Comparative Study of Organic And Conventional Farming: A Review

Pratyumkumar Chhabhaya[1], Milan Vala[2], Dr. Bharat Maitreya[3]
[1, 2, 3] Dept of Botany
[1, 2, 3] Bioinformatics and Climate Change Impacts Management, School of Science,
Gujarat University, Ahmedabad, Gujarat, India

Abstract- *Organic and conventional farming are the two most common farming methods. Our forefathers engaged in organic farming but Farmers nowadays use a conventional method to increase and speed up production. In this comparison, some aspects of organic and conventional farming are discussed. Compare the farming area where the plant is grown. We all know that inorganic farming produces more than organic farming because of fertilizer, weedicide and pesticide. Early research comparing the effectiveness of organic and conventional systems revealed that organic systems have lower yield response ratios. Organic farming has a high soil carbon ratio when compared to conventional farming. It has been indicated that organic farming reduces nutrient losses due to leaching and runoff/erosion. Organic processing is primarily reliant on nonchemical control methods based on systems. In traditional systems, chemical management is the most common method. Due to price premiums, organic farming is typically more profitable than conventional farming.*

Keywords- Organic farming, Conventional farming.

I. INTRODUCTION

Organic farming, Organic farming is an agricultural system that uses ecologically based pesticides and biological fertilizers mainly derived from animal and plant wastes, as well as nitrogen-fixing cover crops. Organic farming has been practiced by our forefathers for over 1000 years. Organic farming was performed using the natural resources of the river bank at that time. Nutrients came from soil matter, plant waste, animal manure, and other sources of organic farming. The importance of dead and decayed plant and animal matter in enhancing soil fertility was also mentioned in an ancient manuscript (Behera, *et al*, 2012)[1].Various people have reacted to the idea of organic agriculture in different ways. Among the majority of them, this means using organic manures and natural plant protection practices instead of conventional fertilizers and pesticides. Some consider it to be farming that incorporates the use of fertilizers and organic manures, as well as chemical and natural plant defense inputs.**Conventional Farming,** Conventional (Inorganic) farming is a form of farming that involves the use of pesticides and other chemicals to increase crop yields. Fertilizer encourages plant growth in inorganic farming. To control pests and diseases, insecticides are sprayed. Weeds are regulated with chemical herbicides. Fertilizers are used to supplement nutrients, herbicides are used to control weeds, pesticides are used to protect plants, and livestock is only used in extreme cases. Production is not incorporated into the ecosystem, but rather extracts further by manipulating the environment, fertilizing excessively, and failing to correct nutrient imbalances (**Zeng *et al***)[2]. Farmers have been using conventional farming to increase productivity in order to meet rising demand. However, since this method of farming relies heavily on synthetic fertilizers, pesticides, and herbicides, it has raised significant environmental issues that have damaged biodiversity (Lupwayi *et al*., 2001)[3].

II. HISTORY OF ORGANIC FARMING

Lord Northbourne coined the word Organic farming in his book, Look to the Land (written in 1939, Published 1940). He represented a holistic, ecologically sustainable approach to farming based on his idea of "the Farm as Organism."The organic farming movement was founded by Sir Albert Howard. “An Agricultural Testament” is the outcome of his 25-year study at Indoor in India.

Biodynamic agriculture, founded by Rudolf Steiner (Pawar, 2009)[4] in Germany, was likely the first systematic organic farming method. Lady Eve Balfour initiated the Hughley experiment on a farm in England in 1939, inspired by Sir Albert Howard's work. It was the first scientific comparison of organic and inorganic farming on a side-by-side basis. Derrick (Coleman, 1989)[5] reports in 1991, under the heading "Organic Agriculture in Australia," that "interest in organic farming has risen substantially in Australia in the last few years," and that "there are a number of farmers who have used organic methods for many years and have well developed systems." “Organic farming in Australia has made a steady increase in acceptance and popularity amongst the farming sector over the last 20 years or so,” Penfold claimed in 2000(Paull, 2008.)[6]. After the 1960s, organic agriculture science and practice spread around the world. In 1970, William Albrecht(Albresht 1998)[7] proposed a concept of ecological agriculture, in which the ecological theory was applied to the organic farming production method (Coleman 1989)[5].As a result of the high yielding variety's need for more fertilizer and water, the north-eastern Trans Gangetic plain has become an unfertile land, according to (Tripathy and Khan 2020)[8].

III. HISTORY OF INORGANIC FARMING

Most African soils are weak and poor in fertility (International Centre for Soil Fertility and Agricultural Development (IFDC) 2005), making them unsuitable for agricultural production (Singh 2003)[9]. Inadequate nutrient use from fertilizers, fertilizer rates and varieties, and effective application methods all lead to farmers' fields' low yields and low economic returns. Increased cultivation on less productive lands, according to (Salimonu 2007)[10], is a major cause of declining yield among small-holder farmers (Nenna, 2014).[11]
Fertilizer is a term used to describe chemically synthesized plant nutrient compounds that are added to the soil to supplement fertility. Inorganic or mineral fertilizers are mined from mineral deposits that need little refining, such as lime, potash, or phosphate rock, or are produced industrially using chemical methods, such as urea (Singh 2003)[9]. (Idachaba 1994)[12] established a few key elements that revolve around the productivity per unit of land, namely high yield seed varieties that are fertilizer sensitive and pest resistant. In India, the cultivation of inorganic farming has a long history. There was a period when India's agriculture and farming system was unable to meet the excessive food demand of an expanding population due to the country's largely excessive population growth. In the 1960s, India's "Green Revolution" introduced inorganic farming. The use of fertilizer and pesticides became commonplace with the advent of inorganic cultivation. Farmers were actually overjoyed to see the field's production, as inorganic farming provides a greater amount of production to the farmer. However, as the disease spreads among humans, people are becoming more aware of the need to investigate the cause of the event, and the truth emerges. The fertility of the soils is shrinking day by day, and crop production is decreasing (bijaya Majumdar 2021)[13].

Comparison of Organic and Inorganic farming

IV. WHY TO COMPARE?

Organic farming is an increasingly increasing sector of the food industry, supplying producers in developed countries with fresh and high-value opportunities (Crowder, 2015)[14]. Organic farming proponents point to possible environmental, human health, and social advantages (Kremen, 2012)[15], (Reganold, 2016) [16]. The contrasts of organic and traditional agriculture that have already been made have sparked a widely visible and polarized controversy with significant consequences for agricultural policy.; and Certified organics is the most common legally specified alternative method that can be compared to traditional agriculture which is open to customers as an option. Organic systems' success in comparison to traditional systems is often used to support or oppose development and extension efforts to encourage organic farming (Connor 2013)(Tittonell 2014)(Ponisio *et al*, 2014)[17,18,19].

The distinction between organic and traditional is a misleading one. Both organic and traditional cropping systems slide along a gradient of input usage intensity, volume, and crop and habitat diversification outside of researcher-managed trials. Such real-world difference between organic and traditional cropping systems is underappreciated in binary comparisons; and technical problems in how comparisons are produced may adversely affect the validity of conclusions reached. Investments in research may be best used on figuring out how to develop a variety of cropping systems, including those that come somewhere between certified organic and inorganic (Tittonell 2014) (Shennan2008.)[18,20].

V. WHAT TO COMPARE?

As previously mentioned, organic and traditional brands span a wide variety of cropping systems; as a result, the examples used to compare and how the contrast is presented may have a huge effect on the outcomes. This is especially true of organic programs, which, in our experience, are more dynamic, flexible, and knowledge-intensive to handle, and which have less well-developed sets of standard management practices that are used across several farms.

1. Comparison of Field Plot

The majority of comparative studies, particularly in terms of productivity, are focused on repeated plot experiments in which researchers decide on the design of each cropping scheme, often with farmer feedback (Poudel *et al*. 2001)[21], but rarely on a thorough survey of the region's dominant systems. Indeed, because of the broader history of study and expansion, selecting representative traditional treatments usually has more knowledge and expertise than selecting representative organic treatments. Researchers have recorded a steep learning curve when handling experimental organic systems, which can have an effect on efficiency(Martini *et al* 2004)[22], and the relative lack of study in organic cropping systems has left information gaps that could lead to less-than-optimal organic system performance(Tittonell 2014)(Ponisio *et al*, 2014)[18,19].

Opinions vary on how to design scientifically rigorous comparisons, with some arguing that processes with identical rotations, nutrient input ratios, and cultivars can be compared(Kirchmann*et al.* 2014)[23]. However, while such equalizing comparisons may be scientifically appealing, they may not be appropriate when contrasting practical organic and traditional systems, especially if the goal is to compare "best" management systems. Single-season yield comparisons that ignore the substitution of economic species with cover crops may be deceptive, implying that production is best represented as yield area–1 time–1 rather than yield area–1 alone(Kirchmann *et al.* 2014)(Cassman KG. 2007)[23,24].

When scaling up findings from small-plot trials, the issue of arriving at erroneous conclusions is still a major concern. Authors also debated whether it is fair to conclude that cropping device efficiency in field trials is equivalent to when they are used on a practical farm scale, where farmers must balance several crops, fields, and sometimes animal components(Goulding *et al.*)[25]. In the absence of herbicides, for example, optimum mechanical weeding timing is crucial for maximal organic yields, but this is not always feasible in commercial operations(Kravchenko *et al.* 2017)[26]. Furthermore, the degree of biological dominance of arthropod pests can be highly determined by the local land use and plant types (Rusch *et al.* 2016)[27], which is not taken into account in plot studies.

2. On Farm Comparison

Since experimental comparisons have drawbacks, tracking and comparing running farms could be a feasible option. If a common variety of areas, soil types, surrounding land usage, cropping systems, and size are defined, this approach accounts for heterogeneity in each management type(Drinkwater *et al.* 1995)[28]. To discern critical associations, inherently confounding variables may be calculated and evaluated. Comparing several instances of a particular type of method will reveal useful knowledge about the productivity and environmental implications of different management decisions(Bowles *et al.* 2015)[29].

Farmers make management choices based on a number of factors, including market demand, cost of production, and ease of management, among others, and do not always aim to optimize output, according to such on-farm reports. Farmers, for example, will plant at climatically inconvenient times to take advantage of high produce prices early or late in the season, considering yield penalties(Drinkwater *et al.* 1995)[28]. (Kniss et al. 2016)[30] used results from yield surveys of working farms as a calculation of the relative efficiency of organic and traditional farming, which may be ambiguous unless the different management goals and marketing methods adopted by farmers are specifically accounted for. If the crop is a small component of total production, is grown mainly for rotation benefit, or is grown as part of a varied food supply for direct marketing avenues, yields of a crop in large-scale advanced traditional farms are likely to be higher than those from diverse organic operations where yield maximization is less significant.

The decision to execute tests or track farms is based on the characteristics to be evaluated. Cropping system impacts on soil microbial species, as well as disease and weed populations, may be assessed in small-plot experiments if plots are wide enough to prevent edge effects; however, whole-farm and landscape-level studies are needed for highly mobile arthropods, birds, and bats. Where farms rely on crop residue or fodder production by livestock and manure addition to fields, whole-farm experiments may be more relevant for nutrient cycling comparisons. It's difficult to replicate such spatial and temporal complexities in experiments. The use of crop or farm models(Cavero *et al.* 1998) (Groot *et al.*)[31,32] is a third option; however, research into correctly reflecting nutrient cycling and productivity in organic systems is poor.

3. Productivity

Early research contrasting the efficacy of organic and conventional systems showed that organic systems have lower yield response ratios (YRRs)(Stanhill. 1990.)[33], but subsequent systemic analyses concluded that legumes can provide enough nitrogen to counteract synthetic fertilizer usage and that organic systems can have enough calories to feed the world's population(Badgley *et al.* 2007)[34]. This research was widely criticized for a number of reasons, including the inability to account for climatic restrictions on cover crop production(Connor 2008)(Cassman KG. 2007)[35,24]. Since then, meta-analytical approaches have been used to determine relative efficiency, with figures of organic yields ranging from 5% to 34% lower than traditional yields(Tittonell 2014)(Seufert *et al.*)[19,36].

YRRs (Yield Response Ratio) vary significantly due to variations in crop types, rotation schemes, and ecosystems, but trends found differ due to differences in data collection and methodological techniques used in these studies. As traditional yield capacity grows and organic systems face nutrient supply restrictions, yield differences continue to widen(de Ponti *et al.* 2012)(Kniss et al. 2016)[37,30]. In comparison, (Ponisio et al. 2014)[19] observed that biological diversification in the form of rotations or multiple cropping would minimize yield gaps to 8–9%, compared to 19% for all studies together, and that increased investment in organic science could further reduce the remaining yield gap. Ponisio & Kremen (Ponisio et al. 2014)[19] countered with proof of organic and ecologically controlled farmland's positive impact on pest suppression and pollination services at the landscape level, as well as the fact that where higher yields raise farmers' incomes, even traditional practices will drive land expansion and deforestation (Meyfroidt *et al.* 2014)[38]. The majority of the YRR estimates above are still focused on small-plot studies, which may not be indicative of farm-scale results. When measuring YRRs, results from genuinely novel therapies, which are only encountered on working farms, the meta-analytical accuracy suffers as well. Zero-tillage organic management and traditional systems with greatly decreased nitrogen inputs are two examples of systems developed to test output under nutrient constraint. As a result,(Cassman, 2007)[24] recommended that small-plot comparisons in systematic evaluations be used only where the best management principles for each method analyzed are used(Cassman KG. 2007)[24].

4. Soil Carbon

In terms of both soil quality gains and climate change mitigation, the degree to which organic management raises soil carbon is of concern (Freibauer *et* al)[39]. Soil organic carbon (SOC) is critical for improving cation exchange capability, soil physical structure (aggregate stabilization, water infiltration, and water-holding capacity), and soil biological properties, as well as nutrient and water cycling and pathogen suppression(Papadopoulos *et al.* 2014)(Reeve *et al.* 2016)(Fernandez *et al.* 2016)[40,41,42]. With some exceptions, several studies show that under organic management, daily organic inputs can more than replace carbon lost during tillage, resulting in SOC concentrations increasing for a period of time following conversion to organic management(Messmer *et al.* 2012)(Lynch *et al.* 2011)(Teasdale *et al.* 2007)(Gattinger *et al. 2012)*[43,44,45,46]. Most organic activities raise SOC mainly in active labile pools in the top 0–15 cm of soil, according to a multistate study that found labile SOC increased 44% in organic treatments relative to traditional treatments over a four-year cycle, while overall SOC increased just 16 percent(Carol *et al*)[47]. Tillage methods, on the other hand, may obscure the distinctions between organic and traditional management(Six *et al.*)[48]. Increases in bulk density and declines in aggregate structure and SOC are closely linked to tillage. Where all depths are considered, no-till systems concentrate SOC from a 0–20-cm depth, while tilled systems disperse SOC at deeper depths, so there is always no distinction between systems(Govaerts *et al.* 2009)[49]. It is premature to comment on the impact of organic reduced/no-till systems on SOC and carbon sequestration due to the minimal production of organic reduced tillage systems to date(Mader *et al.* 2012)[50].

5. Nutrient Cycle

Organic farming has been shown to minimize nutrient losses by leaching and runoff/erosion, especially where cover crops are used, but this is not always the case. Differences in place, processes, and management strategies lead to contradictory assumptions, rendering large generalizations troublesome. Organic management and increased soil organic matter will minimize nutrient loss by leaching and/or erosion(Bender *et al.* 2015)[51] and enhance nutrient usage quality. According to a meta-analysis, leaching losses in organic processes were smaller on a region level but comparable to traditional on a yield basis. Organic farming has been shown to minimize nutrient losses by leaching and runoff/erosion, especially where cover crops are used(Macrae *et al.* 2010) (Scialabba *et al.* 2010)[52,53], but this is not always the case. Differences in location, processes, and management strategies contribute to conflicting assumptions, rendering strong generalizations problematic. Organic management and increased soil organic matter (SOM) will reduce nutrient loss by leaching and/or erosion(Bender *et al.* 2015)[56] and improve nutrient usage quality(Fernandez *et al.* 2016)(Snapp *et al.* 2010)[54,55]. According to a meta-analysis of ^{15}N isotope studies, practices that combine C and N inputs (organic inputs, diverse, and legume rotations) increased overall ^{15}N preservation in cereals and soil more than other practices. Another meta-analysis found that leaching losses in organic systems were smaller in terms of area but comparable to traditional in terms of yield(Mondelaers *et al.* 2009)[57]. Multiple researches in one watershed reported that SOM decreased nitrate leaching even though nitrogen was overapplied(Anglade *et al.* 2015)[58], that organic farms had lower N leaching losses than traditional farms(Benoit *et al.* 2016)[59], and that an on-farm paired comparison found organic activities had lower N leaching and N2O losses (30 percent area-scaled and 12 percent yield-scaled)(Benoit *et al.* 2014)[60]. Hedgerows and other perennial plants have more habitat heterogeneity, which helps to reduce deforestation and nitrogen emissions(Scialabba *et al.* 2010)[61].

6. Control of Pest

Crop losses due to pests (including weeds and diseases) are projected to be between 26% and 40% for major crops, figures that have remained relatively constant over the last 40 years despite significant changes in pesticide use(Oerke 2006)[62]. Globally, an estimated 3.6 billion kg of active ingredients are added per year(Pretty *et al*. 2015)[63], causing significant damage to habitats and human health(Mahmood *et al.* 2016)[64]. Improved pest management services that minimize or remove the need for pesticide applications support human and ecosystem health from a biodiversity viewpoint. Although certain organically certified pesticide materials are used for aboveground arthropod pests and foliar pathogens, organic cultivation depends mainly on systems-based nonchemical methods of control. Although certain organically certified pesticide materials are used for aboveground arthropod pests and foliar pathogens, organic processing depends mainly on systems-based nonchemical methods of control(Zehnder *et al.* 2007)[65]. Chemical management is the most common method in traditional systems, with varying degrees of cultural and biological incorporation(Lee *et al.* 2015)[66]. Pest control effectiveness is difficult to generalize about since it is highly dependent on pest strength, type, and distribution, as well as seasonal, regional, and crop-specific factors(de Ponti *et al.* 2012)[37].

7. Weed Management

The high emphasis on herbicide-resistant cultivars and herbicide applications for weed control in traditional systems(Mortensen *et al.*2012)[67], as well as the difficulty weed management poses to organic farmers in the absence of these tools, is well known(McErlich *et al.* 2014)[68]. Organic farmers depend on a variety of practices (the appropriately called "many little hammers" approach) to achieve suppression since no particular combination of cultural, mechanical, and biological methods is uniformly efficient(Harker *et al.* 2013)[69]. Nonetheless, organic farmers consider weed control to be a high priority for science. Since organic systems rely heavily on well-timed tillage for weed control, they are vulnerable to yield failure if weather or other factors cause tillage operations to be delayed(Kravchenko *et al.* 2017)[70]. Adjustments in seeding speeds, rotation nature, and plant spacing have shown promise in some schemes, but the scope for breeding more successful crop varieties has yet to be realized[20]. In the other hand, a strong dependence on herbicides has resulted in significant issues such as water runoff, detrimental ecosystem effects, and a rise in herbicide-resistant weeds, prompting calls for a rediversification of management methods(Mortensen *et al.* 2012)[71] and recognition of the evolutionary aspects of weed control(Menalled *et al.* 2016)[72].

8. Profitability and Economics

According to a recent meta-analysis of 54 crops and their related rotations, organic farming is typically more lucrative than conventional farming due to price premiums, and that price premiums of only 5–7% will be needed to achieve comparable returns to conventional farming[14]. Organic practices that enhance soil quality, weed control, and water conservation will help you make more money in the long run(Kleemann 2013)[73]. Farmers in India believe that expanding organic production would raise profitability due to possible economies of scale(Panneerselvam *et al.* 2015)[74], and that organic can be more profitable considering yield penalties, according tomultistate studies(Patil S *et al.* 2014) (Forster *et al.* 2013)[75,76]. Organic systems can generate large profits and provide a strategic edge with low risk-to-return products, such as bananas(Castro *et al.* 2015)[77], and systems with low labor requirements, such as lemon orchards(Testa *et al.* 2015)[78]. Organic systems have higher labor costs, but lower production costs(Crowder, 2015)[14], which, when combined with price discounts, will minimize financial risk for farmers(Patil S *et al.* 2014)[75]. Profitability in developing countries is often influenced by economies of scale and the degree of business integration. Farmers in Nepal were more likely to choose organic production due to proximity to market, age, level of preparation, association with organizations, and greater farm scale(Karki *et al.* 2012)[79]; similarly, in the Philippines, training opportunities, resource availability, and organizational support were influential(Salazar2014.)[80]. Human ideals and philosophy, rather than financial benefit, may have an impact(Galt2013)[81], as shown by the intellectual foundations of organic revolutions in Brazil(Dalcin *et al.* 2015)[82] and Iran.

9. Conclusion

Based on literature, organic farming is more profitable than inorganic farming. Despite the financial gains, organic farming has other advantages, such as reducing environmental deterioration and enhancing soil texture, which leads to improved efficiency.It benefits humans, the environment, and the land. Organic food, as we all know, is high in nutritious content and free of toxic fertilisers, herbicides, and pesticides. It has been reviewed that organic farm soil is more nutrient than inorganic farm soil. Organic farms have higher labour costs than inorganic farms.

REFERENCES

[1] Behera, K. K., Alam, A., Vats, S., Sharma, H. P., & Sharma, V. (2012). Organic farming history and techniques. In Agroecology and strategies for climate change (pp. 287-328). Springer, Dordrecht.

[2] Zheng, A. L. T., Karam, D. S., Zawawi, R. M., & Rajoo, K. S. Conventional vs Organic Farming. Science, 81, 577-589.

[3] Lupwayi, N. Z., Monreal, M. A., Clayton, G. W., Grant, C. A., Johnston, A. M., & Rice. W. A. (2001). Soil

microbial biomass and diversity respond to tillage and Sulphur fertilizers. Canadian Journal of Soil Science. 81:577-589.

[4] R.K. Pawar (2009). 'Organic Farming for Sustainable Hortiulture' (Book) . Jaipur, India. P.8-9.

[5] Coleman DC (1989) Agro-ecosystem and sustainable agriculture. Ecology 70:15-90.

[6] Paull, J. (2008). The lost history of organic farming in Australia. Journal of Organic Systems, 3(2), 2-17.

[7] Albresht H, Matthes A (1998) 'The effect of organic and integrated farming on rare arable weeds on the Forschungsverbund Agrarokosysteme Munchen (FAM) Research station southern Bavariya. Biol conserve 86:347-356.

[8] As

[9] Singh HB 2003. Role of manure and fertilizer in agriculture. In: Developing Agric-input Market in Nigeria (DAIMINA) project (IFDC) Alabama, USA, P. 50.

[10] Salimonu KK 2007. Attitude to Risk in Resource Allocation Among Food Crop Farmers in Ogun State, Nigeria. Doctoral Dissertation, Unpublished. Department of Agricultural Economics and Extension. Nigeria: University of Ibadan.

[11] Nenna, M. G. (2014). Factors affecting application of inorganic farming practices by small farmers in kogi state, Nigeria. Journal of Agricultural Sciences, 5(1-2), 51-58.

[12] Idachaba FS 1994. The Dilemma of Fertilizer Subsidies in African Agriculture. Invited Paper Delivered at the International Fertilizer Industry Association (IFA) Regional Conference for Africa, Dakar, Senegal, 1-3 February.

[13] Bijaya Majumdar,' 2021A Comparative Analysis Between Organic and Inorganic Farming: 'Study on Some Selected Villages of Ranchi District, Jharkhand' Tata institute of social science, Tuljapur, India.

[14] Crowder DW, Reganold JP. 2015. Financial competitiveness of organic agriculture on a global scale. PNAS 112:7611–6.

[15] Kremen C, Miles A. 2012. Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. Ecol. Soc. 17:40.

[16] Reganold J, Wachter J. 2016. Organic agriculture in the twenty-first century. Nat. Plants 2:15221.

[17] Connor DJ. 2013. Organically grown crops do not a cropping system make and nor can organic agriculture nearly feed the world. Field Crops Res. 144:145–47

[18] Tittonell P. 2014. Ecological intensification of agriculture—sustainable by nature. Curr. Opin. Environ. Sustain. 8:53–61.

[19] Ponisio LC, M'Gonigle LK, Mace KC, Palomino J, de Valpine P, Kremen C. 2014. Diversification practices reduce organic to conventional yield gap. Proc. R. Soc. B 282:20141396.

[20] Shennan C. 2008. Biotic interactions, ecological knowledge and agriculture. Philos. Trans. R. Soc. B 363:717–39.

[21] Poudel DD, Ferris H, Klonsky K, Horwath WR, Scow KM, et al. 2001. The sustainable agriculture farming system project in California's Sacramento Valley. Outlook Agric. 30:109–16.

[22] Martini EA, Buyer JS, Bryant DC, Hartz TK, Denison RF. 2004. Yield increases during the organic transition: improving soil quality or increasing experience? Field Crops Res. 86:255–66.

[23] Kirchmann H, Katterer T, Bergstrom L, Borjesson G, Bolinder M. 2016. Flaws and criteria for design ¨ and evaluation of comparative organic and conventional cropping systems. Field Crops Res. 186:99–106.

[24] Cassman KG. 2007. Editorial response by Kenneth Cassman: Can organic agriculture feed the world—science to the rescue? Renew. Agric. Food Syst. 22:83–84.

[25] Goulding K, Trewavas AJ, Giller K. 2011. Feeding the world—a contribution to the debate. World Agric. 2:32–38.

[26] Kravchenko AN, Snapp SS, Robertson GP. 2017. Field-scale experiments reveal persistent yield gaps in low-input and organic cropping systems. PNAS 114:926–31.

[27] Rusch A, Chaplin-Kramer R, Gardiner MM, Hawro V, Holland J, et al. 2016. Agricultural landscape simplification reduces natural pest control: a quantitative synthesis. Agric. Ecosyst. Environ. 221:198–204.

[28] Drinkwater LE, Letourneau DK, Workneh F, van Bruggen AHC, Shennan C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. Ecol. Appl. 5:1098– 112.

[29] Bowles TM, Hollander AD, Steenwerth K, Jackson LE. 2015. Tightly-coupled plant-soil nitrogen cycling: comparison of organic farms across an agricultural landscape. PLOS ONE 10: e0131888.

[30] Kniss AR, Savage SD, Jabbour R. 2016. Commercial crop yields reveal strengths and weaknesses for organic agriculture in the United States. PLOS ONE 11: e0165851.

[31] Cavero J, Plant RE, Shennan C, Williams JR, Kiniry JR, Benson VW. 1998. Application of epic model to nitrogen cycling in irrigated processing tomatoes under different management systems. Agric. Syst. 56:391–414.

[32] Groot JC, Oomen GJ, Rossing WA. 2012. Multi-objective optimization and design of farming systems. Agric. Syst. 110:63–77.

[33] Stanhill G. 1990. The comparative productivity of organic agriculture. Agric. Ecosyst. Environ. 30:1–26.

[34] Badgley C, Moghtader J, Quintero E, Zakem E, Chappell MJ. 2007. Organic agriculture and the global food supply. Renew. Agric. Food. Syst. 22:86–108.
[35] Connor D. 2008. Organic agriculture cannot feed the world. Field Crops Res. 106:187–90.
[36] Seufert V, Ramankutty N, Foley JA. 2012. Comparing the yields of organic and conventional agriculture. Nature 485:229–33.
[37] de Ponti T, Rijk B, van Ittersum MK. 2012. The crop yield gap between organic and conventional agriculture. Agric. Syst. 108:1–9.
[38] Meyfroidt P, Carlson K, Fagan M, Gutierrez-Velez V, Macedo M, et al. 2014. Multiple pathways of commodity crop expansion in tropical forest landscapes. Environ. Res. Lett. 9:074012.
[39] Freibauer A, Rounsevell MDA, Smith P, Verhagen J. 2004. Carbon sequestration in the agricultural soils of Europe. Geoderma 122:1–23.
[40] Papadopoulos A, Bird NRA, Whitmore AP, Mooney SJ. 2014. Does organic management lead to enhanced soil physical quality? Geoderma 213:435–43.
[41] Reeve JR, Hoagland LA, Villalba JJ, Carr PM, Atucha A, et al. 2016. Organic farming, soil health, and food quality: considering possible links. Adv. Agron. 137:319–67 .
[42] Fernandez AL, Sheaffer CC, Wyse DL, Staley C, Gould TJ, Sadowsky MJ. 2016. Associations between soil bacterial community structure and nutrient cycling functions in long-term organic farm soils following cover crop and organic fertilizer amendment. Sci. Total Environ. 566:949–59.
[43] Messmer M, Hildermann I, Thorup-Kristensen K, Rengel Z. 2012. Nutrient management in organic farming and consequences for direct and indirect selection strategies. In Organic Crop Breeding, ed. ET Lammerts van Buren, JR Myers, pp. 15–38. Oxford, UK: Wiley-Blackwell.
[44] Lynch DH, MacRae R, Martin RC. 2011. The carbon and global warming potential impacts of organic farming: Does it have a significant role in an energy constrained world? Sustainability 3:322–62.
[45] Teasdale JR, Coffman CB, Mangum RW. 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agron. J. 99:1297–305.
[46] Gattinger A, Muller A, Haeni M, Skinner C, Fliessbach A, et al. 2012. Enhanced top soil carbon stocks under organic farming. PNAS 109:18226–31.
[47] Organic and Conventional Agriculture: A Useful Framing? Carol Shennan,1 Timothy J. Krupnik,2 Graeme Baird,1 Hamutahl Cohen,1 Kelsey Forbush,1 Robin J. Lovell,1 and Elissa M. Olimpi.
[48] Six J, Elliott E, Paustian K. 2000. Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. Soil Biol. Biochem. 32:2099–103.
[49] Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre KD, Dixon J, Dendooven L. 2009. Conservation agriculture and soil carbon sequestration: between myth and farmer reality. Crit. Rev. Plant Sci. 28:97–122.
[50] Mader P, Berner A. 2012. Development of reduced tillage systems in organic farming in Europe. Renew. Agric. Food Syst. 27:7–11.
[51] Bender SF, van der Heijden MGA. 2015. Soil biota enhance agricultural sustainability by improving crop yield, nutrient uptake and reducing nitrogen leaching losses. J. Appl. Ecol. 52:228–39.
[52] Macrae RJ, Lynch D, Martin RC. 2010. Improving energy efficiency and GHG mitigation potentials in Canadian organic farming systems. J. Sustain. Agric. 34:549–80.
[53] Scialabba NEH, Muller-Lindenlauf M. 2010. Organic agriculture and climate change. Renew. Agric. Food Syst. 25:158–69.
[54] Fernandez AL, Sheaffer CC, Wyse DL, Staley C, Gould TJ, Sadowsky MJ. 2016. Associations between soil bacterial community structure and nutrient cycling functions in long-term organic farm soils following cover crop and organic fertilizer amendment. Sci. Total Environ. 566:949–59.
[55] Snapp SS, Gentry LE, Harwood R. 2010. Management intensity—not biodiversity—the driver of ecosystem services in a long-term row crop experiment. Agric. Ecosyst. Environ. 138:242–48.
[56] Bender SF, van der Heijden MGA. 2015. Soil biota enhance agricultural sustainability by improving crop yield, nutrient uptake and reducing nitrogen leaching losses. J. Appl. Ecol. 52:228–39.
[57] Mondelaers K, Aertsens J, Van Huylenbroeck G. 2009. A meta-analysis of the differences in environmental impacts between organic and conventional farming. Br. Food J. 111:1098–119.
[58] Anglade J, Billen G, Gamier J, Makridis T, Puech T, Tittel C. 2015. Nitrogen soil surface balance of organic versus conventional cash crop farming in the Seine watershed. Agric. Syst. 139:82–92.
[59] Benoit M, Garnier J, Beaudoin N, Billen G. 2016. A participative network of organic and conventional crop farms in the Seine Basin (France) for evaluating nitrate leaching and yield performance. Agric. Syst. 148:105–13.
[60] Benoit M, Garnier J, Anglade J, Billen G. 2014. Nitrate leaching from organic and conventional arable crop farms in the Seine Basin (France). Nutr. Cycl. Agroecosyst. 100:285–99.
[61] Scialabba NEH, Muller-Lindenlauf M. 2010. Organic agriculture and climate change. Renew. Agric. Food Syst. 25:158–69.

[62] Oerke EC. 2006. Crop losses to pests. J. Agric. Sci. 144:31–43.
[63] Pretty J, Bharucha ZP. 2015. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects 6:152–82.
[64] Mahmood I, Imadi SR, Shazadi K, Gul A, Hakeem KR. 2016. Effects of pesticides on environment. In Plant, Soil and Microbes, Vol. 1: Implications in Crop Science, ed. KR Hakeem, MS Akhtar, SNA Abdullah, pp. 253–69. Cham, Switz.: Springer Intl. Publ.
[65] Zehnder G, Gurr GM, Kuhne S, Wade MR, Wratten SD, Wyss E. 2007. Arthropod pest management ¨ in organic crops. Annu. Rev. Entomol. 52:57–80.
[66] Lee KS, Choe YC, Park SH. 2015. Measuring the environmental effects of organic farming: a meta-analysis of structural variables in empirical research. J. Environ. Manag. 162:263.
[67] Mortensen DA, Egan JF, Maxwell BD, Ryan MR, Smith RG. 2012. Navigating a critical juncture for sustainable weed management. BioScience 62:75–84.
[68] McErlich AF, Boydston RA. 2014. Current state of weed management in organic and conventional cropping systems. In Automation: The Future of Weed Control in Cropping Systems, ed. SL Young, FJ Pierce, pp. 11–32. Dordrecht, Neth.: Springer.
[69] Harker KN, O'Donovan JT. 2013. Recent weed control, weed management, and integrated weed management. Weed Technol. 27:1–11.
[70] Kravchenko AN, Snapp SS, Robertson GP. 2017. Field-scale experiments reveal persistent yield gaps in low-input and organic cropping systems. PNAS 114:926–31.
[71] Mortensen DA, Egan JF, Maxwell BD, Ryan MR, Smith RG. 2012. Navigating a critical juncture for sustainable weed management. Bioscience 62:75–84.
[72] Menalled FD, Peterson RK, Smith RG, Curran WS, Paez DJ, Maxwell BD. 2016. The eco-evolutionary ´ imperative: revisiting weed management in the midst of an herbicide resistance crisis. Sustainability 8:1297.
[73] Kleemann L, Abdulai A. 2013. Organic certification, agro-ecological practices and return on investment: evidence from pineapple producers in Ghana. Ecol. Econ. 93:330–41.
[74] Panneerselvam P, Hermansen JE, Halberg N, Arthanari PM. 2015. Impact of large-scale organic conversion on food production and food security in two Indian states, Tamil Nadu and Madhya Pradesh. Renew. Agric. Food Syst. 30:252–62.
[75] Patil S, Reidsma P, Shah P, Purushothaman S, Wolf J. 2014. Comparing conventional and organic agriculture in Karnataka, India: Where and when can organic farming be sustainable? Land Use Policy 37:40–51.
[76] Forster D, Andres C, Verma R, Zundel C, Messmer MM, Mader P. 2013. Yield and economic performance of organic and conventional cotton-based farming systems—results from a field trial in India. PLOS ONE 8:e81039.
[77] Castro LM, Calvas B, Knoke T. 2015. Ecuadorian banana farms should consider organic banana with low price risks in their land-use portfolios. PLOS ONE 10:e0120384.
[78] Testa R, Fodera M, Di Trapani AM, Tudisca S, Sgroi F. 2015. Choice between alternative investments in agriculture: the role of organic farming to avoid the abandonment of rural areas. Ecol. Eng. 83:227–32.
[79] . Karki L, Schleenbecker R, Hamm U. 2012. Factors influencing a conversion to organic farming in Nepalese tea farms. J. Agric. Rural Dev. Trop. Subtropics (JARTS) 112:113–23.
[80] Salazar RC. 2014. Going organic in the Philippines: social and institutional features. Agroecol. Sustain. Food Syst. 38:199–229.
[81] Galt RE. 2013. From Homo economicus to complex subjectivities: reconceptualizing farmers as pesticide users. Antipode 45:336–56.
[82] Dalcin D, Leal de Souza AR, de Freitas JB, Padula AD, Dewes H. 2014. Organic products in Brazil: ˆ from an ideological orientation to a market choice. Br. Food J. 116:1998–2015.