# ORGANIC AGRICULTURAL PRODUCTION SYSTEMS

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**Summary**

- Organic food production systems face challenges such as lower yields, higher production costs, and limited evidence of significant health advantages compared with conventional production systems.
- While a transition to organic agriculture may be appropriate for smaller individual farms which can supply direct to their consumers, it appears unlikely that wide-spread shift to fully commercial scale organic agriculture on its own is an option for either sustainable agriculture or food security.
- Organic agriculture may offer some benefits for farmers, including some environmental sustainability benefits, meeting Western market demand, and attracting premium prices.
- The most benefit is likely to be seen when combinations of aspects of both organic and conventional systems are combined to contribute toward sustainable productivity increases in global agriculture.

## What is organic agriculture?

Organic agriculture was defined by IFOAM (International Federation of Organic Agriculture Movements) in 2008 as “a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved”.

Despite the global increase in land used for organic agriculture, from 18 million ha in 2014 to 60.8 million ha in 2020, it still only represents just over 1% of the agricultural land used for food production (FAOSTAT 2020). The expansion of organic agriculture has been driven by consumer demand, primarily in developed regions like Europe, North America, and Asia/Oceania (Willer and Kilcher 2015), where organic food is perceived as being more environmentally sustainable and both more nutritious and safer compared to food produced using conventional agriculture (Baranski et al. 2017). However, do these perceptions align with scientific evidence? This document is a summary of some of the economic, social, environmental, and health impacts of organic agriculture compared to conventional systems.

## Production

The evaluation of organic agriculture as a productive alternative to conventional agriculture depends on its yield potential and its ability to meet global food demand. Despite significant technological advancements in conventional agriculture since the Green Revolution, a large portion of the world's population, around 800 million people, remains chronically undernourished (FAO, IFAD, UNICEF, WFP and WHO. 2023). This issue will be exacerbated by projections of increased food demand due to population growth and rising incomes. For example, van Dilk et al. (2021) estimate the total global food demand is expected to increase by 35% to 56% between 2010 and 2050. To meet these escalating needs, global agricultural production will need to increase, a formidable challenge as land, water, and natural resources become increasingly scarce. Ideally this increase needs to occur in tandem with a significant reduction in the amount of food that is currently lost or wasted, estimated to be one third of food produced globally (FAO 2019; United Nation Environmental programme 2021).

Comparing yield differences between organic and conventional agriculture is complex, as there are a range of confounding factors that need to be controlled when making comparisons (Meemken and Qaim 2018). However, several meta-analyses of paired studies for different food crops (i.e., cereals, roots/tubers, oilseed, legumes/pulses, fruits/vegetable) have found that organic agriculture typically yields 19% to 25% less than conventional systems (Boschiero et al. 2023; Alvarez 2021; Ponisio et al. 2015; de Ponti et al. 2012; Seufert et al. 2012) and that yield variability is greater than in conventional crops (Schrama et al. 2018). The extent of the yield gap varies across crop management systems and crop types, with legumes and fruits showing smaller gaps than cereals and root crops. These differences in yield are in part attributed to limitations in the availability of essential nutrients, such as nitrogen (N) and phosphorus (P) in organic systems (Berry et al. 2002). Organic inputs release nutrients too slowly to meet plant demands, and their nutrient ratios can't be easily adjusted, making it challenging to optimise the required plant nutrient concentrations (Seufert and Ramankutty 2017). In addition, the restrictions on synthetic chemical use and GMOs in organic agriculture limit pest and disease control options, resulting in higher yield gaps in environments with significant pest and disease pressures. At present, organic agriculture is therefore not a viable alternative to conventional agriculture to feed our growing population because of its lower yield potential.

**Nutrition and health effects**

Whether organic foods are significantly healthier and more nutritious than their conventional counterparts remain a subject of debate. While consumers often perceive organic foods as being healthier due to lower contamination by pesticide residues and heavy metals, and having higher amounts of beneficial compounds (e.g. antioxidants, (poly)phenolics, vitamins and certain minerals) (Gundala and Singh 2021; Seufert et al. 2017), comprehensive reviews have reported varying findings (e.g. Baranski et al. 2017; Baranski et al. 2014; Brandt et al. 2011; Huber et al. 2011; Smith-Spangler et al. 2012; Hunter et al. 2011). For instance, Smith-Spangler et al. (2012) conducted a meta-analysis of 237 studies and found little evidence to support the claim that organic foods are significantly more nutritious than conventional ones. However, other studies, such as Baranski et al. (2014), which analysed 343 peer-reviewed publications, suggested that organic crops tend to have higher concentrations of secondary metabolites like polyphenolics, potentially linked to a reduced risk of chronic diseases. Hunter et al. (2001) compared the micronutrient content of plant foods produced by organic and conventional agricultural methods from 33 studies (describing 908 micronutrient comparisons) and found that organically grown plant foods generally contained higher concentrations of micronutrients compared to conventionally grown foods. Higher micronutrient contents per se may convey no extra benefit to the consumer, unless there is a deficiency of those micronutrients in the diet causing ill health or disease. Additionally, for some micronutrients the tolerance between adequacy and toxicity can be small.

One aspect where there is more consensus is that organic foods typically have lower concentrations of chemical pesticide residues than conventionally grown foods (Baranski et al. 2014; Smith-Spangler et al. 2012; Huber et al. 2011; Williams et al. 2001), but as all food has to pass quality standards and be below designated thresholds in chemicals, all food is safe, whether organic or conventionally produced. Despite these findings, and those that have reported higher nutrient and beneficial compounds in organic food, the extent to which organic foods offer clinical health benefits to humans remains largely unknown, and more research is needed to establish a clear link between organic food consumption and improved health outcomes (Dangour et al. 2010; Smith-Spangler et al. 2012).

**Environmental effects**

One of the main reason consumers purchase organic food is that they perceive it has a lower environmental impact (i.e., climate change, biodiversity, acidification potential, energy use, soil degradation, eutrophication) than food grown in conventional systems (Gracia and de Magistris 2008; Stein-Bachinger et al. (2021). However, a comparison of systems is complex and varies depending on which environmental indicator is being considered and how many, and whether the assessment is per unit of land or per unit of output (Boschiero et al. 2023; Clark and Tilman 2017; Tuck er al. 2017; Meier et al. 2016; Tuomisto et al. 2012; Mondelaers et al. 2009).

Several meta-analyses have attempted to address this question. A study by Clark and Tilman (2017) analysed 46 paired organic and conventional agricultural systems for a broad range of foods across various environmental indicators and found that organic systems required more land but used less energy and had a higher potential for eutrophication when measured per unit of food. Greenhouse gas emissions and acidification potential were similar between the two systems. Another recent analysis by Boschiero et al. (2023) compared 77 paired studies of cropping systems and found that organic systems had a better environmental performance for climate change, ozone depletion, ecotoxicity, and resource use (abiotic, mineral, and metal resources) when measured per unit of food. However, organic systems had a poorer environmental performance for land use and ionizing radiation. When results were assessed on a per area basis, in line with most studies, organic systems generally performed better than conventional systems across all assessed environmental indicators. When literature was assessed on a per unit of output basis, between organic systems and conventional systems performance on assessed environmental indicators, results were mixed. These findings emphasise the importance of considering both the specific environmental indicators and the unit of measurement when evaluating the environmental effects of organic agriculture compared to conventional agriculture.

**Biodiversity loss**

At an individual farm scale, it has been shown that organic agricultural systems can have positive effects on biodiversity including greater species richness and abundance compared with conventional agriculture (Stein-Bachinger et al. 2021). However, a critical aspect that is sometimes overlooked is because organic systems are less productive, assuming the global population does not decrease (at least for a few decades), larger areas of land will be required to maintain food production.

The expansion of agricultural land could involve the conversion of non-agriculture areas into productive agricultural land, potentially accelerating biodiversity loss due to the decline of natural habitat in these previously non-farmed areas (Meemken and Qaim 2018; Bateman and Balmford 2023). This land-use change effect might outweigh the positive environmental benefits of organic agriculture per unit of land.

This perverse outcome of potentially accelerate biodiversity loss due to organic agriculture and other so-called ‘nature friendly’ agriculture such as rewilding, has prompted the consideration of alternative systems. Bateman and Balmford (2023) for example have suggested the idea of 'land sparing', which involves consolidating areas of natural habitat into larger blocks in non-farmed areas, alongside adopting lower-impact ways to increase yields in the areas that are still farmed, using methods to enhance crop and livestock yields more sustainably than current high-yield practices e.g., genomic screening and gene editing to accelerate animal and crop breeding.

**Nitrogen fertiliser**

Nitrogen (N) is an essential nutrient for both plants and animals, playing a pivotal role in global food production to sustain the ever-expanding population. Organic agriculture prohibits the use of synthetic N fertiliser, relying instead on sources like manure, compost, and other plant and animal byproducts, as well as biologically fixed N in some systems. Often there are limited amounts of composts available in the scale required. However, as described, organic systems are typically lower yielding than conventional systems, with N limitation an important contributing factor, arising from the slow or insufficient release of N from organic sources to meet plant requirements (Berry et al. 2002).

In light of ongoing global food security and malnutrition challenges, synthetic N fertilisers are indispensable for sustaining food production, as N deficiency can adversely affect yields and therefore overall food supply. Although quantifying the precise impact is complicated, using data on crop production, crop yields, nitrogen crop content, livestock and human protein and nutrient budgets (Smil 2004; Stewart 2005; Erisman et al. 2008), it has been estimated that synthetic N fertilisers are responsible for feeding 50% of the global population (Ritchie 2017). This implies that without them, organic agriculture which doesn't allow the use of synthetic N fertilisers, would only be able to support half of the population.

**Cost of organic food**

Organic food is commonly more expensive than conventionally grown food due to several key factors. Firstly, the strict use of natural fertilisers and pesticides in organic agriculture, which are typically more expensive than their synthetic counterparts, results in higher production costs (Meemken and Quaim 2018). Organic agricultural methods are also labour-intensive, relying on manual techniques like hand-weeding instead of chemical controls further raising production costs (Valkila 2009). As noted, organic agriculture tends to yield smaller crops than conventional agriculture, necessitating more land and resources, further driving up costs. Certification expenses to meet organic standards that undergo regular inspections contribute to higher prices, especially for small-scale farmers. The growing demand for organic food has outpaced supply in some markets, exacerbating price increases as producers try to meet consumer needs. All of these factors mean that organic food remains less affordable for economically disadvantaged consumers, particularly in developing countries, and price remains a significant barrier for many when considering organic products.

**Price premium**

Studies have shown that some consumers often say that they are willing to pay a price premium for organic food products. For instance, a meta-analysis by Wei and Renwick (2019) found that consumers, on average, were willing to pay a 31% price premium for organically produced red meat and a 29% premium for dairy products. However, despite some willingness to pay more for organic food, or indeed more for any food with claimed enhanced attributes, actually achieving the market price premium can be challenging, as noted by Lucci et al. (2019). Consequently, the organic agriculture sector remains relatively small in comparison with conventional agriculture.

**Sri Lanka – a case study on organic agriculture**

The collapse of organic agriculture in Sri Lanka serves as a cautionary tale of a well-intentioned agricultural transition that led to economic turmoil and social unrest.

In mid-2021, the Sri Lankan government abruptly announced a 10-year plan to change the country's agriculture to organic. This included banning the importation and use of synthetic fertilisers and pesticides, pushing millions of farmers and growers into organic agriculture without adequate preparation that led to unpredicted chaos in the agricultural sector (Nordhaus and Shah 2022).

With a lack of organic alternatives, rice production decreased by 20%, forcing the nation, once self-sufficient, to spend $450 million on rice imports. Tea production, a significant export, dropped by 18%, resulting in substantial subsidies and compensation to be paid to farmers. In a survey of 703 farmers growing maize, potato, chilli and onion across eight districts of the country, it was found overall the total cultivated area declined by 26% compared with the previous season when they farmed conventionally, and on average, depending on the crop, their yields decreased between 46% to 68% (Hewage et al. 2022). This agricultural crisis exacerbated an economic downturn in the country, culminating in a default on $40 billion in foreign debt.

Although the ban on the use of synthetic fertilisers and pesticides was eventually reversed, Sri Lanka's fertiliser supply has never fully recovered. While external factors (COVID-19; Ukraine war) contributed to the crisis, the hasty adoption of organic agriculture played a pivotal role. The Sri Lankan case serves as a stark reminder to countries such as New Zealand where agriculture plays a significant role in the economy, that while there may be benefits to organic agriculture, a transition can have negative economic and social consequences and emphasises the need for a balanced approach and careful consideration of the implications when making such transitions in farming systems.

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