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Ecological Agriculture, Climate Resilience and a Roadmap to Get There

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Chapter One

INTRODUCTION

AGRICULTURE is the most important sector in many developing countries and is central to the survival of hundreds of millions of people. In most developing countries, agriculture, which provides the bulk of employment, is not a commercial activity per se, but a way of life. Most agricultural production in these countries involves small land holdings, mainly producing for self-consumption. Women are the key agricultural producers and providers. Hence agriculture is critical for food and livelihood security, and for the approximately 500 million smallholder households, totalling 1.5 billion people, living on smallholdings of two hectares of land or less (De Schutter, 2008). Smallholdings account for 85 percent of the world's farms.

Agriculture is also deeply connected with issues of development and poverty alleviation, as about 75 percent of the world's poor live in rural areas where agriculture is the main economic activity (G-33, 2010). Paradoxically, women, despite playing a crucial role in agricultural production, make up over 60 percent of the hungry.[1] The World Bank has warned that the agriculture sector must be placed at the centre of the development agenda if the Millennium Development Goals of halving extreme poverty and hunger by 2015 are to be realized (World Bank, 2008). For the poorest people, GDP growth originating in agriculture is about

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[1] Hunger stats, World Food Programme, http://www.wfp.org/hunger/stats

four times more effective in reducing poverty than that originating outside the sector. The large share of agriculture in poorer economies suggests that strong growth in agriculture is critical for fostering rural development and overall economic growth.

However, climate change threatens the livelihoods and food security of billions of the planet's poor and vulnerable, as it poses a serious threat to agricultural production. Agriculture, in the dominant conventional and industrial models that are practised today, is also a major contributor itself to greenhouse gas emissions. There is increasing realization of the need to address the linkages between development, agriculture and climate change, but there are differences in opinion on how to address these linkages.

There has also been increasing attention directed to the potential of soil carbon sequestration by smallholders to capture carbon dioxide emissions while at the same time generating emission credits on carbon markets. However, such market mechanisms are a smokescreen for developed countries to offset their emissions, enabling them to maintain relatively high levels of emissions domestically while paying someone else to soak up their excess carbon. These mechanisms are unlikely to benefit small farmers; on the contrary, continued emissions are likely to increase the vulnerabilities of poor agriculturalists threatened by increasing temperatures and rainfall variability.

What are instead needed are immediate and significant emission reductions by the developed countries to prevent further disastrous impacts on food security, as well as a change in their current fossil fuel- and energy-intensive models of agriculture. Linked to this is the question of whether new and additional public funding will be forthcoming for climate change, including for agriculture and in particular, adaptation efforts, in developing countries.

A focus on the climate challenge to ecosystems and livelihoods rather than on carbon commerce is needed, as the adaptation needs of developing countries are paramount. As such, we should heed the call of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD)[2] to the international community and national governments to systematically redirect agricultural knowledge, science and technology towards sustainable, biodiversity-based ecological agriculture and the underlying agroecological sciences.

This is because the ecological model of agricultural production, which is based on principles that create healthy soils and cultivate biological diversity and which prioritizes farmers and traditional knowledge, is climate-resilient as well as productive. Ecological agriculture practices are the bases for the adaptation efforts so urgently needed by developing-country farmers, who will suffer disproportionately more from the effects of climate change. Many answers lie in farmers' fields and farmer knowledge, for example, how to create healthy soils that store more water under drought conditions and how to grow a diversity of crops to create the resilience needed to face increased unpredictability in weather patterns.

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[2] The IAASTD is a comprehensive assessment of agriculture and was co-sponsored by the World Bank, United Nations Food and Agriculture Organization (FAO), UN Environment Programme (UNEP), UN Development Programme (UNDP), World Health Organization (WHO), UN Educational, Scientific and Cultural Organization (UNESCO) and Global Environment Facility (GEF). Its reports, which drew on the work of over 400 experts, were approved by 58 governments in 2008.

This paper proposes a development-oriented agenda on agriculture and climate change, which has at its centre issues of concern to developing countries – including food security, livelihood security and rural development – especially given that developing countries will be disproportionately affected by climate change. As such, it calls for a reorientation of research, institutional, policy and funding support towards ecological agriculture. A simultaneous dismantling of the incentives, including via the current international trade regime, that are propping up unsustainable and high-emissions agriculture is needed. The paper also rejects false solutions that are premised on the soil carbon market, and instead calls for sustainable, predictable and significant public financing to support the transition to ecological agriculture and other necessary strategies for adaptation to climate change.

Chapter Two

CLIMATE CHANGE AND AGRICULTURE

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, more extreme weather events and inexorably rising temperatures. According to the IAASTD (2009), climate change, coincident with increasing demand for food, feed, fibre and fuel, could irreversibly damage the natural resource base on which agriculture depends, with significant consequences for food insecurity.

In its Fourth Assessment Report (AR4), 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, according to AR4 (IPCC, 2007b). Further warming above 3°C would have increasingly negative impacts in all regions.

Recent studies suggest the IPCC may have significantly understated the potential impacts of climate change on agriculture. New research by Stanford University, for example, suggests that production losses across the continent of Africa in 2050 (consistent with global warming of around 1.5°C) are likely to be in the range of 18 to 22 percent for maize, sorghum, millet and groundnut, with worst-case losses of up to 27 percent to 32 percent (Schlenker and Lobell, 2010). In other research, the International Food Policy Research Institute (IFPRI) suggests that rice production in South Asia, one of the most affected regions in terms of crop production, could decline by 14.3 to 14.5 percent by 2050, maize production by 8.8-18.5 percent and wheat production by 43.7 to 48.8 percent, relative to 2000 levels. IFPRI concludes 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 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).

Climate impacts on agriculture: the role of temperature and rainfall

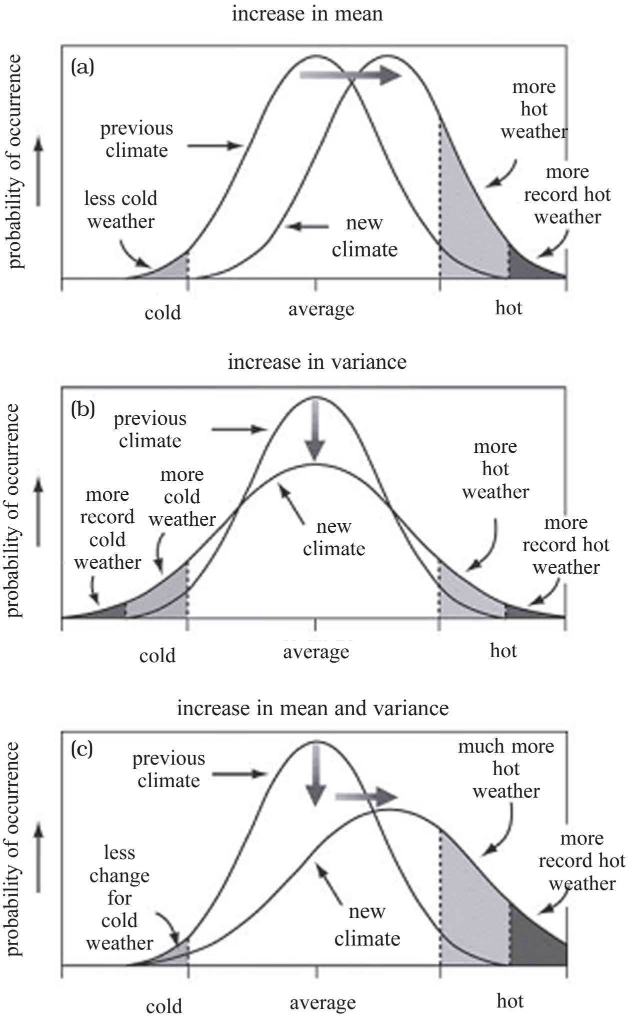
Climate change poses monumental challenges for agriculture with respect to the climate variables most important to crop plants, **temperature** and **rainfall**. Over the next century, temperatures will continue to rise, with more extremes reached more frequently (see Figure 1). In many regions, rainfall will become more unpredictable, with changes in both variability (variance in rainfall amounts from year to year) and distribution (number of rainfall events per year and the amount of rain in each event). Both these changes will have significant impact on where and how we grow our food and fibre crops.

While much concern has been raised about the impacts of climate change on rainfall variability and distribution, changes in temperature may cause the most disruption to overall crop yields in the coming decades. Moreover, it is likely that multiple stresses, for example drought and heat stress, will combine to further complicate the immense challenge of adaptation.

Temperature and crops

Temperature is significant for a range of crop physiological processes, the most important being pollination and grain filling, as well as basic photosynthesis. High temperatures, whether lasting over a series of days or an extreme spike of several hours, can have serious negative effect on these processes, with downstream consequences for crop yields. Especially sensitive are the reproductive organs; extreme heat events of even short

Figure 1: Postulated changes in the distribution of temperatures involving changes in their (a) mean, (b) variance and (c) both, with the frequency of occurrence of extreme conditions



Source: From Porter and Semenov (2005), adapted from Houghton et al. (2001).

duration during flowering or pollination can severely reduce a harvest (Araus et al., 2008; Semenov and Halford, 2009).

More generally and less acutely, high temperatures cause plants to develop more quickly, with grain filling happening more quickly, shortening the growing season and reproductive phase and thus reducing yields (Barnabás et al., 2008; Semenov and Halford, 2009). The phenomenon is not crop-specific: "[a]nalysis of crop responses suggests that even moderate increases in temperature will decrease yields of corn (maize), wheat, sorghum, bean, rice, cotton, and peanut crops" (Hatfield et al., 2008).

Higher nighttime temperatures can also negatively influence yield. US maize yields were predicted to drop significantly in 2010 precisely because of this – high temperatures at night during the past cropping season "didn't give the crop a chance to 'rest' and limited kernel growth" (Berry, 2010). Peng et al. (2004) provide evidence of yield reductions in rice due to higher nighttime temperatures associated with global warming.

Unfortunately the major models that have been developed to evaluate the impacts of climate on agriculture do not model well the temperature dependency of these key variables (Stanford University, 2009), likely leading to serious underestimation of the potential impacts of rising temperatures on agricultural production and yields. Moreover, most recent scholarship also calls into question an over-optimistic reliance on the potential for increased carbon dioxide (CO_2) concentrations to counter the yield-reducing effects of increasing temperatures (for example, see Long et al., 2005 and Long et al., 2006).

Temperature thresholds and a changing climate

Higher temperatures will affect crop yields more or less in a linear fashion up to certain thresholds. Once those thresholds are passed, crop yields drop off dramatically as essential reproductive and physiological processes – in particular, pollen viability, seed development and photosynthesis – are crippled or shut down entirely. For example, temperatures above 35-38°C are deadly to maize pollen and an important photosynthetic enzyme loses activity above 35°C (Rosenzweig et al., 2001; Stone, 2001; Maestri et al., 2002; Barnabás et al., 2008; Hatfield et al., 2008).

Researchers associated with Stanford University's Program on Food Security and the Environment have been looking closely at the possible impacts of rising temperatures on crop yields globally. They summarize that "the shift in average temperatures alone will cause relevant temperature thresholds for crops, such as 35°C or 40°C, to be exceeded on more days in most regions. ... Nearly all models agree that many major cropping regions will experience a rapid increase in days above 35°C, with most models projecting a more than doubling of the rate of exposure by mid-century" (Stanford University, 2009).

Schlenker and Roberts (2009) use crop models and a large dataset of yields from the US Midwest to estimate the effect of temperature increases on maize yields, with troubling results. Their results "suggest a marked dropoff of yields when canopies[3] are exposed to temperatures above 30°C" (see Figure 2).

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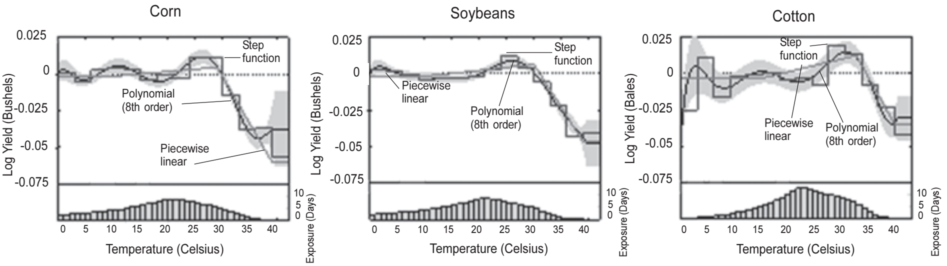
[3] Canopy temperature is usually less than ambient air temperature due to the cooling effects of shade and plant transpiration. One adaptation strategy from ecological agriculture to maintain lower canopy temperatures is to include taller plants in the cropping system that can provide shade.

Figure 2: Nonlinear relation between temperature and yields



Source: From Schlenker and Roberts (2009).

In summary, “the clear message from the crop community is that [temperature] thresholds are well defined, they can be effective over short time-periods and can extensively damage yield productivity” (Porter and Semenov, 2005).

Rainfall and drought

Access to water, through precipitation or irrigation, is the single most important factor in crop production. Consequently, lack of access to water, particularly at critical times in the stages of the crop life cycle, is the single greatest abiotic stress factor limiting crop productivity (Araus et al., 2008). The same reproductive processes threatened by heat stress described above – flowering, pollination and grain filling – are similarly most sensitive to water stress (Rosenzweig et al., 2001).

Of course, crop productivity can also suffer from too much rain (hurricanes and floods), as well as rain at the wrong times or in the wrong form (hail). Climate change is predicted to bring more extreme weather events (Solomon et al., 2007; IPCC, 2011), with additional consequences for food production above and beyond those of extreme temperatures and drought.

Combined heat and drought stresses

Temperature and soil moisture are, of course, related. Higher temperatures lead to increased plant evapotranspiration as well as evaporation of soil moisture. Decreased soil moisture leads to a shortening of the growing period, threatening plants more frequently with low moisture stress towards the end of the season (Rosenzweig et al., 2001; Stanford University, 2009).

Plants have evolved many different biochemical responses to stresses, and research shows that different stresses can trigger different response pathways, which are unfortunately not always complementary. For example, one possible plant response to higher temperatures is to increase evapotranspiration, which cools the plant canopy, a response that is likely deadly in a situation also of water stress. Conversely, in a situation of water stress plants reduce evapotranspiration, thereby heating the canopy. Both heat and water stresses at the same time thereby pose greater threats to the survival of crop plants than either stress individually.

"*Farmers and breeders have long known that it is often the simultaneous occurrence of several abiotic stresses, rather than a particular stress condition, that is most lethal to field crops*" (Mittler, 2006).

Conventional agriculture is a major contributor to climate change

While agriculture and food security will be adversely affected by climate change, agriculture is also a major contributor to the climate problem. In particular, the industrial, monoculture model of agricultural production, highly dependent on synthetic fertilizers and massively energy-intensive for technology and transport, is responsible for a significant amount of global annual greenhouse gas emissions.

According to the IPCC, agriculture directly releases into the atmosphere large quantities of three different greenhouse gases – carbon dioxide, methane and nitrous oxide – amounting to around 10-12 percent of global anthropogenic greenhouse gas emissions annually (Smith et al., 2007). More current estimates put the figure at 14 percent (FAO, 2009).

Of global anthropogenic emissions in 2005, agriculture accounted for about 58 percent of nitrous oxide and about 47 percent of methane emissions, both of which have far greater global warming impact than carbon dioxide. Nitrous oxide emissions from agriculture are mainly associated with synthetic 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.

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.

Conventional industrial agriculture is also heavily reliant on fossil fuels. For example, Bellarby et al. (2008) estimate that total greenhouse gas emissions from fossil fuel and energy use and farm operations and production of chemicals from agriculture are in the range of 0.399-1.656 Pg CO_2-eq. The large range of values reflects different management practices. Production of synthetic fertilizers contributes the largest amount, followed by use of farm machinery, irrigation and pesticide production.

The manufacture of synthetic fertilizers ***alone*** contributes a significant amount of greenhouse gas emissions, between 0.6-1.2 percent of the world's total annual emissions (Bellarby et al., 2008). This is for two reasons: first, because the production of fertilizers is energy-intensive and emits carbon dioxide, and second, the production of synthetic nitrogen fertilizers releases huge amounts of the greenhouse gas nitrous oxide – many times more potent than carbon dioxide – into the atmosphere. Alarmingly, nitrous oxide emissions are increasing precipitously – global emissions from this source are predicted to rise by 35-60 percent by 2030 (Solomon et al., 2007).

At the same time as they pose a huge climate threat, industrial agricultural systems are highly vulnerable to climate change. The industrial model and the crop varieties designed to work well within it depend on energy- and water-intensive irrigation as well as other fossil fuel-intensive inputs such as mechanized harvesting, fertilizers and pesticides. Highly vulnerable to reductions in the availability of fuel and water, and in the long term economically unsound, the model will not survive (Vandermeer et al., 2009). Nothing less than a system change is needed in the face of the climate change threat.

CHAPTER THREE

ECOLOGICAL AGRICULTURE IS ESSENTIAL TO MEET THE CLIMATE CHALLENGE

CLIMATE change will require a range of adaptation approaches across many elements of agricultural production systems, from small changes in the crop varieties grown to decisions to abandon cropping completely. For example, in some rain-fed regions in Africa, there just will not be enough predictable moisture to continue to grow crops; in these areas, agriculturalists may change to livelihood strategies based entirely on pastoralism, or they may need to move to other regions or to cities. In other areas more animals may be integrated into the farming system to reduce dependency on crop production (Jones and Thornton, 2008).

In all areas, farmers working to adapt to climate change will need to adopt new practices that help to increase the resilience of their cropping systems – through building healthier soils, increasing the biological diversity of the system and, particularly in rain-fed regions (where most poor farmers farm), incorporating more water harvesting and water management techniques. As we outline in the final section of the paper, these are practices that governments and other funding agencies must prioritize as they promote transitions to climate-resilient agricultural systems.

Building healthy soils

By increasing the health of soils, farmers can increase the water-holding capacity of the soil and the infiltration capacity – augmenting the speed at which water can percolate into soils and thus the ability to take more advantage of heavier rains that are expected under climate change (Tirado and Cotter, 2010). Moreover, by building healthier soils, farmers can increase productivity. Given that climatic changes will likely significantly reduce yields over time, any increase in productivity through better soil health and fertility will serve to moderate the productivity reduction expected. For example, research from 30-year side-by-side trials of conventional and organic farming methods (involving leguminous cover crops and/or periodic applications of manure or composted manure) at the Rodale Institute has shown that organic corn yields were 31 percent higher than conventional in years of drought.[4]

Many well-established agroecological practices increase soil health and fertility, and with these, productivity. Prominent among these practices is the addition of manure or compost. At the same time that these additions bring necessary nutrients into the system, they also improve the structure of the soil, making it better able to hold onto both nutrients and water. And with an improved soil structure, water is able to infiltrate better and more water is captured during periods of intense rainfall. Evidence from the Tigray region in Ethiopia shows that compost can increase crop yields significantly; on average, composted fields gave higher yields, sometimes double, than those treated with chemical fertilizers (Edwards et al., 2009).

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[4] http://www.rodaleinstitute.org/fst30years/yields

Other ecological agriculture practices that can improve soil structure and increase fertility include growing green manures (crops that are tilled into the soil after they are grown to add nutrients and structure), cover cropping to add nutrients and keep soil covered during a fallow season, mulching and crop rotation (Magdoff, 1998). These are all standard practices in agroecological systems which work to increase fertility naturally and use the diversity of the system to control pests and diseases, while increasing habitats for pollinators and other beneficial organisms.

Building resilience through diversity

System resilience can be built through increasing biological diversity (Altieri and Koohafkan, 2008). Practices that enhance biodiversity allow farms to mimic natural ecological processes, enabling them to better respond to change and reduce risk. Experience suggests that farmers who increase diversity suffer less damage during adverse weather events, compared to conventional farmers planting monocultures (Altieri and Koohafkan, 2008; Ensor, 2009; Niggli et al., 2009).

In cropping systems, diversity can be increased through increasing the variety of crops grown at one time on the parcel of land, and by adding trees and/or animals into the system. Farmers can also increase the diversity of the system by increasing crop diversity itself – growing different varieties of the same crop that have different attributes, for example, shorter-season varieties that may be beneficial if the season is shortened by inadequate rainfall, or varieties that provide more nutritious forage for animals. Supporting soil health increases the diversity of organisms in the soil, which are responsible for benefits such as increased access to nutrients and reduction of overall disease burden. Diverse agroecosystems can also adapt to new pests or increased pest numbers (Ensor, 2009).

It is important to note here the role of women, as they play a key role in managing biodiversity, and thus in adapting to climate change. For example, women in Rwanda produce more than 600 varieties of beans; in Peru, Aguaruna women plant more than 60 varieties of manioc (CBD, 2009).

Emphasizing water management and harvesting techniques

Adapting to climate change will require even more emphasis than is currently given to improving water management and water harvesting in rain-fed regions. Many traditional techniques already in use to improve rainwater use efficiency can be shared using farmer-to-farmer methods.

For example, the zaï techniques of the Sahel have received much attention: water pits used by farmers in Burkina Faso and Mali to reclaim thousands of hectares of degraded lands in the last decades. Farmers have become increasingly interested in the zaï as they observe that the pits efficiently collect and concentrate runoff water and function with small quantities of manure and compost. The practice of zaï allows farmers to expand their resource base and to increase household security. Yields obtained on fields managed with zaï are consistently higher (ranging from 870 to 1,590 kg/ha) than those obtained on fields without zaï (average 500-800 kg/ha). Altieri and Koohafkan (2008) describe a number of other successful traditional water harvesting techniques from around the world actively used by farmers in rain-fed environments.

Increasing productivity in the face of climate change

Given the threats posed by climate change to crop yields, it is important that agriculture practices are able to maintain and even increase productivity. Fortunately, the practices that enhance climate resiliency that are found in ecological agriculture also work to raise productivity, primarily because they improve soil structure and increase fertility.

For example, in a comprehensive meta-analysis, Badgley et al. (2007) examined a global dataset of 293 examples and estimated the average yield ratio (organic:non-organic) of different food categories for the developed and developing world. On average, in developed countries, organic systems produce 92 percent of the yield produced by conventional agriculture. In developing countries, however, organic systems produce 80 percent ***more*** than conventional farms. The data also suggest that leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertilizer currently in use.

Many other specific examples exist of ecological agriculture practices increasing productivity. These are summarized in Lim (2009). Some examples that focus on ecological agriculture practices particularly important for increasing climate resilience are highlighted:

- Soil and water conservation in the drylands of Burkina Faso and Niger have transformed formerly degraded lands. The average family has shifted from being in cereal deficit of 644 kg per year (equivalent to 6.5 months of food shortage) to producing an annual surplus of 153 kg.
- Projects in Senegal promoted stall-fed livestock, composting systems, green manures, water harvesting systems and rock phosphate. Yields of millet and peanuts increased

dramatically by 75-195 percent and 75-165 percent respectively.

- More than 1,000 farmers in low-soil-fertility areas in the North Rift and western regions of Kenya increased maize yields to 3,414 kg/ha (71 percent increase in productivity) and bean yields to 258 kg/ha (158 percent increase in productivity) as compared to traditional agriculture, by incorporating soil fertility management, crop diversification and improved crop management.
- Forty-five thousand families in Honduras and Guatemala have increased crop yields from 400-600 kg/ha to 2,000-2,500 kg/ha using green manures, cover crops, contour grass strips, in-row tillage, rock bunds and animal manures.
- The states of Santa Caterina, Paraná and Rio Grande do Sul in southern Brazil have focused on soil and water conservation using contour grass barriers, contour ploughing and green manures. Maize yields have risen from 3 to 5 tonnes/ha and soybeans from 2.8 to 4.7 tonnes/ha.
- The high mountain regions of Peru, Bolivia and Ecuador are some of the most difficult areas in the world for growing crops. Despite this, farmers have increased potato yields threefold, particularly by using green manures to enrich the soil. Using these methods, some 2,000 farmers in Bolivia have improved potato production from about 4,000 kg/ha to 10-15,000 kg/ha.

Chapter Four

FALSE SOLUTIONS: THE CARBON MARKET THREAT

BECAUSE agroecology provides real solutions to the climate challenge, the coordinated support of agroecological practices and institutions dedicated to those efforts is a crucial objective for the global community to facilitate agricultural adaptation to climate change. These twinned tasks of support and coordination for climate resilience cannot be left to the private sector or a hypothetical market.

Unfortunately, a number of institutions, most prominent among them the World Bank, have been arguing that the carbon market must be one of the main sources of funding for climate change adaptation efforts (see, for example, World Bank, 2010). In this scenario, funding is mobilized for mitigation projects that deliver adaptation co-benefits.

Carbon market basics

There are actually two types of carbon markets: compliance markets and voluntary markets. Where legal emission reduction requirements exist, such as with Kyoto Protocol obligations or within the European Union, regulated entities often have the option to fulfil some of their emission reduction obligations by supporting emission reductions in other parts of the world. They purchase offset credits on a ***compliance*** market in fulfilment of these obligations. For example, the United Nations Framework

Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) generates compliance-grade credits that can be bought and sold on the European Emissions Trading System (EU-ETS) for firms that are legally required to reduce their emissions. However, the EU-ETS does not allow any CDM afforestation/reforestation credits to count as offsets, as these emission reductions are not permanent.

Voluntary markets also trade in offset credits. Corporations wishing to improve their environmental image or individual consumers wishing to offset their consumption will buy ***voluntary*** credits. The standards for voluntary credits are often not as rigorous as those credits produced for the compliance market. Most temporary emission reduction credits, such as those associated with forestry projects, are bought and sold on the voluntary market.

Creating agricultural soil carbon offset credits

The World Bank and others argue that it is possible to measure the carbon sequestered in soils through particular agricultural practices and turn this carbon into an offset credit. Entities that buy these carbon credits would at the same time be supporting the adoption of beneficial agricultural practices, such as the use of manure or compost, cover cropping or mulching fields. These practices are not only mitigation practices but also contribute to the adaptive capacity of farmers. While they are beneficial efforts in their own right, the commodification of the mitigation benefit to be sold as a carbon credit is extremely problematic as well as distracts from the urgent need for climate adaptation in agriculture.

There are a number of fatal flaws with this proposal:

- A compliance market for soil carbon currently does not exist (ActionAid International, 2011). The CDM does not include soil carbon projects and severely limits forestry projects. Biological carbon in soil and trees is understood to be temporary; in creating the CDM, Parties to the UNFCCC were interested in providing incentives for projects with environmental integrity that would lead to permanent emission reductions. The World Bank and other proponents base their optimism on the market they expect will develop someday – a dangerous faith-based strategy with no empirical evidence to support their claims and altogether inappropriate to the climate challenge faced by hundreds of millions of small farmers around the world.
- Soil carbon credits are currently sold on the voluntary market; however, the volume of the voluntary market is minuscule compared to the compliance market. Such a small market (several hundreds of millions of dollars currently) cannot provide the billions of dollars required ***annually*** for agricultural adaptation alone. Moreover, as more biological carbon projects (forestry, agroforestry and soil carbon projects) are developed and flood the market with temporary credits, the value of credits will fall and with it, revenues for any particular project as well. [The average price of soil carbon currently on the market is $1.20/ton (Hamilton et al., 2010). Agricultural soils could store roughly 0-1 ton/hectare/year depending on soil type and practices used.] Very few projects in very few locations will benefit from sales of soil carbon credits on the voluntary market. This is not sufficient or sustainable and hence a rather inappropriate strategy for long-term adaptation finance.

- Carbon sequestered in soils can only ever be considered as temporarily sequestered, limiting the attractiveness to investors of these credits. Any change in practices can lead to reversal, as could an increase in average temperatures due to global warming. An increase in soil moisture will likely increase soil emissions of nitrous oxide and methane, leading to an actual increase in greenhouse gas emissions from soils, rather than sequestration. All these technical factors combine to make soil carbon a dubious commodity for investors interested in something that can be bought and sold numerous times for profit.
- For revenues from carbon finance to be sustainable, continued emissions are required somewhere in order to generate the market for offset credits (FERN et al., 2011). It means developed countries will continue on a path of emitting greenhouse gases, leaving emission reductions to be undertaken by communities in developing countries. This leaves developing-country agriculture at risk from continued emissions and the ensuing climate change, and dis-incentivizes the necessary transition to a low-carbon economy in the developed world.
- And in fact, mitigation is not necessary for much of developing-country agriculture. As noted earlier, the major emissions from agriculture come from industrial systems dependent on synthetic fertilizers and confinement of animals and their manure in massive feedlots. Mitigation emphasis in agriculture needs to be towards the reduction of nitrous oxide and methane emissions of developed countries, not carbon sequestration in smallholder systems in developing countries.
- Adaptation will require much more than just the practices that might be supported in carbon markets, such as addition of manure or compost. In fact, tying farmers to particular practices linked with producing soil carbon

credits, and the need for farmers to maintain those practices for the length of time that credit is traded, takes away the flexibility that farmers will need to adapt to changing climates (Tschakert, 2004).

- Finally, the cost of measuring carbon in soils is quite high, and much of the money actually goes to pay the salaries of consultants and technicians from developed countries. Measurement, reporting and verification of sequestered carbon – all of which are necessary to create a commodity that might be attractive to investors – divert already scarce resources towards non-productive ends. Public monies invested in the process create markets that principally deliver private gain for consultants, investors and commodity speculators, rather than adaptation and a reduction in smallholder vulnerability.

For all these reasons, a soil carbon market is a false solution for the sustainable, predictable and significant financing needed to support the transition to ecological agriculture and other necessary strategies for adaptation.

For developing countries, adaptation has to be the main and overriding concern of development and climate policy. Allowing adaptation to happen in an *ad hoc* manner through projects designed to create carbon credits is worse than bad policy.

Chapter Five

A ROADMAP TOWARDS CLIMATE RESILIENCE THROUGH ECOLOGICAL AGRICULTURE

ADAPTATION of agricultural systems to changing climates is an enormous challenge that will require the concerted effort of governments, researchers and farmers, working together and starting immediately. Because temperatures will continue to rise over the coming decades, we find ourselves in a race against time, to an unknown destination. The effort to create climate-resilient agricultural systems must be prioritized at all levels – from the local to the global, with an important role for national governments to coordinate efforts. Lack of a well-coordinated and well-funded adaptation strategy threatens the lives and livelihoods of millions.

An essential component of climate-resilient agriculture, as explained above, is ecological agriculture. To move on the road to a climate-resilient agriculture, agricultural practices and policies, at the national and international levels, must be systematically and urgently redirected towards ecological agriculture, in order to ensure it can reach its full potential, especially in addressing this enormous challenge.

Farmers, in particular women who make up the majority of the world's small producers, must play a key role on the road to climate-resilient agricultural systems. To do so, they must be integrated into the research and development systems and given tools to do their own on-farm research and the capacity to share their knowledge with other farmers in farmer-to-farmer networks. The challenges facing agriculture are too great to ignore the important potential of farmers, their knowledge and their innovation skills to contribute to the creation of climate-resilient agricultures.

In stark contrast, the world seed, agrochemical and biotechnology markets are dominated by a few companies. In 2004, the market share of the four largest agrochemical and seed companies reached 60 percent for agrochemicals and 33 percent for seeds, up from 47 percent and 23 percent in 1997 respectively (World Bank, 2008). These companies have a vested interest in maintaining a monoculture-focused, carbon-intensive industrial approach to agriculture which is dependent on external inputs (Hoffmann, 2011). Efforts are needed to address the challenges this situation raises.

Below we outline a roadmap towards climate resiliency with five essential elements:

- Increasing investment in ecological agriculture
- Managing climate risks and reducing vulnerability
- Stopping climate-destructive agriculture by dismantling perverse incentives and subsidies that promote unsustainable and high-emissions agriculture
- Implementing a research agenda for climate-resilient ecological agriculture
- Building supportive international policy frameworks.

1. Increasing investment in ecological agriculture

Ecological agriculture practices contribute to resilience and increase adaptive capacity through: improving and sustaining soil quality and fertility; developing and supporting communal water conservation and water catchment systems; enhancing agricultural biodiversity; and developing and supporting agroforestry systems, including conversion of degraded lands to perennial small-scale agroforestry. Governments must specifically reorient agriculture policies and significantly increase funding to support climate-resilient ecological agriculture. They must, at a minimum:

- Focus national agriculture policy frameworks urgently and immediately on agricultural adaptation, giving ecological agriculture a central role in agriculture adaptation strategies. In particular, increased emphasis on the conservation and use of agricultural biodiversity, building healthy soils, and developing and sharing water harvesting and other water management techniques as elements of adaptation strategies is critical.
- Conduct in-depth assessments of agricultural conditions and policies at the national level, to identify both barriers to a transition to ecological agriculture and gaps in policy, and ensure policy coherence such that ecological agriculture is promoted and facilitated.
- Shift subsidy priorities such that the initial costs and risks of farmers' transition efforts to implement ecological farming practices are borne by public funds (Herren et al., 2011), and encourage more diverse crop production with long-term soil health and improved environmental impacts.
- Directly fund adoption of agroecological practices that reduce vulnerability and increase resilience, such as soil-fertility-enriching and climate-resilient practices (e.g., use of compost to enhance soil health, water storage and soil quality).
- Devote a large share of their agricultural budget to promoting ecological agriculture. The support should include mechanisms (both traditional extension and more far-reaching farmer-to-farmer networking methods) to train

farmers in the best options for ecological agriculture techniques, the development of ecological infrastructure including water supply, improvement of soil fertility, and the provision of credit and marketing.

- Enhance agrobiodiversity for climate resilience through supporting conservation and use of local knowledge and seeds; supporting peasant seed systems and community seed banks; prioritizing plant breeding efforts to adapt seeds for future environments, particularly increased temperatures; and banning patents on seeds.

2. Managing climate risks and reducing vulnerability

A key priority for developing countries is to adopt ecological agriculture practices that help their farmers to adapt to climate change. Public financing and transfer of appropriate technologies by developed countries are needed, not only for the adoption of ecological agriculture but also to put in place the required infrastructure, communications and other enabling conditions to ensure that developing countries can adapt to climate change. Governments and funding agencies must:

- Focus on building adaptive capacity and resilience, thereby reducing vulnerability, as well as improve social safety nets to enable farmers and the rural poor to cope with climate-related disasters. This includes implementing a range of policies that support the economic viability of smallholder agriculture and thus reduce their vulnerability, for example, improving access to credit for smallholders; and building and reinforcing basic infrastructure, such as water supplies and rural roads that can facilitate access to markets. Special attention and specific support should be given to women smallholder farmers.

- Strengthen small-scale farmers', women's, indigenous and community-based organizations to, among other objectives: access productive resources, participate in agricultural decision-making and share ecological agriculture approaches for adaptation.
- Involve farmers, through these organizations, in evaluating risks and generating adaptation options.
- Increase investment in national and regional meteorological services, to enhance the collection and use of weather data, and to improve the effectiveness and reach of communication and information technologies to farmers and others in rural communities with up-to-date seasonal weather and long-term climate information, including but not limited to early warning systems.

3. Stopping climate-destructive agriculture by dismantling perverse incentives and subsidies that promote unsustainable and high-emissions agriculture

Current agriculture policies are geared to promoting conventional agriculture practices that are responsible for the bulk of agricultural greenhouse gas emissions. Perverse incentives, including those perpetuated under the current international trade regime governed by the World Trade Organization and bilateral free trade agreements, entrench this unsustainable system. Agricultural incentives and subsidies therefore need to be redirected away from climate-destructive monocultures and climate-harmful inputs (e.g., synthetic fertilizers) towards climate-resilient practices of the small-farm sector. Governments should:

- Avoid and phase out perverse incentives and subsidies that promote or encourage the use of chemical pesticides, synthetic fertilizers and fuel, or that encourage land degradation (IAASTD, 2009; World Bank, 2008), particularly where these are provided to multinational corporations.

- Reduce the use of synthetic fertilizers by removing tax and pricing policies that contribute to their overuse.
- At the international level, modify key market distortions that act as a disincentive to the transition to ecological agricultural practices at the national level in developing countries. These include the significant subsidization of agricultural production in developed countries and their export to developing countries (Hoffmann, 2011). As long as these conditions prevail and are not significantly altered, it is difficult to imagine how developing-country producers can implement a paradigm shift towards ecological agriculture at the required massive scale.
- Ensure that trade commitments made at the multilateral and bilateral levels provide developing countries enough policy space to enable support for the agriculture sector, expansion of local food production, and effective instruments to provide for local and household food security and farmers' livelihoods and meet rural development needs. This is needed before farmers in developing countries can start investing in ecological agriculture and climate-resilient practices.
- Reallocate funds saved from the removal of perverse incentives, and developed-country domestic support and export subsidies, to climate change, in particular for adaptation efforts; this could provide a major source of new and additional public financing to enable developed countries to meet their financial obligations under the UNFCCC (South Centre, 2010), while also providing public financing for adaptation in developing countries.

4. Implementing a research and knowledge-sharing agenda towards ecological agriculture and climate resilience

Too often, national and global agricultural research agendas have been dominated by conventional agriculture approaches and the promise of new technologies. Ecological agriculture has been sidelined, yet it has thrived and has proven successful despite the lack of public support (Pretty, 2006). Farmers' knowledge is a basic and important component of the research/development continuum and research from the scientific community should complement and build on this knowledge. Research and development efforts must be refocused towards ecological agriculture in the context of climate change, while at the same time strengthening existing farmer knowledge and innovation. Moreover, current agriculture research is dominated by the private sector, which focuses on crops and technologies from which they stand to profit most. This research perpetuates industrial, input-dependent agriculture, including synthetic fertilizers, rather than solutions for the challenges facing developing-country farmers. In this light, governments, development agencies and research institutions must:

- Place ecological agriculture and climate adaptation at the forefront of the international and national agriculture research agendas; this means providing public resources for ecological agriculture interventions. At the same time, address current intellectual property systems that act as drivers towards corporate consolidation and corporate dominance of agriculture research.
- Focus research and development efforts towards climate adaptation and ecological agriculture practices that can contribute to adaptation and resilience. Such efforts should as a priority include research on soil-building practices and water harvesting and management techniques essential to adaptation.

- Generously fund efforts to conserve crop diversity, both *in situ* and *ex situ*. Efforts to pair crop-producing regions with climate analogues for future climates and to coordinate breeding efforts towards those future climates are essential for adaptation and must receive significant funding and research support.
- Support research on ecological agriculture approaches that mitigate greenhouse gas emissions from agriculture, such as practices that reduce or eliminate the use of synthetic nitrogen fertilizers.
- Identify research priorities in a participatory manner, enabling farmers to play a central role in defining strategic priorities for agricultural research; and increase networking and knowledge sharing between farmers and researchers.
- Reorient research and extension systems to support farmer-to-farmer agroecological innovation; increase the capacities of farmer and community organizations to innovate; and strengthen networks and alliances to support, document, and share lessons and best practices.
- Ensure farmers have access to information about climate-resilient practices, through both formal and informal means, including extension services, farmers' organizations, climate farmer-to-farmer field schools and cross-visits.

5. Building supportive international policy frameworks

A range of international institutions can make positive contributions by supporting and enabling the adoption of climate-resilient, ecological agriculture, including the Food and Agriculture Organization (FAO), the World Food Programme (WFP), the International Fund for Agricultural Development (IFAD), the centres of the Consultative Group on International Agricultural Research (CGIAR), the World Meteorological

Organization (WMO) and the UNFCCC. These institutions should support the range of efforts to be undertaken at national and regional levels described above, and cooperate and coordinate efforts to mobilize necessary resources at the international level. Key policy considerations for the work of these intergovernmental bodies include:

- The need for sustainable, predictable and significant public funding for ecological agriculture and climate resilience, rather than speculative and volatile market-derived funding. International agencies must play an active role in mobilizing public resources.
- Prioritizing adaptation and food security as the overriding objectives for agriculture and development policy in a changing climate. Agricultural adaptation must be unlinked from mitigation, to prevent the diversion of resources from adaptation towards measurement, reporting and verification of carbon stocks.
- Implementing the key findings of the IAASTD, which call for, among others, a redirection of agricultural policy towards supporting ecological agriculture at the national and international levels.
- Increasing the scale of the work to promote climate-resilient ecological agriculture practices by the Rome-based UN agencies: FAO, WFP, IFAD. This should include technical support to enable countries to transition to and prioritize ecological agriculture, funding for adaptation and climate-resilient strategies based on ecological agriculture, and appropriate policy advice that supports the implementation of ecological agriculture.
- The need for the CGIAR centres to leverage research and research partnerships, and the funding thereof, which focus on ecological agriculture, agricultural biodiversity and small farmers in developing countries. The recommendations

described in point 4 above are particularly relevant for the CGIAR and its centres.

- Ensuring the conservation and sustainable use of agricultural biodiversity and related traditional knowledge systems to promote climate resilience, including through the relevant work on agricultural biodiversity carried out by the FAO Commission on Genetic Resources for Food and Agriculture, the International Treaty on Plant Genetic Resources for Food and Agriculture, and the Convention on Biological Diversity (CBD). In addition, the CBD, in its consideration of climate change issues, should ensure that ecological agriculture practices that contribute to climate resilience are promoted.
- Reviving the work of the UN for a global framework for corporate accountability, including the reinstatement of obligations under the aborted UN Code of Conduct on Transnational Corporations.

UNFCCC-specific recommendations

1. **Increasing investment in ecological agriculture**

- Annex II Parties[5] to the UNFCCC must ensure sustainable, predictable and significant public funding for climate-resilient ecological agriculture, through support to the Green Climate Fund, the Adaptation Fund, as well as bilateral and other multilateral climate funding mechanisms.
- Bilateral and multilateral funding agencies must prioritize climate-resilient ecological agriculture in their agriculture funding portfolios.

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[5] Annex II Parties consist of the OECD (Organization for Economic Co-operation and Development) members of Annex I (see footnote 6), but not the countries with economies in transition. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change.

2. **Managing climate risks and reducing vulnerability**
    - Under the Nairobi work programme, the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) should undertake a review of agroecological practices and their contribution to climate resilience.
    - As they develop their National Adaptation Plans, governments should incorporate actions in the agriculture sector, in particular provision of support to smallholders in the adoption of climate-resilient agroecological practices. Developed countries should provide funding for these actions through bilateral and multilateral climate finance and other mechanisms.

3. **Stopping climate-destructive agriculture by dismantling perverse incentives and subsidies that promote unsustainable and high-emissions agriculture**
    - UNFCCC Parties should initiate in the SBSTA a review of Annex I[6] subsidies, taxes and pricing policies, and other domestic measures that support high-emissions agriculture.

4. **Implementing a research and knowledge-sharing agenda towards ecological agriculture and climate resilience**
    - In the context of implementing Article 4.1(c),[7] Parties to the UNFCCC should initiate a SBSTA review of ecological agriculture approaches that mitigate greenhouse gas emissions from agriculture, such as practices that reduce or eliminate the use of synthetic nitrogen fertilizers, and animal production models that recycle animal waste as fertility inputs in crop production.

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[6] Annex I Parties include the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

[7] Article 4.1(c) of the UNFCCC refers to international promotion and cooperation in the development, application, diffusion, including transfer, of mitigation technologies to developing countries in all relevant sectors.

- Under the Adaptation Framework, the Adaptation Committee should coordinate a review of agroecological climate-resilient strategies and technologies for adaptation in agriculture.

5. **Building supportive international policy frameworks**

- Parties to the UNFCCC must prioritize agriculture (ecological, climate-resilient agriculture) within the UNFCCC Adaptation Framework, in the Nairobi work programme and the work programme on loss and damage.
- Annex II Parties should provide support to countries in the National Adaptation Plan process to integrate ecological agriculture into national adaptation plans.
- The Adaptation Committee should initiate a workstream on agriculture to coordinate work in the sector among the different elements of the Adaptation Framework.
- The Adaptation Committee should encourage and facilitate transfer of ecological agriculture technologies relevant to reducing vulnerabilities and building of adaptive capacity and resilience in agricultural systems.

CHAPTER SIX

CONCLUSION

THE world needs climate-resilient agriculture.

FAO and the World Bank have been promoting a concept called "climate-smart" agriculture. While we agree with many of the ecological agriculture principles and policy recommendations put forward under this framing to support a transition to ecological agriculture, we disagree with the significant emphasis its proponents place on the role of the carbon market for financing agricultural adaptation and mitigation.

Agricultural adaptation and food security in a changing climate will provide the world with a Red Queen challenge – it will take all the running we can do just to keep in the same place, just to continue to produce the same amount of food as we do currently. At times the practices adopted to run in this race will have mitigation co-benefits. However, distracting attention and diverting resources from significant adaptation challenges by trying to achieve a "triple-win" through counting and selling carbon is not only bad policy, it is dangerous.

Prioritizing agricultural adaptation and the link to food security then must be paramount. This necessary emphasis should be explicitly reflected in the UNFCCC approach to and work on adaptation, both within the context of the recently established Adaptation Framework and within consideration of the means needed for implementation: financial resources, technology transfer and capacity building.

Clearly, ecological agriculture is and should be central to agricultural adaptation. Ecological agriculture ***is*** climate-resilient, and the benefits to farmers in developing countries in particular would be manifold. Concerted effort is therefore needed to facilitate the transition to ecological agriculture. Anything less would put the lives and livelihoods of millions at risk.

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ECOLOGICAL AGRICULTURE, CLIMATE RESILIENCE AND A ROADMAP TO GET THERE

The phenomenon of climate change poses a serious threat to agricultural production and, therefore, to the lives and livelihoods of the hundreds of millions who are dependent on agriculture. Adaptation to the increased variability in weather patterns requires the adoption of ecological farming practices which are climate-resilient as well as productive.

This paper looks at how ecological agriculture, by building healthy soils, cultivating biological diversity and improving water harvesting and management, can strengthen farmers' capacity to adapt to climate change. Accordingly, the authors call for a reorientation of policy, funding and research priorities from the dominant industrial agriculture model to ecological agriculture. At the same time, recourse to carbon markets to finance adaptation efforts through trade in soil carbon credits is rejected as an unsustainable, wrong-headed approach to meeting the climate challenge.

Instead, facing the vagaries of climate change demands a concerted effort by governments, multilateral agencies, researchers and farmers to support the transition to ecological agriculture. Towards this end, this paper outlines a roadmap of measures for promoting truly climate-resilient farming systems.

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