Organic Farming and Translational Research - Bridging the gap between research and practical applications in organic agriculture

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Greenhouse technology is vital to modern horticulture, enabling controlled-environment agriculture to enhance productivity, quality, and sustainability. This chapter explores greenhouse cultivation's evolution, principles, and applications, emphasizing its role in the horticultural sector. It examines the historical development of greenhouses, from ancient Roman practices to modern high-tech structures, along with advancements in materials and environmental control mechanisms. The economic aspects of greenhouse farming, including construction costs, operational expenses, and profitability, are analyzed to highlight its feasibility for high-value crop production. The chapter also reviews the present status of greenhouse farming in India, focusing on technological advancements, market trends, and government initiatives that support farmers through subsidies for polyhouse construction. Despite its benefits, greenhouse farming faces challenges such as high initial investments, the need for technical expertise, and climate-specific design considerations. However, emerging innovations, including automation and AI-driven precision agriculture, offer promising solutions for enhancing efficiency and affordability. By examining the principles, economic viability, and future prospects of greenhouse cultivation, this chapter underscores its transformative potential in ensuring food security, resource efficiency, and sustainability in modern agriculture.

Keywords: *Organic farming, Green revolution, Organic manures*

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Introduction

Organic farming is rooted in the principle that "Nature can provide for everyone's needs but not for greed, as articulated by Mahatma Gandhi. While India witnessed remarkable agricultural growth during the Green Revolution, with food grain production rising from 50 million tons at the time of independence to approximately 273.38 million tons by the end of the 2016-17 fiscal year, this growth came with significant environmental and health concerns. The Green Revolution, which expanded food production across 159.59 million hectares of cultivated land, was driven by the introduction of advanced technologies, supported by policies and enhanced by agrochemicals, machinery, and irrigation (Press Information Bureau, GOI, 2017; Agriculture Census, 2010-11). These innovations played a crucial role in improving agricultural productivity and addressing India's food security (Charyulu & Biswas, 2010).

However, they also led to farmers' increased dependence on purchased inputs like fertilizers and pesticides. The extensive use of these inputs raised concerns about their reliance on fossil fuels and costly energy sources, posing serious environmental and health risks. Over the last five decades, this heavy reliance on agrochemicals has led to a plateau in productivity, with diminishing returns becoming evident (Venkateswarlu et al., 2008). In many areas, including regions like Punjab often referred to as the "cancer belt" of India and cashew plantations in Kerala, the adverse effects of agrochemical use, such as the endosulfan crisis, highlight the environmental and health hazards, reflecting the warnings made in Rachel Carson's 1962 work, *Silent Spring*. In an ideal scenario, insecticides and herbicides are designed to be lethal only to their target organisms, ensuring safety for non-target species and humans. However, this principle is often ignored, resulting in the indiscriminate use of these chemicals, which threatens human health and the stability of ecosystems (Aktar et al., 2009). The challenges and sustainability concerns associated with modern agricultural practices prompt us to reconsider historical methods (Balachandran, 2004) and question whether our increasing reliance on external inputs is misguided.

The cycle of crop production is inherently tied to natural processes, and excessive dependence on off-farm inputs is making this system increasingly vulnerable. A viable and sustainable alternative is organic farming, which offers an effective and cost-efficient strategy for achieving long-term agricultural development (IFOAM, 2010). Moreover, organic nutrient sources address issues such as multi-nutrient deficiencies and low organic matter in soils, which are detrimental to the productivity of key food crops in farming communities (Singh et al., 2017). Organic farming is a sustainable agricultural approach that emphasizes cultivating land and growing crops in a way that preserves soil vitality and health. This is achieved through the use of organic materials, such as crop residues, animal manure, and aquatic waste, along with beneficial microorganisms (bio-fertilizers) that help release essential nutrients for crops, fostering sustainable production in an environmentally friendly and pollution-free setting (Narayanan, 2005; Guruswamy & Gurunathan, 2010; Makadia & Patel, 2015).

According to the United States Department of Agriculture (USDA), organic farming is defined as a system that minimizes or largely eliminates the use of synthetic inputs, such as fertilizers, pesticides, hormones, and feed additives. Instead, it focuses on practices like crop rotations, the use of crop residues, animal manures, off-farm organic waste, mineral rock additives, and biological methods for nutrient mobilization and plant protection. The Food and Agriculture Organization (FAO) describes organic agriculture as a unique production management system that enhances agro-ecosystem health by promoting biodiversity, biological cycles, and soil biological activity. This is achieved through the use of on-farm agronomic, biological, and mechanical techniques while excluding all synthetic off-farm inputs.

Main principles of Organic Farming

The principles of organic farming, as outlined by Chandrashekar (2010), emphasize sustainability, ecological balance, and ethical practices in agriculture. These principles include utilizing local resources and operating within closed systems to maintain long-term soil fertility and health, while minimizing pollution from agricultural activities. Organic farming also focuses on producing nutritious food in sufficient quantities, reducing reliance on fossil fuels, and providing livestock with conditions that meet their natural physiological needs. Additionally, it aims to support the livelihoods of farmers, helping them thrive both economically and personally. These principles are fundamentally based on the four ethical pillars defined by IFOAM (2005): Health, which focuses on the well-being of soil, plants, animals, and humans; Ecology, which stresses alignment with natural systems; Fairness, which promotes equity among stakeholders and consideration for future generations; and Care, which underscores the importance of responsible and precautionary management in farming practices. Together, these pillars establish the foundation for a comprehensive and sustainable agricultural system.

The main pillars of organic farming

According to Roychowdhury et al., (2013), the main pillars of organic farming encompass several critical components that ensure its effectiveness and sustainability.

1. Organic threshold standards are fundamental, establishing clear guidelines and benchmarks to define organic farming practices, ensuring consistency and quality.
2. Reliable certification and regulatory mechanisms are equally vital, providing transparency, maintaining trust, and ensuring adherence to organic principles through proper oversight.
3. The integration of technology packages is another crucial pillar, involving innovative, sustainable, and adaptable agricultural practices that enhance productivity while preserving ecological balance.
4. An efficient and feasible market network supports the viability of organic farming by connecting producers with consumers, ensuring fair pricing, and fostering market growth for organic products. Together, these pillars form a robust framework for promoting and sustaining organic agriculture.

Organic farming in India

Historical backgrounds

The roots of organic agriculture in India are deeply connected to its cultural and historical heritage. This concept reflects an ancient philosophy of living in harmony with nature, as depicted in the Vedas from the later Vedic period. These texts emphasize a symbiotic relationship with the environment, rather than its exploitation. Organic farming practices and the use of natural inputs are also mentioned in other important ancient Indian texts, such as the Rigveda, Ramayana, Mahabharata, and Kautilya's Arthashastra. Traditional Indian agriculture has long been shaped by practices developed through the collective wisdom of rural villages and farming communities over thousands of years. These methods naturally aligned with organic farming principles, using locally available resources to maintain soil fertility and crop productivity while safeguarding ecological balance. To gain a clearer understanding of the evolution of organic farming in India, a timeline of key milestones in this field is presented in **Table 1**, offering a chronological overview of the developments that contributed to the modern form of organic agriculture.

Table 1. Historical perspective of organic farming in India

Source	Description
Ancient period	Oldest practice 10000 years old, dating back to Neolithic age, practiced by ancient civilization like Mesopotamia, Hwang-Ho basin etc.
Ramayana	All dead things - rotting corpse or stinking garbage returned to earth are transformed into wholesome things that nourish life. Such is the alchemy of mother earth - as interpreted by C. Rajagopalachari
Mahabharata (5500 BC)	Mention of Kamadhenu, the celestial cow and its role on human life and soil fertility.
Rig Veda (2500–1500 BC)	Mention of organic manure in Ria Veda 1, 161, 10, 2500–1500 BC, is Green Manure in Atharva Veda II 8.3, (1000 BC). In Sukra (IV, V, 94, 107–112) it is stated that to cause healthy growth, the plant should be nourished by dungs of goat, sheep, cow, water as well as meat. A reference of manure is also made in Vrksayurveda by Surpala (manuscript, oxford, No 324 B, Six, 107-164)
Kautilya Arthashastra (300 BC)	Mentioned several manures like oil cake, excreta of animals.
Brihad-Sanhita (By Varahmihir)	Described how to choose manures for different crops and the methods of manuring.
Holy Yuan (590 AD)	At least one third of what you take out from soils must be returned to it implying recycling or post-harvest residue.

(Source: Bhattacharyva & Chakraborty, 2005)

Mahatma Gandhi strongly advocated for organic farming through his initiatives across various regions of India. However, the widespread promotion of the Green Revolution led to a decline in the adoption of the organic farming practices supported by the Gandhian movement. Research indicates that small-scale farmers, especially in developing countries, are more likely to adopt agricultural practices such as crop rotation and mixed cropping, which are key components of organic farming. These farmers often integrate livestock rearing with their agricultural activities, using manure to enhance soil fertility. Additionally, studies suggest that while conventional agriculture tends to benefit larger farms, organic farming is more effective on smaller plots. A study by Gupta and Verma (1997) comparing grain production between organic and conventional methods found that the advantages of organic rotation diminish as farm size increases. The study also concluded that organic farming was more profitable and productive on smaller farms than conventional methods.

Government initiative

The prosperous markets of developed nations have been a primary driver of the growth of the 'certified organic' sector, which remains in its early stages in India. In 1999, it was estimated that only 0.001 percent of India's total agricultural land was dedicated to certified organic farming. Over the past two decades, non-governmental organizations and community groups have played a leading role in promoting organic agriculture across various regions of the country. In response to the growing interest in organic farming, the Government of India established a dedicated unit within the Agricultural and Processed Food Export Development Authority (APEDA) under the Ministry of Commerce and Industries (MOCI). In 2000, the MOCI introduced the 'National Programme of Organic Products' (NPOP), followed by the launch of the

'India Organic' logo in 2002. These initiatives aim to enhance the export potential of Indian organic products. Additionally, the Department of Agriculture and Cooperation has launched the 'National Project on Organic Farming' to encourage organic practices as part of a broader strategy to reduce chemical pesticide usage and promote environmentally sustainable agriculture. Despite the potential for higher returns and greater international acceptance associated with organic farming, many farmers remain hesitant to transition, as they rely on agriculture for their livelihoods, and any changes could result in immediate financial repercussions. To facilitate this shift toward organic farming among smallholder farmers, it is essential to provide subsidies for organic inputs. While such initiatives represent progress, they must be viewed in the context of the substantial subsidies the Central Government has allocated for the production and importation of chemical fertilizers and pesticides. There is significant potential for organic farming to thrive in India. With the right institutional and policy support, it would be relatively straightforward to elevate the current 'de-facto organic' farms to certified organic status. This transition could allow small farmers to tap into the profitable market for certified organic products in developed nations, thereby directly improving their economic well-being.

Extent of Organic Area and production in India and World

Currently, Australia holds the top position globally, with 1,229,290 hectares dedicated to organic agriculture. In terms of the percentage of total agricultural land, Italy ranks first, with 9% of its agricultural area classified as organic, while Germany has the highest number of organic farms worldwide, totalling 17,557. India ranks 14th globally, with 528,171 hectares under organic cultivation, representing 0.3% of its total agricultural land, and 44,926 organic farms. Together, Asian countries account for only 7% of the global organic land, with China and India being the primary contributors (Musa et al., 2022).

Table 2. Rank (on basis of total area) under organic agriculture

Rank (on basis of total area)	Country	Area under organic agriculture (ha)	Percentage of total agriculture land	Number of organic farms (registered officially)
1	Australia	1,22,94,290	2.8	1,550
2	China	23,00,000	0.4	1,600
3	Argentina	22,20,489	1.7	1,486
4	USA	16,20,351	0.5	8,493
5	Italy	11,48,162	9.0	45,115
6	Uruguay	9,30,965	6.1	630
7	Spain	9,26,392	3.7	17,214
8	Brazil	8,80,000	0.3	15,000
9	Germany	8,25,539	4.8	17,557
10	United Kingdom	6,04,571	3.8	4485
11	Canada	6,04,404	0.9	3571
12	France	5,52,824	2.0	11,640
13	**India**	**5,28,171**	**0.3**	**44,926**
	World	**3,04,18,261**	**0.65**	**7,18,744**

India ranks 8th globally in terms of cultivable land certified for organic farming, according to APEDA's 2019–20 report. Of the total certified area, 18 percent, or 0.72 million hectares, is designated as cultivable land, while the remaining 85 percent, approximately 3.99 million hectares, consists of forest and wild areas used

for collecting minor forest products. The total area certified for organic farming is 4.72 million hectares. During this period, India produced around 1.24 million metric tons of certified organic products, including a wide variety of food items such as sugarcane, cotton, oilseeds, basmati rice, pulses, spices, tea, fruits, dried fruits, vegetables, coffee, and their value-added derivatives. Organic production in India also includes non-food products like organic cotton fiber and functional food items. Among the states, Madhya Pradesh has the largest area under organic certification, followed by Himachal Pradesh and Rajasthan.

Major products produced in india by organic farming

India's organic farming sector encompasses a diverse range of commodities, reflecting the country's agricultural richness and commitment to sustainable practices. Key products cultivated through organic methods are categorized as follows:

- **Commodities:** Tea, coffee, rice (including basmati), and wheat form the core of staple organic produce.
- **Spices:** A wide variety of spices, such as cardamom, black pepper, white pepper, ginger, turmeric, vanilla, mustard, tamarind, clove, cinnamon, nutmeg, mace, and chili, are prominent in organic farming.
- **Pulses:** Leguminous crops like red gram and black gram are commonly grown organically.
- **Fruits:** Mango, banana, pineapple, passion fruit, sugarcane, orange, cashew nut, and walnut are notable examples.
- **Vegetables:** Crops like okra, brinjal (eggplant), garlic, onion, tomato, and potato are significant in the organic vegetable category.
- **Oilseeds:** Sesame, castor, and sunflower are key oilseed crops grown organically.
- **Others:** Cotton and herbal extracts add to the versatility of India's organic produce.

These products reflect India's capability to integrate traditional practices with modern organic farming principles, catering to both domestic and international markets.

The gaps and causes of intensive farming

Intensive agriculture, characterized by the excessive use of chemical inputs like pesticides and fertilizers, has severely affected regions such as North India (Punjab, Haryana, and Western Uttar Pradesh) and South India (Kerala, Tamil Nadu, Karnataka, and Coastal Andhra Pradesh). These practices, while aimed at boosting crop yields, have led to significant environmental degradation, health crises, and a decline in soil fertility. Promoting organic farming is a crucial strategy to mitigate these ill effects and restore ecological balance.

The Crisis in Punjab: "Cancer Belt" and the "Cancer Train"

The Malwa region of Punjab epitomizes the devastating consequences of unchecked chemical input use. This area, termed India's "cancer capital," has witnessed an alarming rise in cancer cases over the past decade, linked directly to pesticide misuse and deteriorating groundwater quality. Agricultural workers are among

the worst affected due to their direct exposure to these harmful chemicals. The Malwa region consumes 75% of Punjab's total pesticide use despite covering less than 15% of its area, and Punjab accounts for 17% of the total pesticide use in India.
A comprehensive survey conducted by the Punjab State Council for Science and Technology revealed stark cancer statistics:

- Muktsar district reported the highest incidence, with 136 cases per 100,000 population.
- Mansa, Bathinda, and Ferozepur districts also reported high numbers, while Tarn Taran had the lowest incidence at 41 cases per 100,000 population.

Cancer patients from Punjab frequently travel to Bikaner, Rajasthan, via a train colloquially known as the "Cancer Train" (Lalgarh-Abohar-Jodhpur Train No. 339), to access affordable treatment. This grim scenario underscores the urgent need to address the root causes of such health crises.

The way forward: embracing organic farming

To combat these challenges, a shift towards organic farming offers a sustainable solution. Organic practices prioritize the use of natural inputs, minimize environmental contamination, and improve soil health, thus reducing reliance on harmful chemicals. Educating farmers about the long-term benefits of organic farming both for human health and environmental sustainability is essential. By adopting organic methods, farmers can break free from dependency on market-supplied chemical inputs and prevent further degradation of their health and livelihoods. This transition represents not just an agricultural transformation but also a commitment to safeguarding public health and ecological integrity for future generations.

Kerala's endosulfan tragedy: a stark reminder of toxic agriculture

The Endosulfan disaster in Kerala, particularly in the Kasaragod district, serves as a cautionary tale about the dangers of indiscriminate pesticide use. Endosulfan, an organochlorine pesticide, was widely used globally from the 1950s due to its effectiveness against a broad range of pests in agriculture and other sectors. Despite being banned or severely restricted in many countries, India was the largest producer, consumer, and exporter of Endosulfan during its peak usage.

The disaster in kasaragod

The tragedy unfolded over 24 years (1976–2000) when the Plantation Corporation of Kerala (PCK) conducted aerial spraying of Endosulfan on its 4,600 hectares of cashew plantations. Despite repeated warnings about its harmful impacts on human health and the environment, the pesticide was sprayed three times annually. This relentless exposure in populated areas, combined with the contamination of open drinking water sources, led to one of the world's worst pesticide disasters.

Impacts on health and communities

The disaster had devastating effects on the health of residents in 11 Gram Panchayats covering 12 villages, including Enmakaje, Belur, Kumbadaje, and others. The affected populations faced a wide range of chronic and life-threatening conditions:

- **Neurological disorders:** Sensory loss, behavioural disorders, and neurological ailments.
- **Physical and congenital abnormalities:** Congenital anomalies and musculoskeletal disorders.
- **Cardiovascular and dermatological issues:** Chronic cardiovascular diseases and severe skin disorders.
- **Reproductive health impacts:** Evidence of increased infertility and birth defects.

Lessons learned

The tragedy highlights the long-term consequences of prioritizing agricultural productivity over environmental and public health. It underscores the need for:

- Stringent regulation and monitoring of pesticide use, particularly in densely populated and ecologically sensitive areas.
- A shift towards sustainable farming practices like organic farming to reduce reliance on toxic chemicals.
- Increased awareness and education for farmers about the environmental and health impacts of pesticide use.
- Enhanced healthcare facilities and compensation mechanisms for affected communities.

Kerala's Endosulfan tragedy is a sobering reminder of the dangers posed by toxic agricultural practices. It calls for immediate action to adopt safer, sustainable farming methods and protect vulnerable communities from similar disasters in the future.

The benefits of organic farming (de facto regions)

India’s vast agricultural landscape includes significant areas where traditional farming practices, aligned with organic principles, are prevalent. These are particularly notable in regions such as Western India (Western Rajasthan and North Gujarat) and the Northeast Region, where rainfed or dryland agriculture dominates.

Characteristics of de-facto organic farms

Minimal use of agro-chemicals: Approximately 70% of India’s arable land, primarily rainfed, relies on traditional farming practices rather than agro chemicals. Only about 20% of dryland farmers use chemical inputs; the rest maintain soil fertility through manure and green compost.

Reliance on local resources: Farmers in these regions utilize native seeds, traditional knowledge, and locally available resources for pest and disease management and nutrient optimization.

Diverse and resilient systems: The heterogeneity of farming systems in marginal, risk-prone environments encourage sustainable and diversified practices, naturally aligning with organic farming principles.

Uncertified but organic practices: These farms, referred to as ‘de-facto organic’, follow organic methodologies without formal certification. While not verified by organic certification agencies, they rely exclusively on natural methods to sustain productivity and ecological balance.

Potential and market opportunities

- **Targeting certification:** Bringing these farms under certification frameworks could enable smallholder farmers to benefit from the lucrative markets for certified organic products in developed countries.

- **Sustainability and market access:** Certified organic produce from these areas can enhance market access and fetch premium prices, supporting the economic upliftment of small-scale farmers.

Challenges and considerations

- **Certification costs:** Many small farmers lack the financial capacity to bear certification expenses.
- **Awareness and training:** Farmers require education on the benefits of certification and its procedures.
- **Infrastructure and policy support:** Enhanced infrastructure, credit facilities, and policy interventions are needed to facilitate the transition to certified organic farming.
- **Organic farming in N.E. region and western India:** India's North-eastern (N.E.) Region and parts of Western India, such as Western Rajasthan, are uniquely positioned to advance organic farming due to the predominance of traditional, chemical-free agricultural practices. These areas are recognized for their de-facto organic farming systems, where fertilizers and pesticides have never been utilized due to climatic and cultural reasons.

Potential and policy implications

Transition to certified organic farms: With appropriate institutional and policy support, these regions can transition to certified organic farming. This would enable small farmers to tap into premium-priced global markets for certified organic produce, directly contributing to their economic upliftment (Shetty et al., 2013).

Naturally organic zones: Areas like the N.E. Region, Western Rajasthan, the Himalayan region, and the Chota Nagpur Plateau inherently align with organic principles. These zones are naturally suited for organic certification, as chemical fertilizers like urea have historically not been used.

Policy recommendations: The government should designate these areas as reserved organic regions and facilitate the organic certification process at a policy level. This would ensure farmers benefit from higher market prices for certified organic products.

Sikkim as a model state: Sikkim declared India's first fully organic state in 2016 after a 13-year effort (2003–2016), serves as a pioneering model. This achievement highlights the potential of a focused, long-term strategy for converting regions to organic agriculture (Indian Express, 2016; The Hindu, 2016).

Government initiatives

Mission Organic Value Chain Development for North-eastern Region (MOVCDNER): Launched by the Ministry of Agriculture and Farmer Welfare during the 12th Five-Year Plan, this central sector scheme promotes organic farming in the North-eastern states, including Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Tripura, Sikkim, and Nagaland.

Objectives

- Enhance organic production.

- Develop efficient value chains.
- Link farmers to high-value markets for organic products.

By leveraging the natural advantages of regions like the N.E. states and Western Rajasthan, India can expand its organic agriculture footprint, bolstering rural economies and meeting growing domestic and international demand for organic produce.

Challenges of Indian organic farming
Micro-level issues

Organic farming in India faces numerous micro-level challenges that impact its adoption, particularly for small and marginal farmers. These challenges stem from economic constraints, procedural hurdles, and market dynamics.

Economic viability

The conversion of conventional farms to organic ones demands significant investments, which many smallholders find burdensome:

Conversion period costs: Farmers must strictly adhere to international standards during the conversion period, which typically spans 2-3 years. During this phase:

- Yields are often lower as soil nutrients and organic matter are replenished.
- Products cannot be marketed as "organic," denying farmers premium pricing.
- Farmers face direct costs like bio-inputs, machinery upgrades, and bunding to meet organic standards.

Certification and inspection fees

Certifying agencies charge fees that can be prohibitively high for small-scale farmers. For instance, inspection and certification costs (approximately ₹5000) can match or exceed a farmer's annual returns from conventional farming (Brook and Bhagat, 2004).

Marketing constraints

- **Access to markets:** Farmers often struggle to access domestic and international organic markets. Limited demand in the domestic market compounds this issue.
- **Lack of premium pricing during transition:** Products grown during the conversion period cannot be sold as certified organic, preventing farmers from benefiting from higher market prices.
- **Knowledge gaps:** Farmers frequently lack information about marketing opportunities, cultivation practices, and consumer demand for organic products.

Documentation and compliance

- **Mandatory documentation:** Certification requires meticulous record-keeping to verify adherence to organic standards. This is a significant challenge for smallholders, many of whom are untrained in such documentation.
- **Transaction costs:** Farmers face high transaction costs due to inadequate institutional support, such as lack of access to advisory services, training, and affordable certification mechanisms.

- **Soil recovery time:** During the initial years, organic farms typically experience a decline in yields until soil health is restored through bio-fertilizers and organic amendments. This further strains farmers' incomes during the conversion phase.
- **Reduced initial yields**

Limited domestic awareness

While organic products command premium prices in international markets, domestic awareness and demand for organic goods remain limited, restricting opportunities for farmers to earn sustainably within local markets (Das, 2004). Addressing these micro-level issues requires targeted interventions, such as subsidizing certification costs, providing transition support, and improving market linkages to make organic farming economically viable and accessible for small and marginal farmers.

Macro-level issues

Organic farming in India also faces significant macro-level challenges, particularly concerning food security, employment, and environmental sustainability. These challenges highlight the broader implications of adopting organic agriculture across the country.

Food security concerns

- **Yield reductions:** Organic farming often results in lower yields compared to conventional farming, particularly during the 2–3-year conversion period when soil fertility is being replenished (Pandey and Singh, 2012). This raises concerns about India's ability to meet its food security needs, given its history of food production deficits and the high reliance on small and marginal farmers for national food supply.

- **Population pressure:** With a growing population, the lower productivity of organic farming could exacerbate food scarcity unless supported by innovations in organic practices.

Employment opportunities

- **Increased labour demand:** Organic farming is labour-intensive, requiring greater involvement in producing agricultural inputs such as bio-fertilizers and bio-pesticides using locally sourced materials.
- **Regional and national employment potential:** While organic farming could create employment opportunities, a comprehensive assessment of its impact at regional and national levels is necessary to ensure equitable benefits across the workforce.

Environmental sustainability

- **Resource use concerns:** To compensate for potential yield reductions, organic farming might increase reliance on land and water resources. This could lead to unsustainable practices if not carefully managed.

- **Water conservation needs:** In a country where water scarcity is already a critical issue, organic farming practices must prioritize water conservation to remain sustainable, especially in regions dependent on rainfall or with limited irrigation infrastructure.

Economic and environmental costs

The Working Group on Organic and Bio-dynamic Farming of the Planning Commission (GOI, 2001b) highlighted the need to examine the following key areas:

- **Economics of organic crop production:** Understanding the cost-benefit dynamics of organic farming is essential, especially for small-scale farmers.

- **Externalities of conversion:** Transitioning from conventional to organic farming entails both economic and environmental externalities that require thorough evaluation.

- **Comparative studies:** Comparing the social, environmental, and economic costs of chemical-based farming versus organic farming is critical to developing a balanced agricultural strategy.

Conclusion

The large-scale shift to organic agriculture could lead to food shortages due to yield reductions of 10–15% compared to conventional farming systems, particularly in intensive farming areas. However, in traditional rainfed agriculture, which constitutes 70% of India's cultivable land, organic farming holds the potential to boost yields. Even a modest 5–10% increase in yields could help achieve the targeted 4–5% growth rate in agricultural production during India's Tenth Plan period. While organic manure is a renewable source of nutrients, there is a significant gap between its potential and actual utilization. If all cultivable land were converted to organic farming, it would be challenging to meet crop nutrient requirements solely through organic sources. Organic farming systems provide both agronomic benefits, such as enhanced crop yields, and environmental advantages, including sustainable resource use, biodiversity protection, and reduced dependence on costly external inputs. These benefits are important not only for developing nations like India but also for developed countries, where organic practices contribute to environmental protection, energy conservation, and reductions in CO2 emissions. While organic foods are generally considered superior in terms of health and safety, there is no definitive scientific evidence proving their superiority in taste or nutritional value. Many studies on these aspects remain inconclusive. The combination of lower input costs and premium prices for organic products can make organic farming equally or more profitable than conventional farming, even with lower yields. However, studies that fail to account for price premiums often show mixed results regarding profitability. Therefore, premium pricing is crucial for the economic viability of organic farming. In organic systems, pest and disease management is typically preventive rather than reactive, and organic farms tend to experience fewer and less severe pest and disease issues compared to conventional farms.

Conflicts of interest

Authors of Directorate of Seed, Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa, Samastipur, Bihar (India) have no conflicts among author for publications.

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