Evaluation of conventional and organic agricultural production in relation to primary energy inputs and certain pollution gas emissions

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13 Summary

The aim of this study is to evaluate organic and conventional agricultural production in Germany with respect to energy input and specific pollutant gas emissions. The study draws on data and statistics available in national and international scientific publications via the usual library services. In some instances, primary research or personal communication are used where adequate data are not available.

The focal point is the calculation of the primary energy consumption and CO\textsubscript{2}, CH\textsubscript{4}, N\textsubscript{2}O, NH\textsubscript{3} emissions arising from production using inventory analysis. Inventory analysis is the data collection and calculation phase of life-cycle assessment. The systematic approach required of the inventory analysis reveals gaps in knowledge and helps identify the research required to obtain a complete picture. This study is targeted at the decision-makers, in particular the Federal Ministry of Agriculture, Forestry and Food, who are interested in energy consumption and the environmental impact of the different agricultural production methods. All institutes of the Federal Research Centre for Agriculture were informed of the project and requested to participate. An interdisciplinary working group of scientists who defined the approach to be adopted was set up.

At the start of the work, an attempt was made to quantify the CO\textsubscript{2}, CH\textsubscript{4}, N\textsubscript{2}O and NH\textsubscript{3} emissions from all production steps up to the harvesting or the farm gate. However, the study of the literature revealed that the data on biogenic pollutant gas emissions are not available or are of inadequate quality to carry out such a comprehensive quantitative comparison. Hence the model calculations were limited to the production and use of farm inputs. In addition, the current state of knowledge in the field of biogenic pollutant gas emissions is documented and discussed in the context of such a comparison.

Use of production inputs and associated primary energy input and pollutant gas emissions

Energy inputs and pollution gas emissions can be calculated on the basis of individual farm data or on the basis of production statistics and practice guidelines. Obtaining farm based data on a sufficient scale was impossible in this study so the situation of agriculture in the Federal Republic of Germany was reproduced as representatively as possible using statistical data on average production methods and output. This approach allows the comparison of agricultural practices of organic and conventional farming in Germany regardless of individual farm circumstances.

A comparative consideration of all agricultural production methods cannot be carried out within this study. Hence it was necessary to select products. Products for study were selected on the basis of:

1. the utilisation of the arable land in the Federal Republic of Germany,
2. the economic values of plant and animal products.

On this basis, wheat, barley, forage maize, oilseed rape, sugar-beet, potatoes, pork and milk were chosen. Rye and pulses were also included in the comparison because they play a major role in organic farming.
The quantitative system comparison takes into account the production and use of farm inputs. The system boundaries exclude capital goods, labour and biogenic pollutant gas emissions. The allocation of resource consumption and emissions between primary products and by-products, or crops in a rotation, was avoided as far as possible. For rotations, it was confined to cultivation of pulses in organic farming where 50% of the production effects is allocated uniformly to four of the crops following the pulse crop. Allocation in dairy farming was based on the economic value of the products. Hence 90% of the primary energy input and pollutant gas emissions arising from keeping dairy cows was allocated to the milk and 10% to the calf.

Five production systems were studied. These are four conventional systems (K\text{TN}O \text{K}_{\text{RED}}, \text{K}_{\text{TE}1-3} \text{and RS}), and the organic system (ÖKO). The conventional system (K\text{TN}O) is based on production statistics typical of specialised animal and crop production in Germany using data available in the literature. It draws on data for industrial feed-stuffs production published by the TNO in the Netherlands, hence the label K\text{TN}O for milk and pork. The resource conserving (RS) system is a hypothetical conventional system based on the efficient use of organic manure to supplement synthetic fertilisers in crop production and local production and processing of animal feed-stuffs in animal production. The K\text{TE}1-3 system is an animal production system based on assumptions concerning the industrial production of animal feed-stuffs from German grown raw materials provided by the FAL Institute for Animal Nutrition (TE) and with different aspects for the energy-input of by-product of the industrial food-production. The K\text{RED} is a system were the K\text{TN}O data have been subjected to sensitivity analysis: The primary energy inputs into the production of industrial feed-stuffs is reduced by 30% compared with the TNO literature data.

The results show that the primary energy input on a land area basis is clearly higher in conventional farming (K) than in organic farming (ÖKO). The area-related primary energy input of the organic system is 41% of the conventional production method for the cultivation of grain, 27% for rape, 42% for root crops, 27% for maize silage, 32% for grass silage and 72% for pulses. The area related weighted mean energy input for non-leguminous organic crops in the Federal Republic of Germany is 34% of the conventional crops.

Despite a lower crop yield in organic farming, a higher primary energy input was calculated for conventional farming (K) in the unit output based comparison. The primary energy input per tonne product for organic farming is 66% of the conventional farming system for grain, 42% for rape, 78% for root crops, 64% for maize silage, 40% for grass silage and 59% for pulses. This higher primary energy input in conventional farming is caused primarily by the use of mineral nitrogen fertilisers. The primary energy input per product for the resource conserving system, which takes into account combined mineral and organic fertilisation, is the same, or sometimes lower than, in the organic cultivation system.

In the animal production sector the primary energy input in the conventional system (K\text{TN}O) compared to the organic is 53% higher per tonne of pigs produced (live weight) and 85% higher per tonne of milk. This difference is attributed to the lower primary energy inputs into the feed production in organic farming. In the conventional resource conserving system, based on resource conserving local feed-stuffs production and processing, the primary energy input per product was about half that of the conventional system (K\text{TN}O) based on industrial compound feeds. Compared to the organic system a slightly smaller primary energy input per animal product was calculated for the resource conserving system.

A 30% reduction (in relation to K\text{TN}O) in the primary energy input for industrial concentrate feed production (K\text{RED}) reduces the total energy input in milk and pig production by 14%
28 \% respectively. In pig-meat production this leads to small differences between the conventional and organic systems. When interpreting these data it must be taken remembered that the $K_{\text{RED}}$ variant is based on a highly optimistic energy saving on the data in the literature.

The data for the resource conserving system indicates that the primary energy input in animal husbandry can be reduced by reducing energy inputs into feed-stuffs production, whereas changes in the animal production technology have limited influences on primary energy inputs. As data on energy inputs into industrial feed-stuffs are currently very limited, the extent of these possibilities cannot be quantified at present.

The farm input related $\text{CO}_2$, $\text{CH}_4$ and $\text{N}_2\text{O}$- emissions are generally higher both per hectare farmland and per tonne product in conventional farming (K) than in organic farming. The area-related greenhouse gas emissions for grain, root crops and forage crops in conventional farming are about three times those in organic farming. In relation to the product, greenhouse gas emissions are calculated to be twice as high in conventional production. The contribution of agriculture to the anthropogenic greenhouse effect is thus higher with conventional farming. This is attributable primarily to the energy consumption for the production of mineral nitrogen fertilisers in conventional farming. Partial substitution of mineral fertilisers by organic farmyard manure permits significant reductions in greenhouse gas emissions. The hypothetical resource conserving conventional system does not differ from the organic system with regard to the greenhouse gas emissions for most products.

In the animal production sector no quantitative statements concerning its contribution to the anthropogenic greenhouse effects can be made at present. This is primarily because the greenhouse gas emissions associated with the production and supply of industrial compound feeds cannot be calculated from available data. As the industrial feed-stuffs account for the highest proportion of the primary energy input, it can be expected that the greenhouse gas emissions reflect primary energy inputs.

**Biogenic pollutant gas emissions**

Knowledge of biogenic pollutant gas emissions ($\text{CO}_2$, $\text{CH}_4$, $\text{N}_2\text{O}$, $\text{NH}_3$) in the agricultural sector as affected by production methods is still lacking. General data are available for conventional production, but data for organic production are not sufficient to allow a comparison. Hence a comparison of conventional and organic agricultural production, which was the aim of this study, can be derived only by an attempt to apply previously known relationships from the conventional sector to organic farming. The evaluation is therefore largely qualitative, and partially based on assumptions rather than data from comparative studies.

For biogenic $\text{CO}_2$-emissions advantages cannot be claimed for either of the two farming methods. After passing through a change-over phase to organic farming, a steady state equilibrium in carbon exchanges adopted to the respective farming method and local conditions will be established in the long term.

For biogenic $\text{CH}_4$-emissions, there are indications that the $\text{CH}_4$-oxidation potential of agricultural soils can be increased by the substitution of mineral N-fertilisers with organic fertilisers. Current knowledge indicates that the methane emissions per animal in the animal production sector will change only slightly with a change to organic production both as regards emissions directly from the animals and the emissions from the housing and storage of manure.
Because of the lower production performance of the animals in organic farming, higher CH$_4$-emissions can be expected on a unit output basis.

Lower N$_2$O-emissions are expected from organically farmed land. At present, it is not possible to evaluate to what extent the intensified use of farm manure, increased legume cultivation, and the use of undersowing reduce the N$_2$O-emissions. Slightly higher N$_2$O-emissions are expected from organic animal production. Literature data indicate that housing with deep litter, as required in organic farming, results in increased N$_2$O-emissions. It should be remembered that the N$_2$O-emissions from livestock is low compared to emissions from farmland.

The NH$_3$-emissions of arable land in conventional farming in relation to the use of mineral fertilisers are on average proportional to the fertiliser quantities used. There are currently no methods for estimation of the extent to which the substitution of mineral N-fertilisers by organic farm manure and legume cultivation, as specified in organic farming, will affect the NH$_3$-emissions. It is acknowledged that the design of the spreading method for farm manure is decisive for the NH$_3$-emissions. However, conventional and organic farming do not use significantly different methods, so that an evaluation of this is not possible. It is likewise currently not known what differences can be expected from animals and the housing system. Test results indicate tendentiously that the slurry system in conventional pig fattening may lead to higher NH$_3$-emissions than the solid manure system of organic pig fattening. It can be assumed that with higher animal performance, the excretion rates per unit animal output fall.

**Conclusion**

A form of farming with reduced use of mineral N-fertiliser by integration of crop and animal production combined the use of the local concentrate feed-stuffs production is advantageous with regard to primary energy consumption and greenhouse gas emissions. Such a system can be conventional or organic. This does not take account of the biogenic greenhouse gas emissions because data on these are not sufficient to allow a comparison between production systems. Although this study applies inventory analysis more rigorously than previous studies, there is good general agreement between these results and those in the literature. The report provides comprehensive detailed data sets providing a basis for further analyses. The gaps in knowledge for comprehensive evaluation of agricultural production methods with regard to the primary energy input and pollutant gas emissions were revealed and the research requirement was highlighted.