FOOD SUSTAINABILITY

Expansion of organic agriculture

Current global nutrient availability poses a barrier to the complete shift from conventional to organic food production. Policies must be developed to overcome nutrient limitation and increase grower experience with organic production methods.

David W. Crowder and Javier G. Illan

Conventional agriculture, which relies on intensive use of synthetic inputs, produces the bulk of the world's food and energy crops[1]. However, conventional farm systems contribute to global climate change and environmental degradation[1]. Concerns over the negative impacts of conventional agriculture have spurred interest in more sustainable alternative farming systems that replace synthetic inputs with compost, animal manure, and botanical pesticides[1–3]. Organic agriculture is the most popular alternative system worldwide, with global acreage of organic crops growing 550% from 1999 to 2018 — reaching 71.5 million acres[4]. Reviews and meta-analyses have showed that benefits of organic systems, compared to conventional ones producing the same crops, include greater profitability, increased biodiversity, enhanced soil quality, reduced pesticide use, more nutritious foods, and positive shifts in community economic development[1–3]. However, organic agriculture often produces lower yields than conventional agriculture[5], and critics have argued that adopting organic agriculture on a much larger scale would threaten the world's natural resources and fail to feed a growing human population[6].

In *Nature Food*, Barbieri and colleagues address this debate from a unique perspective by asking whether the world is even capable of transitioning to 100% organic cropland from a biophysical perspective[7]. Although organic agriculture is practiced in 186 countries by nearly 3 million producers as of 2018, it still only occupies 1.5% of total agricultural land[4]. The regions of Oceania (8.6%) and Europe (3.1%) have the greatest share of agricultural area devoted to organic production, while North America, Latin America, Asia, and Africa each have less than 1.2% of agricultural land managed using organic practices[4] (Fig. 1). Moreover, while some European countries have over 20% of farmland in organic production, most of the world's largest countries in terms of agricultural area have a relatively low share of organic acreage, including China (0.6%), India (1.1%), Brazil (0.4%), and the United States (0.6%) (ref. [4]). Barbieri et al. argue that discussing whether organic agriculture can feed the world is only relevant if the share of organic agriculture expands dramatically over the next century, however no studies have effectively tackled the question of whether it could expand rapidly from the current 1.5% to 100%.

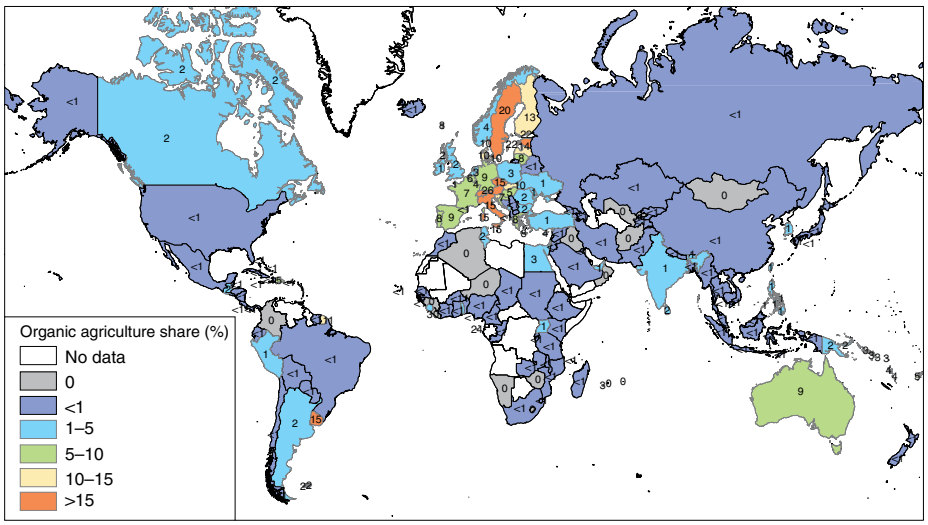

Fig. 1 | Share of agricultural land devoted to organic farming systems. Data shown were taken from ref. [10] and averaged per country for the 186 countries with any organic acreage in 2018.

One of the primary differences between organic and conventional agricultural systems is that organic farms do not use synthetic fertilizers but rather rely on compost, animal manure, and other biological sources of nutrients[7,8]. Organic farming systems also promote more holistic management of soil communities than conventional systems by implementing longer and more diverse crop rotations and through increased integration of crop and animal production[1,7]. However, complete reliance on biological nutrient sources presents a challenge for many organic farmers, and Barbieri et al. question whether nitrogen limitation in particular may prevent rapid expansion of organic farming systems worldwide. In their paper, they present results from a spatially explicit biophysical model used to assess whether organic farming can continue to expand without drastic reorganization of agricultural and trade systems. For example, if organic agriculture were to expand globally, the authors show that farmers would need to increase reliance on production of legume crops that naturally fix nitrogen and would likely need to more broadly integrate crop production and animal husbandry to generate enough animal manure to provide a local source of nitrogen to organic farming systems.

With their modelling approach, Barbieri et al. show nitrogen availability is likely to be a primary impediment to the global expansion of organic agriculture. They simulated variation in the rate of expansion of organic agriculture, and livestock management options, at a resolution of 10 km, so they were able to assess expansion in different world regions with unique starting values for organic acreage and production practices. The authors compared a baseline 'business as usual' scenario,

where organic agriculture expands without any redesign of agricultural systems, with alternative scenarios that explored different options for sourcing nitrogen. They show that organic agriculture could reach 20% of global cropland in the 'business as usual' scenario without major redesign of agricultural systems, but reaching 40–60% would require a dramatic redesign of global agricultural systems to ensure a tighter coupling between livestock and crop production, reduction in food waste, and potentially sourcing nitrogen from human wastewater and conventional manure. Such growth in organic acreage would also need to be accompanied by major shifts in human diets, as the authors show that farms would need to increasingly shift away from production of cereals and livestock, and towards increased production of fruits and vegetables. Legumes would also become considerably more common to allow for sufficient nitrogen availability in farmed soils within crop rotations.

While Barbieri et al. show that the expansion to 100% organic agriculture is unlikely given current constraints associated with global nutrient availability, they do present the positive outlook that organic agriculture can continue to expand. Even in their most conservative projections where organic agriculture expands without other changes to global agroecosystems, the authors show that organic agriculture can reach 20% of global agricultural land, which represents an increase of 1,200% in global acreage. However, to achieve such gains and possibly increase the share of organic cropland beyond 20% of global acreage, policies must be developed to address potential nutrient limitation and increase grower experience with organic production methods[9]. Moreover, organic farm policies should focus on the development of novel and effective methods to manage pests and diseases without synthetic inputs while making organic food more accessible to a broader swath of consumers, many of whom cannot currently afford organic crops that cost on average 30% more than conventional ones[1,2,9]. If these challenges are addressed, organic agriculture can continue to expand rapidly as the most common form of alternative agriculture worldwide. Even so, it remains clear that to continue to sustainably feed the world and mitigate environmental harm, a mix of agricultural systems are needed. Moving away from a binary debate that contrasts a world with 100% conventional agriculture and 100% organic agriculture, more studies should consider how a balance between these two systems — and other alternatives — can best meet the needs of a growing human population. ❐

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Competing interests

The authors declare no competing interests.