Transition to renewable resources - energy balance comparisons of organic and conventional farming systems and potentials for the mitigation of fossil resource use

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Implications

Today, agriculture and food production has major implications for the use of fossil energy and other resources, and a sustainable development implies transition towards new systems, based on renewable resources (Dalgaard et al. 2011).
The reduction of external inputs to the farm through efficient management of materials and energy is a central part of the organic principles (IFOAM 2013), and in most countries standards are implemented in the form of nationally adapted, organic farming regulations, with significant implications for the potential energy and matter flows in- and out of the agricultural systems, and thereby the energy balance and the use of renewable resources.
Consequently, it is important to develop new and more resource efficient production systems mitigating organic farming's reliance on fossil resources, and to compare different pathways towards reduced resource consumption in agriculture.

Background and objectives

In the Danish strategy for development and growth in the organic sector (ICROFS 2008) reduction in the dependency of fossil fuels, together with the related reductions in greenhouse gas emissions and the import of non-organic nutrients has been identified among the most important research areas; which are also highly prioritized in other Nordic countries (Sundberg et al. 2013a, Løes et al. 2013).
As input to the track two discussions about "Transitions to renewable resource" during the NJF seminar no. 461 on "Organic farming systems as a driver for change" this paper presents examples from Danish research, where energy inputs and outputs are compared for organic and conventional farming systems. In these examples, it is quantified how conversion to organic farming effect both the direct and indirect fossil energy embedded in the inputs to agriculture, and how the organic farming regulation of input factors effects the output produced, and thereby the energy balance given as the fossil energy use per unit of product produced in organic and conventional farming, respectively.
These results are presented in addition to the other track two studies presented during the seminar, including studies on organic agriculture's contribution to reach long-term climate goals (Sundberg et al. 2013a) and climate gas and nitrogen emission mitigation via increased grassland productivity and carbon storage (Eriksen et al. 2013) or new green manure management strategies (Carter et al. 2013). Other studies focus on reduced fossil fuel dependency in the whole food chain (Sundberg et al 2013b), in the fields (Johansson 2013) or the livestock housing systems (Koesling et al. 2013), and various aspects and potentials for synergies between different types of organic farming, and new higher biomass production systems, in combination with biogas production (Loes et al. 2013, Råberg et al. 2013, and Gunnarson et al. 2013 among others).
Based on this it is the aim to facilitate the discussion and make conclusions and recommendations for further research and development of more sustainable organic farming systems based on more renewable resources.

Key results and discussion

Scenarios for developments in the agricultural sector has shown significant effects of conversion to organic farming as a measure to reduce both the net energy use, the emissions of greenhouse gases, and nitrogen losses (Dalgaard et al. 2011, 2003; Halberg et al. 2007; Pugesgaard et al. 2013). For all major types of crops, the average energy use was lower for organic compared to conventional farming (Table 1), but the average yields were also lower (Dalgaard et al. 2001).

Table 1. Modelled average energy use in MJ/SFU* for the major crop types in Danish Agriculture (Dalgaard et al. 2001). *) 1 SFU equals the fodder value in 1 kg of barley.

	Cereals	Grass/Clover	Row crops	Permanent grass
Conventional farming	2.7	2.4	2.4	1.0
Organic farming	2.2	0.9	1.8	0.7

For dairy livestock production we see the same overall tendency, where conventional farming show a higher production per ha, but at the same time an even higher energy consumption; especially with higher energy inputs embedded in feed and fertilisers imported (Figure 1).

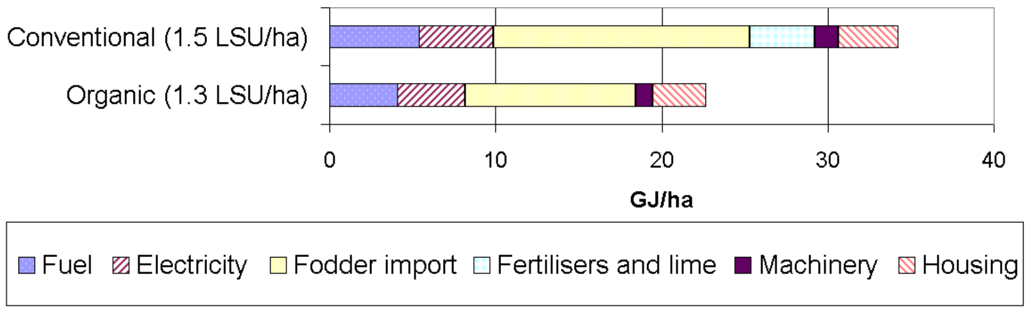

Figure 1. Average energy use per area in the organic and conventional dairy farm sector of Denmark (Dalgaard et al., 2003). 1 LSU equals one dairy cow of large race.

In both organic and conventional systems there are significant potentials for energy savings in the range of 0-20% (Meyer-Aurich et al. 2013, Dalgaard et al. 2006), but to move the systems further towards fossil energy and climate gas emission neutrality, the inclusion of energy production in form of combined energy and food systems are needed.

It has been assessed that a positive fossil energy balance could be achieved for organic farming in Denmark via large scale implementation of Short Rotation Coppice (SRC) production, but on the cost of a potentially, relatively higher reduction in the food production (Jørgensen et al. 2005, Dalgaard et al. 2006). Therefore other possibilities, where energy production can be combined with the existing food production, have moreover been investigated. For instance, Christen and Dalgaard (2013) showed promising results for the use of buffer strips along water courses to catch nutrients, and harvest biomass for bioenergy; for instance in the form of SRC or Short Rotation Forestry (SRF) harvested for Combined Heat and Power (CHP) production, or green matter for biogas production.

In that context, Pugesgaard et al. (2013) evaluated a range of organic biogas production systems, and concluded that a significant surplus energy production in the form of heat and electricity could be produced (Figure 2). These systems also reduced the greenhouse gas emissions from between 4.2-4.4 Mg CO_2-eq./ha/yr in the reference situations (Ref. A and B) to respectively 2.9 Mg CO_2-eq./ha/yr and 2.8 Mg CO_2-eq./ha/yr in systems where biogas was produced from either grass-clover or silage maize harvested on 10% of the area (S1 and S2), compared to 0.8 Mg CO_2-eq./ha/yr and 0.6 Mg CO_2-eq./ha/yr in systems where either 20% of the area was harvested for grass-clover biogas production and the dairy production was reduced proportionally and substituted by a higher cash crop production (S3), or an additional 20% area with meadow grassland was harvested and added to the biogas production on top of the 20% grass-clover area harvested (S4).

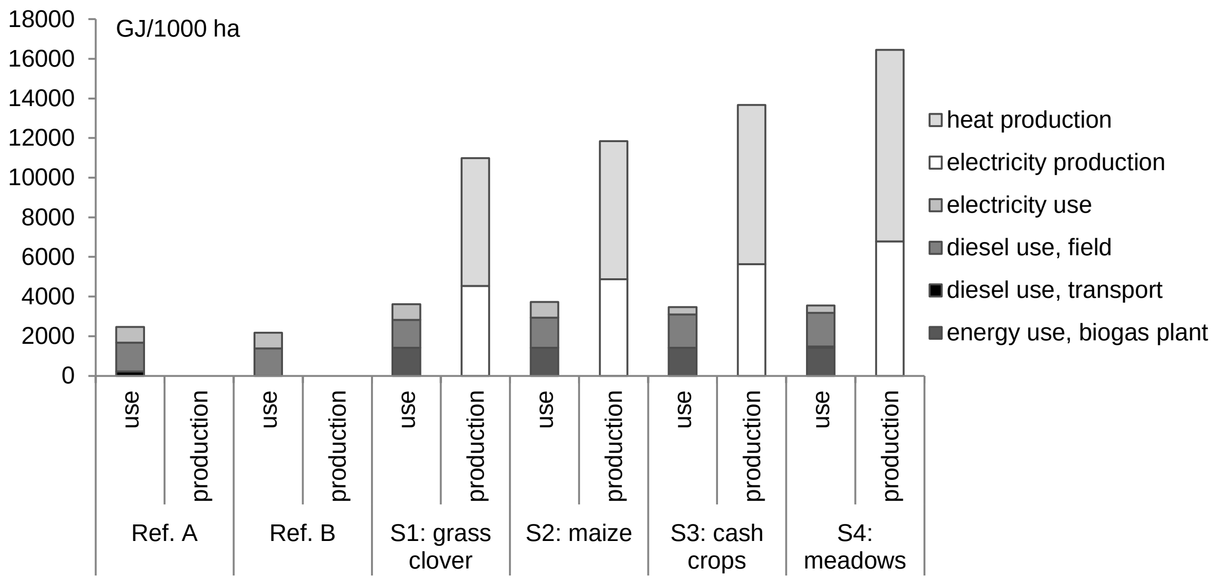

Figure 2. Comparison of energy use versus energy production on organic model dairy farms without biogas (Ref. A with slurry import, and Ref. B without slurry import), and three scenarios for conversion to organic farming with biogas production based on Grass Clover (S1), Maize (S2), increased cash crop production with maize for biogas, and reduced livestock production (S3), and biogas production based on imported meadow grass (S4). (Pugesgaard et al., 2013). *) Diesel use for transport includes solely external import of slurry and organic matter.

Summary

Based on the presented examples and literature studies it is concluded that

- Typically, conversion to organic farming leads to a lower total fossil energy use. However, organic farming practices also result in a lower amount of production per area of agricultural land, another product quality, and eventually another product price than per unit of similar conventional products.
- In the examples presented, the reductions in the energy inputs were higher than the reductions in outputs from the production. Consequently, the energy efficiencies, defined as output per energy input, are typically higher in organic compared to conventional farming examples.
- A higher use of locally produced forage crops in organic dairy production may reduce the energy use via reductions in the energetically costly import of concentrates.
- The fossil energy use reductions lead to similar reductions in emissions of carbon dioxide (CO_2). This gas contributes with between one fourth and one third of the total greenhouse gas contribution from agriculture.
- There are high potentials for synergies between bioenergy production, improved nutrient cycling, and emissions of nutrients and other greenhouse gasses than CO_2.
- The potential for bio-energy production is higher in conventional than in organic farming. Fully utilizing this potential, conventional farming apparently has a more favourable energy balance and a lower net greenhouse gas emission than organic farming. However there are still many unanswered questions concerning possibilities for combined food-energy systems, which may change this conclusion.

References and acknowledgements

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