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Short Communication

Organic agriculture and food security: A decade of unreason finally implodes

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ABSTRACT

Persistent claims over the past decade that transformation of world agriculture to organic methods could feed the world have been grossly overoptimistic because they have used faulty methodology. Estimation of organic productivity based on yield ratios (typically 0.75) of pairs of comparable crops grown organically or with nitrogen fertilizer fails to acknowledge the land that must be allocated to legumes for biological nitrogen fixation (BNF) by legumes to supply nitrogen for the growth of non-legume crops, either in situ or in imported manure. The consequent smaller area of land available for cereal crops further, and more significantly, reduces the overall productivity of organic compared to conventional agriculture. A recent paper that applied published yield ratios to demonstrate adequate productivity of world agriculture transformed to organic methods failed in its objective by demonstrating that the error in calculation proposed an organic system with at least three times more circulating nitrogen than the land allocated to legumes could possibly provide. Future estimates of organic productivity should return to the basics of BNF that have, in the past, established that around half of current world population could be fed organically.

Uncritical promotion of organic agriculture (OA) as a solution to world food security is both scientifically flawed and dangerous in its impact on public opinion. OA in this debate is understood as cropping without recourse to artificial chemicals, bringing both advantages and limitations. One limitation alone, however, is sufficient to disqualify the notion of feeding the world organically, and that is the supply of nitrogen (N). All sustainable cropping must replace nutrients removed in product, and for the major nutrient, N, this cannot be postponed without loss of yield. In fields under OA, N must be supplied to non-legumes by either *in situ* biological N fixation (BNF) of intercropped or rotated legumes, or from *ex situ* BNF as manure (a general term used here to cover animal and plant wastes, alone or mixed, raw or composted, and not to be confused with green manure).

Discussions of the potential for organic agriculture (OA) to feed the world have been active for many years. Until relatively recently, the view established by analyses of N requirements was for supporting a population of around 3–4 billion (Buringh and van Heemst, 1979; Smil, 2000). But that was broken in 2007 with the strong support of FAO given to a study (Badgley et al., 2007) that was initially presented at one of their conferences. That study calculated the productivity of OA as the ratio of recorded yields of individual crops grown either with legume-based N (including manures) to those crops grown with synthetic N fertilizer as in conventional agriculture (CA) and concluded that OA could indeed feed the world, then of population 7 billion. Average OA/CA crop yield ratios presented for all food groups were either slightly less or slightly greater than unity for developed and developing countries, respectively.

Published criticisms of the study's conclusion (Connor, 2008; Goulding and Trewavas, 2009) identified the failure of the ratios to include the land used for BNF by legumes, either *in situ* for rotations and intercrops or *ex situ* for imported manure, that are the only sources for N in OA. In the context of promoting a transformation of agriculture to organic methods the legume land must be included in the calculation of system productivity. Thus, a leguminous green-manure crop (GrM) grown only to provide N for a following cereal crop would, as a 1:1 GrM-cereal OA system with a usual OA/CA crop yield ratio (av. 0.75), produce 0.75 CA yield but over two units of land. System level OA/CA production would be 0.38, thus requiring 2.6 OA land units for equivalent CA, *i.e.* an extra 1.6 land units. The impact of additional land is greater than the OA/CA crop yield ratio.

Criticism has not, however, prevented continuing abuse of OA/CA yield ratios to support overoptimistic predictions of the productivity of OA. Two more well-cited yield comparisons (Seufert et al., 2012; Ponisio et al., 2014) differ in selection of data sets and statistical procedures but in both cases extend the discussion of OA/CA crop yield ratios, now more commonly less than unity, to comparison of the productivity of organic v. conventional systems. Criticism of Seufert et al. (2012) that was refused by the journal was subsequently published elsewhere (Connor, 2013). The limitations of that paper in a well-cited journal are so serious that they should have been published in the same journal for debate among the same audience.

The myth that these papers promulgate of the potential of OA to

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feed the world has been important during the last decade in the promotion of OA, and the closely related "agro-ecology" (Altieri, 2002; Wezel et al., 2013), as alternative paradigms for agricultural production for Europe (Moudrý et al., 2018; Wezel et al., 2018) but also for adoption in aid projects for developing countries. My concern is for the resource-poor farmers, especially in Sub Saharan Africa, who overwhelmingly are targets for help and advice to apply organic methods from misguided community organizations based in other countries. Soil fertility is so low there after at least a century of intensive nutrient extraction without replacement that denial of the need for N fertilizer makes the process of agricultural renovation impossible.

But, hopefully this decade-long march of unreasonable use of OA/CA crop yield ratios to estimate the productivity of OA has reached its end. Previous use was in qualitative arguments until a recent study (Muller et al., 2017) used the Seufert et al. (2012) ratios to calculate the productivity of world agriculture transformed to OA. The authors claim to show that OA could feed a world of today's population (7.6 billion) or that anticipated for 2050 (9.8 billion). For that, they allocate 20% of 1400 Mha of cropping land to legumes that, with a net average fixation of 100 kg N/ha/y across all legume crops and environments (Herridge et al., 2008), might fix 28 Mt N/y. And yet the world organic system these authors construct has 105 Mt N/y in animal manure alone without accounting for extraction in crop and animal products and inevitable losses in production and storage. The OA/CA crop yield ratios they use to estimate OA productivity introduce much more N into their model calculations than legumes could supply on the land area allocated to them. For perspective, current input of BNF into world agricultural systems is 33–46 Mt N/y of which the most secure estimates are 21 Mt N fixed by legume crops, including 16 Mt N by soybean (Herridge et al., 2008). Input of fertilizer N is around 113 Mt/y (FAO, 2015) and that defines the challenge of a transformation of world agriculture to OA. Even allowing for an efficiency gain of fertilizer use of 30% would require, at an average net BNF contribution of 100 kg N/ha/y, the allocation of 800 Mha of land to legume.

In the transformation proposed by Muller et al. (2017), a much larger proportion of available land would be required in legumes than is reflected in the OA/CA yield ratios and so productivity of the proposed system would be much less than in CA, certainly less than one half. Rather than demonstrating the validity of a transformation of world agriculture to OA, the authors have unintentionally revealed that OA/CA yield ratios of individual crops are misused in calculation of OA productivity at system level. The result is an overoptimistic estimation of global OA productivity.

The authors need a different model that estimates productivity of OA from legume N and allocates sufficient land to that purpose. Scientific debate requires that Journals are open to criticism and debate and do not unreasonably align themselves with alternative ideologies or paradigms. The public good requires that decision makers are protected from false information. In this case the future of world food supply is at stake, as is also rational debate about the agricultural development that is urgently required in undeveloped countries.

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