Changing agriculture in a changing climate

Changes in weather patterns are going to affect agriculture with impacts differing according to region. The developing countries can reckon with the first effects. The authors look at the role that organic agriculture can play in adaptation. They assess the potential that organic agriculture could have but also look at the contribution that agriculture itself is making to climate change and examine how organic agriculture fares in this respect.

"Year after year the monsoon starts later and the drought period prolongs, putting a heavy charge on crop production. Then, rains start and the degraded soils cannot absorb enough of the water. The gift becomes a punishment and crops and humans suffer again. Climate changes and our cropping practices have to change as well to assure our survival." Such statements can increasingly be heard from farmers in Southern India, for example.

Climate change is real. Mitigation measures have to be taken, but even with strong action, climate change will increasingly affect societies and the environment. For agriculture, the most pressing question is how to assure food production in a changing climate, or, framed differently, how to adapt to climate change. The more mitigation action is taken, the easier this task will be. Thus, the other important question is how agriculture may contribute to climate change mitigation.

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The effects of climate change on agriculture

Climate change affects agriculture in various ways. CO_2 levels, temperatures and climate variability and the frequency of extreme events such as heavy rain, floods and droughts will increase. Increasing CO_2 levels and moderately higher temperatures lead to higher production, but beyond temperature increases of 1.5 °C – and global forecasts go well beyond that – production generally decreases. Precipitation, crop growing seasons and weed, pest and disease pressure will change, but the direction of these changes will vary between regions. The general pattern is that low-latitude dry zones will shift to higher latitudes and precipitation will increase around the equator and in high latitudes. These changes will also affect current monsoon and El Niño patterns and effects on water availability and irrigation water requirements can be huge. Generally, these impacts will be larger and increasingly negative in the second half of our century and the negative impacts will be earlier and stronger in lower latitudes. Most affected by food insecurity and livelihood decline are thus developing countries, including the poorest.

Adaptation in organic agriculture

Key topics for adaptation in agriculture can be derived from the future climate change impacts. First, assuring water availability and optimised water management will be crucial. Agricultural production has to better cope with water scarcity and drought,

The late onset of monsoon rains is forcing more and more farmers to change their cropping practices.

but also with waterlogging and flooding. Second, as impacts vary strongly between regions, locally adapted strategies are needed. Third, increased weed, pest and disease pressure will put stress on agricultural production and necessitate a focus on sustaining strong and healthy plants. Fourth, agricultural production faces increasing variability and risks in production conditions.

Organic agriculture is a promising strategy to face these challenges. Many of its core concepts and practices focus on sustaining healthy and fertile soils with high organic carbon levels, a well-aerated structure and a rich diversity of the soil biota. Such soils are able to absorb large amounts of water from heavy precipitation without water logging or erosion. They also store the available water better, thus hedging against water scarcity and droughts and reducing irrigation needs. Practices that support such healthy soils are the use of organic fertilisers such as compost, manure or mulch layers from crop residues, reduced tillage and avoidance of ploughing, and the incorporation of deep rooting forage legumes in crop rotations. Organic agriculture also exhibits a high level of

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Soil carbon sequestration

Plants build organic matter from atmoshperic CO_2 via photosynthesis. Decaying plant matter such as roots after harvesting or crop residues and organic fertilisers such as compost or manure are transformed by biological, chemical and physical soil processes and deposit this organic carbon in soil organic matter, viz. humus. Humus contains fractions of different stability and parts of it remain stored in the soil for a long time, while other parts are decomposed fastly and emitted as CO_2 over time.

diversity among crops, crop rotations and production practices.

Organic agriculture uses local knowledge which is highly adaptive to local variations, and combines it with modern agro-ecological methods. Moreover, the high diversity on organic farms improves economic and ecological stability and increases resilience against adverse impacts of climate change. A higher diversity of income sources hedges against the risk of crop losses. Optimised and diverse crop rotations can break life-cycles of pests. Landscape elements such as fallow land, buffer or flower strips provide resorts for beneficial animals.

Diversification towards combined crop and livestock production also increases resilience. Grasslands can be used for animal feed production, also in situations where no crops can be grown, in particular on marginal and degraded lands. This adds to food security, as it helps utilising land for human nutrition that cannot be used for this directly via crops. Economic risk is also reduced as organic agriculture is a low external input farming system. Absence of costly farm inputs reduce potential financial losses from crop failure, while net profits can still be higher than for conventional farms, in particular if organic price premiums can be realised on the markets. The risk of indebtedness is thus reduced, which is particularly important for smallholders and poor farmers as it helps to avoid the poverty trap.

Agriculture's contribution to climate change

While agriculture is strongly affected by climate change, it is also contributing significantly to it. Direct emissions from agriculture account for 10–12 per cent of total global greenhouse gas emissions. Including emissions from land use change, such as from deforestation to gain cropland, this share rises to 20–30 per cent. The most important direct agricultural emissions are N_2O emissions from fertilised soils and methane emissions from the digestive processes in ruminants, each accounting for 30–35 per cent of total global direct agricultural emissions. Overall, most important are indirect CO_2 emissions from land use change such as deforestation to gain new cropland, reaching about the same level as total direct agricultural emissions. Methane and N_2O from biomass and crop residues burning accounts are next important, together with methane from rice fields (each between 10–15 % of total direct agricultural emissions). Methane and N_2O emissions from manure management and storage, CO_2 and N_2O emissions from fertiliser production and CO_2 emissions from fossil fuel consumption for irrigation and farm machinery are each between 5–10 per cent of total direct agricultural emissions.

Mitigation in organic agriculture

The mitigation potential of agriculture is about the same size as its direct emissions, mainly through soil carbon sequestration (see Box above). Thus, synergies occur between mitigation and adaptation as organic practices increase soil fertility and soil carbon stocks and improve water management of soils. Organic agriculture might also reduce N_2O emissions. While much is still unclear regarding the dynamics of N_2O emissions depending on soil management, fertiliser type and soil characteristics, the correlation between inputs and stocks of plant-available nitrogen in the soil and N_2O emissions is robust and significant.

Nitrogen is a scarce resource in organic agriculture. Therefore, over-fertilisation is less a topic and nitrogen input levels tend to be lower than in conventional agriculture. This translates in generally lower N_2O emissions per hectare and per tonne except for cases where organic yields are exceptionally low. However, nitrogen-use efficiency is often higher in organic systems, which works again towards lower emissions. How these competing factors sum to net emissions per kilogram produce depends on the concrete situation.

Taking a narrow view, organic agriculture does not perform well regarding the other big emission category, namely methane from ruminants. Concentrate-fed ruminants emit less methane than roughage-fed animals. In addition, higher milk yields per cow further reduce emissions per litre milk for conventional production. Yet this picture changes totally when accounting for the production emissions of the concentrate feed. While adequately managed grasslands and pastures can sequester carbon, intensive soy or maize production for concentrate feed emits large amounts of greenhouse gases. Those stem from fertiliser production and use and from soil carbon losses, in particular if these crops are grown on areas gained from recent land use change, e.g. from deforestation or from conversion of pastures to croplands, as it is common in the big soy producing countries in South America. Furthermore, maximising milk yields increases diseases and reduces animal longevity. This increases emissions per kg produce, as the unproductive rearing phase of a larger amount of replacement animals has to be accounted for. To conclude, methane emissions from ruminants show-case the necessity to adopt wide system boundaries.

Organic livestock production is pasture based with adequate, rather low stocking densities. It supports animal health and longevity. Such systems can be carbon neutral as the sequestration in pastures can compensate the methane emissions from animals and manure management. Clearly, less meat and milk is produced in such systems. Sustainable livestock production also shows the necessity to address other aspects than climate change mitigation in agricultural production only. Consumer aspects are relevant as well. Mitigation in the livestock sector is only possible if less meat and milk is consumed. This does not only mitigate climate change but it contributes to resource efficiency in general, as intensive, concentrate-based meat and milk production is very inefficient in providing calories for human nutrition regarding soil, water, nutrient and energy use.

Livestock production illustrates the need for wide system boundaries in other contexts, too. Conventional stockless arable farms depend on synthetic fertilisers while manure and slurry from conventional livestock farms is often disposed rather than efficiently used, leading to greenhouse gas emissions and other environmental problems such as water pollution. This problem is mitigated in organic production systems, where farmyard manure is used efficiently as a fertiliser in crop production, be it on-farm on mixed crop-livestock farms or be it on a regional level between different farms.

Organic agriculture also performs favourably regarding other greenhouse gas emission categories. As open burning of biomass is prohibited in organic systems, the corresponding emissions are avoided. The use of the biomass waste and residues, legume leys and manure as organic fertilisers reduces emissions from fossil fuel use, as energy intensive synthetic fertiliser production is avoided. Organic agriculture usually uses 20 to 50 per cent less fossil energy per hectare and per unit produce than conventional agriculture. This advantage is less marked in cases where weed control is a challenge to organic production and necessitates additional machinery and fuel use.

A particular challenge is rice production. Methane emissions from flooded rice fields can be higher in organic systems, due to the use of organic fertilisers. Switching to different water management such as partial flooding, as promoted in the system of rice intensification SRI, for example, reduces methane emissions but leads to increased N_2O emissions. Further research is needed to determine the net effect of such a change in practices.

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Livestock systems with low stock densities can be carbon neutral. However, lower milk and meat production are the inevitable consequence.

Less soil capping after heavy rains: Soils under organic management have better drainage and water-holding capacity, as the DOK long-term system comparison in Switzerland shows.
Left: Field with mineral fertiliser.
Right: organic field.

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Resource use and organic agriculture

Organic agriculture generates other benefits besides its favourable performance regarding climate change mitigation and adaptation. Its focus on soil fertility directly conserves the resources "healthy and fertile soils" and "water". Reduced and efficient use of nitrogen improves water quality, as runoff and eutrophication can be reduced. The absence of synthetic pesticides also conserves soil and water resources from pollution. Furthermore, the use of organic fertilisers contributes to conserve fertile soils as well, as there are strong indications that the use of synthetic fertilisers can cause losses of soil organic matter. The use and recycling of organic matter helps to conserve phosphorous resources and fossil fuels are conserved due to the reduced energy needs. Finally, local and regional air quality is improved in regions where biomass burning is still common practice, as this is avoided in organic agriculture.

Most of these resource conservation effects are synergies of both the mitigation and adaptation measures resulting from practices that increase soil organic carbon levels. The holistic approach of organic agriculture is in contrast to some mitigation measures promoted in conventional agriculture, such as feed additives to reduce methane emissions from ruminants. Such additives improve feed energy uptake in animals but lead to adverse health effects without any benefits for adaptation. On the other hand, increasing soil organic carbon levels and the corresponding organic core practices such as organic fertilisers or legume leys in crop rotations are increasingly being promoted for climate change mitigation and adaptation in conventional contexts as well.

A systemic, holistic approach is needed

Best agricultural mitigation and adaptation practices complement each other and ideally have further benefits. In particular, mitigation in agriculture needs to look beyond farm production and has to address consumer behaviour and diets. Consumer behaviour is also key when it comes to food waste. In the North, 30–40 per cent of food produce is wasted due to quality and freshment requirements and the demand for continuous availability. In the South, a similar amount is lost due to poor storage. Halving these losses would already reduce agricultural emissions by 15–20 per cent.

Challenges

First, organic yields are 15 to 25 per cent lower than conventional yields under best geo-climatic conditions in intensively farmed regions. If food waste cannot be reduced, organic agriculture thus needs more land than conventional production. However, in less intensive contexts and under water scarcity, organic yields are on a par or even higher than conventional yields (see article on pages 9–13). **Second,** organic agriculture is a complex and knowledge-intensive farming system. Due information and extension services need to be established to assure success of its implementation. **Third,** it is unknown, among other knowledge gaps, how different qualities of synthetic and organic fertilisers compare on a life-cycle basis.

Finally, the strategy of eco-functional intensification as promoted by organic agriculture needs to be scientifically further developed and integrated into dissemination work. It focuses on farm-ecosystem management and on the improved and sustainable usage of ecosystem services like fertile soils, high-diversity habitats, pollination and the soil-food webs. Climate change mitigation, the adaptive capacity to adverse effects of climate change and, finally, the food security of billions will depend on this.

A full list of references can be obtained from the authors and at:
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