Organic farming without fossil fuels – life cycle assessment of two Swedish cases

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Implications

Organic agriculture is dependent on fossil fuels, just like conventional agriculture, but this can be reduced by the use of on-farm biomass resources. The energy efficiency and environmental impacts of different alternatives can be assessed by life cycle assessment (LCA), which we have done in this project. Swedish organic milk production can become self-sufficient in energy by using renewable sources available on the farm, with biogas from manure as the main energy source. Thereby greenhouse gas (GHG) emissions from the production system can be reduced, both by substituting fossil fuels and by reducing methane emissions from manure. The arable organic farm studied in the project could be self-sufficient in energy by using the residues available in the crop rotation. Because of soil carbon losses, the greenhouse gas emission savings were lower with the use of straw ethanol, heat and power (9%) than by using ley for biogas production (35%).

In this research project, the system boundaries were set at energy self-sufficiency at farm or farm-cluster level. Heat and fuel were supplied as needed, and electricity production was equal to use on an annual basis. In practice, however, better resource efficiency can be achieved by making full use of available energy infrastructure, and basing production on resource availability and economic constraints, rather than a narrow self-sufficiency approach.

Background and objectives

One principle of organic farming is the use of renewable resources, yet it depends on fossil fuels. However, with new technologies and the increased emphasis on reduction of GHG emissions, this may change soon. Biomass offers opportunities for energy supply, but requires energy and land, and causes emissions. There are various biomass sources, as well as different technical options. Which of these are preferable? Are there enough biomass residues to supply energy to the production system, or is it necessary to take land from food production for fuel supply? This paper summarizes the findings of our research on how to supply organic agriculture with energy produced on its own land, and the environmental consequences of such production. Greenhouse gas emissions and energy balance of crop production (described in detail in Kimming et al. 2011) and milk production (Kimming et al. 2013) in renewable energy supply systems mainly based on bioenergy were compared with systems based on fossil fuels.

Key results and discussion

The annual energy demand for the milk farm with 100 cows was 300 GJ electricity (0.14 MJ/kg milk), 115 GJ for grain drying and 95 GJ for heating of buildings. Annual tractor fuel demand was 460 GJ. In the arable farm, heat was supplied to the residential building (dimensioned capacity 7.4 kW) the hot water system (1.2 kW), the workshop (1.7 kW) and the grain dryer (227 kW). The total annual tractor fuel demand was 414 GJ, electricity demand was 51 GJ and heat demand 290 GJ.

In the milk production system, biogas from manure was the main energy supply in all scenarios. In Scenario M1, biogas produced from manure and cut straw covered the entire energy demand. In Scenario M2, the manure on the farm was utilized to produce biogas, assumed to be combusted in a CHP system (gas engine). Rapeseed oil was assumed to be used to produce rapeseed methyl ester (RME) in a small-scale production unit at the farm. The tractors ran on RME with minor modification of the original diesel engines. Grain produced on the farm was assumed to be dried in a furnace fuelled with wheat straw from 4 ha.

In the arable system, one scenario (A1) was based on biogas from ley. Assumptions were largely the same as in the milk system. Scenario A2 was based on straw, which was converted to ethanol via hydrothermal pretreatment, to enzymatic hydrolysis and fermentation in a large-scale ethanol plant. The lignin is separated out during hydrolysis and was assumed to be used in an integrated CHP plant for production of process steam and electricity, as well as surplus electricity to cover the power demand of the farm.

The fossil energy savings were 2.63 MJ of primary energy per kg milk in the milk production system and 755 GJ for the whole 200 ha farm in the arable system. In addition to greenhouse gas savings from reduced fossil fuel use, there were substantial savings on the milk farm from the reduction in methane emissions when manure was passed through an anaerobic digestion process before storage. In the arable farm study, the GHG emission saving was 35% in the self-sufficiency scenario based on ley (A1) and 9% in that based on straw (A2). There was less nitrous oxide from the soil in both self-sufficiency scenarios compared with the reference scenario, but the impact on the carbon content of the soil differed significantly, with a larger reduction in soil carbon content when straw was removed from the fields.

In both the milk and the arable system, the biomass resources available as residues on the farm were sufficient for supply of energy for the production. There was consequently no need to reduce the production of food products, or increase the land area needed for the total production system.

How work was carried out

We investigated a crop-based production system with a seven-year crop rotation, as well as a system for milk production, where all feed was produced on the farm. Since the goal was to investigate the impact of changing to a new energy supply system, consequential LCA was used for these studies. The substitution method was used to avoid allocation.

The functional unit (FU) used was 1 kg energy-corrected milk at the farm-gate for the milk study. For the arable farm, the FU was the total supply of energy (heat, electricity and vehicle fuel) for the 200 ha organic farm for 1 year. Impact categories were energy balance and global warming potential (GWP100). GHG emissions were calculated according to IPCC Guidelines (IPCC 2006). In addition, the soil carbon balances of the cultivation systems studied were simulated with the ICBM (Andrén and Kätterer 2001).

For each system (crop or milk) self-supply scenarios and a fossil reference system were defined. The biomass energy systems included straw for power, heating and ethanol; ley, manure and straw for biogas generating power, heat and fuel; and willow for heat and power. The selected technologies are available today, at least at the pilot or demonstration level. The investigation focused on biomass potential, energy balance and GHG emissions.

References

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