

Opinion

Organic Farming and Climate Change: The Need for Innovation

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Abstract: Organic agriculture has experienced remarkable growth in recent decades as societal interest in environmental protection and healthy eating has increased. Research has shown that relative to conventional agriculture, organic farming is more efficient in its use of non-renewable energy, maintains or improves soil quality, and has less of a detrimental effect on water quality and biodiversity. Studies have had more mixed findings, however, when examining the impact of organic farming on greenhouse gas (GHG) emissions and climate change. Life cycle assessments (LCAs) in particular have indicated that organic farming can often result in higher GHG emissions per unit product as a result of lower yields. The organic movement has the opportunity to embrace the science of LCA and use this information in developing tools for site-specific assessments that can point toward strategies for improvements. Responding effectively to the climate change crisis should be at the core of the organic movement's values. Additionally, while societal-level behavioral and policy changes will be required to reduce waste and shift diets to achieve essential reductions in GHG emissions throughout food systems, organic farming should be open to seriously considering emerging technologies and methods to improve its performance and reduce GHG emissions at the production stage.

Keywords: organic farming; climate change; greenhouse gas emissions; life cycle assessment

1. Introduction

The organic farming movement has so far been a success, mostly. Measured in land area, number of farms, or product sales, organic agriculture has experienced stunning growth over the past few decades. Prior to the 1980s, the number of organic farms was “negligible” according to Lockeretz in *Organic Farming: An International History* [1]. Today, organic farms occupy 1% or slightly more of global agricultural land area and considerably more than this in many developed countries [2–4]. Organic product sales have reached USD 55 billion in the United States [5] and USD 100 billion worldwide [4]. This surge has been driven in large part by a societal desire to curb environmental damages caused by agriculture and to consume “wholesome, high-quality foods” [1]. The organic farming community has been steadfast in keeping its core values, but it has also been open to collaborating with the science community to understand and solve problems. Additionally, while scientific research has provided justification for many claims about organic farming and food in terms of reduced fossil-energy consumption, improved soil and water quality, reduced exposure to pesticides, and protection of biodiversity, questions remain about organic farming's net effect on greenhouse gas (GHG) emissions, including carbon dioxide (CO₂), nitrous oxide (N₂O), and methane (CH₄), and its impact on climate change relative to conventional agriculture.

Maintaining a “healthy soil” through the use of cover crops, crop rotation, and organic soil amendments is fundamental to organic farming. This “feed the soil, not the plants” approach represents a long-term commitment to improving and maintaining soil quality and is expected to increase soil organic matter (SOM), thus sequestering more carbon per unit area compared to

conventional farmland, at least over a period of decades until a new SOM equilibrium is reached. Indeed, research supports this understanding of soil carbon dynamics and has demonstrated organic farming's greater efficiency in its use of non-renewable energy as well [2,3,6]. This means that in addition to storing more carbon in soil, organic farms are also directly and indirectly emitting less carbon from combusted fossil fuels by using less natural gas, diesel, and gasoline and using no synthetic fertilizers or pesticides in their management of soil fertility and pests. All of this would strongly suggest that a transition to organic farming would lead to a reduction in net GHG emissions. However, there are compelling studies indicating that this is not the case, and most of this emerging evidence hinges on organic farming's lower average yields.

A meta-analysis published by Skinner et al. in 2014 [7] revealed that organic crop systems generated lower N₂O emissions from soil per unit area but not per unit yield. In fact, they calculated that organic yields would need to increase by 9% just to match emissions per unit output from conventional systems. Similarly, the available data they reported for rice suggested higher CH₄ emissions for organic compared to conventional management on a yield basis. Several years later, Skinner et al. [8] reported the findings of a field study at the DOK (Bio-Dynamic, Bio-Organic, Konventionell) long-term cropping systems comparison trial in Therwil, Switzerland, over a 571-day period during which they compared GHG emissions from soils in five different crop production systems. They focused on emissions of N₂O and CH₄ because, according to the authors, more than half of the total amounts of these GHG emissions come from agriculture. They reported a 40% reduction in N₂O emissions in organic compared to non-organic systems on a per-hectare basis. Yield-scaled comparisons to correct for the lower yields in the organic systems showed no significant difference in N₂O emissions for silage corn between the systems. They concluded that yield-scaled N₂O emissions did not differ between organic and non-organic treatments at the DOK site.

2. Life Cycle Assessments

Quantifying soil GHG dynamics is obviously a necessary part of assessing environmental performance, but other methods and approaches are also needed to understand whole-farm systems and identify problem areas and potential solutions. Life cycle assessment (LCA) provides a means of accounting for all of the environmental impacts of resource extraction and use, as well as the pollution generated along part or all of a product's existence from the acquisition of raw materials through the product's use and disposal (cradle to grave). The number of LCA-based analyses published on farming and food systems has increased dramatically since about 2005 [9]. These studies, which sometimes do have conflicting results, offer some interesting insights and raise some difficult questions.

Venkat [10] analyzed 12 pairs of organic and conventional crop systems in California using LCA with publicly available data, mostly derived from publications of the University of California. The general trend reported in the literature prior to this study, according to the author, had been for lower GHG emissions in organic systems per unit land, but more mixed results for emissions per unit output due to lower yields from organic production. Indeed, in Venkat's study, organic production had lower GHG emissions in five comparisons, while conventional production had lower emissions in the other seven. On average, GHG emissions from organic production per unit product were 10.6% higher than conventional production. This analysis indicated that during the shift from conventional to organic management, when higher rates of carbon sequestration are expected, this transition period often performed better than either conventional or organic production. Once soil SOM has reached a new steady state, after 15–30 years, the advantage disappears.

Two studies by Aguilera et al. [11,12] provide an interesting contrast to Venkat [10], as they analyzed cropping systems in relatively similar climates. In their first paper [11], the authors compared GHG emissions of 38 pairs of conventional and organic herbaceous crops in Spain using LCA. The crops included vegetables (open-air and greenhouse), cereals, and legumes (pulses). They reported a general pattern of lower GHG emissions per unit output under organic compared to conventional production with the exception of rice, which generated higher emissions under organic management

due to greater methane production. Fossil fuels accounted for the greatest fraction of emissions for both conventional and organic systems under open-air management. Under greenhouse vegetable production, infrastructure accounted for the largest fraction of emissions. The authors summarized their findings by stating that production-based emissions from organic crops averaged 30% lower than conventional crops, with the exception of rice.

In their second paper [2], the authors used similar methods and reported on GHG emissions from 42 pairs of organic and conventional perennial crop production systems in Spain, including fruits, nuts, olives, and vineyards. GHG emissions from organic systems averaged 39% lower than their conventional counterparts per unit product. This was attributed mostly to greater carbon sequestration in the organic systems, which used cover crops and recycled pruning residues. By contrast, Venkat [10] reported slightly lower GHG emission for organic wine grapes in California but considerably greater emissions for organic almonds and walnuts compared to their conventional counterparts. Such vastly different findings suggest that site-specific conditions and practices may have highly influential effects on the final outcomes. Assumptions built into the modeling may be another important factor in explaining differences.

Reviews by Lynch et al. [13] and Gomiero et al. [6] and a meta-analysis by Tuomisto et al. [14] summarize much of the literature on the environmental performance of organic farming prior to 2010, including LCA studies. Based on an extensive review of about 130 published studies using a variety of methods to quantify energy use and global warming potential (GWP) in crop and livestock production systems, Lynch et al. [13] concluded that organic systems performed better than conventional systems in energy efficiency per unit area and per unit product in most cases. Their findings on GWP, were more variable, with organic systems generally performing better per unit area but less often per unit output due to lower yields. Where organic systems performed better, this was mainly attributed to not using synthetic N fertilizers or livestock feed concentrates. In situations in which the yield gap between organic and conventional was large, the GWP favored conventional production. Gomiero et al. [6] provided an equally expansive review of the literature on the environmental impacts of organic compared to conventional agriculture. They reported a general trend of better performance for organic systems per unit area with regard to GHG emissions but variable results and no consistent advantage when compared per unit product.

Tuomisto et al. [14] performed a meta-analysis using European studies to address the question: “Does organic farming reduce environmental impacts?” Despite differences in some product groups, there was no overall trend of lower or greater GHG emissions from organic compared to conventional production systems. They reported studies showing lower GHG emissions from organic olive, beef, and “some crops” but higher emissions for organic milk due to larger amounts of CH₄ and N₂O and lower milk production per animal. Thus, on a product basis, the findings in the literature have been mixed, which would seem to make most generalizations only tentative.

3. Expanding the Scope and Scale

In contrast to earlier studies that focused solely or mostly on production, more recent LCA studies have broadened their scope and expanded the assessment of products beyond the farm gate. Tasca et al. [15] measured and compared the environmental impact of two endive supply chains in Italy using LCA. One system used organic production and local distribution, while the other used an integrated production system and large-scale distribution to retail outlets. A comparison of the two systems limited just to the farm production stage indicated very little difference in climate-change impact when viewed per unit area or per unit output. But the farming stage accounted for only 12–15% of the total climate-change impact along the conventional supply chain. Other steps in both supply chains, such as washing, packaging, cold storage, and transportation, accounted for the rest. Taken as a whole, the organic system with local distribution performed better with respect to climate change, but this had little to do with the use of organic production methods.

Treu et al. [16] compared GHG emissions generated by typical conventional and organic diets in Germany and found them to be about equal despite the average conventional diet having about 45% more meat in it than the organic diet. In fact, meat dominated the carbon footprints of both diets, but lower yields from organic production and, therefore, the need for more land use resulted in larger carbon footprints per unit of organic food, particularly for pork and poultry. Transportation emissions were also somewhat higher for the organic diet in order to bring in products from further distances. The authors suggested that shifting toward less animal-based foods in diets would be a more effective means of reducing GHG emissions than expanding organic production.

An analysis by Smith et al. [17] used LCA to examine the consequences on GHG emissions if England and Wales were to convert 100% of food production to organic management. In order to maintain the same level of production, they reported that increased land use in other countries would be needed to compensate for the 40% lower yields expected from organic production. This would result in greater GHG emissions to produce the same amount of food organically. According to the authors, increases in carbon sequestration in agricultural soils would offset only a fraction of the increased emissions from converting land overseas to food production.

These LCA studies, taken in whole, certainly do not support the general assertion that a wholesale expansion of organic farming would be a productive response to addressing agriculture's contribution to climate change. While there are a few examples of organic production systems demonstrating superior performance in terms of GHG emissions per unit output, more of the evidence suggests otherwise, and this is a confounding problem as organic farming has been shown to be an improvement over conventional farming with respect to many other environmental measures, including pesticide use and exposure, eutrophication, protection of biodiversity, consumption of non-renewable energy resources, and soil degradation. In their recent perspective article, van der Werf et al. [9] urged caution against relying too heavily upon LCA studies because they often neglect to factor in important measures such as land degradation, biodiversity losses, and the effects of pesticides. Consequently, LCA studies focused on product output efficiency often favor high-yield conventional systems over organic systems which offer lower yields but greater ecosystem services.

Muller et al. [18] addressed some of the concerns raised by van der Werf et al. [9] in their analysis to predict the consequences of a 100% conversion to organic agriculture globally in 2050 on a range of environmental impacts, including greenhouse gas (GHG) emissions. The authors acknowledged that organic systems had lower yields on average, and therefore, a greater amount of land would be required to maintain the same availability of energy and protein for human consumption. They also factored in the influences of potential behavioral or technical changes that reduce food waste, meat consumption, and livestock production on arable cropland. They generated a range of possible scenarios, including one in which "a combination of 60% organic production, 50% less food-competing feed and 50% reduced food wastage would need little additional land" [18]. They also reported that a reduction in GHG emissions could be achieved even with a 100% conversion to organic production, but only with a concurrent reduction in livestock production, meat consumption, and food wastage. The authors acknowledge that in this scenario maintaining sufficient N availability would be a challenge.

4. Responding to the Climate Crisis

The studies by Muller et al. [18], Tasca et al. [15], and Treu et al. [16] demonstrate the value of analyzing the problem of GHG emissions from agriculture at different stages along food supply chains and at different scales of food systems. Based on the current evidence, a transition to organic farming at a national or global scale without other substantial changes in the food system is unlikely to reduce GHG emissions and will likely only worsen the problem. Although global climate change is the most critically important environmental challenge facing humanity presently, the other environmental issues addressed by organic farming are also important. Compromising other ecosystems services in an effort to address GHG emissions would be short-sighted and irresponsible. That is why the all-or-nothing proposition for organic agriculture is potentially misleading and distracting.

Instead, context- and site-specific evaluations would allow for better understanding of where organic production is more appropriate and effective in addressing GHG emissions and where it is not. For example, Aguilera et al. [12] reported that organic fruit and nut orchards produced less GHG per unit product compared to conventional orchards, while Venkat [10] reported the opposite. Understanding how vastly different findings are generated using LCA methodology would give some useful context and details for interpreting the appropriateness of extrapolating results to different situations.

Further, changing agriculture to address climate change will require societal-level shifts in understandings, values, and behaviors [19,20]. Market demand and government policies drive what farmers produce. Consumers who value organic products are willing and able to pay a premium for them. That premium is transferred through the supply chain to producers who require at least part of that additional gross income to cover the higher production costs, often resulting from the need for more labor and management. Organic farmers are in effect being compensated for internalizing the externalities typically resulting from agriculture, such as pollution and environmental degradation. Organic farmers may also need to recoup losses incurred during the transition period (usually three years), during which they produce organically but receive conventional market prices for their output.

What remains of the premium is an additional incentive to continue producing organically, both for farmers who are attracted to organic production solely for the financial opportunities as well as those who are deeply committed to the principles and ideologies of organic farming regardless of the added income. If market incentives from consumers or government policies drive farmers in the future to address GHG emissions on their farms, a truly impressive range of creative solutions could begin to emerge, blending traditional organic practices with new innovations such as automated field monitoring with data analysis to support timely management decisions that improve resource-use efficiency and yields to specialized field equipment that facilitates tillage reductions while suppressing weed competition without herbicides. But in order for organic farmers to creatively innovate and make meaningful contributions toward addressing climate change, their businesses must be financially viable and stable.

Organic farming today has changed considerably since the 1970s when it was referred to as “scientific nonsense” by a panel of scientists at an annual meeting of the American Association for the Advancement of Science [1]. It is impossible to know precisely how organic farming will change over the next half-century, but incentivizing efforts to address GHG emissions is not only prudent but essential for meeting the food production and environmental challenges faced by humanity. Recent calls to find ways to increase organic yields should be examined carefully to ensure they are economically viable and environmentally sound. Even where less expensive off-farm organic amendments are available, applying high N levels to maximize yields will likely also result in N and phosphorus leakage from farms, a practice that contradicts organic farming’s emphasis on nutrient cycling and avoidance of causing water pollution and eutrophication elsewhere. However, continued consideration should also be given to blending the best of conventional and organic practices in a way that fairly remunerates farmers for products as well as protects ecological services, either through market mechanisms with third-party certifications and price premiums or government subsidies.

The organic farming movement has been a leader in developing and farm-trialing new production methods that often are adopted by the wider agricultural community, such as cover cropping, biocontrol of insect pests, and mechanical weed control. That progressive approach to improvement should extend to examining emerging technologies that can reduce GHG emissions through combinations of increasing yields, reducing fossil-fuel energy inputs, and/or other means. If the evidence is compelling that particular new technologies or inputs can support the goals and principles of organic farming’s approach to production and stewardship, then they should be given fair and rational consideration for allowance. Critics of organic agriculture have called out the apparent unwillingness of the movement to revise approved practices. Certainly, some suggested changes, such as limited use of synthetic fertilizers [21], would compromise the integrity of the label, threaten consumer confidence, and possibly result in detrimental environmental impacts. There are others, however, such as accepting new crop

breeding techniques [22–25], which might allow organic farmers to substantively address the current yield gap without the use of additional inputs. Making changes like this would undoubtedly be contentious and risk setting back the industry if consumer confidence is lost. Still, if environmentally sound food production is indeed a foundational value of organic farming, then new innovations for addressing the global climate crisis must be found and put to use.

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References

- Lockeretz, W. What explains the rise of organic farming? In *Organic Farming: An International History*; Lockeretz, W., Ed.; CABI International: Oxford, UK, 2007; pp. 1–8.
- Meemken, E.M.; Qaim, M. Organic agriculture, food security, and the environment. *Ann. Rev. Resour. Econ.* **2018**, *10*, 39–63. [[CrossRef](#)]
- Reganold, J.P.; Wachter, J.M. Organic agriculture in the twenty-first century. *Nat. Plants* **2016**, *2*, 15221. [[CrossRef](#)] [[PubMed](#)]
- Willer, H.; Schlatter, B.; Trávníček, J.; Kemper, L.; Lernoud, J. *The World of Organic Agriculture—Statistics and Emerging Trends 2020*; Research Institute of Organic Agriculture (FiBL): Frick, Switzerland; IFOAM—Organics International: Bonn, Germany, 2020.
- Organic Trade Association. COVID-19 will Shape Organic Industry in 2020 after Banner Year in 2019. 2020. Available online: <https://ota.com/news/press-releases/21328> (accessed on 25 July 2020).
- Gomiero, T.; Pimentel, D.; Paoletti, M.G. Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. *Crit. Rev. Plant Sci.* **2011**, *30*, 95–124. [[CrossRef](#)]
- Skinner, C.; Gattinger, A.; Muller, A.; Mäder, P.; Fließbach, A.; Stolze, M.; Ruser, R.; Niggli, U. Greenhouse gas fluxes from agricultural soils under organic and non-organic management—A global meta-analysis. *Sci. Total Environ.* **2014**, *468*, 553–563. [[CrossRef](#)]
- Skinner, C.; Gattinger, A.; Krauss, M.; Krause, H.M.; Mayer, J.; van der Heijden, M.G.A.; Mäder, P. The impact of long-term organic farming on soil-derived greenhouse gas emissions. *Sci. Rep.* **2019**, *9*, 1702. [[CrossRef](#)]
- Van der Werf, H.M.G.; Knudsen, M.T.; Cederberg, C. Towards better representation of organic agriculture in life cycle assessment. *Nat. Sustain.* **2020**, *3*, 419–425. [[CrossRef](#)]
- Venkat, K. Comparison of twelve organic and conventional farming systems: A life cycle greenhouse gas emissions perspective. *J. Sustain. Agric.* **2012**, *36*, 620–649. [[CrossRef](#)]
- Aguilera, E.; Guzmán, G.I.; Alonso, A.M. Greenhouse gas emissions from conventional and organic cropping systems in Spain. I. Herbaceous crops. *Agron. Sustain. Dev.* **2015**, *35*, 713–724. [[CrossRef](#)]
- Aguilera, E.; Guzmán, G.I.; Alonso, A.M. Greenhouse gas emissions from conventional and organic cropping systems in Spain. II. Fruit tree orchards. *Agron. Sustain. Dev.* **2015**, *35*, 725–737. [[CrossRef](#)]
- Lynch, D.; MacRae, R.; Martin, R. The carbon and global warming potential impacts of organic farming: Does it have a significant role in an energy constrained world? *Sustainability* **2011**, *3*, 322–362. [[CrossRef](#)]
- Tuomisto, H.L.; Hodge, I.D.; Riordan, P.; Macdonald, D.W. Does organic farming reduce environmental impacts? A meta-analysis of European research. *J. Environ. Manag.* **2012**, *112*, 309–320. [[CrossRef](#)]
- Tasca, A.L.; Nessi, S.; Rigamonti, L. Environmental sustainability of agri-food supply chains: An LCA comparison between two alternative forms of production and distribution of endive in northern Italy. *J. Clean. Prod.* **2017**, *140*, 725–741. [[CrossRef](#)]
- Treu, H.; Nordborg, M.; Cederberg, C.; Heuer, T.; Claupein, E.; Hoffmann, H.; Berndes, G. Carbon footprints and land use of conventional and organic diets in Germany. *J. Clean. Prod.* **2017**, *161*, 127–142. [[CrossRef](#)]
- Smith, L.G.; Kirk, G.J.D.; Jones, P.J.; Williams, A.G. The greenhouse gas impacts of converting food production in England and Wales to organic methods. *Nat. Commun.* **2019**, *10*, 4641. [[CrossRef](#)] [[PubMed](#)]
- Muller, A.; Schader, C.; El-Hage Scialabba, N.; Bruggemann, J.; Isensee, A.; Erb, K.H.; Smith, P.; Klocke, P.; Leiber, F.; Stolze, M.; et al. Strategies for feeding the world more sustainably with organic agriculture. *Nat. Commun.* **2017**, *8*, 1290. [[CrossRef](#)] [[PubMed](#)]
- Heller, M.C.; Keoleian, G.A. Greenhouse gas emission estimates of US dietary choices and food loss. *J. Ind. Ecol.* **2015**, *19*, 391–401. [[CrossRef](#)]

20. Niles, M.T.; Ahuja, R.; Barker, T.; Esquivel, J.; Gutterman, S.; Heller, M.C.; Mango, N.; Portner, D.; Raimond, R.; Tira, C.; et al. Climate change mitigation beyond agriculture: A review of food system opportunities and implications. *Renew. Agric. Food Syst.* **2018**, *33*, 297–308. [[CrossRef](#)]
21. Conner, D.J. Organic agriculture cannot feed the world. *Field Crops Res.* **2008**, *106*, 187–190. [[CrossRef](#)]
22. Roland, P.C.; Adamchak, R.W. *Tomorrow's Table: Organic Farming, Genetics and the Future of Food*; Oxford University Press: Oxford, UK, 2009.
23. Ryffel, G.U. I have a dream: Organic movements include gene manipulation to improve sustainable farming. *Sustainability* **2017**, *9*, 392. [[CrossRef](#)]
24. Vincelli, P. Genetic engineering and sustainable crop disease management: Opportunities for case-by-case decision-making. *Sustainability* **2016**, *8*, 495. [[CrossRef](#)]
25. Nawaz, S.; Klassen, S.; Lyon, A. Tensions at the boundary: Rearticulating 'organic' plant breeding in the age of gene editing. *Elem. Sci. Anth.* **2020**, *8*, 34. [[CrossRef](#)]



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