

Current trends, challenges and future perspectives of organic agriculture

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Abstract

Organic agriculture has emerged as a significant approach for promoting sustainable food production by reducing dependence on synthetic agricultural inputs, improving soil health, conserving biodiversity, and enhancing ecosystem resilience. Growing concerns regarding environmental degradation, climate change, food safety, and the long-term sustainability of conventional farming systems have increased global interest in organic production. This review provides a critical synthesis of the historical development, current trends, challenges, and future perspectives of organic agriculture. The evolution of organic farming from traditional ecological practices to a globally recognized sustainable production system is discussed, along with its increasing market importance and economic potential. The expansion of organic markets has been driven by rising consumer demand for safe and environmentally friendly products, improved awareness of sustainable consumption, and the development of organic value chains. The adoption of organic agriculture depends strongly on farmers' knowledge, awareness, motivation, and access to supportive resources. This review highlights the importance of farmer education, extension services, technical training, market opportunities, economic incentives, and institutional support in encouraging the transition toward organic farming. Despite its environmental and socio-economic benefits, organic

agriculture faces several challenges, including constrained access to organic inputs, elevated production costs, certification hurdles, insufficient technical knowledge, labor requirements, and challenges in accessing reliable markets. Addressing these constraints requires collaborative efforts involving farmers, researchers, policymakers, private organizations, and consumers. The review also emphasizes emerging opportunities for organic agriculture development through technological innovation, sustainable farming practices, improved policy frameworks, climate-smart approaches, and strengthened organic value chains. Future advancements in digital agriculture, biological inputs, ecological management strategies, and participatory research can enhance the productivity, profitability, and resilience of organic farming systems. In conclusion, organic agriculture represents a promising pathway toward sustainable agricultural development by balancing environmental conservation, economic viability, and food security. Continued research, supportive policies, and effective knowledge transfer mechanisms will be essential for expanding organic agriculture and maximizing its contribution to sustainable global food systems. © 2026 The Author(s)

Keywords: Agricultural sustainability, Biodiversity, Environmental conservation, Farmer adoption, Organic agriculture, Soil health

Citation: Ejaz, A., & Abbas, Z. (2026). Current trends, challenges and future perspectives of organic agriculture. *Journal of Plant Production and Sustainability*, 2(1), 96–111. <https://doi.org/10.63072/jpps.26009>

Introduction

Organic agriculture has gained increasing global attention as a sustainable farming approach that seeks to reduce dependence on synthetic agricultural inputs while promoting environmental conservation, soil health, biodiversity, and food safety. Growing concerns regarding the adverse effects of intensive conventional farming systems on ecosystems and human health have encouraged farmers, consumers, and policymakers to explore alternative production systems based on ecological

principles (Khan et al., 2024). Organic farming emphasizes the use of natural resources, biological processes, crop diversification, and environmentally friendly management practices to maintain agricultural productivity while minimizing negative environmental impacts (Holst et al., 2012). The increasing demand for organically produced food has contributed to the growth of organic farming in many parts of the world, including developing countries. Organic production systems are increasingly considered a pathway toward sustainable agricultural development by improving soil fertility, conserving natural resources, reducing chemical pollution, and enhancing ecosystem services (Dominy &

Haynes, 2002; Ditta & Khalid, 2016; Husen et al., 2024). These advantages have encouraged greater interest among farming communities and agricultural stakeholders in adopting organic practices across various cropping systems.

Organic agriculture promotes several environmentally beneficial practices, including the application of organic fertilizers, crop rotation, cover cropping, integrated pest management, and biological control methods (Ditta et al., 2018). These approaches contribute to improved soil structure, enhanced nutrient cycling, reduced environmental contamination, and increased biodiversity within agricultural landscapes (Latif & Abbas, 2025; Topa et al., 2025). In addition, organic production systems may improve the quality and market value of agricultural products due to increasing consumer preference for safe and environmentally responsible food production methods (Vishnoi & Goel, 2024). Despite its potential benefits, the shift from conventional to organic agriculture involves several challenges. Farmers often face difficulties related to the availability and cost of organic inputs, limited technical knowledge, certification requirements, market access, and uncertainty regarding short-term productivity changes during the transition period (Rizzo et al., 2024). These constraints can particularly affect smallholder farmers who may have limited financial resources and access to agricultural extension services. Nevertheless, the growing market demand for organically produced goods presents significant opportunities for agricultural transformation. Studies have indicated that organic production systems can contribute to sustainable livelihoods by reducing input dependency, improving long-term soil productivity, and creating opportunities for premium markets (de Araújo Barbosa Borges et al., 2019). Organic agriculture is therefore increasingly recognized as a promising approach for balancing agricultural productivity with environmental sustainability. Recent scientific evidence confirms that organic principles support the transition to climate-neutral food systems by eliminating mineral fertilizers and enhancing soil carbon sequestration. Ultimately, organic farming's holistic methodology fosters climate-sensitive behavioral shifts and strengthens overall agricultural resilience against extreme weather variability (Mueller-Lindenlauf & El-Hage, 2026).

Intensive agriculture and synthetic fertilizers cause severe global soil degradation, threatening long-term food security and climate resilience (Ali et al., 2023). A long-term study indicates that integrating legume-based cropping systems with organic nutrient management significantly enhances soil carbon, biological activity, and microbial health. These sustainable practices consistently outperform conventional chemical management, offering a robust strategy for enhancing crop productivity and ecological resilience (Bünemann et al., 2024). In Pakistan, where agricultural production plays a central role in rural livelihoods and economic development, organic agriculture has potential to address emerging concerns related to soil degradation, excessive chemical input use, and sustainable resource management. The adoption and expansion of organic farming practices require supportive policies, improved farmer awareness, development of local organic

input systems, certification mechanisms, and stronger market linkages. Understanding current trends, challenges, and future prospects of organic agriculture is essential for promoting sustainable agricultural development in the country.

Historical development of organic agriculture

The origins of organic agriculture can be traced back to traditional farming systems in which agricultural production depended on natural resource management, locally available inputs, and ecological interactions. Early farming practices relied on organic materials such as compost, animal manure, crop residues, and biological processes to maintain soil fertility and sustain crop production. However, the expansion of intensive agriculture during the twentieth century resulted in increased dependence on synthetic fertilizers, pesticides, and other external inputs to enhance productivity, leading to concerns regarding environmental degradation and long-term agricultural sustainability (García-Cano et al., 2025). The modern organic agriculture movement emerged during the mid-twentieth century as a response to the environmental and social concerns associated with industrialized farming systems. This movement emphasized ecological balance, soil conservation, reduced chemical dependency, and the integration of natural processes into agricultural production. Increasing global concerns regarding food security, environmental sustainability, nutrition, and the responsible use of natural resources have highlighted the need for sustainable food production systems and dietary practices that contribute to healthier populations and long-term environmental sustainability (Varzakas & Smaoui, 2024).

Initially, organic agriculture was considered a niche production system practiced by a limited number of environmentally conscious farmers. However, increasing consumer demand for chemical-free and sustainably produced food has transformed organic farming into a rapidly expanding agricultural sector. The developments of organic certification systems, improved market opportunities, and institutional support have further contributed to the broader spread of organic agriculture worldwide (Singh et al., 2015). In developing countries, organic agriculture has received increasing attention due to its potential to improve soil fertility, reduce dependence on costly external inputs, and provide alternative livelihood opportunities for smallholder farmers. The adoption of organic practices has been associated with improved soil health, enhanced biodiversity, and reduced environmental contamination through the replacement of synthetic agricultural chemicals with ecological management approaches (Meshram et al., 2026). In Pakistan, the development of organic agriculture is relatively recent compared with conventional agricultural systems; however, interest in organic production has increased due to growing awareness about environmental sustainability, food quality, and the adverse effects associated with excessive chemical input use. Farmers and agricultural stakeholders have shown increasing interest in adopting organic practices to improve soil productivity and promote more sustainable farming systems (Coppens et al., 2016; Bondancia et al., 2022). Despite increasing interest, the wider expansion of organic farming in Pakistan remains limited due to several factors, including insufficient awareness among farmers, limited availability of

certified organic inputs, inadequate technical guidance, certification challenges, and underdeveloped marketing systems. These constraints have slowed the transition toward organic production and highlight the need for stronger institutional support, farmer education, and improved value chains (Ahmed & Khan, 2017; Qureshi & Ali, 2018). The historical evolution of organic agriculture demonstrates a transition from traditional ecological farming systems to a modern sustainability-oriented approach. With increasing concerns regarding climate change, soil degradation, food safety, and resource conservation, organic agriculture has the potential to contribute significantly to sustainable agricultural development. Strengthening research, policy support, and market infrastructure will be essential for expanding organic agriculture and realizing its future potential in Pakistan (Zamin et al., 2025).

Current trends in organic agriculture

Organic agriculture has emerged as an important component of sustainable food production systems due to mounting concerns over environmental degradation, climate change, food safety, and the long-term sustainability of intensive agricultural practices. The growing dependence on synthetic fertilizers, pesticides, and other external inputs in conventional agriculture has encouraged researchers, farmers, and consumers to explore alternative production systems based on ecological principles. Organic farming emphasizes soil health improvement, biodiversity conservation, reduced chemical dependency, and efficient utilization of natural resources, making it an important approach for sustainable agricultural development (Folina et al., 2025). One of the major global trends in organic agriculture is the increasing consumer demand for organically produced food. Growing awareness regarding food quality, human health, environmental protection, and sustainable consumption patterns has contributed to the expansion of organic markets worldwide. Consumers are increasingly interested in products produced with fewer synthetic chemicals and with greater consideration for environmental impacts, creating new opportunities for organic farmers and value chain actors (Anwar et al., 2011). This trend has encouraged the diversification of organic commodities, including cereals, fruits, vegetables, industrial crops, livestock products, and processed organic foods (Fig. 1).

The expansion of organic farming systems represents another important trend shaping the future of sustainable agriculture. Organic agriculture has gradually moved from a small-scale alternative farming approach to a globally recognized production system supported by certification programs, international markets, and sustainability initiatives. The increasing adoption of organic practices reflects broader efforts to reduce environmental impacts, improve ecosystem services, and develop resilient agricultural systems (Pandian et al., 2026). The adoption of sustainable agricultural practices is also influencing the development of organic farming. Practices such as conservation agriculture, agroforestry, integrated nutrient management, crop diversification, and biological pest

management are increasingly incorporated into sustainable production strategies. These approaches support soil fertility improvement, enhance biodiversity, reduce environmental degradation, and improve the resilience of farming systems under changing climatic conditions (Omokaro et al., 2025). Technological innovation is becoming an emerging trend in organic agriculture development. Advances in digital agriculture, precision farming tools, remote sensing technologies, and improved biological inputs are providing new opportunities to enhance the efficiency and productivity of organic systems. These innovations can help farmers improve decision-making, optimize resource use, and overcome some limitations traditionally associated with organic production.

The establishment of organic value chains and market-oriented production systems is another significant trend. As organic markets expand, increasing attention is being given to certification systems, traceability mechanisms, processing facilities, and direct marketing approaches. Stronger organic value chains can improve farmer access to premium markets and increase economic returns while maintaining environmental sustainability. Despite these positive trends, several challenges continue to influence the ongoing growth of organic agriculture. Limited access to organic inputs, higher production costs, insufficient technical knowledge, certification barriers, and uncertain market conditions remain important constraints. Farmers often require additional training and support to successfully transition from conventional to organic farming systems because organic production depends heavily on ecological knowledge and management skills. Knowledge development and capacity building are therefore becoming increasingly important components of organic agriculture advancement. Effective extension services, farmer training programs, participatory research, and knowledge-sharing networks can improve farmers' understanding of organic practices and increase adoption rates. Strengthening education and technical support systems is essential for ensuring that farmers can effectively manage organic production challenges (Kansanga et al., 2021; Kumar et al., 2025).

Market development also remains a critical factor determining the future growth of organic agriculture. Although consumer interest in organic products is increasing, inconsistent market access, limited consumer awareness in some regions, and insufficient price incentives may restrict farmer participation. Improving consumer awareness, strengthening certification systems, and developing transparent supply chains can enhance confidence among both producers and consumers (Górska-Warsewicz et al., 2021; Nautiyal & Lal, 2025). The future trajectory of organic agriculture will depend on balancing emerging opportunities with existing challenges. Increasing consumer demand, environmental awareness, technological innovation, supportive policies, and sustainable production practices provide significant opportunities for expanding organic farming worldwide. However, achieving long-term success will require coordinated efforts among farmers, researchers, policymakers, private organizations, and consumers to develop supportive environments for sustainable organic production systems. Current trends indicate that organic agriculture is moving toward a more integrated and scientifically supported production approach (Szóke et al., 2024). The combination of

ecological farming principles, technological innovation, market development, and institutional support can strengthen the contribution of organic agriculture to sustainable food production, environmental conservation, and improved rural livelihoods. Modern organic agriculture is increasingly leveraging advanced, real-time biosensors to optimize soil health, detect pathogens, and boost yields without synthetic inputs. These technologies support climate-smart farming by facilitating the active monitoring and mitigation of greenhouse gas emissions. This integration enables intelligent resource management and offers cost-effective, sustainable food production solutions (Gangwar, 2026).

Market development and economic potential of organic agriculture

The organic agriculture market has experienced substantial growth in recent years due to increasing consumer awareness regarding food quality, environmental sustainability, and the health implications associated with conventional agricultural practices. Rising demand for organically produced food has encouraged the expansion of organic value chains and created new economic opportunities for farmers, processors, and other stakeholders involved in sustainable food systems (Hansmann et al., 2020). The growth of organic markets has been supported by changing consumer preferences, increased availability of certified organic products, and greater recognition of the environmental benefits associated with organic production systems. Studies have indicated that consumers are often willing to pay higher prices for organic products due to perceived benefits related to food safety, ecological sustainability, and reduced chemical residues. This price premium can provide opportunities for farmers to improve profitability and enhance the economic viability of organic farming systems (Smoluk-Sikorska et al., 2024). The strengthening of organic value chains plays an important role in connecting producers with expanding consumer markets. Organic farming provides opportunities for small-scale farmers to participate in specialized markets through improved product differentiation, direct marketing approaches, and access to premium-value products. However, the success of organic value chains depends on effective certification systems, market infrastructure, consumer trust, and coordination among different stakeholders (Ume, 2023).

Increasing consumer interest in sustainable food products has also stimulated diversification within the organic sector, including the development of processed organic foods and value-added products. The growing demand for organic commodities reflects broader changes in consumer behavior and increasing recognition of the relationship between agricultural production, environmental protection, and human health (Sharma et al., 2021). Although the organic market continues to expand globally, challenges such as higher production costs, certification requirements, limited market access, and supply chain constraints remain important considerations. Addressing these challenges through supportive policies, improved market networks,

technological innovation, and farmer training can strengthen the economic potential of organic agriculture and support its long-term development (Tiwari, 2023). Organic product demand is driven by the interconnected dynamics of economic stability, sustainability values, and digital marketing across both mature and transitional markets. Sustainable market growth depends on balancing price sensitivity with environmental awareness, alongside strategic digital communication to build trust and long-term loyalty (Parkhomenko et al., 2026).

Farmer knowledge and awareness of organic agriculture

Farmers' knowledge and understanding of organic farming principles are among the most important factors influencing the adoption, implementation, and long-term success of organic agricultural systems. Effective organic production requires farmers to understand ecological processes, soil fertility management, crop diversification, compost preparation, biological pest management, and the appropriate use of organic inputs. Limited knowledge of these practices can restrict farmers' ability to successfully convert from conventional to organic production systems (Rahul, 2021). Research conducted among farming communities has shown that farmers often possess a general awareness of organic agriculture but may have limited understanding of specific technical practices required for successful organic production. A study assessing farmers' knowledge in Latin America reported that while many farmers understood the basic concepts of organic farming, gaps existed regarding compost utilization, pest and disease management, and other specialized organic practices. Access to agricultural information and training programs was identified as an important factor for improving farmers' knowledge and technical capacity (Damiani, 2003). Similarly, studies from India have indicated that farmers may have insufficient knowledge regarding organic inputs, natural pest management techniques, and certification requirements. Many farmers continue to rely on traditional practices such as the application of farmyard manure and crop rotation, while lacking awareness of improved organic production technologies and scientific management approaches (Tripathi et al., 2026). These findings highlight the importance of strengthening extension services and farmer education programs to facilitate the wider adoption of organic agriculture.

Education level, farming experience, and access to information have been identified as important determinants of farmers' ability to adopt organic practices. Farmers with higher education levels and greater exposure to agricultural information are generally more likely to understand and implement organic farming methods. Training programs, demonstrations, and farmer-to-farmer knowledge exchange can improve awareness and increase confidence in adopting sustainable agricultural practices (Erekalo et al., 2025). Participation in farmer organizations and organic farming networks can also enhance knowledge sharing and encourage the adoption of environmentally sustainable practices. Farmers involved in organic farming groups often have better access to technical information, training opportunities, and market-related knowledge compared with farmers operating individually (Dube et al., 2025). Social networks and community perceptions also influence farmers' attitudes

toward organic agriculture, as cultural values, traditional beliefs, and peer interactions can affect decisions regarding the adoption of new farming practices (Chaudhary et al., 2017).

Previous studies have demonstrated that farmers' knowledge of organic farming is influenced by multiple factors, including education, farming experience, access to extension services, availability of training programs, and social conditions. Improving farmer knowledge through capacity-building initiatives is considered essential for increasing adoption rates and ensuring the sustainability of organic production systems (Tezcan et al., 2009). Research has further indicated that inadequate awareness regarding the benefits and management requirements of organic farming remains a major limitation in many agricultural regions. Farmers with limited knowledge may experience difficulties in selecting appropriate organic inputs, maintaining soil fertility, managing pests, and meeting quality standards required for organic markets (Hossain et al., 2025; Kaur et al., 2026). Increasing awareness about environmental benefits, soil improvement, reduced chemical dependency, and potential market opportunities can encourage greater participation in organic agriculture (Ahmed & Khan, 2017). Farmer training and extension interventions have been shown to positively influence knowledge levels and adoption behavior. Studies evaluating agricultural training programs found that improved access to technical guidance increased farmers' understanding of organic inputs, production methods, and sustainable management practices, thereby improving their capacity to produce high-quality organic products (Liu et al., 2022; Sáenz et al., 2024). Farmer knowledge represents a fundamental component of successful organic agriculture development. While many farmers possess traditional knowledge that supports ecological farming practices, continuous education, scientific training, and institutional support are required to improve technical skills and facilitate wider adoption of organic production systems (James et al., 2009).

Farmer interest and motivation toward organic agriculture

Farmers' interest and willingness to adopt organic agriculture are fundamental factors influencing the expansion and sustainability of organic production systems. The decision of farmers to switch from conventional to organic farming is influenced by several interconnected factors, including market opportunities, economic returns, environmental awareness, availability of resources, and access to institutional support. Understanding these factors is essential for promoting wider adoption of organic agricultural practices. Research indicates that increasing consumer preference for organic products and growing awareness regarding environmental sustainability are important drivers encouraging farmers to consider organic farming. Studies have reported that many farmers express interest in adopting organic production methods due to perceived benefits such as improved soil health, reduced dependence on synthetic inputs, and opportunities to access premium markets. However,

uncertainty regarding profitability, limited technical knowledge, and insufficient support services may reduce farmers' willingness to transition to organic systems (Okafor et al., 2026). Economic factors play a significant role in shaping farmer's interest in organic agriculture. Higher market prices for organic products, reduced dependence on expensive synthetic inputs, and potential improvements in long-term soil productivity have been identified as important motivations for farmers considering organic conversion. Farmers with previous experience in organic practices often demonstrate greater confidence and interest due to their understanding of potential economic and environmental benefits (Tiwari, 2023) (Fig. 2).

The availability of supportive infrastructure, including access to organic inputs, extension services, training opportunities, and reliable markets, strongly influences farmers' decisions regarding organic adoption. Studies have shown that farmers are more likely to adopt organic practices when they receive technical assistance, have access to market networks, and receive institutional encouragement from government and agricultural organizations (Santiphop et al., 2012). Interest among farmers in organic agriculture is also associated with environmental and health-related considerations. Concerns regarding soil degradation, chemical residues, environmental pollution, and sustainable resource management have encouraged some farmers to explore alternative production systems. Research has shown that farmers motivated by environmental protection and reduced chemical use are more likely to show interest in organic farming practices (Renouf et al., 2010). Studies from different regions have demonstrated increasing interest among farmers toward organic agriculture due to the potential for improved profitability, healthier food production, and ecological benefits. Strengthening organic markets and improving connections between producers and consumers are therefore important for encouraging farmer participation. Successful organic farming relies heavily on collaborative networks and localized knowledge sharing rather than standardized practices. Regional multi-actor partnerships and farmer-to-farmer learning groups create a shared identity that drives regional innovation and long-term sustainability across the agricultural sector (Leonneg & Nielson, 2026).

Social factors, government policies, and community-level influences also contribute to farmers' attitudes toward organic agriculture. Studies have indicated that farmer networks, social learning, policy incentives, and institutional support can influence perceptions and adoption decisions related to organic farming. Effective promotion of organic agriculture requires consideration of economic, environmental, and social factors that collectively shape farmer behavior (Mazhar et al., 2021). Although farmer enthusiasm in organic agriculture is increasing, several barriers continue to limit adoption, including production risks, insufficient knowledge, certification difficulties, and uncertain markets. Research suggests that awareness campaigns, farmer training programs, financial incentives, and improved access to organic value chains can enhance farmers' confidence and encourage wider adoption of organic farming systems (Patel & Singh, 2018). Farmer interest represents a critical component in the growth of organic agriculture. Strengthening farmer capacity, improving economic incentives, and developing supportive institutional frameworks are essential strategies for increasing

the adoption of organic production practices and achieving sustainable agricultural development (Ntshangase et al., 2018).

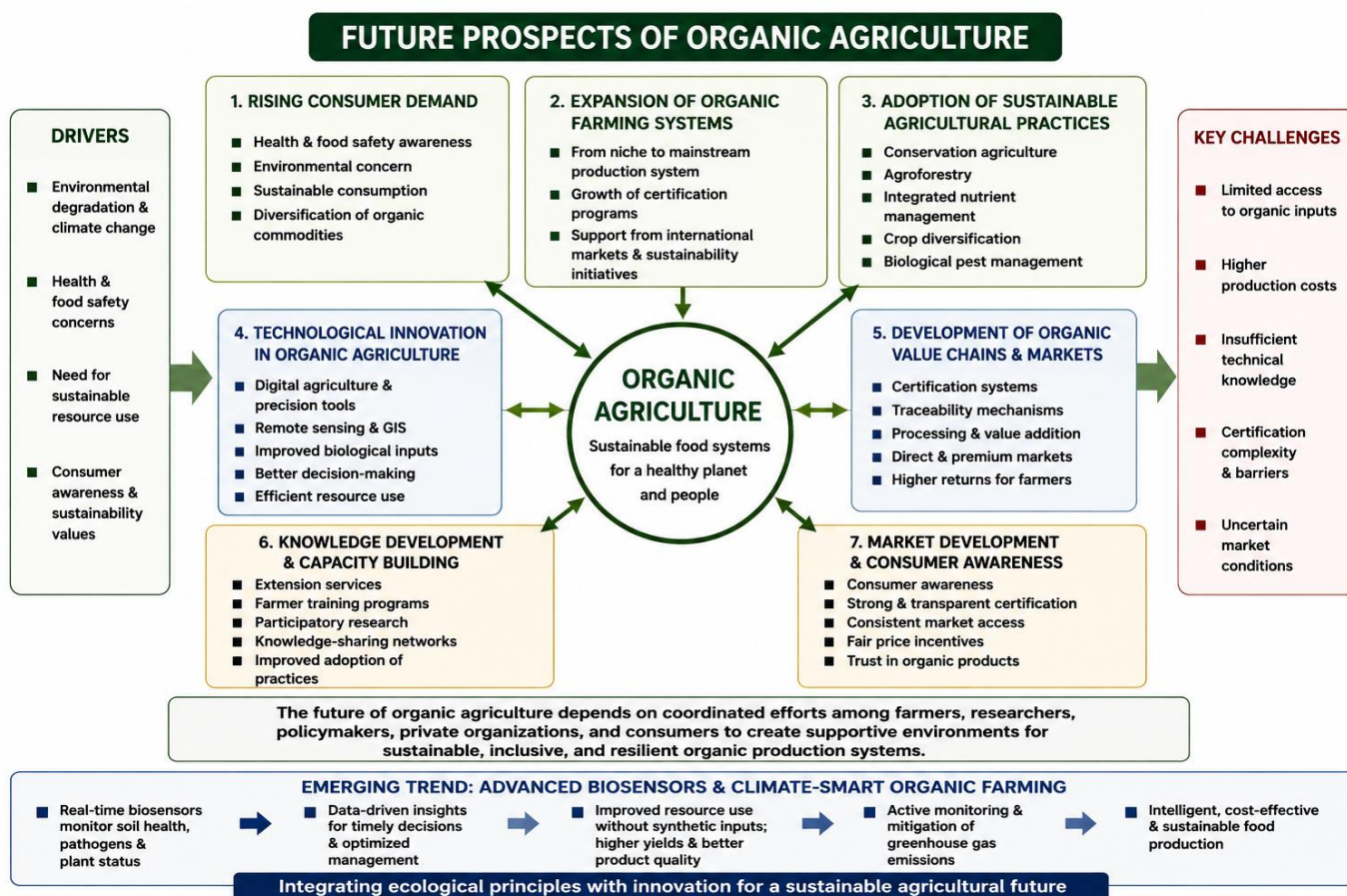


Fig. 1 Current trends in organic agriculture and emerging pathways toward sustainable food production. The schematic illustrates the major drivers, trends, opportunities, and challenges shaping modern organic agriculture, including increasing consumer demand, expansion of organic farming systems, adoption of sustainable agricultural practices, technological innovation, development of organic value chains and markets, knowledge development and capacity building, and consumer awareness. The emerging integration of advanced real-time biosensors enables monitoring of soil health and plant pathogens, data-driven decision-making, efficient resource management, and monitoring of greenhouse gas emissions, supporting climate-smart, cost-effective, and sustainable organic food production.

Factors influencing farmer interest and adoption of organic agriculture

Farmer's inclination towards organic production is shaped by a combination of economic, environmental, social, institutional, and knowledge-related factors. Organic farming is considered an environmentally sustainable production approach that reduces dependence on synthetic pesticides and fertilizers, promotes soil health, conserves natural resources, and supports ecological balance. The decision of farmers to adopt organic practices depends not only on awareness of these benefits but also on the availability of supportive conditions that make organic production technically feasible and economically attractive (Asghar & Salman, 2018). Economic considerations are among the most influential factors affecting farmers' willingness to adopt organic farming. Potential improvements in profitability, reduced dependence on costly external inputs, and access to premium markets for organic products can encourage farmers to shift toward organic production methods. Studies have indicated that

organic farming may provide economic benefits through improved soil productivity, reduced input dependency, and higher product prices, although profitability may vary depending on production conditions and market availability (Bhat et al., 2016). Market demand plays an important role in influencing farmer decisions regarding organic agriculture. Increasing consumer awareness and preference for environmentally friendly and chemical-free products can create incentives for farmers to adopt organic practices. A strong and reliable market for organic products encourages farmers by improving income opportunities, whereas weak market linkages and uncertain demand can limit adoption (Azam & Shaheen, 2019).

The economic viability of organic farming is also influenced by transition costs and production risks. Organic systems often require initial investments in organic inputs, certification, labor, and knowledge development, while financial returns may not always be immediate during the conversion period. However, long-term benefits, including improved soil health, ecosystem services, and access to premium markets, can increase the attractiveness of organic

farming over time (Bravo-M et al., 2016). Education, training, and agricultural extension services are important factors influencing farmers' awareness and confidence in adopting organic practices. Farmers with better access to technical information are more likely to understand organic production methods, manage biological processes, and overcome challenges associated with reducing synthetic input use. Effective extension programs can improve farmers' knowledge and support successful transitions toward sustainable farming systems (Chouichom & Yamao, 2011). Environmental concerns are another important motivation for farmer's openness to organic agriculture. Increasing awareness of soil degradation, water contamination, biodiversity loss, and the negative impacts of intensive chemical use has encouraged farmers to consider environmentally friendly alternatives. Organic farming practices contribute to improved soil quality, reduced chemical pollution, and enhanced ecosystem sustainability, which can positively influence farmers' attitudes toward organic production (Singh & Kumar, 2019).

Government policies and institutional support have a significant influence on the uptake of organic farming practices. Financial incentives, subsidies, technical assistance, research support, and favorable policy frameworks can reduce barriers associated with the transition to organic farming. Such support mechanisms can help farmers manage initial investment requirements and encourage wider adoption of organic production systems (Tena et al., 2016; Kundu et al., 2017). Social and cultural factors also contribute to farmers' decisions regarding organic farming adoption. Farmers' perceptions, traditional knowledge, community attitudes, and willingness to participate in sustainable agricultural initiatives can influence their acceptance of organic practices. Farmers with stronger environmental awareness and interest in sustainable resource management are often more likely to adopt organic methods, whereas resistance to changing established farming practices may slow adoption (Tabriz et al., 2021). Community networks and local market development can further strengthen farmer's commitment to organic farming. Participation in farmer organizations, knowledge-sharing groups, and locally established organic value chains can provide farmers with technical support, market information, and collective opportunities for selling organic products. The presence of supportive communities and accessible markets can therefore enhance farmers' confidence in adopting organic farming systems (Ríos Guayasamín et al., 2016). Farmer interest in organic production is influenced by multiple interacting factors, including profitability, market opportunities, environmental awareness, education, institutional support, and social conditions. Understanding these factors is essential for developing effective strategies that encourage farmers to adopt organic practices and contribute to the sustainable development of agricultural systems (Singh & Grover, 2011). As it is clear from research, farmers view the expansion of organic rice systems as a significant risk driven by high input costs, land limitations, and intense weed management demands. Contractual agreements often pressure producers into

maintaining mixed conventional-organic systems, while complete conversion remains unappealing due to anxieties over financial viability and unreliable marketing channels. For widespread adoption to occur, agricultural frameworks must prioritize relieving these on-farm operational strains and economic uncertainties to make organic transition a practical choice for farmers (Istiyanti et al., 2026).

Challenges and opportunities for organic agriculture development

Although organic agriculture offers significant environmental, ecological, and socio-economic benefits, its adoption and expansion are associated with several technical, economic, institutional, and market-related challenges. The transition from conventional farming systems to organic production requires substantial changes in farm management practices, knowledge systems, and resource utilization strategies. Farmers need to adopt ecological approaches, including crop rotation, organic nutrient management, biological pest control, and soil conservation practices, which may require additional skills and technical understanding (Abirami et al., 2025). One of the major challenges associated with organic agriculture is the limited knowledge and technical capacity among farmers regarding organic production methods. Unlike conventional farming systems that often rely on readily available synthetic inputs, organic farming requires a better understanding of ecological processes and integrated management approaches. Insufficient training, limited extension services, and inadequate access to technical information can restrict farmers' ability to successfully implement organic practices (Zavare & Chavan, 2015). Strengthening farmer education and extension programs is therefore essential for improving the adoption and long-term sustainability of organic farming systems.

The availability and affordability of organic inputs represent another important constraint. Organic fertilizers, biological pest management products, certified seeds, and other approved inputs may be costly or difficult to access in many regions, particularly for smallholder farmers. Higher initial investment requirements and uncertainty in the early conversion phase can discourage farmers from shifting away from conventional production systems (Singh & Zavare, 2017). Development of local organic input production systems and improved supply chains can help reduce these barriers. Organic certification and market-related challenges also influence the growth of organic agriculture. Certification procedures are often complex, time-consuming, and expensive, creating difficulties for small-scale producers who wish to access premium organic markets. In addition, inadequate market infrastructure, weak producer-consumer linkages, and limited price incentives may reduce the economic attractiveness of organic farming (Bald, 2022; Panpakdee & Hoaihongthong, 2025). Improving certification accessibility, strengthening organic value chains, and developing transparent marketing systems are important steps toward supporting organic producers (Fig. 3).

Research has also highlighted that organic farming may face productivity-related challenges, especially during the transition process when soils and farming systems adjust to reduced dependence on synthetic inputs. Temporary yield reductions, increased labor requirements, and greater

management complexity can create uncertainty for farmers considering conversion to organic production (Kshirsagar, 2006). However, long-term improvements in soil health, biodiversity, and ecosystem functioning can contribute to the sustainability and resilience of organic farming systems. Climate variability and changing environmental conditions present additional challenges for organic agriculture. Although organic systems are generally recognized for improving soil quality and ecosystem services, farmers may require improved adaptation strategies to manage risks associated with droughts, extreme weather events, emerging pests, and changing production environments. Integrating scientific research, traditional ecological knowledge, and innovative technologies can enhance the resilience of organic farming systems. Organic certification alone merely offsets agricultural emissions rather than achieving full climate neutrality. For total neutrality, the food system requires a major dietary shift toward plant-based consumption. Combining organic production standards with plant-centered eating provides the ultimate path to sustainable food systems (Mueller-Lindenlauf & El-Hage, 2026).

Despite the growing global importance of organic agriculture, several challenges continue to limit its widespread adoption and expansion. These challenges are associated with production constraints, economic risks, knowledge gaps, market limitations, certification requirements, and institutional barriers. Addressing these constraints is essential for improving the sustainability, profitability, and accessibility of organic farming systems. One of the major challenges faced by organic farmers is the limited availability and high cost of organic inputs, including organic fertilizers, biological pest control products, and certified planting materials. The dependence on locally available resources and the insufficient development of commercial organic input markets can increase production costs and create difficulties for farmers seeking to shift away from conventional towards organic systems (Walia et al., 2022). High initial investment requirements and uncertain economic returns throughout the transition phase may further discourage farmers from adopting organic practices (Scortecci et al., 2012). Limited technical knowledge and inadequate access to agricultural extension services represent another important barrier to organic agriculture adoption. Organic farming requires specialized knowledge related to soil fertility management, ecological pest control, crop diversification, and resource conservation. Farmers who lack access to training and technical guidance may experience difficulties in implementing organic practices effectively and maintaining productivity in the initial conversion stages (Martinelli & Filoso, 2008; Singh & Grover, 2011).

Market access remains a critical challenge for organic producers. Although demand for organic commodities is increasing globally, many farmers continue to face difficulties in accessing reliable markets, establishing value chains, and obtaining fair prices for their products. Weak market infrastructure and limited consumer awareness can reduce economic incentives for farmers to adopt organic production systems (Raza et al., 2021). In addition, limited demand in some regions compared with conventional

agricultural products may restrict the growth potential of organic markets (Meghana & Shastri, 2020). Certification and labeling requirements can also create challenges, particularly for smallholder farmers. Organic certification processes often involve financial costs, technical documentation, and compliance requirements that may be difficult for resource-limited farmers to manage. Strengthening affordable certification systems and improving transparency in organic supply chains are important steps toward increasing farmer participation in organic markets (Kumar et al., 2021). The development of organic agriculture also faces challenges related to research gaps, policy limitations, and insufficient institutional support. Effective expansion of organic farming requires investment in scientific research, farmer education, extension networks, and supportive policies that reduce risks associated with adoption. Government programs, financial incentives, and technical assistance can play an important role in creating a favorable environment for organic agriculture development (Shukla et al., 2017; Msomba et al., 2024). A systematic evaluation of global literature across developing nations identifies six primary barriers to organic food consumption, categorized under Innovation Resistance Theory. High price premiums, limited market availability, and low consumer awareness emerge as the most critical impediments hindering market growth. Addressing these structural, financial, and psychological obstacles through strategic marketing and improved distribution networks is vital for transitioning these regions from organic producers into robust consumer markets. (Ghali, 2026)

Despite these challenges, organic agriculture provides several significant opportunities for sustainable agricultural development. Increasing consumer demand for environmentally friendly and health-oriented food products has created expanding markets for organic commodities. This growing demand provides opportunities for farmers to obtain premium prices, diversify income sources, and participate in emerging sustainable food value chains (Niggli, 2015). Organic farming practices also offer important environmental benefits, including improved soil health, reduced chemical pollution, enhanced biodiversity, and more efficient use of natural resources. Long-term improvements in soil fertility and ecosystem functioning can contribute to sustainable productivity and resilience under changing environmental conditions (Mariappan & Zhou, 2019; Meghana & Shastri, 2020). Government support and institutional interventions represent important opportunities for accelerating the spread of organic agriculture. Policies that provide financial incentives, technical assistance, research support, and market development initiatives can reduce barriers and encourage farmers to move toward organic production systems (Kshirsagar, 2008). Strong extension services can further improve farmer knowledge and confidence by providing practical training on organic management techniques and sustainable farming approaches (Scortecci et al., 2012). Technological innovation also offers new opportunities for improving organic farming efficiency and productivity. Development of improved organic fertilizers, biological pest management methods, digital advisory services, and climate-smart organic practices can help farmers overcome production constraints while maintaining ecological principles (Sentiés-Herrera et al., 2014).

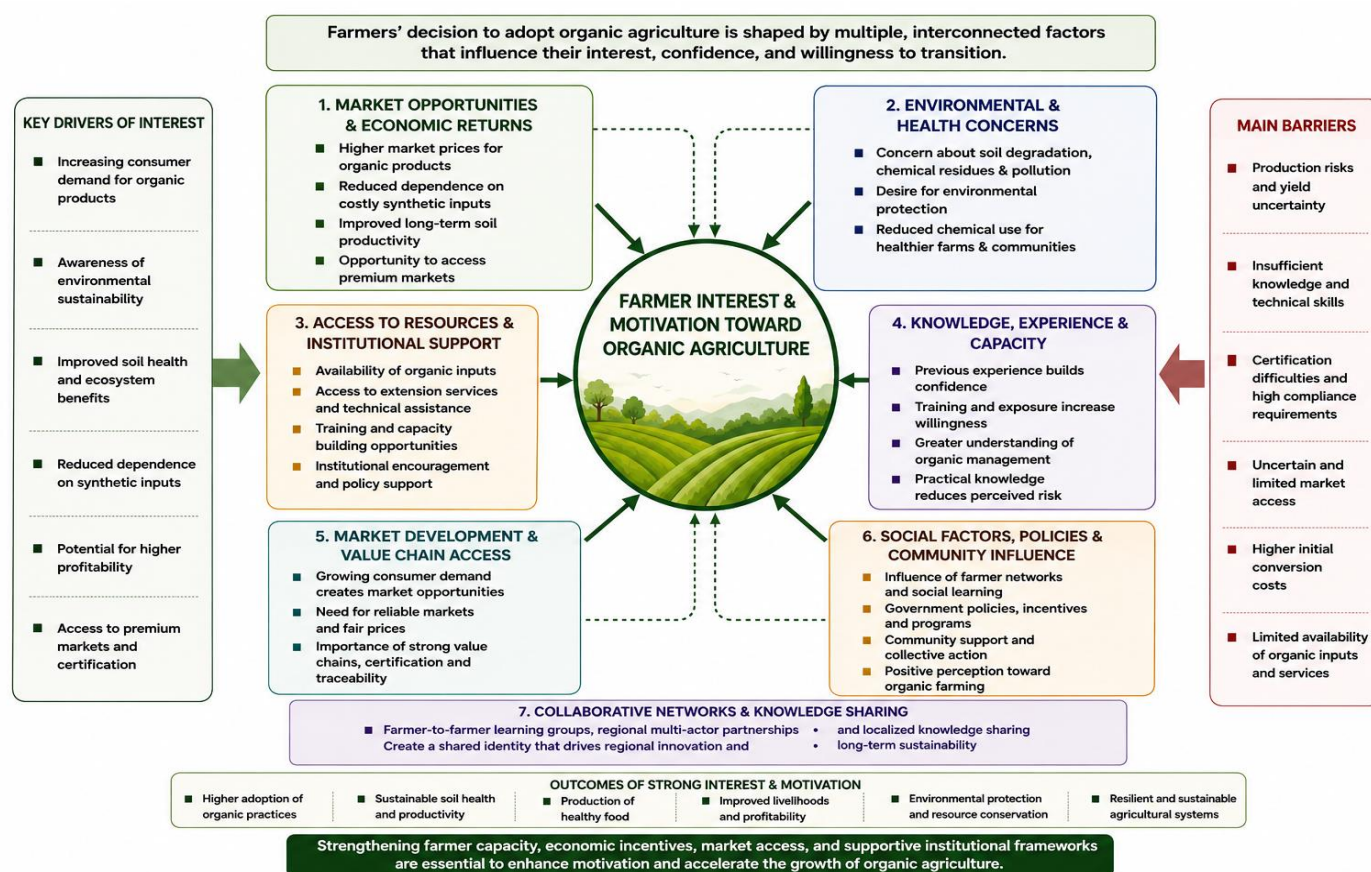


Fig. 2 Factors influencing farmer interest and motivation toward organic agriculture. The diagram shows key drivers, including economic benefits, environmental and health concerns, knowledge and training, institutional support, market access, social networks, and supportive policies, alongside major barriers such as production risks, certification difficulties, limited knowledge, and uncertain markets. Strengthening these factors can enhance organic farming adoption and support sustainable agricultural development.

Future perspectives of organic agriculture

The future development of organic agriculture is receiving increasing attention due to rising global heightened concerns regarding environmental degradation, climate change, food safety, and the sustainability of conventional agricultural systems. Organic farming is increasingly recognized as an approach that can contribute to sustainable food production by reducing dependence on synthetic agricultural inputs, improving soil quality, conserving biodiversity, and supporting ecological balance. Growing consumer demand for environmentally responsible and health-oriented food products is expected to continue driving the expansion of organic markets worldwide (Sentiés-Herrera et al., 2014). Future trends in organic agriculture are expected to include the expansion of organic production systems, increased integration of sustainable agricultural technologies, development of efficient value chains, and greater consumer acceptance of organic products. The increasing demand for organic food and other value-added products is creating new economic opportunities for farmers while encouraging improvements in organic production, processing, and marketing systems (Willer & Lernoud, 2022). Advances in precision agriculture, digital technologies, remote sensing, and data-based farm management may further support organic

farmers by improving resource-use efficiency and decision-making while maintaining ecological principles (Reganold & Wachter, 2016).

Climate change adaptation represents an important future direction for organic agriculture. Organic farming systems have the potential to improve resilience against environmental stresses through enhanced soil organic matter, improved water retention, increased biodiversity, and reduced ecosystem disturbance. However, future research is needed to develop climate-smart organic practices that can maintain productivity under changing environmental conditions (Lori et al., 2017). Despite its potential, several challenges may influence the future expansion of organic agriculture. Restricted input supplies, inflated certification costs, insufficient technical expertise, labor requirements, and trouble reaching dependable markets remain important barriers for farmers. Addressing these constraints will require stronger extension systems, improved research support, affordable certification mechanisms, and effective policy interventions (Singh, 2013). Market development and consumer awareness will continue to play a major role in shaping the future of organic agriculture. Increasing consumer interest in sustainable food systems provides opportunities for farmers to receive premium prices and improve economic returns. However, maintaining consumer trust requires transparent certification systems,

quality control mechanisms, and improved traceability throughout organic supply chains (Thøgersen et al., 2017).

Institutional support and government policies will also be essential for strengthening the organic sector. Financial incentives, research investment, farmer training programs, and supportive regulatory frameworks can reduce barriers to adoption and encourage more farmers to switch to organic production practices. Collaboration among policymakers, researchers, private organizations, and farming communities will be necessary to develop sustainable strategies for organic agriculture development (Chauhan et al., 2026). The future of organic agriculture will also depend on integrating scientific innovation with traditional ecological knowledge. Research on improved organic nutrient management, biological pest control, beneficial microorganisms, crop diversification, and sustainable livestock integration can enhance the productivity and resilience of organic systems. Such innovations can help overcome concerns regarding yield limitations and improve the competitiveness of organic farming in global food systems (Seufert & Ramankutty, 2017). The future of organic agriculture will be influenced by the interaction of technological advancement, market development, environmental challenges, and supportive institutional frameworks. Although several barriers remain, increasing awareness of sustainability issues and growing demand for environmentally friendly food production provide significant opportunities for the continued expansion and improvement of organic farming systems worldwide (Tabriz et al., 2021).

The empirical findings indicate that forecasted productivity growth relies on an unsustainable expansion of arable land, pesticides, and fertilizers in Pakistan. This intensified input dependence occurs concurrently with a significant contraction in vital water and energy supplies. Ultimately, the research shows that immediate implementation of precision agriculture and integrated nutrient management is imperative to mitigate impending ecological risks (Iqbal et al., 2026). Agricultural cooperatives utilize collective action to empower small-scale farmers, but traditional management and capital constraints frequently hinder their efficiency. While expanding organic markets present significant growth opportunities, overcoming strict certification barriers requires professionalizing financial practices and digitizing supply chains. Integrating modern business strategies with cooperative values ultimately enables successful market adaptation, ensuring long-term economic resilience and food security (Paraschou et al., 2025). Replacing chemical fertilizers with bio-organic alternatives enhances multi-nutrient cycling while significantly reducing greenhouse gas emissions. This sustainable practice promotes beneficial bacterial diversity and strengthens soil network

stability. Furthermore, it stimulates specific carbon-fixing genes that convert CO₂ into stable organic compounds (Perveen et al., 2023; Ren et al., 2026).

Conclusion and Recommendations

Organic agriculture has evolved from traditional ecological farming practices into a globally recognized approach for sustainable food production. Increasing concerns regarding environmental degradation, climate change, declining soil quality, and food safety have accelerated interest in organic farming systems as an alternative to input-intensive conventional agriculture. The growth of the organic farming sector has been supported by growing consumer demand for environmentally friendly products, improved awareness of sustainable food systems, and the development of organic markets and value chains. The successful adoption and long-term sustainability of organic agriculture depend largely on farmers' knowledge, awareness, motivation, and access to appropriate resources. Education, technical training, extension services, market opportunities, and institutional support play essential roles in encouraging farmers to embrace organic production systems. Economic incentives, supportive policies, and improved market infrastructure can further strengthen farmer participation and enhance the profitability of organic farming. Despite its potential benefits, organic agriculture continues to face several challenges, including limited availability of organic inputs, higher production costs, certification difficulties, insufficient technical knowledge, labor requirements, and uncertain market conditions. These constraints highlight the need for integrated strategies involving researchers, policymakers, agricultural organizations, private stakeholders, and farming communities. Strengthening research and development, improving access to organic technologies, and establishing efficient value chains are essential for overcoming existing barriers. Future progress in organic agriculture will depend on the integration of ecological principles with scientific innovation and sustainable management practices. Advances in digital agriculture, biological inputs, climate-resilient farming approaches, and improved knowledge-sharing systems provide opportunities to enhance the productivity and resilience of organic farming. Furthermore, increasing consumer awareness and supportive policy frameworks can contribute to the continued growth of organic markets worldwide. Conclusively, organic agriculture represents a promising pathway for achieving sustainable agricultural development by balancing environmental protection, economic viability, and food security. Although challenges remain, coordinated efforts toward capacity building, technological advancement, market development, and policy support can accelerate the adoption of organic farming and strengthen its contribution to sustainable global food systems.

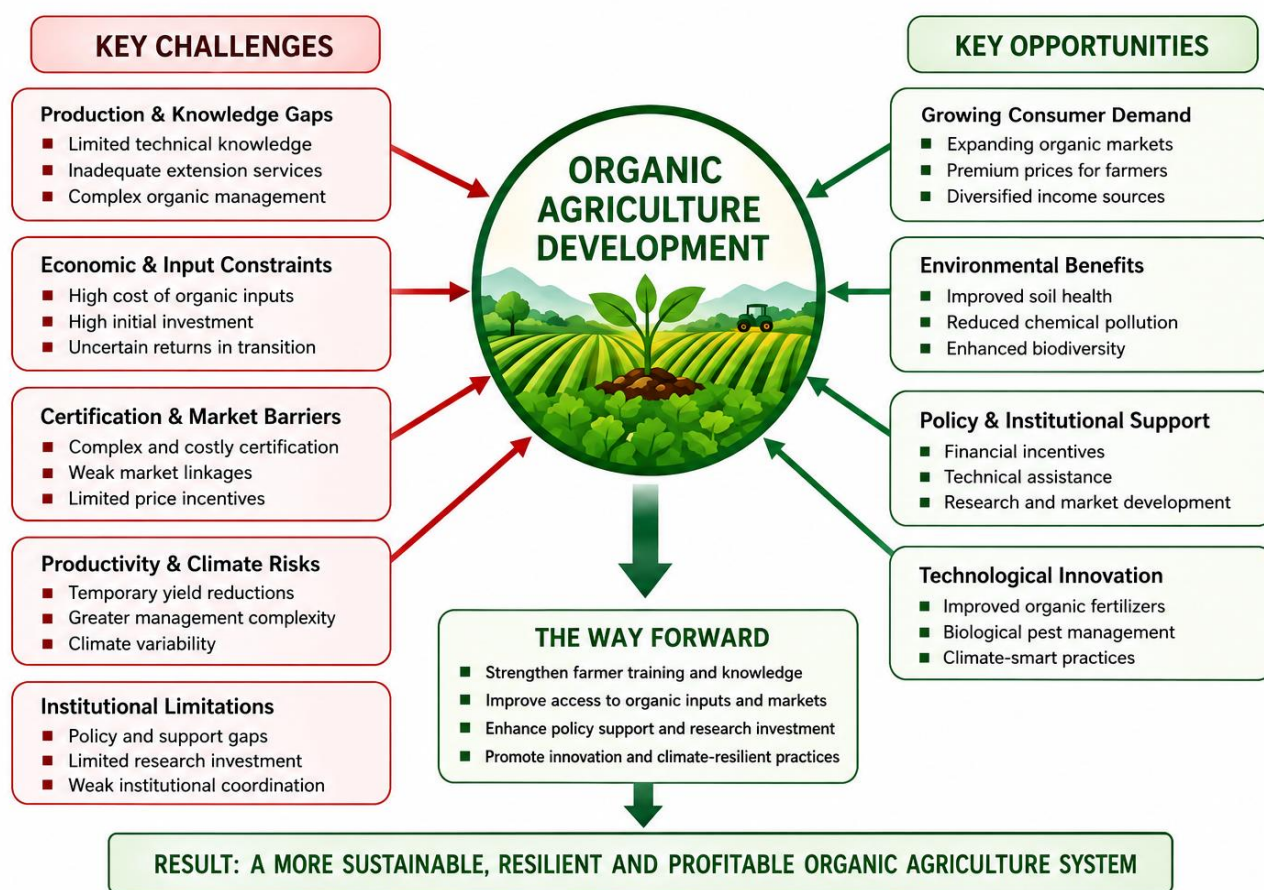


Fig. 3 Challenges and opportunities for organic agriculture development. The diagram shows major challenges, including limited technical knowledge, costly organic inputs, certification and market barriers, productivity risks, and institutional constraints, alongside opportunities from growing markets, environmental benefits, policy support, and technological innovation. Strengthening farmer training, input and market access, research, and supportive policies can promote wider adoption and sustainable development of organic agriculture.

Declarations

i. Ethics approval and consent to participate

Ethical approval and informed consent were not required for this study as it did not involve human data, or animals.

ii. Consent for publication

Consent for publication is not applicable.

iii. Data availability

All data generated or analyzed during this study are included in this article.

iv. Competing interests

Authors have declared that no competing interests exist.

v. Authors' contributions

A.E. conceptualized and designed the review; A.E. and Z.A. conducted the literature search and analysis; A.E. prepared the first draft of the manuscript; Z.A. contributed to the interpretation of the literature and critically revised

the manuscript. Both authors read and approved the final manuscript.

vi. Funding

No funding was received for the design, data collection, analysis, interpretation, or writing of this research manuscript.

vii. Acknowledgement

Not applicable.

viii. SDGs addressed

Zero Hunger (SDG 2), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), Life on Land (SDG 15)

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