The Role of Organic Farming for Climate Change Mitigation and Sustainable Development: A Review

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Abstract

Climate Change, exacerbated by human activities such as fossil fuel combustion and greenhouse gas emissions like carbon dioxide (CO_2), is a pressing global crisis that disrupts long-term weather patterns, ecosystems, and human well-being. Organic agriculture offers a viable solution to mitigate these effects. By lowering greenhouse gas emissions and enhancing soil carbon sequestration, organic farming strengthens ecosystem resilience. Practices such as eliminating synthetic fertilizers and pesticides, rotating crops, and utilizing organic waste foster robust agricultural systems capable of enduring extreme weather and water scarcity. This paper provides an in-depth analysis of how organic farming contributes to climate change mitigation, detailing practices that support soil carbon sequestration, reduce nitrogen oxide (N_2O) emissions, and boost biodiversity. It also addresses challenges such as emissions measurement and consumer behaviour, emphasizing the need for further research and supportive policies. Organic agriculture not only advances sustainable development but also promotes food security and environmental sustainability in the face of climate change.

Keywords: Organic Farming, Climate Change Mitigation, Soil Carbon Sequestration, Sustainable Development.

Introduction

The critical issue of climate change is well-known, yet its full gravity may not always be recognized. Understanding climate change and its effects on the rapidly evolving world is essential. Climate Change refers to significant and enduring shifts in temperature and weather patterns. Human Activity is the primary cause of climate change. The prolonged use of fossil fuels—such as coal, oil, and gas—for energy and power is a major contributor to greenhouse gas emissions. These gases trap the sun's heat, leading to rising global temperatures. While many perceive climate change as simply an increase in temperatures, it is far more complex. The Earth functions as an interconnected system, where changes in one area can trigger a cascade of impacts across other aspects of the environment (*What Is Climate Change? | United Nations*, n.d.).

When considering actions to combat climate change, it is crucial to examine the global natural Corban Dioxide (CO_2) fluxes thoroughly. Examining the four primary worldwide natural CO_2 flows within land ecosystems may offer valuable insights: CO_2 absorption by plants via photosynthesis, CO_2 releases from organisms and plants' respiration; and biomass decomposition, CO_2 absorption by seas, CO_2 releases from seawater out gassing (Pawłowski et al., 2021). Agriculture serves as a notable source of greenhouse gas emissions, ranking second after energy utilization, and these emissions arise from both soil and animal digestion processes, along with energy consumption throughout agricultural production stages. Fortunately, implementing changes in agricultural system management can help mitigate the adverse effects that this sector has on the atmosphere and climate (Kwiatkowski et al., 2023). Climate change mitigation is of utmost importance, as is adapting to its effects, particularly in the agricultural sector, where food security is paramount. The key to mitigating climate change lies in the ability of agricultural soils to capture CO_2 by increasing organic matter (Muller et al., 2012). Embracing organic practices can also play a significant role in adaptation efforts. Enhancing soil organic matter not only increases water retention capacity, but also fosters stable, fertile soils, reducing vulnerability to droughts, extreme precipitation events, floods, and waterlogging (Pawłowski et al., 2021). Thuse The European Union (EU) Green Deal has introduced the "Organic Farming Action Plan" to create a sustainable farming system that can adapt to the challenges of climate change. Which aims to help achieve the United Nations' Sustainable Development Goals (UN-SDGs) by promoting environmentally friendly agricultural practices. The EU Green Deal's "Organic Farming Action Plan" aims to revolutionize organic farming, making it more sustainable and aligning with the three pillars of sustainable development: the economy, society, and the environment. This ambitious proposal is set to drive the evolution of European organic production. According to this plan, reaching the objectives will be possible through investment and innovation in sustainable farming (El Chami, 2020).

Carefully managing nutrients and storing carbon in soils are important for dealing with and reducing the impact of climate change in different climate zones and local conditions (Sartaj Wani et al., 2013). Hence Organic farming (OF) serves as a robust and sustainable solution for addressing climate change and its fluctuations. It provides a practical approach for adapting to climate change and has potential for researching crop yields and the institutional framework of organic farming to reduce and store carbon (Gong et al., 2022). OF aims to reverse the impacts of climate change and improve resilience and sustainability by addressing important issues and challenges caused by a changing climate. Therefore, It is essential to make focused and strong efforts to curb the rise in global temperatures to 1.5 °C, and the agricultural sector is well positioned to actively contribute to the crucial task of combating climate change(Holka et al., 2022).

Adaptation in the agricultural sector is vital and can be observed through a combination of short-term and long-term strategies and organic farming is the best way to adapt to climate change, ensure food security, and sustainably produce high yields with low external inputs (Boeraeve et al., 2022). Organic farming systems provide a vital opportunity to combat climate change by effectively managing nutrients, resulting in a significant decrease in N_2O emissions from the soil. Additionally, the practice of organic agriculture holds great potential for mitigating climate change through the sequestration of carbon in soils (Ondrasek et al., 2023). In an initial assessment, it is projected that refraining from using mineral fertilizers could potentially result in a reduction of approximately 20% in emissions. Furthermore, carbon sequestration offers the opportunity to counterbalance around 40–72% of the global annual agricultural greenhouse gas (GHG) emissions. However, further research is imperative to validate and strengthen these figures. In developing countries, organic farming methods offer comparable or even superior yields compared to conventional practices, providing a crucial solution for guaranteeing food security and sustainable livelihoods for rural communities amidst climate challenges. Choosing certified organic products can help farmers earn more money and promote environmentally-friendly agricultural practices worldwide (Scialabba & Mller-Lindenlauf, 2010).

Common organic practices play a vital role in facilitating adaptation for instance by enhancing soil organic matter, not only do we boost water retention capabilities, but we also foster the development of more resilient and fertile soils. Consequently, this helps in minimizing the susceptibility to droughts, intense rainfall, floods, and waterlogging. Moreover, the promotion of greater agroecosystem diversity in organic farms serves to further bolster the process of adaptation (Muller et al., 2012). As in so the Stakeholders must strengthen and advocate for sustainability (economic, environmental, and social) as well as investments in organic farming (Cidón et al., 2021), since organic production epitomizes a holistic approach to farm management and food production, incorporating leading environmental and climate action methodologies. It also emphasizes the rich biodiversity, the conservation of natural resources, and the implementation of superior animal welfare and production standards, which perfectly aligns with the growing consumer preference for goods made with natural ingredients and methods. Reducing the impact of climate change by significantly decreasing greenhouse gas (GHG) emissions is essential and relies on fully understanding the concept of the carbon footprint (Ozlu et al., 2022). Furthermore, increasing soil organic carbon in agroecosystems is a great way to help fight climate change, adapt to it, and ensure food security all at the same time. However, the identification of optimal management practices to achieve these objectives is essential (Koishi et al., 2020). In general, organic farming faces obstacles from climate change, and geopolitical crises therefore Policies and regulations need to be carefully designed to address these challenges. These measures are pivotal in fostering a more sustainable organic agriculture model that prioritizes food safety and security (Ondrasek et al., 2023). The potential role of agriculture in mitigating climate change is significant, but there is still a lack of knowledge and awareness about this issue in society. To enhance environmental quality by reducing atmospheric CO_2 levels and increasing soil carbon sequestration, strategic investments are imperative (Pawłowski et al., 2021).

Understanding Organic Farming:

Organic farming can be characterized as a holistic method of production that prioritizes the reduction or complete elimination of synthetic inputs, such as compound fertilizers, growth regulators, pesticides, and additives in farm animal feed. In order to maximize its potential, the organic agriculture system relies on a set of practices. Which includes crop rotation, the use of green manures, the incorporation of legumes, the application of animal manures, the management of crop residues, the integration of organic waste from outside the farm, and the implementation of biological pest control measures. These strategies focus on keeping the soil healthy and increasing plant growth, as well as dealing with pests, diseases, and weeds (Yuvaraj et al., n.d.). OA claims to be more environmentally friendly than conventional agriculture and capable of addressing sustainable development objectives by utilizing green technologies, which can lead to economic, social, and ecological benefits (Cidón et al., 2021). It stands as a continuously expanding global concept that underscores the importance of employing sustainable and eco-friendly methods. Embracing OA has the potential to enhance ecosystem services, boost biodiversity, curb environmental pollution, shrink carbon footprints, and mitigate greenhouse gas emissions. Consequently, it yields food devoid of harmful agrochemical residues, thereby fortifying food safety and security. Additionally, OA represents a sustainable farming approach that prioritizes the adoption of holistic and environmentally-friendly natural methods to produce top-notch crops and livestock for food or feed (Ondrasek et al., 2023). Therefore, it is imperative to prioritize the critical task of reducing the impact of climate change by limiting greenhouse gas (GHG) emissions, a goal that can be accomplished through a thorough understanding of the carbon footprint concept (Ozlu et al., 2022).

Relationship between Agriculture and Climate:

Agriculture ranks as the second-largest contributor to greenhouse gas emissions, following energy consumption and these emissions arise from soil and animal digestion processes, as well as from energy usage throughout various stages of agricultural production (Kwiatkowski et al., 2023). Agriculture is responsible for 18% of greenhouse gas emissions, mainly from carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Hence, it's important to reduce these emissions to help address climate change. Additionally, Soil management around the world can affect these emissions, showing the importance of understanding how photosynthesis, greenhouse gases, and agricultural practices interact, particularly in relation to soil and related systems. Improving soil health indicators might increase greenhouse gas emissions at first, but it will also enhance the soil's capacity to capture carbon through photosynthesis, which can ultimately help tackle climate change (Ozlu et al., 2022). Organic agriculture (OA) claims to be more environmentally friendly than conventional agriculture and capable of addressing sustainable development objectives by using green technologies, resulting in economic, social, and ecological benefits (Cidón et al., 2021).

Roll of Organic Agriculture for Climate Change Mitigation and a Way Toward Sustainability

1. **Role of Soil Organic Carbon in Agricultural Systems for Mitigation**

The most effective method for mitigating environmental impact in agriculture is to preserve and enhance soil organic carbon within agricultural systems (P. Smith et al., 2008).

2. **Organic Agriculture and Lower N_2O Emissions from Nitrogen Application**

In organic agriculture, nitrogen input per hectare is generally lower than in conventional agriculture, leading to reduced nitrous oxide emissions from nitrogen application (Mäder et al., 2002).

3. **Reduced CH_4 and N_2O Emissions in Organic Agriculture**

In organic agriculture, the recycling of leftover biomass as nutrients improves soil fertility and reduces the need for external inputs. This practice reduces methane (CH4) and nitrous oxide (N2O) emissions because organic matter is reused sustainably instead of being burned (P. Smith et al., 2007).

4. **Mitigation through Manure Management**

Organic farms employ on-farm or cooperative strategies to effectively manage farmyard manure while integrating crop and livestock operations. This proactive approach reduces reliance on artificial nitrogen fertilizers and helps to lessen the environmental impact often associated with both crop farms that do not raise animals and intensive livestock operations (Scialabba & Hattam, 2002).

5. **Impact of Reduced Concentrate Feed Use in Organic Animal Agriculture Less Direct Land Use Change:**

Organic animal farming reduces the demand for concentrated feed, thereby alleviating the pressure to clear forests for feed production. This, in turn, lowers CO_2 emissions caused by soil carbon loss from land use changes (Shibata & Terada, 2010).

6. **Energy Efficiency:**

Organic farming typically requires less fossil energy per hectare and unit of food produced compared to conventional farming, mainly because it relies less on synthetic inputs and energy-intensive practices. (Schader et al., 2012).

7. Benefits of Organic Agriculture on Soil Quality and Fertility-Enhanced Soil Quality:
Organic farming enhances soil quality by increasing nutrients, improving soil structure, and boosting aeration, resulting in healthier and more productive soils (Mäder et al., 2006).

8. Benefits of Diversity in Organic Agriculture:
Organic agriculture fosters greater variety among crops, rotations, and production practices, resulting in increased biodiversity levels compared to conventional monoculture-based systems. This diversity, including set-aside areas and landscape elements, improves ecological and economic stability.

9. Resilience to Climate Change:
Organic farming's enhanced biodiversity fortifies farms against climate change impacts by providing various revenue streams, reducing occurrences of pests and diseases, and optimizing nutrient and water utilization in the soil (J. Smith et al., 2011).

10. Reducing greenhouse gas emissions in agricultural systems brings economic benefits for farmers.
Research has demonstrated that the utilization of organic fertilizer and proper tillage practices can significantly enhance soil carbon storage and diminish greenhouse gas emissions (Gong et al., 2022).

Challenges of Organic Agriculture

The challenges of effectively addressing climate change through organic and general agriculture include

1. Limited understanding of basic processes like N_2O emissions, soil carbon sequestration through roots, and life-cycle emissions of organic fertilizers.
2. Lack of accurate emissions accounting methods that reflect diverse agricultural outputs and ecosystem services.
3. Difficulty designing policies that support both mitigation and adaptation without disadvantaging systemic approaches due to emission quantification challenges.
4. Ensuring sustainability by not overlooking factors like pesticide use, eutrophication, acidification, and soil erosion amid the focus on mitigation (Muller et al., 2012).
5. At present, there is a limited understanding of the comparison between organic and non-organic farming in terms of soil emissions of nitrous oxide (N_2O) and methane (CH_4) (Skinner et al., 2019).

Future research aspects:

To effectively bridge crucial knowledge gaps in OA, future studies should prioritize the exploration of the following key areas:

1. Comparing organic and conventional farming to understand their benefits and limitations in various contexts, informing decision-making and policy.
2. Explore organic agriculture value chain, market potential, consumer preferences, and economic benefits to farmers to improve market competitiveness and profitability.
3. Investigate the long-term impacts of organic agriculture on ecosystem services, biodiversity, environmental pollution, and carbon footprints to assess sustainability and effectiveness on a larger scale (Ondrasek et al., 2023).
4. Potential for carbon sequestration from above- and below-ground inputs, influenced by crop types, soil types, management practices, and climate conditions.
5. The environmental impact of organic fertilizer, including strategies to reduce greenhouse gas emissions from mulching, green manures, and cover crops.

6. Relationships between soil carbon levels and emissions of nitrous oxide.
7. Plant adaptation to environmental stress and effective breeding strategies.
8. Use of diverse agro-ecological systems, including agroforestry, to enhance climate resilience and carbon sequestration.
9. Impact of different farming systems, beyond individual practices, on climate change mitigation and adaptation(Muller et al., 2012).

Conclusion

In confronting the escalating challenge of climate change, organic agriculture emerges as a pivotal strategy with multifaceted benefits. The sustainable farming approach not only substantially reduces greenhouse gas emissions, especially nitrogen oxides and carbon dioxide, but also improves soil health, biodiversity, and resilience to extreme climates. Organic farming utilizes practices such as crop rotation, green manuring, and reduced reliance on synthetic inputs. These techniques help to nurture nutrient-rich soils that have the remarkable ability to sequester carbon. This, in turn, contributes to mitigating climate change impacts and promoting food security in diverse agroecological settings worldwide.

Moreover, organic agriculture supports sustainable development goals by promoting economic prosperity, social equity, and environmental stewardship. The European Union's Green Deal and similar initiatives underscore the global recognition of organic farming's potential to address climate change while ensuring food safety and environmental sustainability. Challenges such as emissions quantification and consumer behavior remain significant, requiring continued research and policy innovation to maximize organic agriculture's efficacy in climate change mitigation.

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