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Energy use and greenhouse gas emissions in organic and conventional farming systems in the Netherlands

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ABSTRACT

Organic agriculture is often considered to contribute to reducing energy use and greenhouse gas (GHG) emissions, also on a per unit product basis. For energy, this is supported by a large number of studies, but the body of evidence for GHGs is smaller. Dutch agriculture is characterized by relatively intensive land use in both organic and conventional farming, which may affect their performance in terms of energy use and GHG emissions. This paper presents results of a model study on energy use and GHG emissions in Dutch organic and conventional farming systems. Energy use per unit milk in organic dairy is approximately 25% lower than in conventional dairy, while GHG emissions are 5-10% lower. Contrary to dairy farming, energy use and GHG emissions in organic crop production are higher than in conventional crop production. Energy use in organic arable farming is 10-30% and in organic vegetable farming 40-50% higher than in their respective conventional counterparts. GHG emissions in organic arable and vegetable farming are 0-15% and 35-40% higher, respectively. Our results correspond with other studies for dairy farming, but not for crop production. The most likely cause for higher energy use and GHG emissions in Dutch organic crop production is its high intensity level, which is expressed in crop rotations with a large share of high-value crops, relatively high fertiliser inputs and frequent field operations related to weeding.

1. Introduction

Two of the most pressing sustainability issues are the depletion of fossil energy resources and the emission of atmospheric greenhouse gases (GHGs) carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) to the atmosphere. Agriculture consumes fossil energy and hence contributes to the depletion of fossil energy resources as well as to the emission of CO_2. With a share of 4.3% in the national total, direct energy use (i.e. on farm use of electricity and fuels for heating and machinery, including natural gas combustion in the greenhouse sector) in the Netherlands is relatively small [1]. However, indirect energy use in agriculture, i.e. energy use associated with the production of inputs and storage, transport and processing of outputs, is not included in this figure. Total direct and indirect energy use in the entire Dutch agro-food complex is not reported in statistics and estimates are not available.

Agriculture is both a sink and a source of atmospheric GHGs. Agriculture assimilates atmospheric CO_2 via crop production, part of which may be temporarily stored as organic matter in soils or used as a renewable energy source. Agriculture emits CO_2 by using fossil energy and through oxidation of soil organic matter. Nitrous oxide emits during storage and application of fertilizers and manures and CH_4 is a by-product of enteric fermentation in ruminant farm animals. In 2007, on farm emissions of N_2O and CH_4 in Dutch agriculture contributed 41 and 53% to the national total emissions of these two GHGs, and 7.5% to the national total emission of CO_2-equivalents [2]. As for energy, however, this estimate excludes all indirect emissions and CO_2 emissions from fuel combustion in agriculture. Formal estimates of all direct and indirect emissions of CO_2, CH_4 and N_2O caused by Dutch agriculture are lacking.

Organic agriculture is often considered to contribute to reducing energy use and GHG emissions, both on a per unit area basis as well as on per unit product basis. For energy, this is supported by a relatively large number of studies [3–9]. The body of evidence

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for GHGs is smaller [4,5,7,8,10], with some studies indicating not much differences between organic and conventional in terms of GHG emissions per unit product or organic suggested performing worse [11].

Energy use and GHG emissions per ha in organic farming are often considerably lower than in conventional farming, which can be attributed to lower input use per ha in organic farming. However, energy use and GHG emissions per ha are inappropriate indicators for an environmental impact with global dimensions. In this case, more legitimate indicators are energy use and GHG emissions per unit product. Because of generally lower yields per ha in organic farming [12], differences in energy use and GHG emissions per unit product between organic and conventional farming systems will be smaller than when expressed per unit area [4,13].

Due to high prices of labour and land, Dutch agriculture is characterized by relatively intensive land use in both organic and conventional farming [14–16]. This is expressed in many aspects of Dutch organic and conventional agriculture, including the adoption of crop rotations with a large share of high-value crops such as potatoes and vegetables, high animal stocking rates, the use of relatively high levels of external inputs such as feeds and fertilisers and weak links between animal production and crop production in terms of size and exchange of (by-) products [14]. With reference to the values of organic agriculture, De Wit and Verhoog [14] argue that Dutch organic agriculture shows signs of 'conventionalization'. In the process of conventionalization, organic farming develops toward a slightly modified version of modern conventional agriculture, in which economies of scale become increasingly important and farms increasingly rely on purchased off-farm inputs such as feeds, fertilizers and machinery. Such development might possibly have negative effects on issues like energy use, nutrient losses and recycling, all of which are core values of the organic farming community [14]. The question thus is whether in the Dutch context of intensive farming practices energy use and GHG emissions are different in organic and conventional farming systems. Based on earlier work [17], this paper presents results of a model study on energy use and GHG emissions in current Dutch organic and conventional farming practice, covering dairy farming, arable farming and field grown vegetables. The farming systems for which energy use and GHG emissions are quantified may be representative for intensified organic and conventional farming systems in densely populated regions elsewhere in Europe.

2. Methodology

2.1. Methodological considerations

When comparing organic and conventional farming, definition of the farming systems is critical [11,18]. Results of a study comparing a 'perfect' organic farming system (e.g., without imports of fertilizers and feeds, use of fertility building crops, high internal efficiencies) and a 'dirty' conventional system (e.g., standard fertilizations and sprayings, no catch crops, low internal efficiencies) will be different from those of a study comparing the opposite situation. Results may also be strongly influenced by the agricultural products that are part of the analysis. These may be products for which differences in yield per ha between organic and conventional are relatively small (e.g. grains, pulses, grass-clover), but it may also involve crops with larger yield differences such as potato *Solanum tuberosum* L. or vegetables [13]. Therefore, conclusions for one set of agricultural products may not hold for another. Ideally, the farming systems that are to be compared should produce the same products in equal ratios, i.e. the ratio of potatoes, white cabbage and milk produced within the organic farming system should match the ratio in the conventional farming system. While this may be hard to realize even in model studies, some degree of equality in the organic and conventional product sets ('food packages') that are to be compared is indispensible to avoid comparing apples and oranges.

2.2. Definition of model farms

This study quantifies direct (on farm) and indirect (upstream) energy use and GHG emissions resulting from agricultural production (Fig. 1). Energy use and emissions occurring downstream, i.e. after products leave the farm gate, have not been taken into account, with the exception of GHG emissions associated with N losses from the farming systems. Energy use and GHG emissions were quantified for farming systems reflecting current Dutch organic and conventional farming practice. In the Netherlands, most farms, whether organic or conventional, are specialized farms, producing either milk, arable crops or vegetable crops.

To cover the dairy farming sector, eight organic and six conventional specialized model dairy farms on sand and clay soils were defined [17]. In this paper only the results for four organic and three conventional model dairy farms on sandy soil are presented (Table 1), did not yield additional insights. Definitions of dairy model farms were based on model farms used in earlier studies [19,20]. Feed crops cultivated include grass and maize *Zea mays* L. on the conventional dairy farms and grass/clover mixtures and maize on the organic dairy farms. Farms were classified as 'intensive', 'average' or 'extensive' on the basis of pre-defined milk production per ha feed crops, covering the range in intensities found in practice. On all dairy model farms, stable types were slurry-based, except the extensive organic farms for which a slurry-based stable and a deep pit stable were defined. The definition of the model farms is such that the organic dairy farms were less intensive in terms of milk production per ha, used less concentrates per cow and applied more grazing than the conventional farms (Table 1), again reflecting current practice. The intensive and average conventional farms and the intensive organic farm exported part of their slurry.

To cover the arable and vegetable farming sectors, four model farms were defined, based on farming systems research over the past years [21–24]: one organic and one conventional arable farm on clay soil (both growing potato, sugar beet *Beta vulgaris* L., wheat *Triticum aestivum* L., carrot *Daucus carota* L., onion *Allium cepa* L. and pea *Pisum sativum* L.) and one organic and one conventional vegetable farm on sandy soil (leek *Allium porrum* L., bean *Phaseolus vulgaris* L., carrot, strawberry *Fragaria* L., head lettuce *Lactuca sativa* L. and Chinese cabbage *Brassica pekinensis* L.). Rotations in the two pairs of farms were similar, but not entirely equal (Table 2). Rotation length was four years on the conventional arable farm and six years on all other model farms. Standard crop yields were assumed. For conventional crops, these yields are 5-year averages as based on routinely sampling of data from a representative selection of agricultural holdings [25]. For organic crops, yields were based on organic farming systems research, summarised by Wijnands & Holwerda [26]. On the conventional farms, nutrient management is based on pig slurry and mineral fertilizers. Per ha on the conventional arable farm, 16 Mg pig slurry is applied in late summer, partly combined with catch crop cultivation. On the conventional vegetable farm, 15 Mg per ha pig slurry is applied in spring. Nutrient management on the organic farms was based on cattle slurry, solid cattle manure and vinasse, a by-product of the sugar beet industry containing readily available N. Spring applied fertilizer doses per ha on the organic arable farm are 16 Mg solid cattle manure, 4 Mg cattle slurry and 1.1 Mg vinasse. On the organic vegetable