern Region (MOVCNDR)

This scheme supports organic cultivation of niche crops through Farmer-Producer Organizations (FPOs), providing financial assistance of ₹25,000 per hectare for three years along with support for capacity building and post-harvest infrastructure (Layaraja M & Layaraja C, 2020).

6.4 National Food Security Mission (NFSM)

Launched in 2007, NFSM promotes sustainable agricultural practices, including organic and natural farming approaches such as Bharatiya Prakritik Krishi Padhati (BPKP) (Layaraja M & Layaraja C, 2020).

7. Research Priorities for Strengthening Pest and Disease Management

Future investigations should focus on developing weather-based forecasting systems for agricultural insects, pests, and diseases to enable timely interventions. Continuous surveillance and scientific management of emerging pests and pathogens are essential. Research is also needed to identify the genetic and ecological basis of resistance in major crop pests and diseases. Further emphasis should be placed on evaluating bioagents, beneficial microorganisms, and botanicals for their insecticidal and disease-suppressive potential. Designing crop-specific disease management modules and establishing environment-based economic threshold levels for key pests across different agroclimatic zones are equally important. In addition, systematic monitoring of resistance to insecticides, fungicides, and other plant protection measures must be

strengthened to ensure sustainable crop protection strategies.

8. Conclusion and Future Perspective

The evolution of Indian agriculture—from traditional ecological practices to chemically intensive systems and now toward renewed interest in organic methods—reflects an ongoing search for sustainability, resilience, and food security. While the Green Revolution significantly strengthened national food production, its long-term ecological and health implications have highlighted the need for more balanced production models. In this context, organic farming emerges not merely as an alternative technique but as a systems-based approach that reconnects agricultural productivity with ecological processes. The discussion presented in this work demonstrates that organic farming is rooted in well-defined principles and supported by contemporary scientific research. Its emphasis on soil regeneration, biodiversity conservation, nutrient recycling, biological pest regulation, and responsible resource use aligns closely with the goals of sustainable development. At the same time, the sector faces genuine constraints, including transitional yield gaps, higher production costs, limited technical awareness, input availability challenges, and market imbalances. These limitations underscore the importance of continued research, farmer training, infrastructure development, and policy support. India's expanding institutional framework, certification systems, and government initiatives indicate a growing commitment to strengthening the organic sector. However, the long-term success of organic agriculture will depend on integrating scientific innovation with traditional ecological wisdom, ensuring economic viability for farmers, and maintaining rigorous quality standards. Ultimately, organic farming should be viewed not as a replacement for all conventional systems but as a strategic component of a diversified and resilient agricultural future capable of balancing productivity, environmental stewardship, and human well-being.

Author's Contribution

All authors of the paper have made substantial contributions to the conceptualization and design of the manuscript and data acquisition.

Conflict of Interest

No conflict of interest declared by the authors.

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