Organic farming and the challenges of climate change

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Climate change is without question one of the largest challenges that humankind has ever faced. This is not the least due to the enormous consequences that climate change will have for ecosystems and human society. Unfortunately, climate change also poses a very difficult problem for politicians to deal with. The core of the problem affecting modern democracies is that most people experience very little relationship between greenhouse gas emissions, climate change and their everyday life. There is both a temporal and spatial separation between emissions and impacts of climate change. The industrialized countries, which currently emit most of the greenhouse gases, are in general the least vulnerable to climate change effects. Additionally, many of the detrimental effects of climate change will happen far later (decades to centuries) than the greenhouse gas emissions. It is therefore difficult to achieve substantial popular support for necessary and effective measures to mitigate climate change.

Agriculture and food production plays an important role in this connection due to the importance of climate change for agriculture's production basis and because of the large emissions of greenhouse gases from agriculture. For agriculture, the climate change challenge is therefore double – it must both adapt to the changes and at the same time reduce its emissions of greenhouse gases.

Agriculture's emissions

Agricultural production results in emissions of several greenhouse gases, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Methane and nitrous oxide are 23 and 296 times more powerful greenhouse gases than CO_2.

CO_2 from biological processes is in principle neutral in relation to the global warming, since CO_2 assimilated from the atmosphere during plant photosynthesis will eventually be transformed in the ecological food-web and respired again as CO_2. However, there are large stores of carbon in soils and vegetation that if released will more than triple current atmospheric CO_2 concentrations. Therefore even small changes in soil and vegetation stocks through changes in land use and management may significantly affect global warming. In particular, conversion of forests to agriculture and the cultivation of carbon rich wetlands can lead to large emissions of CO_2 and N_2O. Further, agriculture has an energy consumption, primarily of fossil fuels, that also contributes to CO_2 emissions. This can in part be compensated for through use of biomass for energy production.

The carbon contents of agricultural soils can be influenced through the addition of crop residues and animal manure. The increase in soil carbons storage is particularly large under grasslands, and a part of the carbon accumulation occurs in the subsoil. In addition, the intensity of soil tillage plays a role for soil carbon storage. Adoption of no tillage systems, which reduces soil disturbance, will thus lead to reduced soil organic matter turnover and increased soil carbon contents.

Methane is formed during decomposition of organic material under completely anaerobic (oxygen-free) conditions, such as those found in the digestive systems of animals and in ecosystems that are permanently waterlogged (e.g., from rice paddies). Ruminant digestion is the greatest single source of methane in agriculture. However, methane can also be formed during manure storage, in particular from liquid manure stored at relatively high temperatures. There are some possibilities for reducing methane emissions from enteric fermentation by changing feeding practices, e.g. by increasing the fat content of feed and substituting sugar with starch in the feed. Treatment of manure in biogas plants has large potentials for reducing the greenhouse gas emissions from manure storages.

Nitrous oxide is primarily formed as an intermediate product in the bacterial nitrogen cycle. It can be formed either through the nitrification of ammonium to nitrate or through the denitrification of nitrate to dinitrogen (N_2). In either case, nitrous oxide formation depends on the availability of mineral nitrogen (ammonium and nitrate) in the soil. A number of soil conditions affect the bacterial nitrogen cycle leading to nitrous oxide emissions, including high water content, a mixture of anaerobic and aerobic zones, accessibility of organic matter, and soil pH. Emissions of nitrous oxide can be reduced by avoiding excessive nitrogen fertilisation and reducing losses through ammonia volatilisation and nitrate leaching. Measures that increase soil aeration will tend to reduce nitrous oxide emissions during periods of high soil mineral nitrogen concentrations.

On a global scale, greenhouse gas emissions from agriculture are estimated at 17-32 per cent of total emissions. A very large proportion of this is related to livestock production. The large uncertainty is related to how much of the emissions from clearing forests and cultivation of new land can be attributed to agriculture.

Climate impacts of food consumption

European studies have shown that the consumption of food products, beverages, tobacco and other stimulants contributes 21-31 % of the total EU greenhouse gas emissions. Meat and dairy products are the foods that have the greatest impact on climate (see Table 1). Vegetables generally have the smallest contribution to global warming.

Agricultural production is the link in the production chain, which for all food products is associated with the largest emissions, whereas in general only a smaller part of the emissions come from manufacturing, packaging and transport. Initiatives to support climate-friendly food should therefore primarily be directed to improving agricultural practices.

Life-cycle analyses of food production systems in Denmark have shown that the annual emissions of a milk cow is about 14 ton CO_2, from a sow with associated production of fatteners about 7.5 ton CO_2, and arable crop production about 3.5 ton CO_2 per ha. An analysis of available measures for reducing emissions show that the realistic potential for emissions reductions in Danish agriculture is about 15, 20 and 30 % for dairy, pig and arable production systems, respectively. At the global level the largest reduction potentials are found for accumulation of carbon in restoring degraded lands and avoiding CO_2 emissions from intensive cultivation of peat soils.

Emissions from organic farming

Organic farming contributes to emissions of the same greenhouse gases as conventional farming. However, management is in many respects different in organic systems, and this affects both soil carbon storage and emissions of methane and nitrous oxide. There are few experimental and modelling studies that compare greenhouse gas emissions from organic and conventional farming. However, they mostly point to lower emissions from organic systems on a per area basis, whereas there is often little difference in emissions, when organic and conventional systems are compared on a unit product (kg or litre) basis. This is particularly the case for cool temperate climates, where conventional systems normally out-yield organic systems. The higher rate of soil organic matter turnover in warmer climates improves crop nitrogen supply under organic farming in these climates, and organic farming therefore typically does not result in large yield reductions in warm temperate, subtropical and tropical climates. This also means that the greenhouse gas effect of organic farming will be relatively more positive for warmer climates.

In some respects organic farming provides clear benefits over conventional systems: (1) No fertilisers or pesticides are used, which eliminates the energy consumption associated with the inputs, (2) The biological nitrogen fixation reduces the nitrous oxide emissions during cultivation of legume crops, (3) the higher proportion of green manure crops, cover crops and use of animal manure builds soil carbon contents, and (4) a better soil structure in organic farming reduces risks of high nitrous oxide emissions. However, there are also some possible disadvantages, including the need for intensive soil cultivation to manage weeds, and the nitrous oxide emissions associated with incorporation of nitrogen rich green manure crops and cover crops.

There has so far been little attention within the organic farming research and advice on reduction of the greenhouse gas emissions, and in many respects a better understanding of how management in organic farming affects the processes giving rise to greenhouse gas emissions is needed. There are likely many opportunities for making organic farming systems more climate-friendly. A better integration of bioenergy systems into organic farming would assist this, e.g. through growing perennial nitrogen fixing crops for bioenergy purposes and use of anaerobic digestion of manure and crop residues to produce biogas and improve the quality of manures.

Impacts and adaptation to climate change

Climate change affect cropping systems through a wide range of direct and indirect pathways. The effects may be positive or negative depending on current climate and soils, and depending on the direction of change. So far, research on climate change impacts in agriculture has given little emphasis on changes in frequency of extreme events. However, the impacts of increased climate variability on plant production are likely to increase yield losses above those estimated from changes in mean climate only. This is primarily linked with changes in the frequency of extreme heat waves and changes in rainfall patterns, including more intensive precipitation events and longer drought periods. Changes in climate variability may be particular difficult for many farmers to adapt to, and adaptation strategies to cope with variability may be different than from those dealing with changes in mean climate. Strategies for adapting to increased variability may include measures to avoid periods of high stress or measures that increase resilience of the system by adding diversity in the crop rotation and improving soil and water resources.

Most of the processes causing soil degradation are enhanced by climate change, being promoted by higher temperatures, more intense rainfall and longer drought periods, which lead to lower soil carbon stocks, increased soil erosion and salinization. Yet, higher soil carbon contents and better soil structure will be critical for cropping systems to cope with increased climate variability. There is clearly a need within research, advice and policy to focus more on those aspects of agricultural systems that build resilience. Organic farming has a large role to play here, since such practices to increase resilience are intrinsic components of organic farming systems. Evidence is also accumulating that the agroecological approaches taken in organic farming provide considerable protection of crop and land under heat waves as well as tropical storms.

Table 1. Global warming effects of different food products rated on energy content (kg CO_2-equivalent per MJ).

Food in supermarket	Global warming contribution (kg CO_2-eq. per MJ)
Beef	1.47
Cheese	0.84
Low-fat milk	0.59
Pork	0.46
Chicken, whole fresh	0.41
Eggs	0.31
Onions	0.20
Wheat flour	0.08
Carrots	0.08
Potato	0.06
Oat meal	0.05

Data from www.LCAfood.dk and the National Food Institute, DTU, Denmark, adapted by Lisbeth Mogensen, Aarhus University, Faculty of Agricultural Sciences