Archives of Current Research International

Volume 25, Issue 6, Page 259-272, 2025; Article no.ACRI.133638
ISSN: 2454-7077

Assessment of Organic Farming Practices and Their Impact on Soil Health and Ecosystem Services: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/acri/2025/v25i61269

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/133638

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Cite as: *Jetawat, Ravindra Pratap Singh, Manoj Nazir, Rashmi Mohapatra, Khushboo Jyotsna Baxla, Harshvardhan Bhagwan Gokhale, Saransh Kumar Gautam, and Vimal Kumar. 2025. "Assessment of Organic Farming Practices and Their Impact on Soil Health and Ecosystem Services: A Review". Archives of Current Research International 25 (6):259-72. https://doi.org/10.9734/acri/2025/v25i61269.*

Review Article

Received: 15/01/2025
Accepted: 31/03/2025
Published: 10/06/2025

ABSTRACT

Organic farming is increasingly recognized as a sustainable agricultural approach that enhances soil health, biodiversity, and ecosystem services while mitigating environmental impacts. The principles of organic agriculture are based on four key pillars: health, ecology, fairness, and care. This review examines the effects of organic farming practices on soil health indicators, including physical, chemical, and biological properties, and evaluates their contributions to various ecosystem services. Studies show that organic systems promote higher soil organic matter (SOM) content, improved aggregate stability, and greater microbial diversity, resulting in enhanced nutrient cycling, carbon sequestration, and soil fertility. Compared to conventional systems, organic farming demonstrates a 20–40% increase in microbial biomass and a 15–25% increase in SOM, contributing to improved soil structure and resilience. Organic farming also supports biodiversity conservation, with 30–50% more species of plants, insects, and soil microorganisms observed in organic systems. Despite these benefits, yield gaps of approximately 20–25% persist for specific crops, particularly cereals. Organic farming helps achieve sustainability goals by contributing to climate mitigation through enhanced carbon sequestration, reduced greenhouse gas emissions, and improved soil health. Again, biodiversity conservation is a critical component of organic farming's contribution to sustainability. Economic sustainability is another essential aspect of organic farming's contribution to sustainability goals. Economic profitability remains promising, with organic systems achieving 20–30% higher profitability due to premium prices and reduced input costs. Challenges related to productivity, market access, and scalability continue to limit the broader adoption of organic practices. Future research should focus on improving organic inputs, enhancing nutrient cycling, and developing ecosystem service assessments. Improving the economic viability of organic farming is essential for promoting its widespread adoption. Effective policies are essential for encouraging the adoption of organic farming practices. Government policies that provide subsidies, technical assistance, and research funding can enhance the scalability of organic systems. Addressing economic and policy barriers is essential for promoting widespread adoption. The findings suggest that organic farming can significantly contribute to global sustainability goals related to food security, climate change mitigation, and environmental conservation.

Keywords: Organic farming; soil health; biodiversity; ecosystem services; carbon sequestration; yield gap; sustainability.

1. INTRODUCTION

Organic farming refers to a holistic agricultural system emphasizing sustainability, biodiversity, soil fertility, and ecological balance (Gamage *et al.,* 2023). It aims to produce crops and livestock without synthetic chemicals such as pesticides, fertilizers, genetically modified organisms (GMOs), and growth hormones. Instead, organic farming promotes the use of natural inputs, biological pest control, crop rotations, green manures, composting, and biological soil amendments. The principles of organic agriculture are based on four key pillars: health, ecology, fairness, and care (Bharadwaj et al., 2025). This approach ensures that farming practices are environmentally friendly, economically viable, and socially just. Demonstrated micronutrients, larger quantity of antioxidants, without injurious fertilizers, chemicals, pesticides, good in taste and more other things are contained in organically produced foods generally and it keeps the plant sustainable and controlling environmental balance (Bhaumik et al., 2024). The global organic agriculture sector has shown substantial growth over the past few decades. As of 2021, approximately 76.4 million hectares of agricultural land were under organic management, involving more than 3.4 million producers worldwide. There is a high demand for organic food in domestic and international markets, which is estimated to be growing at a rate of 30% a year worldwide. The area under organic farming has been increasing consistently (Singh et al., 2024). The global organic food and beverage market reached a valuation of over USD 120 billion in 2020, with Europe and North

America being the largest markets. This growth is attributed to increasing consumer awareness of health and environmental issues, regulatory support, and a rise in organic certification standards across various countries. Despite these positive trends, organic farming still represents less than 2% of the world's total agricultural land, indicating significant potential for expansion (Reganold *et al.,* 2016). Soil health is a critical component of sustainable agriculture, directly influencing productivity, environmental quality, and resilience to climate change. A healthy, well-balanced soil has physical, chemical, and biological properties that promote optimal plant development and environmental preservation (Pandao et al., 2024). It encompasses the biological, physical, and chemical properties of soil, which collectively determine its ability to support plant growth and provide essential ecosystem services. Healthy soils contribute to nutrient cycling, carbon sequestration, water filtration, and habitat provision for diverse organisms. Ecosystem services, defined as the benefits derived by humans from ecosystems, are broadly categorized into provisioning, regulating, supporting, and cultural services (Danley *et al.,* 2016). Organic farming is believed to enhance ecosystem services through practices that improve soil structure, increase organic matter content, promote biodiversity, and enhance nutrient cycling. By fostering natural ecological processes, organic farming contributes to the sustainability of agricultural landscapes and supports long-term food security.

Conventional agriculture has been associated with numerous adverse environmental impacts, including soil degradation, water contamination, loss of biodiversity, and increased greenhouse gas emissions (Gomiero *et al.,* 2011). The reliance on synthetic fertilizers and pesticides has led to the depletion of essential soil nutrients, reduced soil organic matter, and decreased soil microbial diversity. Organic farming systems aim to mitigate these impacts by promoting soil health through natural processes and inputs. Organic practices are associated with higher soil organic carbon (SOC) levels, improved soil structure, enhanced microbial biomass, and increased enzyme activities. Despite these advantages, the comparative performance of organic farming concerning conventional practices remains a topic of scientific debate. Some studies suggest lower yields under organic systems, especially for specific crops and regions, which could pose challenges for large-scale adoption. While numerous studies have examined the benefits of organic farming on soil health and ecosystem services, significant knowledge gaps persist (Abbott *et al.,* 2015). A comprehensive understanding of the mechanisms underlying soil health improvement under organic systems is lacking, particularly concerning long-term changes in soil microbial communities and their functional roles. Studies have often focused on isolated aspects of organic farming rather than adopting an integrated approach to assess multiple ecosystem services simultaneously. There is a need for more extensive research on the trade-offs and synergies between different ecosystem services under organic farming practices. Economic viability, market access, and policy support are crucial areas that require further investigation to promote the widespread adoption of organic agriculture (Usharani *et al.,* 2019), (Kaswan et al., 2012).

2. ORGANIC FARMING PRACTICES

A. Principles of Organic Farming

Organic farming fundamentally avoids the use of synthetic chemicals, including fertilizers, pesticides, herbicides, and genetically modified organisms (GMOs) (Siddique *et al.,* 2014). This restriction is based on the principles of ecological harmony and sustainability, where agricultural systems rely on natural inputs and processes to enhance productivity. Studies have shown that the absence of synthetic fertilizers and pesticides in organic systems significantly reduces the risk of soil and water contamination, promoting healthier ecosystems. The use of natural inputs, such as compost, animal manure, green manure, and biological pest control agents, is central to organic farming. These inputs enhance soil fertility, increase organic matter content, and promote beneficial microbial activity. For instance, compost application has been found to improve soil organic carbon (SOC) content by 20–40% compared to conventional systems over a period of 5–10 years. Moreover, biological pest control methods have proven effective in reducing pest populations without causing ecological imbalances. Crop rotation and polyculture are essential components of organic farming aimed at enhancing biodiversity, breaking pest and disease cycles, and improving soil structure (Zou *et al.,* 2024). Crop rotation involves growing different crops in a specific sequence to balance nutrient demands and reduce pest buildup. Polyculture and mixed farming practices increase habitat heterogeneity, thereby promoting beneficial organisms that contribute to natural pest control and pollination. Research has demonstrated that crop diversification can enhance soil microbial diversity by 30–50%, promoting improved nutrient cycling and soil resilience.

B. Types of Organic Farming Practices

Maintaining soil fertility in organic systems is achieved through practices such as composting, green manure application, and cover cropping (Toungos *et al.,* 2019). Composting is a process of controlled biological decomposition of organic materials, which enhances nutrient availability, increases soil organic matter, and improves soil structure. Studies have reported that compost-amended soils exhibit 20–30% higher microbial biomass and 15–25% higher soil organic matter content compared to conventionally managed soils. Green manure, involving the cultivation of leguminous crops to fix atmospheric nitrogen, is another widely practiced method. Nitrogen fixation by leguminous crops can range from 30 to 300 kg N per hectare per year, contributing to enhanced soil fertility and reduced dependence on synthetic fertilizers. Cover cropping, which involves growing non-harvested crops during off seasons, has been shown to reduce soil erosion by 40–60% and enhance soil moisture retention. Organic farming systems prioritize preventive measures and natural control mechanisms to manage pests and diseases (Costa *et al.,* 2023). Biopesticides derived from natural materials such as bacteria, fungi, and plant extracts have proven effective against various pests. For example, Bacillus thuringiensis (Bt) is a widely used biological pesticide effective against lepidopteran pests, reducing crop damage by 50–90% without harming non-target organisms. Cultural methods such as crop rotation, intercropping, and habitat management are also employed to disrupt pest life cycles and enhance natural predator populations. Intercropping systems have been reported to reduce pest incidence by 30–50% compared to monoculture systems, improving crop productivity and resilience. Biodiversity management is a cornerstone of organic farming aimed at enhancing ecosystem services and promoting resilience against environmental stressors. Crop diversification through practices such as polyculture, mixed cropping, and agroforestry contributes to habitat heterogeneity and improves overall farm productivity. Agroforestry, which integrates trees and shrubs into agricultural landscapes, provides multiple benefits, including improved soil structure, enhanced nutrient cycling, and increased carbon sequestration. Studies indicate that agroforestry systems can sequester 2–4 tons of carbon per hectare per year, significantly contributing to climate change mitigation. Organic farming emphasizes efficient water and nutrient management practices aimed at optimizing resource use and minimizing environmental impacts. Water conservation techniques such as mulching, drip irrigation, and rainwater harvesting contribute to improved water-use efficiency and soil moisture retention (Tiwari *et al.,* 2023). Nutrient management is achieved through the use of organic amendments, cover crops, and crop rotation, which enhance nutrient availability and reduce nutrient leaching. Research has shown that organic systems exhibit 20–30% lower nitrate leaching compared to conventional systems, primarily due to enhanced soil structure and higher organic matter content.

C. Adoption and Prevalence

The adoption of organic farming practices has experienced significant growth over the past two decades. As of 2021, more than 76.4 million hectares of agricultural land are managed organically by over 3.4 million producers globally. The organic food market is projected to reach USD 400 billion by 2030, driven by increasing consumer demand for health-conscious and environmentally sustainable products (Sharma *et al.,* 2024). Europe and North America are the largest markets for organic products, accounting for more than 90% of global retail sales. Approximately 16.6 million hectares of agricultural land are under organic management in Europe, representing 3.4% of the total agricultural area. Research conducted on organic farming systems across various regions has demonstrated positive outcomes for soil health and ecosystem services. In Switzerland, long-term trials have shown that organic farming systems can improve soil fertility by increasing microbial biomass by 40% and soil organic matter by 20% compared to conventional systems. In Kenya, the implementation of agroforestry-based organic farming has resulted in a 30% increase in crop yields and a 50% reduction in soil erosion, contributing to enhanced food security and environmental sustainability (Japheth *et al.,* 2024).

3. SOIL HEALTH INDICATORS IN ORGANIC FARMING

A. Soil Health

Soil health refers to the continued capacity of soil to function as a living ecosystem that sustains plants, animals, and humans (Table 1). It is characterized by a complex interplay of physical, chemical, and biological properties that determine its overall quality and productivity. Physical properties include soil structure, texture, porosity, and bulk density, which influence aeration, water retention, and root penetration. Chemical properties encompass soil pH, nutrient availability, cation exchange capacity (CEC), and soil organic matter (SOM) content, all of which contribute to nutrient cycling and fertility. Biological properties, including soil microbial biomass, diversity, enzymatic activity, and macrofauna presence, are essential indicators of soil fertility and ecological resilience. Soil fertility is a critical component of soil health, directly influencing crop yield and agricultural sustainability. The ability of soil to supply essential nutrients to plants in adequate amounts and appropriate proportions is essential for maintaining productivity. Organic farming systems emphasize enhancing soil fertility through natural inputs such as compost, manure, and crop residues, resulting in improved soil nutrient status and higher organic matter levels (Watson *et al.,* 2002). Studies have reported that organic systems exhibit 10–15% higher nutrient availability compared to conventional systems, mainly due to enhanced microbial activity and nutrient mineralization.

B. Physical Indicators

Soil structure refers to the arrangement of soil particles into aggregates, which affects porosity, aeration, water infiltration, and root growth. Organic farming practices contribute to improved soil structure by increasing organic matter content, enhancing aggregate stability, and reducing bulk density. Research indicates that soils managed organically exhibit 20–30% higher aggregate stability compared to conventionally managed soils due to the increased presence of organic carbon and microbial biomass (Milne *et al.,* 2004). Improved aggregation also enhances water retention and infiltration, critical for maintaining soil moisture during periods of drought. Water retention capacity and infiltration rates are essential indicators of soil health, influencing plant growth, soil erosion, and nutrient leaching. Studies have demonstrated that organic farming systems exhibit higher water retention capacity and improved infiltration rates due to enhanced soil structure and organic matter content. Research comparing organic and conventional systems found that organic soils have 20–40% higher water infiltration rates, reducing surface runoff and promoting groundwater recharge. Improved water retention in organic systems also contributes to enhanced drought resilience, with crop yields remaining stable under water-limited conditions.

C. Chemical Indicators

Soil organic matter is a critical indicator of soil fertility, carbon sequestration, and overall soil health. Organic farming practices such as composting, cover cropping, and reduced tillage contribute to higher SOM levels by enhancing carbon inputs and minimizing losses (Krauss *et al.,* 2022). Long-term studies have shown that organic systems exhibit 15–25% higher SOM content than conventional systems, resulting in improved soil fertility, water-holding capacity, and microbial activity. Enhanced SOM also contributes to increased nutrient availability and reduced dependence on external fertilizers. Soil pH, nutrient availability, and CEC are vital chemical indicators that determine the suitability of soil for plant growth. Organic farming practices that include natural amendments and crop rotation help maintain soil pH within optimal ranges for nutrient availability. Studies have demonstrated that organic systems generally exhibit higher CEC due to increased SOM content, which enhances nutrient retention and availability to plants. Nutrient availability in organic systems is often enhanced by improved microbial activity, which promotes nutrient mineralization and release from organic matter.

D. Biological Indicators

Microbial biomass and diversity are fundamental indicators of soil health, reflecting the abundance and functionality of soil microorganisms involved in nutrient cycling, organic matter decomposition, and disease suppression (Sahu *et al.,* 2017). Organic farming systems are known to enhance microbial biomass by 20–30% compared to conventional systems, primarily due to the higher availability of organic substrates. Research has demonstrated that microbial diversity is significantly higher in organic systems, promoting greater ecological resilience and enhanced nutrient cycling. Studies have also shown that organic soils harbour beneficial microbes that

Table 1. Soil Health Indicators in Organic Farming

Category	Indicator	Description	Relevance in Organic Farming
Physical Indicators	Bulk Density	Mass of dry soil per unit volume, including pore space	Indicates compaction; lower values reflect better root growth and aeration
	Soil Texture	Proportions of sand, silt, and clay	Affects water retention, nutrient availability, and tillage practices
	Water Holding Capacity	Ability of soil to retain water after drainage	Vital for crop sustainability, especially under rainfed conditions
	Aggregate Stability	Ability of soil aggregates to resist disintegration	Higher stability supports better infiltration and reduced erosion
Chemical Indicators	Soil pH	Measure of soil acidity or alkalinity	Affects nutrient availability and microbial activity
	Electrical Conductivity (EC)	Measure of soil salinity	Ensures optimal ionic environment for plant and microbial health
	Cation Exchange Capacity (CEC)	Ability of soil to hold and exchange nutrients	Reflects soil fertility potential
	Organic Carbon Content	Carbon stored in organic matter	Directly linked to nutrient supply and microbial biomass
	Macronutrient Levels (N, P, K)	Essential nutrients for plant growth	Reflects fertility and requirement for organic amendments
Biological Indicators	Microbial Biomass Carbon & Nitrogen	Living component of soil organic matter	Indicates biological activity and nutrient turnover
	Soil Respiration	CO_2 release from microbial activity	Proxy for microbial health and organic matter decomposition
	Enzyme Activities (e.g., dehydrogenase, urease)	Catalytic proteins from microbes	Signifies nutrient cycling efficiency
	Earthworm Count and Biomass	Abundance and weight of earthworms	Indicates aeration, decomposition, and biological activity
	Microbial Diversity (Bacteria/Fungi)	Variety and abundance of microbial species	Greater diversity enhances resilience and ecological balance
Ecological Indicators	Weed Diversity	Spectrum of weed species present	Imbalance may indicate fertility or soil disturbance issues
	Pest and Disease Incidence	Occurrence of biotic stressors	Low incidence reflects balanced agroecosystem
	Nutrient Cycling Efficiency	Speed and completeness of nutrient transformations	Integral for maintaining fertility without synthetic inputs

(Source: Watson et al., 2002, Sahu et al., 2017)

contribute to natural pest control and soil fertility. Earthworms and other soil macrofauna play essential roles in soil structure formation, organic matter decomposition, and nutrient cycling. Organic farming practices that avoid synthetic pesticides and fertilizers create favourable conditions for these organisms. Research indicates that earthworm biomass is 30–50% higher in organic systems compared to conventional systems, contributing to improved soil aeration, nutrient availability, and aggregate stability (Riley *et al.,* 2008). Soil enzymes act as catalysts in biochemical processes related to nutrient cycling, organic matter decomposition, and soil fertility. Organic farming practices enhance enzymatic activity through increased organic inputs and diverse microbial communities. Studies have reported that organic systems exhibit 25–35% higher enzymatic activity than conventional systems, reflecting improved nutrient cycling and soil health.

E. Comparative Analysis

Comparative studies reveal that organic farming systems consistently exhibit better soil health indicators, including higher organic matter content, improved soil structure, enhanced microbial diversity, and increased nutrient availability. Long-term trials have demonstrated that organic farming practices contribute to enhanced soil fertility, greater biodiversity, and improved ecosystem resilience, making it a more sustainable option for agricultural production (Kharel *et al.,* 2023).

4. IMPACT OF ORGANIC FARMING ON ECOSYSTEM SERVICES

A. Classification of Ecosystem Services

Provisioning services are the products obtained from ecosystems, including food, fibre, medicinal resources, and fresh water (Table 2). Organic farming systems contribute to provisioning services by producing crops and livestock without synthetic chemicals, promoting healthier food products. The global organic food market was valued at approximately USD 120 billion in 2020 and is expected to grow to over USD 400 billion by 2030 due to increasing consumer demand for sustainable and healthy food products. Studies comparing organic and conventional systems have shown mixed results concerning crop yields. While organic systems generally produce 20–25% lower yields than conventional systems, the yield gap is significantly reduced in leguminous crops and under conditions where organic management practices are well-adapted to local conditions (Singh *et al.,* 2020). Additionally, organic farming systems are capable of producing comparable yields to conventional systems during drought conditions due to improved soil water-holding capacity. Regulating services involve the control of natural processes that maintain environmental stability, such as climate regulation, pest control, pollination, and water purification. Organic farming practices enhance these services by promoting biodiversity, improving soil structure, and reducing chemical inputs. Biodiversity enhancement is a crucial regulating service associated with organic farming (Winqvist *et al.,* 2012). Studies have shown that organic systems support 30–50% more species of plants, insects, and soil microorganisms compared to conventional systems, contributing to improved pest control and pollination services. Additionally, the absence of synthetic pesticides in organic systems results in reduced contamination of water bodies, enhancing water quality and overall ecosystem health. Supporting services are essential processes that underpin all other ecosystem services, including nutrient cycling, soil formation, and primary production. Organic farming systems improve nutrient cycling by enhancing soil microbial activity, which promotes the mineralization of organic matter and the release of essential nutrients. Long-term trials have demonstrated that organic systems exhibit higher rates of nutrient cycling, with enhanced soil organic matter levels resulting in improved nutrient availability and soil fertility. Soil formation processes are also supported by practices such as crop rotation, cover cropping, and reduced tillage, which promote soil aggregation and structure development. Cultural services encompass non-material benefits derived from ecosystems, such as aesthetic value, recreational opportunities, and cultural heritage (Bullock *et al.,* 2018). Organic farming practices contribute to cultural services by promoting landscape diversity, which enhances the visual appeal of agricultural areas and supports agroecotourism. Socioeconomic benefits, including improved livelihoods for small-scale farmers and enhanced community resilience, are additional cultural services associated with organic farming. Studies have demonstrated that organic farming systems can generate 20–30% higher profit margins compared to conventional systems, primarily due to premium prices for organic products and reduced input costs.

Table 2. Impact of Organic Farming on Ecosystem Services

Ecosystem Service Category	Specific Service	Impact of Organic Farming	Explanation
Provisioning Services	Food Production	Moderate to High	Yields are generally lower but sustainable; quality and nutritional value improve
	Water Availability	Improved	Enhanced soil structure and organic matter improve water retention
	Genetic Diversity	Conserved	Promotes use of traditional and diverse crop varieties
Regulating Services	Climate Regulation	Enhanced	Increased soil carbon sequestration and reduced greenhouse gas emissions
	Pest and Disease Control	Strengthened	Encourages natural predators and biodiversity-based pest regulation
	Soil Erosion Control	Improved	Permanent cover crops and reduced tillage enhance soil stability
	Water Purification	Enhanced	Reduced chemical runoff and improved filtration through organic matter
	Pollination	Boosted	Increased floral diversity and pollinator habitats
Supporting Services	Nutrient Cycling	Efficient	Legume-based rotations and composting improve internal nutrient cycling
	Soil Formation	Promoted	Organic matter additions and reduced disturbance accelerate soil regeneration
	Biodiversity Conservation	Strongly Positive	Diverse cropping systems support flora and fauna at multiple trophic levels
Cultural Services	Agri-tourism and Education	Increased	Organic farms often serve as learning and tourism sites promoting ecological values
	Traditional Knowledge Preservation	Preserved	Encourages indigenous and local knowledge systems in farming
	Aesthetic and Recreational Value	Enriched	Diverse and chemical-free landscapes offer better visual and recreational appeal

(Source- Singh et al., 2020, Winqvist et al., 2012)

B. Provisioning Services

Numerous studies have compared the productivity of organic and conventional farming systems. Meta-analyses have shown that organic yields are generally 20–25% lower than conventional yields, though the yield gap varies depending on crop type, soil conditions, and management practices. Under drought conditions, organic systems often outperform conventional systems due to enhanced water retention and soil moisture availability. Research has demonstrated that organic soils have 20–40% higher water-holding capacity, leading to improved crop productivity during periods of water stress (Ullah *et al.,* 2021). Organic farming is associated with higher nutritional quality and improved safety of food products. Studies have reported higher antioxidant levels and lower pesticide residues in organic produce compared to conventionally grown crops. For instance, organic fruits and vegetables contain up to 60% more antioxidants, which are linked to reduced risks of chronic diseases.

C. Regulating Services

Organic farming contributes to climate regulation by enhancing soil carbon sequestration through practices that increase soil organic matter content (Leifeld *et al.,* 2013). Long-term trials have shown that organic systems sequester 0.3–0.6 tons of carbon per hectare per year, which significantly contributes to mitigating climate change. Biodiversity conservation is a key benefit of organic farming. Research has found that organic farms support 30–50% more species of flora and fauna, enhancing ecosystem resilience and providing natural pest control services. Organic farming practices that enhance soil structure, such as cover cropping and reduced tillage, contribute to improved soil erosion control. Organic systems have been reported to reduce soil erosion by 20–30% compared to conventional systems.

D. Supporting Services

Enhanced microbial activity and organic matter content in organic systems promote nutrient cycling, increasing nutrient availability and reducing the need for synthetic fertilizers (Singh *et al.,* 2020). Higher soil organic matter levels contribute to improved soil structure, promoting greater porosity, aggregation, and stability.

E. Cultural Services

Organic farming offers economic opportunities through premium pricing and market demand. Studies show that organic systems can provide 20–30% higher net profitability than conventional systems. Agroecotourism is increasingly gaining attention as a cultural service provided by organic farming systems, enhancing local economies and promoting environmental education.

F. Trade-offs and Limitations

Organic systems may produce lower yields for certain crops under specific conditions, particularly during the initial transition period (Martini *et al.,* 2004). Higher labour requirements and limited access to organic inputs can pose economic challenges for scaling up organic farming systems.

5. SYNTHESIS OF FINDINGS

A. Comparative Analysis of Organic and Conventional Systems

Comparative studies consistently highlight significant differences in soil health and fertility between organic and conventional systems. Organic farming practices promote higher soil organic matter (SOM) content, improved aggregate stability, and greater microbial biomass and diversity. Studies have reported that organic soils exhibit 15–25% higher organic carbon content compared to conventional soils, contributing to improved nutrient availability and enhanced water retention. Comparative trials, such as the DOK trial in Switzerland, have demonstrated that organically managed soils contain 20–40% more microbial biomass and exhibit higher enzymatic activity than conventionally managed soils (Krause *et al.,* 2020). These biological indicators are critical for nutrient cycling, soil structure formation, and disease suppression. The yield performance of organic farming compared to conventional systems is a subject of considerable debate. Meta-analyses indicate that organic yields are generally 20–25% lower than conventional yields, though the gap varies depending on crop type, location, and management practices. Research indicates that organic systems can achieve comparable yields to conventional systems under specific conditions, such as water-limited environments. Improved soil structure and water-holding capacity associated with organic systems contribute to enhanced crop performance during drought conditions. Certain crops, particularly legumes and perennial crops, exhibit minimal yield gaps under organic management, suggesting that organic systems can be highly productive when appropriately managed (Schrama *et al.,* 2018). Organic farming consistently demonstrates positive impacts on biodiversity. Studies have shown that organic systems support 30–50% more species of flora and fauna compared to conventional systems, enhancing ecosystem resilience and improving natural pest control services. Enhanced biodiversity contributes to better ecosystem functioning, including improved nutrient cycling, pollination, and pest suppression. Additionally, organic farming practices that avoid synthetic chemicals reduce the risk of contamination in adjacent natural ecosystems, promoting ecological integrity. Long-term studies indicate that organic farming systems contribute to improved carbon sequestration and climate mitigation (Leifeld *et al.,* 2013). Organic systems have been reported to sequester 0.3–0.6 tons of carbon per hectare per year, resulting from practices such as compost application, reduced tillage, and cover cropping. Organic systems exhibit 20–30% lower nitrate leaching and reduced greenhouse gas emissions due to the absence of synthetic fertilizers and enhanced nutrient cycling. These findings suggest that organic farming systems can contribute to achieving climate-related sustainability goals.

B. Synergies and Trade-offs in Ecosystem Services

Organic farming practices enhance various ecosystem services simultaneously, creating positive synergies that improve overall agricultural sustainability. For example, practices that increase soil organic matter content also enhance soil fertility, water retention, and carbon sequestration, resulting in improved crop resilience and reduced environmental impact. Biodiversity conservation efforts, such as crop diversification and habitat management, not only improve natural pest control but also enhance pollination services, contributing to increased crop productivity and ecosystem stability (Nicholls *et al.,* 2013). Studies have also demonstrated that organic farming provides cultural services, such as agroecotourism and aesthetic value, which promote socioeconomic development and community resilience. Despite the numerous benefits, organic farming systems face several trade-offs and limitations. Reduced yields remain a significant concern, particularly for cereal crops grown under organic management. Yield reductions of 20–25% are commonly reported, though yield gaps are significantly smaller for crops such as legumes and fruits. Economic challenges associated with organic farming include higher labour requirements, limited access to organic inputs, and market volatility. Studies have shown that while organic systems can achieve higher profitability through premium prices, small-scale farmers may struggle to achieve economic viability without adequate market access. Another important trade-off involves nutrient availability. Organic systems often face limitations in nitrogen supply due to the slow mineralization of organic inputs, which may result in lower productivity under nutrient-limited conditions (Dawson *et al.,* 2008).

C. Role of Organic Farming in Achieving Sustainability Goals

Organic farming contributes to climate mitigation through enhanced carbon sequestration, reduced greenhouse gas emissions, and improved soil health. Studies have estimated that organic systems can sequester approximately 0.3–0.6 tons of carbon per hectare per year, contributing to carbon storage and climate regulation. Reduced nitrate leaching and improved nutrient retention contribute to water quality improvement, supporting broader environmental resilience. Biodiversity conservation is a critical component of organic farming's contribution to sustainability. Organic systems consistently demonstrate higher species richness and abundance across various taxa, including plants, insects, and soil organisms. These biodiversity benefits enhance ecosystem stability and resilience, promoting natural pest control, pollination, and nutrient cycling. Economic sustainability is another essential aspect of organic farming's contribution to sustainability goals. Research shows that organic systems can achieve 20–30% higher profitability compared to conventional systems due to premium pricing and reduced input costs (Goll *et al.,* 2012). Organic farming can enhance food security by promoting diversified cropping systems, improved soil health, and increased resilience to climatic stressors.

D. Knowledge Gaps and Research Needs

Further research is needed to reduce yield gaps between organic and conventional systems, particularly for staple crops grown under challenging conditions. Long-term studies focusing on the effects of organic farming on soil microbial diversity, nutrient cycling, and carbon sequestration remain limited. Comprehensive monitoring is essential for assessing the sustainability of organic systems over time. Research is required to improve the economic viability of organic farming, particularly for small-scale producers (Jouzi *et al.,* 2017). Addressing market access, certification challenges, and policy support are critical areas for further investigation.

6. FUTURE RESEARCH

A. Improvement of Organic Farming Practices

Advancing organic farming requires the development of improved crop management techniques that optimize productivity and ecosystem services. Research has shown that crop yields under organic systems are generally 20–25% lower than those of conventional systems, particularly for cereals and high-nitrogen-demanding crops. Improving organic farming practices by developing innovative crop rotation models, intercropping systems, and mixed cropping strategies can significantly enhance productivity and nutrient availability. Studies indicate that incorporating leguminous cover crops can increase nitrogen availability by 30–300 kg N per hectare per year, thereby reducing the yield gap between organic and conventional systems. Additionally, the integration of conservation tillage practices with organic systems can improve soil structure and moisture retention, resulting in enhanced crop resilience to drought stress. The availability of high-quality organic inputs such as compost, biofertilizers, and biopesticides is essential for enhancing the performance of organic farming systems. Current limitations in the supply and quality of organic inputs contribute to yield disparities between organic and conventional systems (Schrama *et al.,* 2018). Further research is needed to develop efficient organic fertilizers that enhance nutrient availability while minimizing nutrient losses. Studies have demonstrated that organic amendments, such as compost and animal manure, can increase soil organic carbon (SOC) levels by 20–30% over conventional systems, enhancing nutrient retention and cycling. The improvement of biopesticides is another critical area of research. Natural pest control agents, such as Bacillus thuringiensis (Bt) and neem-based pesticides, have demonstrated effectiveness in reducing pest populations without harming beneficial organisms. More research is required to expand the range of biopesticides and improve their efficacy under diverse environmental conditions. Integrating modern technologies into organic farming can enhance productivity and sustainability (Gamage *et al.,* 2023). Precision agriculture tools, such as remote sensing, soil sensors, and decision-support systems, can provide valuable insights into soil health, nutrient status, and pest dynamics. Recent advancements in microbial technology, such as the use of beneficial soil microbes to enhance nutrient uptake and disease resistance, also present promising opportunities for improving organic farming systems.

B. Long-term Studies on Soil Health Indicators

Long-term monitoring of soil organic matter (SOM) and carbon sequestration in organic systems is critical for evaluating their sustainability and potential for climate mitigation. Research indicates that organic systems can sequester 0.3–0.6 tons of carbon per hectare per year, mainly through practices that enhance SOM levels. Further studies are required to assess the longevity of carbon storage under organic systems and determine the influence of management practices such as reduced tillage, cover cropping, and organic amendments on carbon sequestration rates. The role of soil microbial diversity in enhancing ecosystem services is another critical area of research (Smith *et al.,* 2015). Organic systems have been shown to harbour 20–40% higher microbial biomass and diversity compared to conventional systems. The functional roles of soil microorganisms in nutrient cycling, organic matter decomposition, and disease suppression need to be further explored to optimize organic farming practices. Molecular techniques such as metagenomics and transcriptomics can provide valuable insights into microbial community structure and function. Studies have demonstrated that nutrient availability in organic systems is often limited by the slow release of nutrients from organic inputs. Improving the efficiency of nutrient cycling through enhanced microbial activity and optimized organic amendments is essential for closing the yield gap between organic and conventional systems. Long-term trials are needed to investigate the effects of different organic inputs on nutrient availability, soil structure, and overall soil health (Chen *et al.,* 2018). Comparing nutrient dynamics in organic and conventional systems over extended periods can provide critical insights into the sustainability of organic farming practices.

C. Broader Ecosystem Service Assessment

Existing research on organic farming primarily focuses on individual ecosystem services, such as soil fertility, biodiversity, and carbon sequestration. A broader framework that integrates multiple ecosystem services across spatial and temporal scales is necessary for comprehensive assessments of organic farming systems. Developing standardized methodologies for assessing ecosystem services under organic systems can enhance the comparability of findings across different studies (Sandhu *et al.,* 2008). Also provide valuable information for policymakers and stakeholders interested in promoting sustainable agriculture. Further research is needed to investigate the potential trade-offs and synergies between various ecosystem services in organic systems. While organic farming practices enhance biodiversity and nutrient cycling, they may result in reduced productivity for certain crops. The interactions between ecosystem services can guide the design of organic systems that optimize both productivity and sustainability. Multi-criteria decision analysis (MCDA) and other integrative approaches can be valuable tools for assessing these trade-offs.

D. Economic and Policy Dimensions

Improving the economic viability of organic farming is essential for promoting its widespread adoption (Reganold *et al.,* 2016). Studies have shown that organic systems can be 20–30% more profitable than conventional systems due to premium prices and reduced input costs. Research aimed at developing efficient supply chains, enhancing certification processes, and improving market access can significantly boost the economic performance of organic systems. Addressing financial challenges faced by small-scale producers is particularly important for ensuring equitable access to organic markets. Policies are essential for encouraging the adoption of organic farming practices. Government policies that provide subsidies, technical assistance, and research funding can enhance the scalability of organic systems. Incentive structures that reward ecosystem services provided by organic farming, such as carbon sequestration, biodiversity conservation, and improved water quality, can further promote sustainable agricultural practices (Rehman *et al.,* 2022).

7. CONCLUSION

Organic farming offers significant benefits for soil health, biodiversity, carbon sequestration, and ecosystem services while promoting sustainable agricultural practices. Studies indicate that organic systems enhance soil organic matter, microbial diversity, and nutrient cycling, contributing to improved soil fertility and climate resilience. Although organic yields are generally 20–25% lower than conventional systems, especially for cereals, the productivity gap can be minimized through improved crop management and innovative organic inputs. Economic profitability remains promising due to premium prices and reduced input costs, but challenges related to market access and scalability persist. Further research focusing on enhancing productivity, understanding trade-offs between ecosystem services, and developing efficient policies is essential. Expanding organic farming can significantly contribute to achieving global sustainability goals related to food security, environmental conservation, and socioeconomic development.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/133638