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Mitigating and Adapting to Climate Change through Ecological Agriculture

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Contents

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Chapter One

INTRODUCTION

THE Intergovernmental Panel on Climate Change (IPCC) warns that warming of the climate system is "unequivocal", as evident from increases in air and ocean temperatures, widespread melting of snow and ice, and sea level rise (IPCC, 2007a). Agriculture will therefore have to cope with increased climate variability and more extreme weather events. A recent report warns that unchecked climate change will have major negative effects on agricultural productivity, with yield declines for the most important crops and price increases for the world's staples – rice, wheat, maize and soybeans (Nelson et al., 2009).

The IPCC projects that crop productivity would increase slightly at mid- to high latitudes for local mean temperature increases of up to 1-3°C (depending on the crop) (Easterling et al., 2007). However, at lower latitudes, especially in the seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C). In some African countries, yields from rain-fed agriculture, which is important for the poorest farmers, could be reduced by up to 50 percent by 2020 (IPCC, 2007b). Further warming above 3°C would have increasingly negative impacts in all regions.

The number of people at risk of hunger will therefore increase, although impacts may be mitigated by socio-economic development. Overall, however, the assessment is that climate change will affect food security in all its dimensions – food availability, access to food, stability of food supplies and food utilization (FAO, 2009).

The impacts of climate change will fall disproportionately on developing countries, despite the fact that they contributed least to the causes. Furthermore, the majority of the world's rural poor who live in areas that are resource-poor, highly heterogeneous and risk-prone will be hardest hit by climate change. Smallholder and subsistence farmers, pastoralists and artisanal fisherfolk will suffer complex, localized impacts of climate change and will be disproportionately affected by extreme climate events (Easterling et al., 2007). For these vulnerable groups, even minor changes in climate can have disastrous impacts on their livelihoods (Altieri and Koohafkan, 2008).

Chapter Two

AGRICULTURE'S CONTRIBUTION TO CLIMATE CHANGE

WHILE agriculture will be adversely affected by climate change, it also contributes to the problem. Agriculture directly releases into the atmosphere a significant amount of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), amounting to around 10-12 percent or 5.1-6.1 Gt CO_2-eq/yr of global anthropogenic greenhouse gas emissions annually (Smith et al., 2007). More current estimates put the figure at 14 percent or 6.8 Gt CO_2-eq/yr (FAO, 2009).

Of global anthropogenic emissions in 2005, agriculture accounted for about 58 percent of nitrous oxide and about 47 percent of methane (Smith et al., 2007), both of which have far greater global warming impact than carbon dioxide. Nitrous oxide emissions from agriculture are mainly associated with nitrogen fertilizers and manure applications, as fertilizers are often applied in excess and not fully utilized by crops, such that some surplus is lost to the atmosphere. Fermentative digestion by ruminant livestock contributes to agricultural methane emissions, as does cultivation of rice in flooded conditions.

However, if indirect contributions (e.g., land conversion to agriculture, synthetic fertilizer production and distribution and farm operations) are factored in, it is estimated that the contribution of agriculture could be as high as 17-32 percent of global anthropogenic emissions (Bellarby et al., 2008). In particular, land use change, driven by industrial agricultural production methods, would account for more than half of total (direct and indirect) agricultural emissions. Deforestation to expand arable land and poor agricultural soil management lead to significant carbon dioxide emissions as carbon stocks above and below ground are depleted (IFOAM, 2009).

Conventional industrial agriculture is also heavily reliant on fossil fuels. The manufacture and distribution of synthetic fertilizers contributes a significant amount of greenhouse gas emissions, between 0.6-1.2 percent of the world's total (Bellarby et al., 2008). This is because the production of fertilizers is energy-intensive and emits carbon dioxide, while nitrate production also generates nitrous oxide.

Future emissions growth

Total greenhouse gas emissions from agriculture are expected to increase, reaching 8.3 Gt CO_2-eq/yr in 2030 (Smith et al., 2007). If food demand increases and dietary shifts occur as projected, then annual agricultural emissions may rise further.

Agricultural emissions of nitrous oxide are projected to increase 35-60 percent up to 2030 due to increased nitrogen fertilizer use and increased animal manure production, while methane emissions related to global livestock production are also projected to increase by 60 percent up to 2030 (FAO, 2003). Direct emissions of carbon dioxide from agriculture are likely to decrease or remain low; however, indirect causes such as converting land to agriculture would contribute substantial emissions.

Chapter Three

AGRICULTURE'S MITIGATION POTENTIAL — MAKING THE CASE FOR ECOLOGICAL AGRICULTURE

ALTHOUGH agriculture is a significant contributor to climate change, it also has considerable mitigation potential. The IPCC estimates the global technical mitigation potential from agriculture by 2030 to be about 5.5-6.0 Gt CO_2-eq/yr (Smith et al., 2007), with soil carbon sequestration being the mechanism responsible for most (89 percent) of the mitigation potential. Therefore, agriculture could potentially change from being one of the largest greenhouse gas emitters to a much smaller emitter and even a net carbon sink (Bellarby et al., 2008).

The responsibility lies on the developed countries to mitigate climate change domestically, by changing their industrial agricultural practices. At the same time, developing countries also need to shift their agricultural policies and practices towards ecological agriculture, which would be essential for adaptation and which will not contribute to future climate change.

There are a variety of practices that can reduce agriculture's contribution to climate change. These include crop rotations and improved farming system design, improved cropland management, improved nutrient and manure management, improved grazing-land and livestock management, maintaining fertile soils and restoration of degraded land, improved water and rice management, fertilizer management, land use change and agroforestry (Bellarby et al., 2008; Niggli et al., 2009; Smith et al., 2007).

These practices essentially entail a shift to more sustainable farming that builds up carbon in the soil and uses less chemical fertilizers and pesticides (Bellarby et al., 2008; ITC and FiBL, 2007). Many of these techniques are already common practice in what can be termed "ecological agriculture". Ecological agricultural approaches, including organic agriculture, generally integrate natural, regenerative processes, minimize non-renewable inputs (pesticides and fertilizers), rely on the knowledge and skills of farmers and depend on locally adapted practices to innovate in the face of uncertainty (Pretty and Hine, 2001).

Ecological agriculture fosters biodiversity and is in itself biodiverse – not only in terms of the harvested elements (both intra- and interspecies genetic diversity) but also in terms of the components necessary to maintain the agroecosystem (Ensor, 2009) (see Box 1). It depends on and sustains agricultural biodiversity, and has come about through the innovation of farmers over time. Biodiverse agriculture mimics nature and works with nature, in contrast to conventional industrial agriculture, which tends to simplify agricultural systems and reduce diversity.

Ecological agriculture and in particular, organic agricultural systems, have inherent potential to reduce emissions and to enhance carbon sequestration in soils (Scialabba and Müller-Lindenlauf, 2010). The total mitigation potential of organic agriculture has been estimated at 4.5-6.5 Gt CO_2-eq/yr, with potentially much higher amounts possible depending on agricultural management practices (Muller and Davis, 2009). The financial requirements are low, as carbon sequestration and low-emissions farming can be achieved through inexpensive means (IFOAM, 2009), are immediately available and can be implemented without long delays in research and development (Scherr and Sthapit, 2009).

Box 1: Common characteristics of biodiverse farms

- Species and structural diversity are combined in time and space through vertical and horizontal organization of crops.
- Higher biodiversity of plants, microbes and animals supports crop production and mediates a reasonable degree of biological recycling of nutrients.
- The full range of micro-environments is exploited.
- Effective recycling practices maintain cycles of materials and waste.
- Biological interdependencies provide some level of biological pest suppression.
- Reliance on local resources plus human and animal energy.
- Reliance on local varieties of crops and incorporation of wild plants and animals.

Source: Adapted from Ensor (2009), based on Altieri and Koohafkan (2008)

Reducing emissions

Agricultural soils can be managed to reduce emissions by minimizing tillage, reducing use of nitrogen fertilizers and preventing erosion (Scherr and Sthapit, 2009). Practising organic agriculture also reduces nitrous oxide and methane emissions from biomass waste burning (which accounts for about 12 percent of agricultural emissions), as burning is avoided (Muller and Davis, 2009). Moreover, organic standards ban the certification of recently cleared or altered primary ecosystems such as forests, slowing emissions from forest conversion to agriculture (IFOAM, 2009), while the use of catch and cover crops in organic systems prevents soil erosion and hence soil carbon loss.

In particular, the careful management of nutrients and hence the reduction of nitrous oxide emissions from soils – the most important source of agricultural emissions – is a significant contribution of organic agriculture (Scialabba and Müller-Lindenlauf, 2010).

Approximately 20 percent of agricultural emissions could be reduced by converting to organic agriculture, through its omission of synthetic nitrogen fertilizers – 10 percent due to lower energy demand as a result of avoiding emissions incurred during fertilizer production, and 10 percent due to lower nitrous oxide emissions as a result of lower nitrogen input than in conventional agriculture (Niggli et al., 2009; Scialabba and Müller-Lindenlauf, 2010).

Nitrogen input in ecological agriculture instead comes from the application of manure and compost, or is provided by the focus on agricultural biodiversity, in particular rotations that include legumes (Ensor, 2009; ITC and FiBL, 2007). In addition, catch and cover crops extract plant-available nitrogen that was unused by the preceding crop, reducing the amount of reactive nitrogen in the topsoil and hence nitrous oxide emissions (Ensor, 2009; Scialabba and Müller-Lindenlauf, 2010).

Soil carbon sequestration

The highest mitigation potential of ecological agriculture lies in carbon sequestration in soils. The technical potential of carbon sequestration in world soils may be 2-3 billion mt per year for the next 50 years (Lal, 2009). Carbon sequestration is encouraged by practices that leave residues and reduce tillage to encourage buildup of soil carbon. Increasing the role of perennial crops and agroforestry further allows carbon storage while crops are being produced (Ensor, 2009; Lal, 2009; Scherr and Sthapit, 2009). While these strategies are not exclusive to ecological agriculture, they clearly resonate with ecological principles.

For example, ecological agriculture practices such as crop rotation, cover crops, manuring and application of organic amendments such as compost restore degraded soils and hence increase soil carbon sequestration (Scialabba and Müller-Lindenlauf, 2010). Ecological agriculture also stresses the importance of maintaining and enhancing biodiversity (e.g., field margins, hedges, trees or bushes), which is an effective mitigation strategy, due to carbon sequestration in soil and plant biomass.

It is estimated that a conversion to organic agriculture would considerably enhance the sequestration of carbon in soils. Organic systems have been found to sequester more carbon than conventional farms (Bellarby et al., 2008; ITC and FiBL, 2007; Niggli et al., 2009). Niggli et al. (2009) estimate that a conversion to organic farming would mitigate 40 percent (2.4 Gt CO_2-eq/yr) of the world's agriculture greenhouse gas emissions in a minimum scenario, or up to 65 percent (4 Gt CO_2-eq/yr) in a maximum scenario (including no-tillage) of carbon sequestration. Other estimates point to higher potentials of 6.5-11.7 Gt CO_2-eq/yr (Muller and Davis, 2009).

Nonetheless, the increase in soil organic matter will eventually reach equilibrium and the mitigation effect can be reversed if the carbon stored is released (e.g., by ploughing of no-tillage systems) (Scialabba and Müller-Lindenlauf, 2010). While the total sequestration capacity of soils is finite, there are an estimated 50 to 100 years of remaining sequestration potential (Smith et al., 2007).

Chapter Four

CONCURRENT BENEFITS FOR ADAPTATION

ECOLOGICAL agriculture optimally integrates mitigation and adaptation, as many of its approaches that mitigate climate change are also effective adaptation strategies. Adaptation is a priority for developing countries, whose farmers will have to cope with the severe consequences of climate change on agriculture.

Soil carbon sequestration is a clear example of a mitigation measure that also enhances adaptation and the sustainability of crop production (Smith, 2009). The increased soil organic matter enhances soil fertility and quality, improves water-holding capacity and increases productivity and resilience, which are important for adaptation to future climate change (Lal, 2009). In particular, ecological agriculture practices such as crop rotation, composting, green manures and cover crops can reduce the negative effects of drought while increasing productivity (ITC and FiBL, 2007; Niggli et al., 2009). Organic matter also enhances water capture in soils, significantly reducing the risk of floods (ITC and FiBL, 2007; Niggli et al., 2009).

Agricultural biodiversity is the keystone of ecological agriculture. It contributes to mitigation – diverse plants and trees in crop rotations and in the surrounding agroecosystem sequester carbon, while the incorporation of legumes reduces nitrous oxide emissions. At the same time, resiliency to climate disasters is closely linked to agricultural biodiversity. Practices that enhance biodiversity allow farms to mimic natural ecological processes, enabling them to better respond to change and reduce risk. Thus, farmers who increase interspecific diversity suffer less damage during adverse weather events, compared to conventional farmers planting monocultures (Altieri and Koohafkan, 2008; Ensor, 2009; Niggli et al., 2009). Moreover, the use of intraspecific diversity (different cultivars of the same crop) is insurance against future environmental change. Diverse agroecosystems can also adapt to new pests or increased pest numbers (Ensor, 2009).

Other examples of coincident mitigation and adaptation strategies include application of animal manure, which reduces fertilizer use and improves soil structure and water-holding capacity; reduction of tillage intensity with improved residue management, which increases soil carbon while retaining soil moisture; and restoring degraded lands, which sequesters carbon and enhances soil resilience (Smith, 2009).

Chapter Five

CONCLUSION

CLIMATE change will undoubtedly pose serious challenges for agriculture. However, with appropriate focus on ecological agriculture to provide adaptation, mitigation and increased productivity options, a "win-win-win" scenario for agriculture is possible. This is because ecological agriculture would not only be beneficial in terms of climate change adaptation and mitigation, but would also constitute the paradigm shift in agriculture that is deemed necessary to increase productivity while ensuring sustainability and meeting smallholder farmers' food security needs (IAASTD, 2009).

There is therefore a clear need to invest more resources, research and training into ecological agriculture, as well as to provide the appropriate policy and funding support (IAASTD, 2009). Many components of ecological agriculture can also be applied to improve all farming systems, including conventional ones. A crucial factor would be investment in the conservation, protection and enhancement of agricultural biodiversity, which underpins ecological approaches in agriculture.

The following steps should be urgently taken:

- Further research is needed on the adaptation and mitigation options provided by ecological agriculture, taking into account context and location specificities such as soil types, crop types, management practices and climate conditions.

- Arrangements should be made for the sharing of information and experiences, transfer of and training in good practices that constitute adaptation and mitigation in ecological agriculture, including through extension services.
- Countries should urgently adopt and implement adaptation and mitigation action plans for agriculture, focusing in particular on ecological agriculture.
- Financing assistance for adaptation and mitigation measures in the agriculture sector in developing countries should be prioritized, especially if they constitute ecological agriculture practices.

While maximizing the synergies between adaptation and mitigation in ecological agriculture means that the above strategies could be developed simultaneously, there also needs to be a prioritization of the actions, depending on the national context of the country and the current status of its agriculture.

The key priority for developing countries would be to adopt ecological agriculture practices that help their farmers to adapt to climate change. Public financing and transfer of appropriate technologies by developed countries to make this a reality is needed. On the other hand, developed countries must also take action to mitigate climate change domestically, by changing their industrial agricultural practices and catalyzing the shift to ecological agriculture. If developing countries are practising conventional agriculture, they should also place emphasis on making the shift to ecological agriculture so that it provides both adaptation and mitigation benefits.

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MITIGATING AND ADAPTING TO CLIMATE CHANGE THROUGH ECOLOGICAL AGRICULTURE

While agricultural productivity is adversely affected by climate change, agriculture is itself a significant contributor to global warming. Agricultural activities have been identified as a major source of the greenhouse gas emissions responsible for climate change.

However, as this paper explains, agriculture also has considerable potential for climate change mitigation. In particular, the adoption of "ecological agriculture", which integrates natural regenerative processes, minimizes non-renewable inputs and fosters biological diversity, can have tremendous scope for reducing emissions and enhancing soil carbon sequestration. At the same time, many ecological agricultural practices also constitute effective strategies for adapting to climate change, which is a priority for developing countries.

This paper looks at the various ways in which ecological agriculture integrates mitigation and adaptation capacities, and calls for more investment and policy support to be devoted to this productive and sustainable form of farming.

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