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Does organic farming reduce environmental impacts? – A meta-analysis of European research

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ABSTRACT

Organic farming practices have been promoted as, *inter alia*, reducing the environmental impacts of agriculture. This meta-analysis systematically analyses published studies that compare environmental impacts of organic and conventional farming in Europe. The results show that organic farming practices generally have positive impacts on the environment per unit of area, but not necessarily per product unit. Organic farms tend to have higher soil organic matter content and lower nutrient losses (nitrogen leaching, nitrous oxide emissions and ammonia emissions) per unit of field area. However, ammonia emissions, nitrogen leaching and nitrous oxide emissions per product unit were higher from organic systems. Organic systems had lower energy requirements, but higher land use, eutrophication potential and acidification potential per product unit. The variation within the results across different studies was wide due to differences in the systems compared and research methods used. The only impacts that were found to differ significantly between the systems were soil organic matter content, nitrogen leaching, nitrous oxide emissions per unit of field area, energy use and land use. Most of the studies that compared biodiversity in organic and conventional farming demonstrated lower environmental impacts from organic farming. The key challenges in conventional farming are to improve soil quality (by versatile crop rotations and additions of organic material), recycle nutrients and enhance and protect biodiversity. In organic farming, the main challenges are to improve the nutrient management and increase yields. In order to reduce the environmental impacts of farming in Europe, research efforts and policies should be targeted to developing farming systems that produce high yields with low negative environmental impacts drawing on techniques from both organic and conventional systems.

1. Introduction

Organic farming is often perceived to have generally beneficial impacts on the environment compared to conventional farming (Aldanondo-Ochoa and Almansa-Sáez, 2009; Gracia and de Magistris, 2008). Organic farming is regulated internationally by *Codex Alimentarius* Guidelines (established by The United Nations' Food and Agricultural Organisation (FAO) and the World Health Organisation) and by the International Federation of Organic Agriculture Movements' (IFOAM) Basic Standards. The latter are based on four principles (IFOAM, 2008): i) health: organic agriculture is intended to produce high quality food without using mineral fertilisers, synthetic pesticides, animal drugs and food additives that may have adverse health effects, ii) ecology: organic agriculture should fit the cycles and balances in nature without exploiting it by using local resources, recycling, reuse and efficient management of materials and energy, iii) fairness: organic agriculture should provide good quality of life, contribute to food sovereignty, reduce poverty, enhance animal well-being and take future generations into account, iv) care: precaution and responsibility have to be applied before adopting new technologies for organic farming and significant risks should be prevented by rejecting unpredictable technologies, such as genetic engineering.

Codex Alimentarius Guidelines and IFOAM Basic Standards provide a minimum baseline for national and regional standards worldwide. National standards take the local conditions into account and tend to be stricter than the IFOAM Basic Standards. In the European Union (EU), organic farming is regulated according to the European Council Regulation No 834/2007 (EC, 2007), which sets the basis for national standards in the EU. All organic producers are inspected by organic inspection bodies, which may be private or managed by government. In many countries private certification

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bodies have their own stricter standards than national standards require. In this paper, organic farming was regarded as farming that is certified according to national standards. Conventional farming in this paper, describes non-organic farming systems that use pesticides and synthetic fertilisers and other farming practices that are regionally typical.

A range of different approaches has been used in order to compare environmental impacts of organic and conventional farming systems. Some studies have focused only on a particular aspect, for example biodiversity (Bengtsson et al., 2005; Feber et al., 2007; Fuller et al., 2005; Hole et al., 2005; Rundlöf et al., 2008), land use (Badgley et al., 2007), soil properties (Maeder et al., 2002; Stockdale et al., 2002) or nutrient emissions (Syväsalo et al., 2006; Trydeman Knudsen et al., 2006). Some review studies have assessed the overall contribution of organic farming by combining the research from various impact categories (Gomiero et al., 2008; Hansen et al., 2001; Pimentel et al., 2005). Life Cycle Assessment (LCA) studies have used a product approach to assess the environmental impacts of a product from input production up to the farm gate (Cederberg and Mattsson, 2000; Thomassen et al., 2008). Mondelaers et al. (2009) used a meta-analysis to compare the environmental impacts of organic and conventional farming including studies from around the world, examining land use efficiency, organic matter content in the soil, nitrate and phosphate leaching to the water system, greenhouse gas (GHG) emissions and biodiversity.

The aim of this current study was to systematically review and analyse the studies comparing environmental impacts of organic and conventional farming in Europe. A meta-analysis was used to evaluate the results of peer-reviewed studies comparing the nutrient losses, biodiversity impacts, greenhouse gas (GHG) emissions, eutrophication potential, acidification potential, energy use and land use in organic and conventional farming systems in Europe. Aside from the different geographical focus, this study extends the work of Mondelaers et al. (2009) in covering a larger literature and in extending the coverage to include ammonia emissions, phosphorus emissions, eutrophication and acidification potential and energy use. In addition to comparing the environmental impacts of the systems, this paper also analyses the reasons for the differences between the systems and the reasons for the variation of the results across different studies.

2. Methods

2.1. Literature search

A systematic literature search was performed to find studies comparing environmental impacts of organic and conventional farming in Europe. The ISI Web of Knowledge (www.isiwebofknowledge.com) database was used. The search was performed on 26th September 2009 with no restriction on publication year. The following search term combinations were used: (organic AND conventional AND farming) OR (organic AND conventional AND agriculture). The preliminary search was refined to the subject areas “agriculture”, “plant sciences”, “environmental sciences & ecology” and “biodiversity & conservation”. The document type was defined as “article” and language as “English”. The search resulted in a list of 644 references. First the potential papers were selected based on the title and abstract. This resulted in a list of 275 papers. Finally the full papers were inspected and the papers included in this study were selected based on the following criteria: i) the study was related to European farming systems, ii) the study compared organic and conventional farming and provided quantitative results on at least one of the following aspects: soil organic carbon, land use, energy use, GHG emissions, eutrophication potential, acidification potential, nitrogen leaching, phosphorus losses, ammonia emissions or biodiversity, and iii) the paper was published in a scientific peer-reviewed journal. All types of studies (i.e. original field investigations, modelling studies and Life Cycle Assessment studies) were included in the study. This filtering resulted in 71 papers that were used in the meta-analysis and 38 papers that provided data for the biodiversity review.

2.2. Selection of indicators and data extraction

A range of indicators was selected in order to include all important environmental impact categories and also to compare different allocation methods and research approaches. The indicators were grouped to Life Cycle Assessment (LCA) and non-LCA indicators. LCA indicators were those where all impacts occurring during the production chain from input production up to the farm gate were taken into account (e.g. Thomassen et al., 2008), whereas a non-LCA indicator takes into account only the impacts occurring directly from the farming processes. LCA indicators generally aim at describing the magnitude of the final impact that may be caused by many pollutants, whereas non-LCA impacts in this study are only emissions of particular pollutants. LCA studies generally present the results by allocating the impacts per unit of product and per unit of field area, whereas non-LCA studies generally report results only per unit of field area.

From the 71 studies providing data for the meta-analysis, 170 cases were extracted, since each study generally provided results from multiple farming systems (e.g. arable farming and horticultural farming or, in a LCA study, different products). These cases provided 257 quantitative measures of the environmental impacts of organic and conventional farming. The studies included are presented in the Supplementary material (Table S1). Ten indicators were used to compare the environmental performance of the two systems (Table 1). Impacts were either reported per unit of field area, or per unit of product. In order to compare the impacts between the systems and explain the reasons for the differences, both quantitative and qualitative data were extracted from the studies.

In addition to the results, more data about each case were extracted, including detailed farming practices (e.g. fertilisation, organic matter inputs, crop rotation, crops, livestock and yields), location of the farm, type of the farm (experimental or commercial), number of farms and sample size. The studies were also grouped as either experimental or modelling studies. A study was regarded as a modelling study if the results were based even partly on secondary data or modelling instead of on direct experimental data. LCA studies were automatically considered as modelling studies as

Table 1
Indicators and allocation units used in the meta-analysis. Impacts were allocated per unit of ‘field area’ or per unit of ‘product’ (e.g. per tonne of wheat or pork).

	Allocation of impacts per unit of:	
	Field area	Product
1) Soil organic matter	√	
2) Nitrogen leaching	√	√
3) Nitrous oxide emissions	√	√
4) Ammonia emissions	√	√
5) Phosphorus losses	√	
6) Land use		√
7) Energy use		√
8) Greenhouse gas emissions		√
9) Eutrophication potential		√
10) Acidification potential		√
11) Biodiversity	√	