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Organic Agriculture for Sustainable Food Systems: A Comprehensive Review of Benefits and Constraints

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ABSTRACT

The global population is increasing at a rapid pace, posing significant challenges to sustainable development and food security. This review paper examines the advantages and challenges of organic farming as a potential solution to address the pressing issues in modern agriculture and food production. Organic farming offers a range of benefits, including improved soil fertility, higher profitability, reduced external input usage, land reclamation, improved market access, and enhanced farmer capacity and self-reliance. Organic farming practices prioritize environmental sustainability by reducing chemical usage and reliance on biological methods of pest control, as well as enhancing biodiversity, which strengthens ecological balance and resilience against pests and diseases. However, organic farming also faces challenges that need to be addressed for its widespread adoption. These challenges include uncertainty surrounding legislative environments, psychological and sociological costs of conversion, financial risks during the transition period, securing marketing channels for organic produce, and diminishing profit margins. Efforts should be made to provide farmers with the necessary support, including technical assistance, subsidies, and access to markets, to overcome these challenges. Despite the challenges, the potential of organic farming in promoting sustainable agriculture and ensuring a secure food system cannot be overlooked. It offers a natural and environmentally friendly approach to food production, prioritizing the health of both humans and the ecosystem.

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Introduction

The increasing population is one of the major obstacles to sustainable development. To address the rising population, the production of food should be increased (Soni et al., 2022). The application of artificial fertilizer to enhance productivity is one of the examples of modern agricultural practices that deteriorate the balance of soil nutrients and decrease fertility (Dhiman, 2020). Besides this, genetic engineering, the use of high-yielding varieties, and the abundant use of pesticides to address food shortages have resulted in environmental pollution and the occurrence of new pests and diseases (Veisi et al., 2013). Organic farming practices such as crop rotation, green manures, organic nutrients managements etc. offers effective solutions to address the myriad challenges encountered in modern agriculture and food production (Gamage, et al., 2023). The main principle of organic farming is- health, fairness, ecology, and care- providing vision for environmentally friendly cultivation and production. The goals of organic agriculture encompass producing ample, nutrient-rich food while aligning with natural systems. It involves fostering biological cycles within farming systems, bolstering soil fertility, and utilizing renewable resources in locally structured agricultural setups, minimizing reliance on external organic matter and nutrients (Palaniappan & Annadurai, 2018). It provides a natural way of crop cultivation by prioritizing the environment, agricultural traditions, and sustainability, without synthetic fertilizers, pesticides, or genetic modification. Organic farming, also called biological or ecological farming, blends conventional farming practices with cutting-edge farming technologies to offer benefits such as increased yield stability, improved soil fertility, higher yields and profitability, reduced external input use, land reclamation, improved market access, and enhanced farmer capacity and self-reliance (Ferdous et al., 2021). Furthermore, it highlights crop rotation, organically eradicating pests, varying the types of animals and crops, and improving the soil through

incorporation of compost, animal and green manures, and other fertilizers (Wijnands, F. G., 1999). Organic farmers utilize contemporary tools like tractors, discs, cultivating sleds, compost spreaders, irrigation pumps and pipes, drip irrigation (Ronals & Adamchak, 2008), enhanced crop varieties, methods for conserving soil and water, and the latest innovations in livestock nutrition and management (Reganolg & Wachter, 2016). Organic farming places great importance on the utilization of organic materials, such as compost and cover crops, to enhance soil structure, increase water-holding capacity, and retain nutrients. These practices not only improve soil fertility but also minimize the potential for nutrient leaching. As a result, they promote sustainable agricultural production (Khan et al., 2023). Understanding the relationship between organic agriculture and sustainable farming practices is of utmost importance for various stakeholders, including policymakers, farmers, consumers, and researchers. While organic farming has gained popularity in recent years, there is a need to assess its strengths, challenges, and potential for widespread adoption.

Organic Farming: Advantage, Opportunities, and Challenges

Organic farming offers numerous benefits for sustainable agriculture and addresses various challenges faced in modern food production. Nutrient management in organic farming involves recycling nutrients through organic materials like farmyard manure and crop residues and employing composts and green manuring to better maintain soil fertility and provide essential nutrients for plant growth (Pulleman et al., 2006). The utilization of organic nitrogen through the application of farmyard manure (FYM) sustains crop productivity to a greater extent than relying solely on conventional nitrogen fertilizers. The utilization of organic sources in agriculture fosters the development and beneficial function of mycorrhizae and other organisms present in the soil (Yadev, et al., 2013). This practice helps address the rising occurrence of nutrient deficiencies, including secondary and micronutrients while supporting both high yield and soil fertility thereby ensuring the sustainability of agriculture as an environmentally friendly approach to soil health management (Mishra & Nayak, 2004). The use of manure in the rice-wheat system shows great potential in achieving enhanced productivity levels while guarding against the occurrence of multi-nutrient insufficiencies and preserving soil quality (Bhatt, et al., 2017). Cover crops play a vital role in improving soil health by increasing organic matter, stabilizing soil through aggregate formation, enhancing soil porosity for root growth, improving water infiltration and reducing crusting, and promoting beneficial soil organisms for efficient nutrient cycling and improved soil structure (Baldwin & Creamer, 2006). Morvan et al. (2018) found that organic management fields showed significantly enhanced soil structure in comparison to conventional fields, demonstrating that conventional soils are more prone to forming crusts. Moreover, in the organic management field during rainfall events with intensities of 25 and 40mm/h, there was no runoff, while runoff occurred in the conventional management field with corresponding runoff coefficients of 4.8% and 6.9%. These findings highlight the significance of recent transition to organic farming in silty soil, particularly in terms of aggregate stability, soil crust dynamics, runoff formation, and soil erosion.

Polyculture, a key element of organic farming, involves cultivating a diverse range of crops on a single piece of land. This practice not only attracts a variety of beneficial soil microbes but also utilizes certain crops that act as natural pest repellents, promoting organic pest control. In contrast, traditional monoculture in farming may initially reduce cultivation costs but ultimately leads to soil fertility decline over time and the development of pest resistance to chemical controls (Behera et al., 2012). By embracing polyculture, organic farming enhances biodiversity, pest regulation, and overall sustainability.

Utilizing pesticides for pest control in organic farming poses negative aspects as it can harm beneficial insects and leave residues in the environment that may not comply with organic certification standards. Therefore, focusing on alternative methods becomes crucial. One such method involves employing natural predators or beneficial insects to control pests, a technique widely used in organic farming and is the most naturally sustainable approach (Huffaker & Dahlsten, 1999). For instance, the introduction of certain parasitoids, such as *Aphytis paramaculicornis* and *Coccophagoides utilis*, to combat olive scale, *Parlatoria oleae* infestations in California's olive groves has proven to be effective (Muedoch et al., 1985). Another prevalent strategy is employing physical barriers like fruit bagging, which serves as a protective measure against pests in various crops such as mangoes, guava, litchi, pomegranates, citrus fruits, and pitaya (Grasswitz, 2019). Moreover, organic farmers frequently use natural alternatives such as diluted cow urine, vermiwash, and plant-based bio-pesticides derived from neem, ginger, chilli, and custard apple for pest control (Sofia et al., 2006). These methods underscore the holistic and sustainable nature of organic farming practices.

Crop rotation is another essential practice in organic farming, preventing and managing pests, diseases, and weeds while preserving and enhancing soil fertility (Wijnands, F. G., 1999). It is designed to control weed communities by strategically planning sequences of crops that significantly differ from one another in key variables such as planting or maturation dates, growth habits, competitiveness, cultural practices, and fertility needs. This disruption prevents the dominance of a few weed species and hinders their growth and development (Liebman & Dyck, 1993). It also helps break the weed cycle by alternating crops. Also, cover cropping suppresses weed growth by crowding out unwanted plants and improving soil health, ultimately mitigating weed pressure in the agricultural ecosystem (Schonbeck & Tillage, 2011). Similarly, Crop rotation effectively controls insect pests with limited host ranges, as seen in the central United States where a 2-year rotation of maize with soybean reduces the economic threshold for the northern maize rootworm from 30% to less than 1% (Bullock, 1992). This approach reduces the reliance on chemical controls and promotes sustainable pest and weed management. Similarly, disease management is also possible by rotation of different crops; specifically, the management of soil-borne pathogens (Peters et al., 2003). Certain plant species

play a crucial role in soil sanitation through their ability to act as rotation crops; for instance, Crotalaria spectabilis serves as a trap crop, effectively diminishing root knot nematode populations (Cook, 1988).

Enhancements to plant and animal quality in organic farming are key environmental benefits that contribute to human well-being. These improvements are achieved by implementing effective soil management techniques and optimizing soil conditions (Conacher & Conacher, 1998). Organic farming offers a significant advantage in mitigating soil erosion and associated challenges such as nutrient depletion, decreased yield, flooding, sediment buildup, and eutrophication. By implementing good management practices, organic agriculture has shown remarkable success in reducing these issues compared to conventional farming methods (Pimentel, et al., 1995). Nutrient leaching poses a significant issue, particularly in areas with intensive agriculture, leading to excessive nutrient enrichment in aquatic environments and disruption of marine ecosystems (Helberg, 2012). The prohibition of synthetic pesticides reduces the danger due to pesticide contamination in water bodies (Reganolg & Wachter, 2016). Organic farming has a lower environmental impact and contributes less to pollution compared to traditional farming practices, particularly concerning climate change. Additionally, Reganold and Wachter (2016) suggest that farming organically, contributes to mitigate the degradation of natural environment, particularly in light of increasing global warming concerns. In organic systems, nitrogen inputs are typically lower, resulting in reduced potential for N2O emissions (Meemken & Qaim, 2018) as well as the impact of CH4 emission is limited (Skinner, et al., 2019).

Organic farmers prioritize ecological principles that emphasize diversity in their management approaches. This is achieved through practices such as promoting species richness, balanced crop rotations, maintaining ground cover, protecting natural habitats, and avoiding disruptive practices. These strategies aim to increase species richness and diversity, support sustainable productivity, natural pest regulation, and improve overall system stability and resilience (Pimentel, et al., 1995). The decreased presence of insect pests on long-term organic farms can be largely attributed to factors such as enhanced biodiversity, increased presence of beneficial predators, and alterations in plant nutrient composition (Blundell, et al., 2020). They also suggest that implementing organic methods for cultivating healthy soils can significantly contribute to the achievement of sustainable and resilient crop yields, even when faced with hemipteran pest pressures. Additionally, the lower nitrogen levels in plants grown on organic farms may make them less attractive to herbivores, contributing to the reduced pest pressure observed in organic systems (Mattson, 1980). Different studies suggest that organic farming practices, including the maintenance of organically managed soils and microorganisms, may unintentionally lead to a decrease in plant pest attraction by enhancing plant resistance. Bengtsson et al. (2005) found that rotating different crops, the absence of pesticides and herbicides, and the avoidance of inorganic fertilizers in organic farming leads to increased biodiversity in agricultural landscapes. This, in turn, positively affects abundance and richness of species compared to conventional farming systems.

Organic farming holds significant potential to generate socially and environmentally beneficial outcomes (Singh & Grover, 2011). It has the potential to make significant contributions to socio-economic development and ecological sustainability, particularly in developing countries worldwide (Mariappan & Zhou, 2019). The combination of higher yields achieved in organic agriculture and the growing demand for organic food presents a promising opportunity for sustainable agricultural practices. Research by Ramesh et al. (2005) suggests that after an initial transition period, organic farming can offer a range of benefits and opportunities. The "transition effect" refers to the phenomenon where there is a decline in yields during the early years of transitioning to organic agriculture, followed by subsequent yield increases as the soil develops adequate biological activity. An additional research study by Thakur and Sharma (2005)comparing the economics of Organic Farming System (OFS) and Inorganic Farming System (IFS) has favored OFS in terms of both higher yields and profitability. One critical factor that contributes to the profitability of organic farms is the potential to command more farm gate prices for organically produced goods in comparison to conventionally produced ones (Offerman & Nieberg, 2000). Organic agriculture offers farmers reduced vulnerability by serving as a protective measure against low prices and price volatility in conventional markets, increasing resilience to extreme weather events, and providing a diverse range of outputs through crop-livestock systems (Seufert, 2012). Moreover, it has a greater opportunity to target specialized and international markets compared to conventional farming as organic products can fetch higher prices (Ferdous et al., 2021). Research in Phillippins by Mendoza founds that organic farming yielded slightly lower crop production but generated higher net revenue at 332 USD ha^{-1} compared to 290 USD ha^{-1} in conventional farming, predominantly due to lower cash costs in organic farming and higher expenses related to agro-chemical inputs in conventional farming, constituting 83.2% of the total cash cost (Mendoza, 2004). Consumers commonly believe that organic foods are healthier and more nutritious than conventional foods, possibly because of lower contamination levels and higher concentrations of desirable nutrients (Bourn & Prescott, 2002). Reganold and Wachter (2016) suggest that organic agriculture supports good health among consumers by preventing diseases. Organic foods are recognized for their higher levels of plant secondary metabolites, increased micronutrient content, and greater presence of conjugated fatty acids, contributing to improved human health and a reduced risk of non-communicable diseases (Siddique et al., 2014). Growing consumer demand for organic food stems from concerns regarding the negative impacts of conventional agriculture on the health of both humans and surroundings, particularly in developed countries where organic food is perceived as safer and healthier (Meemken & Qaim, 2018). Studies indicate that organically grown foods, particularly leafy vegetables, and tubers, exhibit higher dry matter content, while organic cereals have lower protein content but higher quality proteins with improved amino acid scores, including significantly higher lysine content

compared to conventional counterparts (Das et al., 2020). Organic agriculture contributes to the holistic well-being of a nation by promoting the health of its consumers, the ecological health of its environment, and economic growth through income generation. Certification in agriculture involves a standardized process that verifies and validates farming practices meet specific criteria or standards. It typically includes assessments, inspections, and adherence to guidelines related to organic, sustainable, or other specialized agricultural methods. Certification helps ensure quality, safety, and compliance with established agricultural practices, allowing farmers to label and market their products accordingly (Jacobsen, 2002).

While organic agriculture offers numerous advantages, it also faces certain challenges and limitations that need to be considered. These include potential yield variations, increased labor requirements, higher production costs, limited access to organic inputs, and potential difficulties in scaling up organic practices to meet growing global food demand. Other challenges are uncertainties surrounding legislation and subsidies, psychological and sociological pressures from peers and family members, financial risks during the transition period, difficulties in securing marketing channels for organic products, and diminishing profit margins due to increased overall food prices (Uematsu & Mishra, 2012). Organic certification is also another challenges in organic agriculture. ISO certification refers to the process of complying with internationally recognized standards developed by the International Organization for Standardization (ISO). ISO certification signifies compliance with internationally accepted norms and practices in quality management and environmental considerations (Jacobsen, 2002). Approximately 80% of organic producers worldwide are small-scale farmers residing in low to middle-income nations. For these individuals, obtaining individual certification would pose financial challenges and logistical complexities that are burdensome to manage (Meinshausen et al., 2019) Understanding and addressing these challenges are essential for the overall growth and success of organic farming. The productivity of organic farming is hindered by the dual factors of nutrient shortages and high weed populations, posing limitations on overall crop yield (Nandwani & Nwosisi, 2016). Organic production imposes stricter limitations on inputs compared to conventional methods, as organic standards aim to minimize or eliminate the use of synthetic or manufactured inputs, emphasizing the optimal utilization of local natural resources (Pacanoski, 2009). A study by Darnhofer et al. (2005) argues that organic pesticides may not necessarily be more environmentally benign, organic produce may still contain synthetic pesticides from nearby farms, and the repeated use of certain organic preparations can lead to the buildup of trace metals in the soil. Furthermore, they doubt the healthiness of organic produce, suggesting that plants may have higher concentrations of secondary metabolites as a defense mechanism and that there may be a higher incidence of fungi and mycotoxin contamination in organic grain. Additionally, they claim that the characteristics of value-added organic food is not necessarily superior to conventional food due to the presence of additives.

Conclusion

In conclusion, organic farming presents a promising alternative for addressing the complex challenges faced by modern agriculture. It provides an eco-friendly and sustainable method for food cultivation, promoting the well-being of both humans and the ecosystem. However, challenges such as cultivation practices, market access, and financial risks must be addressed for its widespread adoption. By overcoming these challenges, organic farming can play a crucial role in fostering a sustainable and resilient agricultural system. Policy makers, farmers, consumers, and researchers need to recognize and support the potential of organic farming to achieve sustainable agriculture and ensure a secure and resilient food system.

Declarations

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