Organic Agriculture: As a Climate Change Adaptation and Mitigation Strategy

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Abstract:

Organic agriculture, as an adaptation strategy to climate change and variability, is a concrete and promising option for rural communities and has additional potential as a mitigation strategy. This article is a short review of this topic. Adaptation and mitigation based on organic agriculture can build on well established practice because organic agriculture is a sustainable livelihood strategy with decades of use in several climate zones and under a wide range of specific local conditions. The financial requirements of organic agriculture as an adaptation or mitigation strategy are low. Further research is needed on yields in organic agriculture and its mitigation and sequestration potential.

Keywords: Organic agriculture, Adaptation, Climate Change, Mitigation, Sustainable

Introduction

Organic agriculture is one among the broad spectrum of production methods that are supportive of the environment. Organic production systems are based on specific standards precisely formulated for food production and aim at achieving agro ecosystems, which are socially and ecologically sustainable. It is based on minimizing the use of external inputs through use of on-farm resources efficiently compared to industrial agriculture. Thus the use of synthetic fertilizers and pesticides is avoided. Codex Alimentarius Commission (FAO/WHO) defines "Organic farming as holistic food production management system, which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system". Organic farming is not only a specific agricultural production system, it is also a systemic and encompassing approach to sustainable livelihoods in general, where due account is given to relevant factors of influence for sustainable development and vulnerability, be this on physical, economic, or socio-cultural levels (Eyhorn, 2007). Organic farming has a long tradition as a farming system and it has been adapted for many climate zones and local conditions; as a result, much and detailed situation-specific information on organic farming is available.

According to the Inter-governmental Panel on Climate Change (IPCC) agriculture currently accounts for 10-12% of global greenhouse gas (GHG) emissions and this figure is expected to rise further. However, this accounting includes only direct agricultural emissions; emissions due to the production of agricultural inputs such as nitrogen fertilizers, synthetic pesticides and fossil fuels used for agricultural machinery and irrigation are not calculated (IPCC, 2007).GHGs attributed to agriculture by the IPCC include emissions from soils, enteric fermentation (GHG emissions from the digestion process of ruminant animals), rice production, biomass burning and manure management (Smith et al., 2007). There are other 'indirect' sources of GHG emissions that are not accounted for by the IPCC under agriculture such as those generated from land-use changes, use of fossil fuels for mechanization, transport and agro-chemical and fertilizer production. The global estimate of natural and anthropogenic sources of Methane (CH4) is presented in Table 1.

The most significant indirect emissions are changes in natural vegetation and traditional land use, including deforestation and soil degradation. Soil carbon losses caused by agriculture account for one tenth of total CO_2 emissions attributable to human activity since 1850. Deforestation is a common land-preparation practice in many agricultural regions that leads to massive loss of carbon stocks and massive CO_2 emissions. The IFOAM Basic Standards for Organic Production and Processing prohibit the clearing of primary eco-systems. The world's soil is however a major store of carbon– approximately three times the amount in the air and five times as much in forests (Bellarby et al., 2008). In general climate is one of the main determinants of agricultural production and climate alteration might cause variability in agricultural production. As climate pattern shifts, changes in the distribution of plant diseases and pests may also have adverse effects on agriculture. At the same time, agriculture proved to be one of the most adaptable human activities to varied climate conditions (Mendelson et al., 2001). It should be necessarily mentioned that refraining from the use of synthetic inputs does not qualify an operation as organic, as far as it is not accompanied by a proper farm design and management that preserves natural resources from degradation.

Organic agriculture (OA) offers an alternative production system and, to a certain degree, has a different food supply and consumption pattern (FDB, 2010). However, climate change mitigation has not traditionally been considered a benefit of organic agriculture. It is covered to a minor degree because it restricts use of mineral fertilizer which promotes the use of manure and, in turn, tends to increase the carbon sequestration in the soil. However, in order to comply with the organic principles (International Federation of Organic Agriculture Movements, 2005) and preserve credibility as the most environmentally friendly production system with regard to climate change, the effect of organic agriculture and food systems on GHG emissions needs to be investigated (Niggli et al., 2008; Scialabba and Muller‐Lindenlauf, 2010). While organic agriculture has a number of aims and possible benefits, such as those related to biodiversity, soil quality, animal welfare, avoidance of pesticides and fairness in the production chain, there is also a need to address how organic agriculture performs in terms of GHG emission, how this is assessed, and what options should be considered for improvement.

The following pages outline how organic agriculture, used as an adaptation strategy, has the potential to address the combined threats of climate change and variability and other stresses. These pages should be read as a short, compact review of the potential of OA as an adaptation strategy and also a mitigation strategy, based on published literature (including reports and web-references), thus providing ample reference for further details. It combines different strands of literature from both the "organic community" and the "climate community."

It also aims at fostering discussion on OA as an adaptation and mitigation strategy beyond the "organic community." Adaptation entered the agenda more prominently only recently, while mitigation has been a topic for long time. This is also reflected in the fact that there is more research available on OA as a mitigation than as an adaptation strategy (e.g., Niggli et al. 2008, IFOAM 2006, 2007, 2008; AgroEco 2006; and also Kotschi and Müller-Sämann 2004). Organic agriculture as a mitigation strategy faces many technical complexities (carbon sequestration and greenhouse gas emissions avoidance measurement and accounting, assessment of differences in crop rotations and practices, etc.), while the biggest challenges for OA as an adaptation strategy are more of a socio-cultural matter. Potential synergies between adaptation and mitigation strategies in agriculture do, however, exist (Rosenzweig and Tubiello 2007; IPCC, 2007a).

In this paper, the main challenges posed by climate change and variability that can be addressed by OA as an adaptation and mitigation strategy are outlined after a short introduction to organic agriculture. The focus is OA as an adaptation strategy because it still receives less attention in the literature. Organic agriculture as a mitigation strategy is covered only cursorily, but references for further reading are given.

Benefits of Organic Agriculture in relation to climate change mitigation

With the right type of agriculture, emissions leading to climate change can be minimized and the capacity of nature to mitigate climate change can be harnessed to sequestrate significant quantities of atmospheric carbon dioxide – especially in the soil. The environmental costs of conventional agriculture are substantial, and the evidence for significant environmental amelioration via conversion to organic agriculture is overwhelming (Kler et al., 2001 and Kler et al., 2002). A review of over 300 published reports (Stolze et al., 2000) showed that out of 18 environmental impact indicators (floral diversity, faunal diversity, habitat diversity, landscape, soil organic matter, soil biological activity, soil structure, soil erosion, nitrate leaching, pesticide residues, CO_2, N_2O, CH_4, NH_3, nutrient use, water use and energy use) is presented in (Table 2), organic farming systems performed significantly better in 12 and performed worse in none. There are also high preconsumer human health costs to conventional agriculture, particularly in the use of pesticides (Conway and Pretty, 1991). It is estimated that 25 million agricultural workers in developing countries are poisoned each year by pesticides (Jeyaratnam, 1990).

Global adoption of organic agriculture has the potential to sequester up to the equivalent of 32% of all current man-made GHG emissions (Robert Jordan et al., 2009). Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It utilises ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. It combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 1998).

1. Recycling wastes of plant and animal origin in order to return nutrients to the land, thus minimizing the use of non-renewable resources;
2. Reduce global warming by lowering emission of greenhouse gases hence temperature rise;
3. Enhances biological diversity within the whole system and increase soil biological activity
4. Minimizes indiscriminate use of pesticides affects on human and animal health, biodiversity of wildlife etc. & cause of environmental pollution.
5. Maintains long-term soil fertility and overcome micronutrient deficiency.
6. Reduce energy loss for both animal and machine, and risk of crop failure.
7. Promote the healthy use of soil, water, and air, as well as minimize all forms of gaseous pollution that may result from agricultural practices.
8. Highly adaptive to climatic change due to application of traditional skills, farmers knowledge, soil fertility building techniques and a high degree of diversity.

Adaptation

Agriculture is highly vulnerable to climate change and our food supply relies on successful adaptation. Adaptation actions include those necessary to restore the resilience of eco-systems and their productivity to enable sustainable economic development. Organic agriculture increases the ability of the farming system to continue functioning when faced with the adverse effects of climate change by increasing resilience within the agro-ecosystem (Borron, 2006 and Ensor, 2009). Organic agriculture creates robust and environmentally benign farming systems that are resilient to temperature extremes, drought and which avoid soil erosion. Organic agriculture also promotes sustainable community based ecosystem management, conservation and restoration activities (Table 3).

The financial requirements of organic agriculture for adaptation are low. Additional costs mainly come from information provision, education and extension services. Organic agriculture however offers innovative farmer based group systems that facilitate best practice knowledge exchange in a systematic and cost free manner. This is particularly important for the empowerment of vulnerable and poor people in rural populations that rely on agriculture for their livelihoods. The basic principles of organic farming help farmers and communities to adapt against the vulnerable effect of climate change. Organic agriculture fulfils many of the requirements identified for successful adaptation strategies (Muller, 2009).

Greenhouse gas emissions of organic versus conventional farming system

A number of studies have evaluated the general environmental impacts of organic versus conventional products and farming systems, mainly in the European or North American context (e.g. Gomiero et al., 2008; Mondelaers et al., 2009). Other published studies have specifically evaluated the Australian (Wood et al., 2006) and Canadian (Lynch, 2009) contexts. The overall conclusions have shown:

- organic matter – soils in organic farming systems have, on average, a higher content of organic matter (e.g. Mäder et al., 2002; Fliessbach et al., 2007; Mondelaers et al., 2009; Murmu et al., 2013);
- biodiversity – organic farming contributes positively to agro-biodiversity and natural biodiversity (e.g. Bengtsson et al., 2005; Hole et al., 2005; Mondelaers et al., 2009);
- pesticides – organic agriculture minimizes the risk of conventional pesticide accidents and pollution, even though some substances such as copper are allowed in organic agriculture in some countries;
- GHG emissions – the conclusion is not that straightforward when assessing the impact of the organic farming system on GHG emissions and nitrate and phosphorous leaching; when expressed per production area, organic farming performs better than conventional farming for these impacts (e.g. Mondelaers et al., 2009), but due to generally lower yields of organic farming, at least in developed countries, this positive effect expressed per unit product is less pronounced or not present at all (Mondelaers et al., 2009).

Soil carbon sequestration impacts on global climate change

Organic agriculture can offer sustainable carbon credits. Although the financial rewards of the credits will likely be moderate, they could support financing the transition from a conventional to an organic system or the adoption of certain climate-friendly practices in both plant and animal production. In addition to their mitigation impact, credits related to organic farming practices offer a variety of valuable co-benefits, such as their indirect contribution to food security, yield stability, sustainability and adaptation to climate change, as can be seen specifically in plant and animal production. The Carbon sequestration by organic and conventional farming systems is presented in Table 4.

Estimates of the total potential of C sequestration in world soils vary widely from a low of 0.4 to 0.6 Gt C/year (Sauerbeck, 2001) to a high of 0.6 to 1.2 Gt C/year (Lal, 2003). Thus, the potential is finite in capacity and time. The global soil carbon (C) pool of 2500 gigatons (Gt) includes about 1550 Gt of soil organic carbon (SOC) and 950 Gt of soil inorganic carbon (SIC). The soil C pool is 3.3 times the size of the atmospheric pool (760 Gt) and 4.5 times the size of the biotic pool. The SOC pool to 1-m depth ranges from 30 tons/ha in arid climates to 800 tons/ha in organic soils in cold regions, and a predominant range of 50 to 150 tons/ha. Conversion of natural to agricultural ecosystems causes depletion of the SOC pool by as much as 60% in soils of temperate regions and 75% or more in cultivated soils of the tropics (Table 5 and 6).

In plant production, the potential for generating carbon credits is mainly seen in compost use, biomass waste and manure storage and handling, fertilizer avoidance, biogas production, agroforestry and in avoided biomass burning. Due to the huge areas under agricultural production, soil carbon sequestration has a considerable global mitigation potential, although the potential per hectare is usually rather low and thus not ideal for the existing carbon crediting mechanisms.

In animal production, the main potential for generating carbon credits is seen in improving lifetime performance by reducing GHG emissions per unit of output. The reduction of concentrate feed has a huge mitigation potential due to the land-use impact of concentrate feed production. However, capturing this in the existing carbon crediting mechanisms will be difficult, mainly due to the global system boundaries often involved. The potential co-benefits of these credits are manifold such as increased energy efficiency, improved livelihoods, improved biodiversity and soil organic matter, and longer term soil fertility, system stability and resilience.

Organic Agriculture – a Strategy to Mitigate Climate Change

Agriculture and all other forms of land use offer two options for the reduction of greenhouse gases. One is to reduce emissions and, thereby, to minimise the production of atmospheric CO_2, CH_4 and N_2O. Agriculture shares this avoidance strategy with industry and other sectors. The second option consists in systematically sequestering CO_2. Human induced sequestration is an option confined to agriculture and other types of land use. Unlike oceans which act as a sink of greenhouse gases in equilibrium with the atmosphere, but with a diminishing contribution as concentrations rise and water temperatures increase, soil and vegetation are sinks that can be systematically used.

The main organic strategies are diversification and an increase of soil organic matter, which both could enhance resilience against extreme weather events. Organic farming avoids nutrient exploitation and increases soil organic matter content, hence soils under organic farming capture and store more water than soils under conventional cultivation. Production in organic farming systems is thus less prone to extreme weather conditions, such as drought, flooding, and water logging. Organic farming accordingly addresses key consequences of climate change, namely increased occurrence of extreme weather events, increased water stress and drought, and problems related to soil quality (IPCC, 2007a).

The greatest potential for reducing greenhouse gas emissions from agriculture would be to change consumer behaviour. Production of meat requires inputs that are seven times as high as the inputs needed to produce the same quantity of non-meat calories. Organic agriculture aims at precisely this goal: consumption of less-processed products and increased consumption of products like cereals, potatoes, pulses and oils.

Greenhouse gas emissions are highest in beef production (CO_2 equivalents per kg meat are higher than 10,000 g), followed by pork, poultry and egg production (2,000 to 3,000 g CO_2 equivalents per kg) and milk (approximately 1000 g CO_2 equivalents per kg). Emissions from production of plant foods are generally below 500 g CO_2 equivalents per kg (Bos et al., 2007; Nemecek, 2006, Ökoinstitut, 2007, Küstermann et al., 2007).

Although ruminants (cattle, sheep, goats) are major methane emitters, they are crucial to global food security as they tap into an area of 3,432 million hectares worldwide that is not suitable for crop production. These animals carry bacteria in their rumen that make plant material digestible, that other animals are hardly able to use, but unfortunately this fermentative process is also emitting methane.

With regard to the mitigation of climate change, important passages from the basic principles in Organic Agriculture are:

- To encourage and enhance biological cycles within the farming system.
- To maintain and increase long-term fertility in soils.
- To use as far as possible, renewable resources in locally organized production systems.
- To minimize all forms of pollution. (IFOAM, 1998)

But the key principle of Organic Agriculture is that it gives priority to the optimal use of inputs and aims to achieve an optimal not a maximal output. "Optimal" in this context means that inputs are used in such a way that they are recycled and can be used again; the term "inputs" is used in a wide sense: it includes natural resources, which are otherwise often called "externalities", such as soil, water, nutrients, energy and biodiversity. Thirdly, unlike conventional agriculture, the maximization of outputs is only of secondary importance.

Managing the farm as an "organism" (Koepf et al., 1976) and respecting the characteristics of natural ecosystems with their four basic parameters: productivity, functional stability, diversity and self-regulative capability (Haber, 1979 cited in Raupp, 2000) represent the overall concept to follow the principles mentioned above. The mitigation potential and direct and indirect reduction on agricultural greenhouse gas emissions arising from the principles of organic agriculture are presented in Table 7 and 8.

Conclusion

Agriculture is currently the most cost-effective, market-ready way to remove carbon dioxide from the atmosphere. Scientific research is needed to determine which agricultural techniques, practices, and systems will achieve actual climate mitigation.

The Farming Systems Trial offers an opportunity to examine the climate mitigation potentials of different existing agricultural systems. The results suggest the huge possibilities for agriculture. The research showed that only the organic systems have sequestered significant amounts of carbon to some extent.

The Farming Systems Trial provides a scientific hope for agriculture's potential to mitigate climate change. Organic agriculture can sequester significant levels of carbon dioxide from the atmosphere while providing ecosystem benefits and high crop yields. These results suggest that farmers who set out to increase soil organic carbon could achieve far greater success in sequestering carbon dioxide, if they were given incentives to achieve this goal.

Further research on this is, however, still needed. Currently the easy access to and increased development of local markets for the products, local processing possibilities, and export infrastructure are of particular importance for organic farming. For this, the role of international institutions and trade policies has to be discussed in context of organic farming. The institutional environment for organic farming as an adaptation and mitigation strategy also has to be identified, in particular, on a global level. To be successful, wider recognition of the potential of organic farming is needed among bodies that currently mainly promote pure conventional agriculture. An important step could be that (National and International) agricultural policy begins to prominently support organic agriculture as an adaptation and mitigation strategy.

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Table 1: Global estimates of natural and anthropogenic sources of Methane (CH4)

CH_4 Sources	Mt CH_4 / yr	Gt C-eq / yr
Natural wetlands	115 (55.150)	0.7 (0.3.0.9)
Energy	93 (75-110)	-
Termites	20	-
Ocean	13 (10-15)	-
Livestock (enteric fermentation and animal waste)	110 (85.130)	0.6 (0.5.0.7)
Rice paddies	60 (20.100)	0.3 (0.1.0.6)
Landfills	55 (36-73)	-
Biomass burning	40 (20.80)	0.2 (0.1.0.5)
Total emissions	598 (500-600)	

Source: Prather el al. (1995), various authors cited in IPCC (2001)

Table 2: Energy use in organic versus conventional agricultural systems

Country and system of production	Energy use ratio of organic to conventional	% increase in energy required for 1% increase in yield in conventional systems
UK		
Winter wheat	38 %	+3.5%
Potato	49%	+4.9%
Carrot	28 %	+1.6%
Calabrese	27 %	+4.2%
USA		
Wheat	68%	1.7%
Philippines		
Rice	33%	+7.2%

Source: Pretty and Ball (2001), adapted from Pretty (1995); Cormack and Metcalfe (2000)

Table 3: Adaptation potential of organic agriculture

Objective	Means	Impact
Alternative to industrial production input (i.e., mineral fertilizers and agrochemicals) to decrease pollution	Improvement of natural resources processes and environmental services (e.g., soil formation, predation)	Reliance on local & independence from volatile prices of agricultural inputs
Landscaping	Creation of micro-habitats (e.g., hedges), permanent vegetative cover & wildlife corridors	Enhanced ecosystem balanced (e.g., pests, prevention), protection of wild biodiversity and better resistance to wind and heat waves
Soil fertility	Nutrient management (e.g., rotations, coralling, cover crops and manuring)	Increased yields, enhanced soil water retention/drainage (better response to droughts and floods), decreased irrigation needs and avoided land degradation

Source: Sartaj et al. (2013)

Table 4: Carbon sequestration by organic and conventional farming systems

	Organic	Conventional	Difference
	-- t CO2 / ha --		
Cash crops			
above ground biomass	3.76	4.95	-1.18
root biomass	1.44	0.89	0.55
Catch crops*			
above ground biomass	0.55	0.22	0.33
root biomass	0.22	0.09	0.13
Weeds			
above ground biomass	0.22	0.04	0.17
root biomass	0.04	0.01	0.03
Gross output (sequestration)	6.23	6.19	0.04
Energy input (emission)	0.15	0.29	-0.14
Net output (sequestration)	6.08	5.91	0.18
Carbon-sequestration efficiency	41.5	21.3	

*Catch crops (intercrops) are sown after the harvest of the main crop in order to capture the nutrients and to provide soil cover. They can also be sown into the main crop. Source: Haas and Köpke (1994)

Table 5: Global Carbon Pools

	Pg C	**Percent**
Oceanic pool	38,000	81.5
Geologic pool	5,000	10.7
Soil pool	2,300	4.9
Soil organic carbon 1550		
Soil inorganic carbon 750		
Vegetation pool	560	1.2
Atmosphere	760	1.6
Total	46,620	100.0

Source: International Geosphere Biosphere Program (1998)

Table 6: Cumulative contribution of soil, biomass and fossil fuel combustion to atmospheric C

ce	**Emission (Pg C)**	**References**
Fossil fuel (1800-1998)	240-300	IPCC (2000)
Land use change	81-191	IPCC (2000)
Soil cultivation	47-58	Lal (1999a)
Soil erosion	19-32	Lal (1999b)
Biomass	19-105	(by difference)

Source: Lal (2001)

Table 7: Direct and indirect reduction on agricultural greenhouse gas emissions arising from the principles of Organic Agriculture

	CO_2	CH_4	N_2O
1. Agricultural land use and management			
Permanent soil cover	+++	-	+
Reduced soil tillage	+	-	+
Restriction of fallows in (semi)arid regions	+	-	-
Diversification of crop rotations incl. fodder production	++	-	+
Restoring the productivity of degraded soils	++	+	-
Agroforestry	++	-	-
2. Use of manure and waste			
Recycling of municipal waste and compost	++	-	+
Biogas from slurry	- -	++	-
3. Animal husbandry			
Breeding and keeping for longevity	-	++	+
Restriction of livestock density	-	+	+
Reduction of fodder import	+	+	-
4. Management of fertilizers			
Restriction of nutrient input (nutrient recycling)	++	-	++
Leguminous plants	+	-	+
Integration of plant and animal production	++	-	+
5. Change of consumer behaviour			
Consumption of regional products	+++	-	-
Shift towards vegetarian products	+	++	-

++ high, + low, - no potential

Source : Sauerbeck 2001; Cole et al. (1997) cited in FAO (2002)

Table 8: Mitigation potential of organic agriculture

Source of GHG	Share of total anthropogenic	Impacts of optimized organic management	Remarks GHG emissions
Direct emissions from agriculture	10–12%		
N_2O from soils	4.2%	Reduction	Higher nitrogen use efficiency
CH_4 from enteric fermentation	3.5%	Opposed effects	Increased by lower energy concentration in the diet but reduced by lower replacement rate and multi-use breeds
Biomass burning	1.3%	Reduction	Burning avoided According to organic standards
Paddy rice	1.2%	Opposed effects	Increased by organic amendments but lower red by drainage and aquatic weeds
Manure handling	0.8%	Equal	Reduced methane emissions but no Effect on N_2O emissions
Direct emissions from forest clearing for agriculture	12%	Reduction	Clearing of primary ecosystems restricted
Indirect emission			
Mineral fertilizers	1%	Totally avoided	Prohibited use of mineral fertilizers
Food chain	?	Reduction	Inherent energy saving but still inefficient distribution systems
Carbon sequestration			
Arable lands		Enhanced	Increased soil organic matter
Grasslands		Enhanced	Increased soil organic matter

Source: Sartaj et al. (2013)