OWC 2020 Paper Submission - Science Forum

Topic 3 - Transition towards organic and sustainable food systems

OWC2020-SCI-352

NITROGEN AVAILABILITY IS LIKELY TO CHALLENGE ORGANIC FARMING PRODUCTION AT THE GLOBAL SCALE

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Preferred Presentation Method: Oral or poster presentation

Full Paper Publication: No

Abstract: Organic agriculture is often proposed as a promising approach to achieve sustainable food systems but Its capacity to meet the global food demand remains debatable. Some studies have investigated this question, but they have missed a critical ecological phenomenon by not considering the role that nitrogen (N) cycling plays in sustaining food production in organic systems. Using a global spatial N cycling model, we show that a 100% conversion to organic agriculture would lead to a large gap in global food production compared to the current – i.e. non-organic situation. Organic food availability would thus not be sufficient to match global food demand. We also show that lower conversion shares would be feasible in coexistence with conventional farming when coupled with demand-side solutions, such as reduction of the per-capita energy intake or food wastage. These results are critical to explore the option space of the global food system in a sound and systemic manner.

Introduction: Sustainable production systems should be promoted in order to curb the environmental impacts caused by intensive agricultural practices while guaranteeing sufficient food production for all. Among such systems, organic agriculture is often reported as a promising option.

The role that organic farming could play in feeding the world has been investigated for a decade now, but this question still generates controversial positions [1–3]☐. Despite a yield gap effect of about 25% [1]☐, many studies conclude that organic agriculture can contribute to providing sufficient food for the future growing population [3,4]☐. However, these studies have not considered the key role that nitrogen (N) cycling plays in sustaining crop yields in organic farming given that the ban of synthetic fertilizers may strongly limit the availability of nitrogen resources globally. Therefore, the role that organic farming may play in feeding the world is still very much an open question.

Material and methods: In this study, we investigate how N availability may impact global food systems in scenarios of large organic farming expansion using a global spatial model simulating cropland soil N cycling in organic farming systems and its feedback effects on food production at the global scale (spatial resolution of 5 arc-min, i.e. ~10 km × 10 km at the equator). The model simulates the productivity of different compartments (organically managed croplands – accounting for the effects of the changes in crop rotations that would come alongside a conversion to organic farming –, livestock animals and permanent grasslands) and accounts for the biomass and N flows among these compartments (as grazed biomass, feed-stuff, and animal manure) as well as the N flows between cultivated soils and the environment. We complement this analysis by analyzing the global production-demand option space – defined as the set of scenarios for which food production meets global food demand – by considering different estimates of the global food demand.

Results: We found that in a fully organic world, cropland energy production would drop down by 57% at the global scale compared to the current – i.e. conventional – baseline. By accounting for 77% of the production gap, we found that nitrogen deficiency is the driver of such drastic production drop. Notwithstanding this global estimate, we also found that both cropland energy production and N availability have a large geographic variability. The adoption of organic systems would lead to drastic production losses in areas such as North America and Europe, while production would increase in others, such as in some areas of Central and South America or Central Asia.

We also found that redesigning livestock production in a fully organic world would be key to sustain crop yields and to limit the gap between global food production and demand. A fully organic world would be characterized by (I) a 20% reduction in livestock populations (expressed in Livestock Units), (ii) a strong shift from monogastric to ruminant animal species, and (iii) strong changes in the global livestock geographic distribution when compared to the current conventional baseline. Altogether, these changes are key to (i) provide manure where croplands need it, and (ii) to limit the use of crop products as livestock feed – i.e. to limit the feed-to-food competition. Note that in the absence of such redesign, a fully organic would not be feasible: global livestock feed requirements would exceed global cropland production. All in all, food production (calculated based on current per-capita energy intake) would be 36% lower in a fully organic world compared to the current situation.

Discussion: Several studies have assessed scenarios of organic farming expansion in terms of global food production [3,5]☐. However, all these studies has missed the key role of N cycling on production systems and its feedback on organic production. By considering N cycling in scenarios of organic drastic geographic expansion at the global scale, we show that organic food production in a fully organic world would be, on average, 37 % lower than previously estimated [3,6]☐. The important gap that we found between food production and food demand in a fully organic world may have major implication for food security. Therefore, the mobilization of supply-side solutions is essential to help narrowing such gap. Importantly, we show here how organic livestock would play a more important and complex role that previously estimated in several scenario-based food studies. Our results clearly show how animals are a key structural component of organic farming systems. This is especially true when referred to ruminants animal species, because of their key ability to value and transform grasslands and legumes hays into products of primary importance, namely manure and nutrient dense food commodities [7]☐. There results are also in line with studies showing that a minimum livestock population is key to maximize food production from croplands [7]☐.

In summary, we report the first spatially explicit assessment of a 100% global cropland conversion to organic management, with full consequences for the N cycle and the global food production. We show how N availability would limit food production in a fully organic world. Nevertheless, organic farming option space remains large, since lower conversion rates are feasible when coupled with a range of supply- and demand-side solutions aiming at narrowing the gap between global food production and demand. Such conversion rates would still bring enormous benefits by reducing several environmental impacts associated with current intensive agricultural systems [3☐]. In addition, the spatially explicit nature of our study underlines how different performances are reached in different global regions, suggesting that organic farming might be a promising solution in some regions, while its implementation would be more challenging in others (e.g. North America). Hence, while organic farming alone is not a panacea, it remains a major piece of the toolbox for moving towards more sustainable food systems.

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Disclosure of Interest: None Declared

Keywords: conventional farming, food security, modeling, nitrogen availability, organic farming, organic livestock