Check for updates

Perspective

Outlook on Agriculture

Outlook on Agriculture
2019, Vol. 48(1) 22–27
© The Author(s) 2019
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/0030727019831702
journals.sagepub.com/home/oag
SAGE

Why organic farming is not the way forward

Holger Kirchmann

Abstract

The aim of this article is to provide information about crop production data based on large-scale organic farming and to point toward major consequences. National statistics show lower organic yields than compiled in meta-analyses from farm- and plot-scale. Yields of organically cropped legumes were 20% and nonlegumes 40% lower than those of conventionally grown crops. Area estimates showed that almost two of three crops were legumes or legume mixtures in organic farming, whereas one of three crops was a legume in conventional cropping. Doubling land use for legumes in organic farming affected the type of food produced, being dominated by milk products and red meat. Over all crops, the organic yield gap was 35%. Since yields are lower under organic than conventional practices, more land is required to produce the same amount of agricultural crops. A 35% yield gap means that 50% more arable land is required. A demand for 50% more farmland imposes huge land use changes and makes one realize the wide-ranging environmental consequences that follow when converting to organic farming. In a relevant comparison between organic and conventional cropping systems, environmental consequences caused by land use change such as lost products (timber, fiber, energy, etc.) and lost ecosystem services (sequestered carbon in soil, wildlife, biodiversity, etc.) must be included. The concept of organic farming was founded on philosophical views about nature, not biological science. Natural means and methods were assumed to be superior. Verification of the reasoning and statements of the founders on why to abandon mineral fertilizers cannot be corroborated by science and is incorrect. Scientific evidence for the concept to abandon synthetic mineral fertilizers as nutrients for crops is lacking. The scientific community is obliged to follow rigorous scientific criteria—not biased views, prejudices, or beliefs.

Keywords

organic crop yield, yield gap, large scale versus farm- or plot-scale, meta-analysis, land use demand, environmental consequences, view on nature, doctrine

Introduction

Organic farming has been attributed with many positive features of food production—superior food quality free from pesticides, low emissions of greenhouse gases, efficient energy use, insignificant nutrient leaching, high biodiversity, and sufficient and sustainable food production. The underlying idea has been that as organic farming applies only natural means and methods, high food quality and good environmental stewardship are for granted outcomes. This view has recently been modified by unbiased reviews identifying the limitations of organic crop production (e.g. Kirchmann and Bergström, 2008; Kirchmann et al., 2016a; Shorrocks, 2017). In this article, national statistical data of organic crop production of Sweden were presented and environmental consequences and reflections about the idea of organic farming highlighted.

Crop production of organic agriculture has been overestimated in meta-analyses

A debate as to whether organic agriculture could provide sufficient food started when Badgley and Perfecto (2007) and Badgley et al. (2007) estimated a 20% yield reduction by organic compared to conventional farming. Similar comparisons using ratios of organic over conventional crop yields have been used by Seufert et al. (2012) and de Ponti et al. (2012). A recent estimate by Ponisio et al. (2015) showed that yield gaps apparently approach insignificance when organic agriculture is intensified.

The mistake of these meta-analyses has been to assume that individual crop-by-crop yield ratios are an estimate of the productivity of systems (Connor, 2013). The productivity of cropping systems is derived from the sum of yields of all crops grown over several years, an estimate not obtained from crop-by-crop of organic and conventional yield ratios used in meta-analyses. For example, years in organic rotations with green-manure crops not harvested reduce

Department of Soil and Environment, Swedish University of Agricultural Sciences, Uppsala, Sweden

Corresponding author:
Holger Kirchmann, Department of Soil and Environment, Swedish University of Agricultural Sciences, Box 7014, 75007 Uppsala, Sweden.
Email: holger.kirchmann@slu.se

production. Frequent growth of legumes in organic systems for biological N fixation reduce total crop production as many legumes typically have lower yields than fertilized nonlegumes. If different crops are grown in organic and conventional rotation, crop-by-crop yield ratios are not a representative measure of productivity.

Furthermore, crop yields are largely determined by nutrient input to farms, simply "you get out what you put in" (Goulding, 2007). A common practice is to use conventional products as the nutrient source certified for organic farming (Oelofse et al., 2013). For example, nutrient inflow through organic materials to 63 organic farms in France—animal manures, organic fertilizers, feedstuff, and straw—accounted for 23% of N, 53% of P, and 73% of K of total input (Nowak et al., 2013a, 2013b). Reliance of organic yields on nutrient input derived from conventional agriculture has not been considered in crop-by-crop yield ratios.

The shortcomings of the production estimates were summarized by Kirchmann et al. (2016b) as follows: (1) to omit more frequent cultivation of legumes in organic rotations which reduces overall productivity, (2) to exclude years without harvest due to green manuring, and (3) to ignore import of nutrients to organic from conventional agriculture.

Organic yields derived from national statistics are lower than for farm- or plot-scale

Few European countries include organic yields in their agricultural statistics, Sweden being an exception (SCB, 2017a, 2017b, 2017c) providing data since 2004. In 2016, about 14% (368,800 ha) of Swedish arable land (2,579,600 ha) had been converted into organic farming (SCB, 2017b). Statistics provide crop-by-crop yield ratios and information about the area of land used for crops. Still, information about land used for green manuring, fallowing, and minor crops is not included.

Grouping crops showed that yield gaps amounted to 60% for nonlegumes and 80% for legume/legume mixtures (Table 1). Over all crops corrected for cropping area, organic yields were 35% lower. One of the main reasons identified as to why organic yields are lower is lower nutrient supply (e.g. Berry et al., 2002; Kirchmann et al., 2007). Legumes and legume mixtures caused the smallest yield gap, which may explain why organic farming was dominated by legume crops, grown on 61.2% of organically cultivated land (Table 1). The equivalent figure for conventionally grown legume crops was 32%. Statistics revealed that legume and legume mixtures were almost exclusively used as fodder mainly in ruminant systems being the dominating form of organic agriculture in Sweden.

Considering legumes being the primary source for the N supply of nonlegumes in organic rotations, the number of legumes can greatly affect yield levels of nonlegumes. From statistical data in Table 1, an arbitrary relationship between the percentage of legumes in rotations and organic yield gaps can be derived using the yield ratio of 0.80 for legumes, and a mean area corrected yield ratio of 0.65 when 62% of organically grown crops were legumes. Extrapolating data indicated that reducing legumes to 50%, that is, growing legumes every second year in organic rotations, would increase the mean yield gap to 40% compared to conventional cropping.

In meta-analyses based on farm- and plot-scale data, smaller organic yield gaps were reported than in agricultural statistics from large-scale farming (Table 1). Suggestions are that pressure of weeds and pests increase when large neighboring areas are managed organically (Leifeld, 2016) and/or that the supply of organic fertilizers derived from conventional agriculture becomes limited and more expensive.

Organic farming requires at least 50% more arable land to fill the production gap

The yield gap that emerges with conversion from conventional to organic farming will require a land use change and an expansion of arable land as pointed out in recent paper (e.g. Connor, 2018; Muller et al. 2017; Searchinger et al. 2018). Based on Swedish statistical data, the condition to compensate for a 35% yield gap would mean increasing the arable land by about 50% (note not 35%) (Figure 1). Increasing arable land for organic production prerequisites land use change.

One of the most important challenges facing society today is how to feed an expected population of some 9 billion by the middle of the 20th century (Pretty et al., 2010). When Borlaug and Dowswell (1994) wrote that "growing less food per acre leaving less land for nature," their concern was to conserve natural land, wild life, and biodiversity by increasing crop yields on existing arable land. Today, there is a general awareness that arable land is a relative finite global resource (e.g. Alexandratos and Bruinsma, 2012; Lambin, 2012).

Environmental evaluations of organic farming must include yield level and demand for more arable land

Comparative studies of conventional and organic systems focusing on emissions commonly relate rates to the area of land cropped. Such studies showed that, for example, leaching losses from organic fields can be both higher or lower compared to conventional fields (Kirchmann and Bergström, 2001). The same was true for greenhouse gas emissions (e.g. Flessa et al., 2002; Leifeld et al., 2013). Losses to the environment depend on the intensity and efficiency of cropping. Extensive organic farming could result in less nutrient losses than more intensive conventional farming (e.g. Drinkwater et al., 1998; Korsaeth and Eltun, 2000).

Expressing emissions per area disregards whether it is a high- or low-yielding cropping system. It is apparent that systems with low emissions would be ranked

Table 1. Organic over conventional crop yield ratios and arable land allocated to different crops in Sweden in 2016.[a]

Type of crop and land use	Organic/conventional yield ratio	Arable land allocated to different crops: Organic arable land (368,800 ha; %)		Conventional arable land (2,210,800 ha; %)	
Nonlegumes					
Winter wheat	0.58	23,160		351,220	
Spring wheat	0.60	12,460		62,430	
Rye	0.53	2140		14,470	
Winter barley	0.57	400		18,680	
Spring barley	0.62	18,950		280,930	
Oat	0.66	33,330		139,590	
Triticale	0.67	4060		26,200	
Maize	—	120		1660	
Failed cereal harvest	—	630		2900	
	0.60 mean	∑ 89,600	24.2	∑ 928,400	42.0
Winter oil seed rape	0.71	5370		78,050	
Other oil seed crops	0.61	1040		16,650	
Failed oil seed harvest	—	120		850	
	0.66 mean	∑6530	1.8	∑95,550	4.3
Food potato	0.64	1680		15,630	
Starch potato	—	3		2900	
Failed potato harvest	—	10		130	
	0.64 mean	∑1690	0.5	∑18,660	0.8
Sugar beet	—	—		30,700	1.3
Legume/legume mixture					
Pea	0.72	3240		21,970	
Bean	0.79	10,710		19,170	
Failed harvest pea	—	70		270	
Failed harvest bean	—	60		140	
	0.76 mean	∑ 14,080	3.8	∑41,550	1.9
Grass clover forage	0.85	183,120		622,340	
Green legume forage	0.73	5120		13,310	
Grain-legume forage	0.74	7090		7,180	
Green cereal-legume forage	0.88	16,560		23,140	
	0.80 mean	∑211,890	57.4	∑665,970	30.1

[a]Certain crops (vegetables, energy forest, etc.), green-manured and fallowed land were not included. Data derived from agricultural statistics of Sweden (SCB, 2017a, 2017b, 2017c).
Note: Bold figures refer to an area-corrected mean yield ratio of a group of crops.

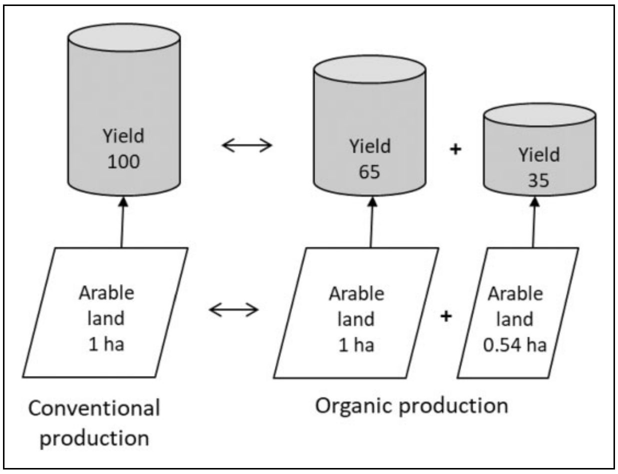

Figure 1. An illustration demonstrating the demand for more arable land when converting conventional to lower yielding organic farming. Relative figures relate to a yield gap of 35%. Note that the additional arable land needed is larger the yield gap of 35% because the extra land also produces a lower yield equivalent to 65% of conventional cropping.

environmentally superior. Given the fact that organic and conventional cropping system differ in production level, the expression per area must be complemented. Expressing emissions per unit product provides a representative measure of environmental impact of crop production. Low emissions per area can result in high emissions per product (Figure 2).

Considering emissions per yield is still an arbitrary comparison of systems. The need for more organic arable land to produce the same amount of crop requires full attention on the comparison between organic and conventional cropping systems. Consequences of land use change—converting forests, grassland, or wetland into arable land—result in lost products (timber, fiber, energy, etc.) and lost ecosystem services (sequestered carbon in soil, wildlife, biodiversity, etc.) (Figure 3). Such drastic measures are often of greater environmental significance than differences at the field level. Consequently, the pro-environmental profile of organic farming becomes uncertain when consequences of land use change are included in organic system evaluations.

The view on nature determines reasoning about organic farming

Nature's beauty and magnificence often determines our view and reasoning about nature including our opinion about organic farming. If one assumes nature to be the most ideal system, natural means and methods are considered to be superior, and consequently organic agricultural practices are favored. An idealistic belief in the superiority and goodness of nature is often one root cause as to why one prefers natural products and methods. A personal valuation of nature seen as more ideal than man-made systems can be a strong motivation to argue for organic farming. Also the initiators of organic farming methods were convinced that nature is our master and therefore abandoned synthetic fertilizers and pesticides.

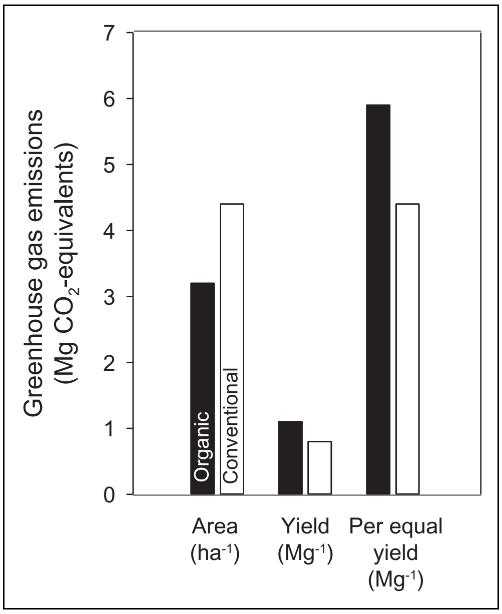

Figure 2. Gaseous emissions expressed as CO_2 equivalents (including CO_2, N_2O, and CH_4) for winter wheat from a comparative organic and conventional field study. Data from Flessa et al. (2002). Mean organic wheat production was 3.0 Mg (yield ratio 0.54) and mean conventional 5.6 Mg ha^{-1}.CO_2: carbon dioxide; N_2O: nitrous oxide; CH_4: methane.

Organic food is often preferred as it is assumed to be natural and toxin-free, whereas conventional food is considered less healthy due to toxic pesticides, and so on. If asked why one prefers organic over conventional food, the answer can be that natural products represent excellent quality, and natural methods are a guarantee for a better environment. Again, naturalness is considered a prerequisite for sound food production. Typically, risks of nature's chemicals are often overlooked, although science teaches us that all food can contain wanted and unwanted compounds formed in nature. For example, toxicity of secondary compounds formed in crops can be much higher than that of synthetic pesticides (Ames, 1983; Ames et al., 1990a, 1990b; Shorrocks, 2017).

Nature's beauty and magnificence is a half-truth and crude measure. Detailed research and reductive science distinguishes between wanted and unwanted characteristics of nature and educates us about possibilities, limitations, and risks. Science corrects a one-sided, ideal, and romantic view on nature by comprehending nature's pros and cons. An insight that natural means and methods are insufficient to support civilization is the way forward.

Concluding remarks

Sufficient food supply is a cornerstone of human welfare, and lack of food is a tragedy leading not only to suffering and loss of life but also to inhuman behavior, political

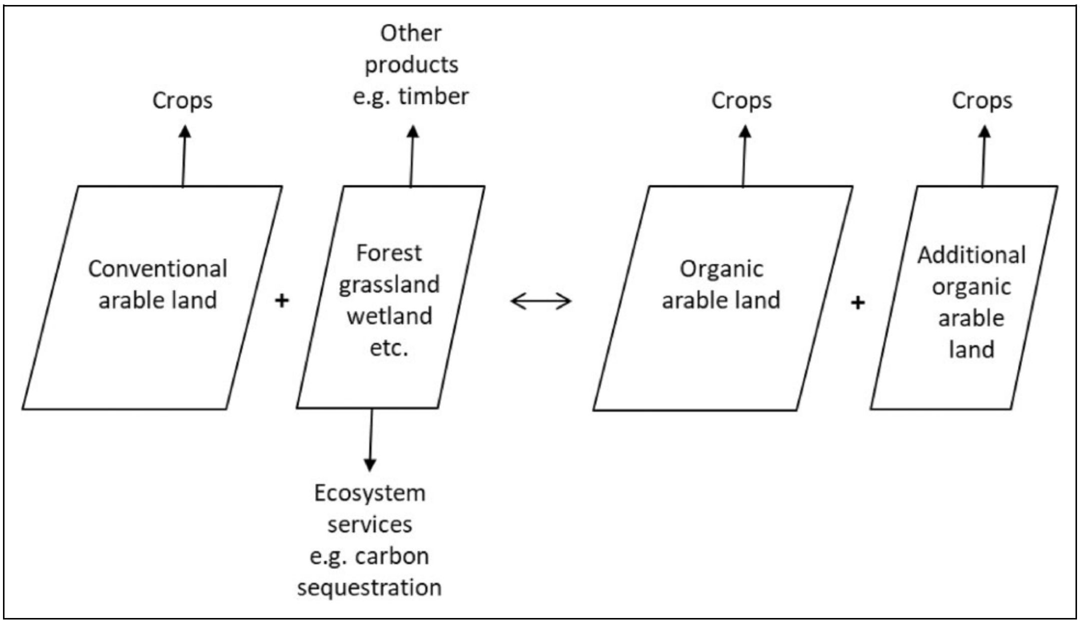

Figure 3. The areal comparison of Figure 1 was extended to illustrate the full consequences of converting natural ecosystems into arable land to compensate for yield gaps by organic crop production. The environmental consequences can include lost products (timber, fiber, energy, etc.) and loss of ecosystem services (sequestered carbon in soil, wildlife, biodiversity, etc.).

instability, and war (Borlaug, 1970). Data from large-scale organic farming (national statistics) indicate that to meet food demand, at least 50% more land needs to be transformed into arable land when converting to organic agriculture. More extensive production is not a true option to reduce the environmental impact of agriculture. In order to achieve full stomachs, clean water, clean air, and preserve natural land, more intense and improved farming methods on existing arable land must be developed. To save natural land is a great act of environmental protection.

Why am I so outspoken about organic farming? There is a bias in the concept of organic farming. The philosopher Dr Steiner, initiator of biodynamic farming, tutored that food products will degenerate through the use of mineral fertilizers to such an extent that these cannot be used as food for humans any more within this century (Steiner, 1924). The agronomist Lady E. Balfour, founder of the Soil Association, stated that artificial fertilizers speed up the rate at which soil organic matter is exhausted (Balfour, 1943). The medical doctor H-P. Rusch, initiator of biological–organic farming, wrote that mineral fertilizer is not a normal, physiological adapted and natural form of plant nutrition degenerating food quality (Rusch, 1978). Analyzing the original reasons why to abandon mineral fertilizers using relevant scientific literature showed that the statements of the initiators have been proved wrong (Kirchmann and Bergström, 2008). The belief of Steiner that mineral fertilizers significantly decrease food quality could not be proved, the opinion of Balfour about accelerated humus decline through mineral fertilizers was false, and the statement of Rusch was refuted as mineral fertilizers can be used as a crop-adapted, balanced, and quality improving nutrient source.

There is no scientific evidence for the validity of the concept to exclude mineral fertilizer for crop nutrition (Kirchmann and Bergström, 2008). However, if theories or concepts despite falsification are not rejected, the principal of science is ignored (Popper, 1959), and concepts become articles of faith or doctrines. Rejection of mineral fertilizers is often treated as a doctrine and background, motivation and proof is seldom asked for.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the authorship and publication of this article.

ORCID iD

Holger Kirchmann https://orcid.org/0000-0003-4779-412X

References

Alexandratos N and Bruinsma J (2012) *World Agriculture Towards 2030/2050. The 2012 Revision*. Rome: Agricultural Development Economics Division. Food and Agriculture Organization of the United Nations. Available at: www.fao.org/economic/esa (accessed 15 January 2019).

Ames BN (1983) Dietary carcinogens and anticarcinogens. *Science* 221: 1256–1264.

Ames BN, Profet M and Gold LS (1990a) Dietary pesticides (99.99% all natural). *Proceedings of the National Academy of Science of the United States of America* 87: 7777–7781.

Ames BN, Profet M and Gold LS (1990b) Nature's chemicals and synthetic chemicals: comparative toxicology. *Proceedings of the National Academy of Science of the United States of America* 87: 7782–7786.

Badgley C and Perfecto I (2007) Can organic agriculture feed the world? *Renewable Agricultural Food Systems* 22: 80–82.

Badgley C, Moghtander J, Quintero E, et al. (2007) Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems* 22: 86–108.

Balfour EA (1943) *The Living Soil: Evidence of the Importance to Human Health of Soil Vitality, with Special Reference to Post-war Planning*. London: Faber & Faber Ltd, 276 pp.

Berry PM, Sylvester-Bradley R, Philipps L, et al. (2002) Is the productivity of organic farms restricted by the supply of available nitrogen? *Soil Use and Management* 18: 248–255.

Borlaug NE (1970) *The Green Revolution, Peace and Humanity—Nobel Lecture, December 11, 1970*. Alabama: Agbioworld, Tuskegee Institute. Available at: https://www.nobelprize.org/prizes/peace/1970/borlaug/lecture/ (accessed 8 February 2019).

Borlaug NE and Dowswell CR (1994) *Feeding a Human Population That Increasingly Crowds a Fragile Planet*. In: *15th World congress of soil science, keynote lecture, supplement to transactions*, Acapulco, Mexico, 10–16 July 1994. Mexico: INEGI and CNA.

Connor DJ (2013) Organically grown crops do not a cropping system make nor can organic agriculture nearly feed the world. *Field Crops Research* 144: 145–147.

Connor DJ (2018) Land required for legumes restricts the contribution of organic agriculture to global food security. *Outlook on Agriculture* 21: 277–282.

de Ponti T, Rijk B and van Ittersum MK (2012) The crop yield gap between organic and conventional agriculture. *Agricultural Systems* 108: 1–9.

Drinkwater LE, Wagoner P and Sarranttonio M (1998) Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* 396: 262–265.

Flessa H, Ruser R, Dörsch P, et al. (2002) Integrated evaluation of greenhouse gas emissions (CO_2, CH_4, N_2O) from two farming systems in southern Germany. *Agriculture, Ecosystems & Environment* 91: 175–189.

Goulding K (2007) Nutrient management on farms, or 'You get out what you put in'. *Journal of the Science of Food and Agriculture* 87: 177–180.

Kirchmann H and Bergström L (2001) Do organic farming practices reduce nitrate leaching? *Communications in Soil Science and Plant Analysis* 32(7&8): 1007–1028.

Kirchmann H and Bergström L (2008) *Organic Crop Production—Ambitions and Limitations*. Dordrecht: Springer Science, 244 pp.

Kirchmann H, Bergström L, Kätterer T, et al. (2016a) *Dreams of Organic Farming. Facts and Myths*. Available at: http://pub.epsilon.slu.se/13967/ (accessed 15 January 2019).

Kirchmann H, Bergström L, Kätterer T, et al. (2007) Comparison of long-term organic and conventional crop-livestock systems in a previously nutrient-depleted soil in Sweden. *Agronomy Journal* 99: 960–972.

Kirchmann H, Kätterer T, Bergström L, et al. (2016b) Flaws and criteria for design and evaluation of comparative organic and conventional cropping systems. *Field Crops Research* 186: 99–106.

Korsaeth A and Eltun R (2000) Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen runoff in an 8-year field experiment in Norway. *Agriculture Ecosystem and Environment* 79: 199–214.

Lambin EF (2012) Global land availability: Malthus versus Ricardo. *Global Food Security* 1: 83–87.

Leifeld J (2016) Current approaches neglect possible agricultural cutback under large-scale organic farming. A comment to Ponisio et al. *Proceedings of the Royal Society B* 283: 20151623.

Leifeld J, Angers DA, Chenu C, et al. (2013) Organic farming gives no climate change benefit through soil carbon sequestration. *Proceedings of the National Academy of Sciences of the United States of America* 110: E984.

Muller A, Schader C, Scialabba NEL, et al. (2017) Strategies for feeding the world more sustainably with organic agriculture. *Nature Communication* 8: 1290.

Nowak B, Nesme T, David C, et al. (2013a) Disentangling the drivers of fertilizing material inflows in organic farming. *Nutrient Cycling in Agroecosystems* 96: 79–91.

Nowak B, Nesme T, David C, et al. (2013b) To what extent does organic farming rely on nutrient inflows from conventional farming? *Environmental Research Letters* 8: 044045.

Oelofse M, Jensen LS and Magid J (2013) The implications of phasing out conventional nutrient supply in organic agriculture: Denmark as a case. *Organic Agriculture* 3: 41–55.

Ponisio LC, M'Gonigle LK, Mace KC, et al. (2015) Diversification practices reduce organic to conventional yield gap. *Proceedings of the Royal Society B* 282: 20141396.

Popper K (1959) *The Logic of Scientific Discovery*. London: Hutchinson & Co, 544 pp.

Pretty J, Sutherland WJ, Ashby J, et al. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability* 8: 219–236.

Rusch HP (1978) *Bodenfruchtbarkeit. Eine Studie biologischen Denkens (Soil Fertility. A case of biological reasoning)*. Heidelberg: Haug Verlag, 3rd Printing, 243 pp.

SCB (2017a) *Use of agricultural land in 2016*. Statistics Sweden, JO 10 SM 1701. Available at: https://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Arealer/JO10/JO10SM1701/JO10SM1701.pdf (accessed 28 January 2019).

SCB (2017b) *Organic farming 2016, converted areas and areas under conversion*. Statistics Sweden, JO 13 SM 1701. Available at: https://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Arealer/JO13/JO13SM1701/JO13SM1701.pdf (accessed 28 January 2019).

SCB (2017c) *Production of organic and non-organic farming 2016. Cereals, dried pulses, oilseed crops, table potatoes and temporary grasses*. Statistics Sweden, JO 14 SM 1701. Available at: https://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Vegetabilieproduktion/JO14/JO14SM1701/JO14SM1701.pdf (accessed 28 January 2019).

Searchinger DT, Wirsenius S, Beringer T, et al (2018) Assessing the efficiency of change in land use for mitigating climate change. *Nature* 564: 249–253.

Seufert V, Ramankutty N and Foley JA (2012) Comparing the yields of organic and conventional agriculture. *Nature* 485: 229–232.

Shorrocks VM (2017) *Conventional and Organic Farming. A Comprehensive Review through the Lens of Agricultural Science*. Sheffield: 5M Publishing Ltd, 574 pp.

Steiner R (1924) *Geisteswissenschaftliche Grundlagen zum Gedeihen der Landwirtschaft (Spiritual Foundations for the Renewal of Agriculture)*. Dornach: Rudolf Steiner Nachlassverwaltung, 5th Printing 1975, 256 pp.