International Federation of Organic Agriculture Movements

The Role of Organic Agriculture in Mitigating Climate Change

- a Scoping Study -

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Acronyms

AAUs	Assigned Amount Units, serialised units of the amount assigned from a Party's initial allocation
CBD	Convention on Biological Diversity
CDCF	Community Development Carbon Fund
CDM	Clean Development Mechanism
CERUPT	Similar to the ERUPT program, however solely for the funding of CDM Projects
CERs	Certified Emission Reductions, credits from a CDM project
COP	Conference of the Parties
ERUs	Emission Reduction Units, credits from a JI project
ERUPT	Emission Reduction Unit Purchasing Tender
GEF	Global Environment Facility
GHG	Greenhouse Gas
IDA	International Development Association
IET	International Emissions Trading
IETA	International Emission Trading Association
IRR	Internal Rate of Return
JI	Joint Implementation
JLG	Joint Liaison Group
LDC	Least Developed Countries
LULUCF	Land Use, Land Use Change and Forestry sector
NAPAs	National Adaptation Programs of Action
OA	Organic Agriculture
OECD	Organization for Economic Cooperation and Development
PCF	World Bank Prototype Carbon Fund
PIN	Project Idea Note
POPs	Persistent Organic Pollutants
RMUs	Removal Units, credits from part of a Party's assigned amount generated from domestic sinks activities within Annex 1 countries
t CO_2 e	Tonnes of Carbon Dioxide Equivalent
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change

Conversion Table

1 kg = 10^3 g
1 Mg = 10^6 g = 1 t
1 Gg = 10^9 g = 1 kt
1 Tg = 10^{12} g = 1 Mt
1 Pg = 10^{15} g = 1 Gt
1 kg N_2O = 44/28 kg N_2O-N ≅ 1.57 kg N_2O-N
1 kg N_2O-N = 28/44 kg N_2O ≅ 0.636 kg N_2O
1 kg CH_4 = 16/12 kg CH_4-C ≅ 1.33 kg CH_4-C
1 kg CH_4-C= 12/16 kg CH_4 ≅ 0.75 kg CH_4
1 kg CO_2 = 44/12 kg CO_2-C ≅ 3.67 kg CO_2-C
1 kg CO_2-C= 12/44 kg CO_2 ≅ 0.273 kg CO_2

Global warming potential (time horizon: 100 years):
1 kg N_2O = 310 kg CO_2-equivalents = 84.5 kg C-equivalents
1 kg CH_4 = 21 kg CO_2-equivalents = 5.73 kg C-equivalents
1 kg CO_2 = 1 kg CO_2-equivalents = 0.273 kg C-equivalents

0. Executive Summary

There is dramatic evidence that various Greenhouse Gases are responsible for Global Warming and climate change. This present study discusses the potential of Organic Agriculture both to avoid and to sequester Greenhouse Gases (GHG), and makes comparisons with conventional agriculture. The second part describes how Organic Agriculture can be considered within the implementation mechanisms of the Kyoto Protocol.

The role of agriculture in climate change

Agriculture is a major contributor to emissions of methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). On a global scale, agricultural land use in the 1990s has been responsible for approximately 15% of all GHG emissions.

One third of all carbon dioxide emissions comes from changes in land use (forest clearing, shifting cultivation and intensification of agriculture). Approximately two thirds of methane and most of nitrous oxide emissions originate from agriculture.

At the same time, agriculture offers options to reduce GHG significantly. 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 carbon dioxide in soils and in plant biomass. It is unique for all types of land use.

However, the potential contribution of the land use sector for climate protection is limited. Although sinks in vegetation and soils have a high potential to mitigate increases of CO_2 in the atmosphere, they are not sufficient to compensate for heavy inputs from fossil fuel burning. The long-term solution lies in developing alternatives to fossil fuel. Yet the contribution from the land use sector could buy time during which alternatives to fossil fuel can take affect. But mainstream agriculture is moving in an opposite direction; increasing releases of GHG from the green sector have made agriculture a producer of global warming rather than a mitigating factor.

The avoidance potential of Organic Agriculture

Organic Agriculture can significantly reduce carbon dioxide emissions. As a viable alternative to shifting cultivation, it offers permanent cropping systems with sustained productivity. For intensive agricultural systems, it uses significantly less fossil fuel in comparison to conventional agriculture. This is mainly due to the following factors,

- Soil fertility is maintained mainly through farm internal inputs (organic manures, legume production, wide crop rotations etc.),
- Energy-demanding synthetic fertilizers and plant protection agents are rejected, and,
- External animal feeds - often with thousands of transportation miles - are limited to a low level.

As a consequence, the organic variants have in most cases a more favourable energy balance.

In avoiding methane, Organic Agriculture has an important though not always superior impact on reduction. Through the promotion of aerobic microorganisms and high biological activity in soils, the oxidation of methane can be increased. Secondly, changes in ruminant diet can reduce methane production considerably. However, technology research on methane reduction in paddy fields – an important source of methane production - is still in its infancy.

Nitrous oxides are mainly due to overdoses and losses on nitrogen. These are effectively minimized in Organic Agriculture because:

- No synthetic nitrogen fertilizer is used, which clearly limits the total nitrogen amount and reduces emissions caused during the energy demanding process of fertilizer synthesis.
- Agricultural production in tight nutrient cycles aims to minimize losses;
- Animal stocking rates are limited. These are linked to the available land area and thus excessive production and application of animal manure is avoided.
- Dairy diets are lower in protein and higher in fibre, resulting in lower emission values.

Another avoidance option is represented by using biomass as a substitute for fossil fuel. Organic Agriculture is well positioned in this sector. It has the advantage that inorganic N-fertilizers are not applied, an input which causes significant emissions of N_2O and partly offsets CO_2 savings.

The sequestration potential of Organic Agriculture

Organic Agriculture has a particular sequestration potential as it follows the key principle of tight nutrient and energy cycles through organic matter management in soils. This is achieved through improved practices in cropland management and in agroforestry.

Various long term trials provide evidence that the regular addition of organic materials to the soil is the only way to maintain or even increase soil organic carbon (SOC). The systematic development and application of organic fertilization technologies has been the domain of Organic Agriculture for many decades and outstanding results have been achieved so far. Key issues of technology development have been:

- To optimise the quantity and application of organic manure. A close integration of crop production and animal husbandry and the systematic recycling of organic waste are basic elements.
- To improve organic waste processing techniques to obtain high quality manure. Through composting of animal and plant residues losses in the humification process are minimized and a higher proportion of the solid humus fraction is achieved.

Long and diversified crop rotations and legume cropping are further characteristics of Organic Agriculture that help to increase SOC.

In conventional agriculture, conservation tillage is largely promoted as a measure to sequester carbon dioxide. This technology combines minimum tillage with organic covers, herbicides and often herbicide resistant GMO crops. Both of the last two are prohibited in Organic Agriculture. Latest research results revealed that gains in soil organic carbon have been overestimated and are partly or completely offset by increased N_2O emissions. Thus it can be concluded that minimum tillage combined with mineral fertilizer application compares less well with Organic Agriculture if the focus is on GHGs in general rather than considering carbon sequestration alone. The task of Organic Agriculture will be to integrate conservation tillage in a way that negative effects are avoided.

Agroforesty – a management system that integrates trees in the agricultural landscape – is another technology which is systematically applied in Organic Agriculture. It is a feasible method to succeed shifting cultivation systems but also to improve and add value to low productive cropland. Agroforestry holds the biggest potential of agricultural carbon sequestration in tropical countries.

Organic Agriculture - a strategy for climate protection

Several the measures mentioned above are often referred to as "recommended management practices". They *could* be used by any type of agriculture, but Organic Agriculture is unique in the sense that it offers a strategy which systematically integrates most of them in a farming system. This strategy comprises compulsory standards superior in their impact on climate protection. It also comprises a well functioning mechanism of inspection and certification that guarantees compliance of the organic principles and standards. The strictness of the system has made Organic Agriculture accountable and a generator for innovation.

As a conclusion, Organic Agriculture could contribute significantly to reduce GHG releases and to sequester carbon in soils and biomass. Secondly, there is sufficient evidence that Organic Agriculture is superior to mainstream agriculture. This is even more important as the capacity of Organic Agriculture to contribute to the mitigation of climate change can be considered as an ancillary benefit to its primary goal of sustainable land use. This primary goal is achieved by gains in soil productivity, consecutive food security, biodiversity conservation and many other benefits.

However, in competition with other strategies Organic Agriculture is disadvantaged. Unlike conservation agriculture for instance, which offers one technology only, Organic Agriculture follows a site-specific farming-systems approach with a whole set of technological changes. Monitoring and impact assessment with respect to carbon sequestration (or GHG avoidance) are therefore comparatively complicated and costly.

Within the LULUCF sector under the Kyoto Protocol, agricultural projects are eligible for Joint Implementation (JI) in the industrial countries. But, unlike forestry, agriculture is not yet accountable in the Clean Development Mechanism (CDM), which aims to stimulate cooperation between industrial and Developing Countries. Apart from this procedural constraint, Organic Agriculture is an issue hardly discussed, neither in national processes of formulating national inventories nor in the international panel on climate change.

Recommendations

In order to include Organic Agriculture as a strategy for climate protection two main avenues should be pursued:

- Lobbying initiatives in various countries at national level, to make Organic Agriculture an explicit part of LULUCF in their national GHG inventories; this is an important step to ensure that Organic Agriculture as a strategy can participate in the Joint Implementation Mechanism.
- A broad initiative, by which Organic Agriculture projects in Developing Countries tap into and utilize financial support from the various existing carbon funds; such an initiative can help to develop suitable instruments for the assessment of carbon sequestration and for the monitoring of project implementation.

The latter is important to make Organic Agriculture accountable within the LULUCF sector.

For the organic movement there is a great task ahead. IFOAM's role could be to provide a forum for information management, to coordinate research projects and to initiate lobbying in this field.

1. Introduction

Scope of the problem

The climate of our world is undergoing a dramatic change. Global warming is increasing rapidly and there is widespread consensus that the current trend is caused by increased emissions of various "Greenhouse Gases" (GHG). These are mainly: carbon dioxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6), methane and nitrous oxide.

Greenhouse Gases allow short-wave solar radiation to pass into the Earth's atmosphere . They absorb some of the long wave thermal radiation that is otherwise emitted back out to space. This process, called "positive radiative forcing", has a warming effect on our atmosphere.[1] Since 1861 global mean temperature has risen by 0.6 ^{o}C. The year 1998 is considered to have been the warmest on record (Malhi et al. 2002).

The emission of Greenhouse Gases into the atmosphere comes with industrialization, through deforestation, shifting cultivation and the expansion of intensive agriculture. The atmosphere has thus become a classical example of a common resource pool that is being overexploited. The most prominent of these changes has been the modification of the carbon cycle. Atmospheric carbon dioxide increased from a pre-industrial concentration of 280 ppm to 368 ppm in 2000, i.e. by 31%. It is very unlikely, that such a concentration has ever been reached before during the past 20 million years (Malhi et al. 2002) and the concentrations are steadily rising. It is, therefore, evident that action has to be taken to stabilize atmospheric greenhouse gas concentrations at a tolerable level. And being a global problem such action can only be achieved through international efforts.

Kyoto Protocol

At their third meeting in 1997, the Conference of Parties (COP-3) to the United Nations Framework Convention on Climate Change (UNFCCC) produced the Kyoto Protocol, a document for appropriate actions to reduce GHG emissions. It included commitments by 38 developed countries to reduce their annual emissions of GHG by 5.2% during the period 2008-2012 below the baseline year of 1990.

"In 1990, those countries emitted 3.87 GtC (gigatonnes of carbon). Emissions from the rest of the world in 1990 were 2.22 GtC (Marland et al. 2000). Thus the Kyoto Protocol would require a reduction of approx. 0.2 GtC yr $^{-1}$ during the five-year commitment period, or a total of 1 GtC. (…) It is widely accepted that a reduction in carbon emissions of 1 Gt will have very little impact on projected climate change. To have a significant impact, reductions over the next few decades have to be much greater (Arnell et al. 2002). For example, to stabilize concentration of CO_2 at 550 ppm by 2150, a stated policy of the European Union (…), carbon emissions will need to be reduced by ca. 136 Gt during the next 50 years from a business as usual scenario. To ensure, that

[1] The radiative forcing due to increases of the well-mixed greenhouse gases from 1750 to 2000 is estimated to be 2.43 Wm^{-2}: 1.46 Wm^{-2} from CO_2; 0.48 Wm^{-2} from CH_4; 0.34 Wm^{-2} from the halocarbons; and 0.15 Wm^{-2} from N_2O (IPCC 2001).

the world is on the path for stabilization at 550 ppm, carbon emissions would need to be reduced by approx. 8 Gt during the first Kyoto commitment period" (Brown et al. 2002).

Such a scenario simply demonstrates the magnitude of the problem. The Kyoto Protocol, although unsatisfactory, is the only international treaty so far. Whether or not it will be ratified, or whether any other post Kyoto treaty will be adopted, all available legal, organizational and technological options need to be considered and to be applied soon to reduce GHG atmospheric concentrations and to lower and stabilize increments over the next century.

Focus of the study and major restrictions

In the first part, after discussing the general role of agriculture in the climate change process, this study reviews the evidence on the capacity of Organic Agriculture to reduce emissions and serve as a sink of atmospheric greenhouse gases. When, for the sake of brevity, we talk about emissions we mean net emissions. This distinction is of particular importance for the whole land use sector because soil and vegetation are not the only sources of GHG emission. They also represent sinks for their sequestration.

In part II of this study the currently developing international mechanism for climate change management is presented and ways in which Organic Agriculture can be utilized within the existing political and institutional frameworks to combat climate change are discussed.

Several aspects posed particular difficulties for this study. First, the subject is extremely complex particularly because of its highly interdisciplinary nature. Climate change management has at least science-related, economical, legal and political implications. Second, we were confronted with a vast literature on the subject, with a wealth of publications from thousands of scientists and other professionals. Third, the climate change management framework is in *statu nascendi*. The Kyoto Protocol has not yet come into force and the implementation of a, hopefully soon, effective treaty is constrained by many unsolved methodological questions.

Hence, this study may be seen as a first and modest contribution to assess the scope of Organic Agriculture in a world where climate change management will become a major impetus by single governments, as well as the international community, and will (hopefully) become a major force in political decision-making and resource allocation.

PART I The Physical Impact of Organic Agriculture

2. Greenhouse Gases and Agriculture

The Kyoto Protocol mentions six greenhouse gases which are very likely to be responsible for climatic change: Carbon dioxide (CO_2), methane (CH_4), nitrous dioxide (N_2O), HfCs, PFCs and SFs. For these gases obligatory targets for reduction were formulated for the period between 2008 and 2012. Agriculture is a main contributor to emissions of CH_4 and N_2O, and also, to a lesser extent, of CO_2. The potential of these gases to cause global warming differs greatly and for the sake of comparability a Global Warming Potential Index is defined[2]. The GWP Index with a time span of 100 years of CO_2, CH_4 and N_2O is 1, 23 and 296, respectively (IPCC 2001).

The 31% increase of carbon dioxide since 1750 is now thought to be responsible for 60% of all GHG induced warming (Malhi 2002) and will increase to approx. 75% in this century (IPCC 2001). N_2O contributes around 6% (IPCC 2001) and CH_4 approximately 20% to global warming (Hütsch 2001).

On a global scale, agricultural land use in the 1990s has been responsible for roughly 15% of GHG emissions (Cole et al. 1997).

2.1 Carbon Dioxide

The global carbon pools

As can be seen from the GWP Index, carbon dioxide (CO_2) is not the most effective Greenhouse Gas. But as it exists in relatively high concentrations it contributes most to global warming. CO_2 forms only a small part of the overall carbon budget. The global carbon cycle as presented in Table 1 shows the enormous emission reservoir of geological and soil carbon in comparison to the small proportion, which is in the atmosphere.

Reduction of terrestrial carbon stocks through land use

It is assumed that a measurable increase of atmospheric CO_2 concentrations started around 1850 (Houghton 1999). In the beginning, increasing net carbon emissions were solely due to land use change. The overall contribution of fossil fuel combustion by all sectors increased continuously and surpassed that of land use change in the 1970s. In 1999, it accounted for two thirds of the current emissions (IPCC 2000). The atmospheric C pool of 760 Pg is increasing at the rate of 3.2 Pg C/yr - at the expense of the geologic, soil and biotic pools.

[2] The GWP Index is defined as the cumulative radiative forcing between the present and a selected time in the future, caused by a unit mass of gas (IPCC 1996, cited in Flessa et al. 2002).

Table 1: 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)

The changes in land use comprise primarily:

- The permanent clearance of forests for pastures and arable crops, as for example practiced widely in Latin America,
- The logging of timber with subsequent regeneration or re-planting as for instance in South East Asia (regenerated forests generally store much less carbon than natural forests).
- Shifting cultivation - a traditional method of agricultural land use which increased significantly with increasing population growth, but which is now of decreasing importance
- An intensification of agriculture (crop and animal husbandry) using more and more external inputs, a trend mainly in the industrial regions of the world. (Malhi et al. 2002)

Among the various processes of changing land use, the expansion of croplands at the expense of natural ecosystems has dominated and continues to dominate the net emission of carbon from the terrestrial biosphere. The tropical forests of South East Asia are the regions of highest activity (Malhi et al. 2002).

Changes in land use have not only reduced vegetation as a carbon sink; they have had even more effect on levels of soil organic carbon. SOC – soil humus, organic litter and soil fauna - represents the largest terrestrial reservoir in interaction with the atmosphere, and the short-term dynamics of organic carbon are largely restricted to the upper 30-50 cm. On a global scale, the organic carbon pool in the upper 1 m of the world's soils is estimated to be at least 1.5 - 2 times higher than that of the standing biomass (Sombroek et al. 1993, FAO 2001). In the humid tropics it is almost equal.

World-wide, SOC has been and is being reduced by changes in agricultural land use:

- The conversion of natural ecosystems such as forests or savannahs into agricultural land ("slash and burn") results in a drastic loss of soil organic matter. In tropical soils it is sometimes decreasing by 75% within a few years (Nye and Greenland 1960).
- The cultivation of the soil favours the oxidisation of SOC and, combined with a lack of organic manuring practices, this is leading to a continuing impoverishment, which may ultimately stabilize at a very low SOC level.
- Soil erosion either by water or by wind is the result of poor land management practices. Soil erosion affecting mainly the upper soil layer with the highest SOC content is the third main pathway to remove and, later on convert, soil organic carbon into carbon dioxide and/or methane.

According to Lal (2001), 43.5% of the global and cumulative carbon emissions from land use change are from soil cultivation, 18.5 % are due to soil erosion and 38% is a consequence of the burning of biomass.

Industrialization of agriculture

Losses of carbon stocks are not the only source of emission from land use. The intensification and industrialization of agriculture in regions like Europe, North America and Japan is the second most important source and is growing in importance. The global doubling of production during the last 30 years was associated with a 6.9 fold increase in nitrogen fertilization, and a 3.5 fold increase in phosphorus fertilization (Tilman 1999). Furthermore, mechanization demands increasing fossil fuel consumption.

Statistics suggest that the overall share of agriculture in the national carbon emission budgets of industrial countries is small. In Germany, for instance, agriculture contributes only 5.8% to the overall national GHG emissions - or 8.8% if processing energy for inputs is included (Zeddies 2002). However, such figures are misleading as these countries have a high overall budget. In absolute terms, the emissions from industrial agriculture are considerable, and this sector is strongly promoted worldwide.

Global calculations as presented in Table 2 estimate that changes in land use constitute a third of all carbon emissions. Actual trends in major carbon fluxes on a yearly basis are shown in Table 3.

Table 2: Cumulative contribution of soil, biomass and fossil fuel combustion to atmospheric C

Source	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 3: Global CO_2 budgets (in PgC/yr)*

	1980s	1990s
Atmospheric increase	3.3 ± 0.1	3.2 ± 0.1
Emission (fossil fuel, cement)	5.4 ± 0.3	6.3 ± 0.4
Ocean – atmosphere flux	- 1,9 ± 0.6	-1.7 ± 0.5
Land-atmosphere flux	- 0.2 ± 0.7	- 1.4 ± 0.7

* based on intra-decadal trends in atmospheric CO_2 and O_2. Positive values are fluxes to the atmosphere; negative values represent uptake from the atmosphere. Error bars denote uncertainty ($\pm 1\ \sigma$). (IPCC 2001)

2.2 Methane

In contrast to carbon dioxide, two thirds of total methane (CH_4) emissions are anthropogenic and come mainly from agriculture (Ahlgrimm and Gaedeken 1990). Most of the methane is neutralized in the Troposphere where it reacts with OH (576 Mt/year), Stratospheric loss is about 40 Mt/year and a significant part (30 Mt/year) is oxidized in soils, the only terrestrial sink for CH_4. At present, methane increases at a global rate of approximately 22 Mt/year.

The sources of methane differ according to regions and levels of agricultural intensification. In Western Europe, 17% of Methane emission is from animal dung, and a third from semi- liquid manure (Stolze et al. 2000)[3]. Corresponding figures may be obtained from other areas with highly intensive animal husbandry liquid manure.

Other important sources are paddy fields and wetlands in tropical countries. Together, they contribute about 30 % to global gross emissions of methane (Prather et al. 1995, see also Table 4).

[3] According to Gibbs and Woodbury (1993) approximately 10% of semi-liquid manure is converted into methane, compared to only 1% of solid manure combined with animal pasture.

Table 4: Global estimates of natural and anthropogenic sources of Methane (CH_4)

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)

2.3 Nitrous Oxide

Nitrous oxide (N_2O) contributes not only to global warming but also to the depletion of stratospheric ozone and has a mean residence time in the atmosphere of approx. 120-150 years (Crutzen 1981). At least 60% of global gross N_2O emission evolves from soils (Prather et al. 1995, cited in Langeveld et al. 1997). It comes from mineral as well as organic nitrogen fertilizers, and from nitrogen fixed by legumes. With the use of nitrogen fertilizers generally increasing, N_2O has also increased considerably. Since 1750 N_2O has risen by 17% (+46 ppb) and it is expected further to increase by 14-53% (38-144 ppb) by 2100 (IPCC 2001).

Table 5: Global estimates of recent sources of N_2O influenced by land-use activities.

N_2O Sources	Mt N / yr	Gt C-eq / yr
Cultivated soils	3.5 (1.8–5.3)	0.9 (0.5–1.4)
Biomass burning	0.5 (0.2–1)	0.1 (0.05–0.3)
Livestock (cattle and feed lots)	0.4 (0.2–0.5)	0.1 (0.05–0.13)
Natural tropical soils—wet forests	3 (2.2–3.7)	0.8 (0.6–1)
Natural tropical soils—dry savannas	1 (0.5–2)	0.3 (0.1–0.5)
Natural temperate soils—forests	1 (0.1–2)	0.3 (0.03–0.5)
Natural temperate soils—grasslands	1 (0.5–2)	0.3 (0.1–0.5)

Source: Prather et al. (1995).

All nitrogen fertilizers – mineral and biological - are sources of nitrous oxide emission. N_2O emission factors vary between 0.2% and 2.3% for mineral N-fertilizer, between 1-1.8% for organic manure, and between 0.2-1% for legume fixed nitrogen (Ambus 2002).

In temperate climates, the N_2O losses of N-fertilizers are in the range of 0.25% - 2.25% (IPCC 1996, Hellebrand and Scholz 2000) and often calculated with mean values of 1,25% N applied to crops. Some examples from the research literature may illustrate the variable and complex nature of the N_2O building process:

- Comparisons of ploughed versus reduced tillage cropping systems in Germany resulted in lower figures for the ploughed variant (DFG Forschungsgruppe 2002).

- Applications of liquid manure typically associated with high losses of NH_3 (up to 30 % of applied NH_4-N), had much lower N_2O values than improved liquid manures (DFG Forschungsgruppe 2002).

In general, it can be stated that N_20 emission measurements often display large inherent variations, reflecting natural soil heterogeneity and different measurement techniques, rather than real differences due to tillage and cropping practices (Choudhary et al. 2002).

2.4 Other Greenhouse Gases

Other relevant greenhouse gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluorides (SF_6) originate from industry and fossil fuel combustion. Currently, tropospheric ozone (O_3) is the third most important greenhouse gas after carbon dioxide and methane (IPCC 2001).

3. 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.

But mainstream agriculture is moving in an opposite direction. Increasing releases of GHG from the green sector have made agriculture a producer of global warming rather than a mitigating factor.

By contrast, Organic Agriculture is a systematic strategy, which may reduce GHG emissions and may enhance the sequestration of carbon, the most important green house gas. Important components of this strategy are: the basic principles to be followed, compulsory standards to be respected, suitable technologies in production and processing to be applied and, last but not least, a system of inspection and certification which guarantees adherence to the process.

Basic Principles

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.

Standards

Unlike sustainable or conventional farming systems, Organic Agriculture follows detailed standards of production and processing, which are enforced by inspection and certification. In the context of the mitigation of GHG some paragraphs of the latest IFOAM Basic Standards (IFOAM 2002) merit particular attention:

- Soil Fertility and Fertilization (4.4): *"…Mineral fertilizers shall only be used in a program addressing long-term fertility needs together with other techniques such as organic matter additions, green manure, rotations and nitrogen fixation by plants (…) Chilean nitrate and all synthetic nitrogenous fertilizers, including urea, are prohibited."* This paragraph emphasizes the reliance on organic manuring techniques, which help to sequester carbon in the soil. However to refrain from synthetic nitrogen has a double impact: A very energy demanding technology is being avoided, an energy, which is entirely based on fossil fuel. With the exclusion of this type of fertilizer an important source of carbon emission is avoided. Furthermore, another aspect of the large-scale production of nitrogen fertilizers merits attention: it leads to exclusive and excessive use. In many cases increased mineralisation of soil organic matter (releasing carbon dioxide) is the consequence. Both the reliance on nitrogen fertiliser and the quantity used have become the main reasons for reduced soil organic carbon. Simplified crop rotations and reduced input of organic materials on farms with little or no cattle are further reasons. All of these have become common practice in conventional agriculture and are prevalent not only in industrial countries but also in many Developing Countries, where nitrogen is often the only fertilizer subsidized.

- Soil and Water Conservation (2.2): *"…Land preparation by burning vegetation shall be restricted to the minimum (…) All operators shall take defined and appropriate measures to prevent erosion (…) Grazing management shall not degrade land ..."*

- Animal nutrition (5.6): *"…The prevailing part (at least more than 50% of the feed shall come from the farm unit itself or be produced in co-operation with other organic farms in the region"*. This paragraph excludes the possibility of highly intensive, industrial animal husbandry, which is one of the main sources of methane emissions.

The mitigation of climate change is not, so far, an explicit goal of Organic Agriculture, but its principles and standards create the pre-requisites to deliver a considerable result in this respect. The binding standards create awareness and an obligation to follow ecological principles and to seek sustainability in production.

Inspection and certification

The compliance with standards is monitored and recognized by a well organized and rather strict system of inspection and certification, a system, which in many countries is further, complemented by a legal framework and supervised by government authorities. At international level, and to allow international trade, there are efforts to harmonise national standards and regulations.

Taken all together, principles, standards and certification instruments in Organic Agriculture represent a unique strategy. Its accountability distinguishes Organic Agriculture from all other ecological movements, such as integrated farming, conservation agriculture or sustainable agriculture, which are less well defined and less accountable. These have no restriction, for instance in using chemical pesticides or fertilizers. At best, there are recommendations to use them only as much as necessary and as little as possible. The accountability makes Organic Agriculture highly credible among consumers, environmentalists and politicians.

Technologies

The strict application of standards demands that new ways of managing agro-ecology have to be sought. This has made Organic Agriculture a generator of technological innovation. A wide range of technologies in production and processing has been developed within the Organic Agriculture movement, many of which have become mainstream in agriculture. Technologies are not "organic per se". They may be used by any type of agriculture. But, it is the systematic approach applied in accordance with the ecological, socio-economic and cultural potentials at a given site, which ultimately results in a wide range of organic farming systems worldwide.

Impact assessment

This high diversity of farming systems is an evident strength of Organic Agriculture. At the same time it poses methodological difficulties when it comes to impact assessment. In principal, the benefits of Organic Agriculture systems can be proven through a systems comparison for a specific site. However, such comparisons are very costly and require enormous effort. They are, therefore, rare and often disputable (DFG-Forschergruppe Klimarelevante Gase 2002). This is a problem, which increases the existing problem for national governments of systematically quantifying the impact of the agricultural sector on GHG in their national inventories. To our knowledge there is as yet no initiative in any country of the world where Organic Agriculture is addressed as a defined and quantifiable sub sector.

4. Emission Reduction through Organic Agriculture

This chapter concentrates on the avoidance of GHG emissions through agriculture and the specific performance of Organic Agriculture. It mainly discusses the release of carbon dioxide from fossil energy combustion, the release of methane from animal husbandry and paddy cultivation and last, but not least, the release of nitrous oxide from nitrogen fertilizers.

4.1 Carbon Dioxide

Avoidance of shifting cultivation

The conversion of natural vegetation into agricultural land is a major source of carbon dioxide emission. In practicing “slash and burn” farmers utilize soil fertility, which has accumulated under natural fallows for decades. They crop the soil for several years before leaving it to fallow again. In the past, this practice has been the main contributor to global carbon emission. As an alternative, Organic Agriculture offers permanent cropping systems with sustained productivity. It comprises a range of land use management practices. The increased and more efficient use of organic manure, ground covering legumes and green manures, a stronger combination of animal husbandry with crop husbandry and a very limited use of mineral fertilizers are technologies which have gained large scale extension particularly in smallholder agriculture (see Table 6). All of these have been and are being developed systematically under Organic Agriculture regimes at various agro-ecological sites in temperate, subtropical and tropical zones (Kotschi 1990, Lampkin 1990, Müller-Sämann and Kotschi 1994, Pretty and Hine 2001 etc.).

Reduction of fossil fuel consumption

A second major source of carbon emission and increasing importance is the use of fossil fuel in agriculture, which relies more and more on external inputs such as synthetic fertilisers, chemical pesticides, agricultural machinery, and imported animal feeds (e.g. Soya bean). All of these consume fossil fuel. In India, for instance, a 10-20% increase in yield following mechanization costs an extra 43-260% in energy consumption (Pretty 1995). As a consequence, the more agriculture is intensified in an industrial manner the more it contributes indirectly to carbon emission.

Organic Agriculture is not exempted from the trend of intensification, but offers more favourable energy balances. A comparison of the energy use per hectare for organic versus conventional is presented in Table 6 (Pretty & Ball 2001). The different examples show a 30-70% lower consumption per unit of land for organic agricultural systems.

Table 6: 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 & Ball (2001), adapted from Pretty (1995); Cormack and Metcalfe (2000)

Other comparisons of European farming systems confirm this range. In Germany, organic farms have 48-66 percent lower CO_2 emissions per hectare compared to conventional systems. (Burdick 1994, Haas & Köpke. 1994, Stolze 2000, DFG-Forschergruppe Klimarelevante Gase 2002). The differences per unit of production are less pronounced and sometimes small, as organic yields were mostly lower than conventional.

There are three measures of Organic Agriculture to reduce the consumption of fossil energy:

- Soil fertility is maintained mainly through farm owned resources - so-called internal inputs (organic manures, legume production, wide crop rotations etc.)
- Energy demanding synthetic fertilizers and plant protection agents are rejected, and,
- External animal feeds with often thousands of transportation miles are limited to a low level.

More energy, however, is consumed in mechanical weed control in Organic Agriculture. Nevertheless the overall balance of the organic variant is far superior.

4.2 Methane

Methane contributes approximately 15% to global warming (Bockisch 2000). Two thirds are of anthropogenic origin and mainly from agriculture (Ahlgrimm and Gaedeken 1990). The avoidance of methane emissions is, therefore, of particular importance for this sector. The following areas of influence indicate that Organic Agriculture has an important, though not always superior, impact on reduction.

Soil management

Approximately 10-15% of atmospheric methane is oxidised in aerobic soils.[4] (Born et al. 1990, Houghton et al. 1992, IPCC 1994). Soil is considered to be the only significant terrestrial sink for methane (Mosier et al. 1993). It is estimated that atmospheric concentration would be double without this sink (Ojima et al 1993).

Oxidation is promoted by high biological activity in soils, by reduced tillage practices and slow release N amendments, whereas repeated applications of only ammonia or urea to soils inhibits the bacterial oxidation of CH_4 (Hütsch 2001). Grassland and forest soils have higher oxidation rates than cropland.

Compost and biogas

The aerobic fermentation of manure through composting is ambivalent. A shift of anaerobic to aerobic storage of manure can reduce CH_4 emissions but will increase N_2O by a factor of 10. In CO_2 equivalents there is no change. Composting is not therefore recommended as a mitigation option (Bates 2001). But controlled anaerobic digestion of manure and waste combined with biogas production is a most promising option for GHG mitigation (Jarvis & Pain 1994).

Animal husbandry

"The emission of methane by ruminants is probably not affected by organic production. The higher proportion and lower productivity of ruminants in organic agriculture may, however, lead to slightly higher emissions of CH_4. On the other hand, standards and breeding programs aim at longevity in order to prolong the productive period in relation to the unproductive life of young cattle. Correspondingly the 'unproductive' CH_4-emission of calves and heifers may be reduced" (FAO 2002). In addition, breeding towards more productivity per animal unit has also been identified as an effective means of reducing methane emissions, an option with limited scope in Organic Agriculture.

Changes in diet represent another possibility. In Germany, for instance, the addition of farm produced sunflower seed in ruminant feeds could reduce methane production by 42 % compared to commercial feed ratios (Zeddies 2002a). The role of feed composition in reducing nitrogen losses is discussed in Chapter 4.3.

Paddy cultivation

Research on technologies reducing methane in paddy fields is still in its infancy. Effective measures to minimize CH_4 production seem to be:

- The use of composted manures with low C/N ratio (Agnihotri et al. 1999 and Singh et al. 2003),

[4] Hellebrand and Scholz (2000) reported assimilation values between -5µg CH_4 m^{-2} h^{-1} (winter) and 10 to 20 µg CH_4 m^{-2} h^{-1} (summer) in central Europe. Overall oxidation rates per year were estimated as high as 700 g CH_4 ha^{-1} a^{-1} on a sandy loam.

- The selection of rice cultivars with lower CH_4 emissions (Yagi et al. 1997) and,
- One or two aeration periods before heading stage (mid season drainage).

Mosier et al. (1998) estimate that the potential to reduce methane emissions is 8-35 Mt CH_4/yr if practices were applied in all areas concerned.

4.3 Nitrous Oxide

The largest part of global atmospheric N_2O evolves from microbial transformation of ammonia to nitrate (nitrification) and from nitrate to N_2 (denitrification). Accordingly, all types of nitrogen, whether mineral fertilizer, organic manure or nitrogen fixing legumes have enhanced N_2O emissions (Bouwman 1990, Houghton et al. 1992).

It is not however, only the total amount of N applied to the system that is important. How efficiently nitrogen can be utilized by plants also matters. Extreme overdoses and high losses - which are quite common in highly intensive agricultural systems - have to be avoided.

Extreme losses are also to be found in tropical countries, where nitrogen is often applied exclusively or unbalanced, and other nutrients, mainly phosphorus, are neglected. In such cases the plants take up only part of the nitrogen and a larger part is lost.

Intensive animal husbandry systems represent another important source of N_2O pollution. They use protein rich animal feeds with only a small part of protein N transformed into meat. According to Berg (1997), reducing N in animal feed is the most efficient and cheapest mitigation option. It reduces losses of all N species, including N_2O, NH_3 and nitrate leaching. For pig fattening in Germany, Berg estimates that N in the diet could be reduced by 20% without economic losses. For dairy farms it could be demonstrated that lower protein feed concentrations (as typically used in Organic Agriculture) resulted in increased N efficiency. At the same time N-losses in animal husbandry were reduced by 10-15 % and in plant/soil amendment by more than 40 % (Jäckle 2003). This reduced nitrate leaching, ammonia and nitrous oxide emissions.

In the Netherlands, farmers following the management strategy developed by van Bruchem could reduce residual nitrogen in animal dung from 324 to 278 kg/cow. This fact is often not considered, assuming that emissions do not respond to different diets. The system described by Jäckle (2003) is based on a strategy aiming towards minimizing external N-inputs and to reduce protein concentrations in animal feed from 18 % to approximately 15 %, at the same time increasing the fibre content of ruminant feed.

System comparisons of organic versus conventional animal husbandry systems in Europe produced different and partly contradictory results. Reitmayr (1995) found that there is no significant difference. Lundström (1997) assessing dairy farms in Sweden found even slightly higher N_2O emissions on the organic variant, and Zeddies (2002a) reports that farms in southern Germany gave 50 % lower N_2O -emissions without mineral nitrogen fertilisers and minimum input of animal feed from outside the farms.

In conclusion, the principles and standards of Organic Agriculture turn out to be effective in minimizing nitrous oxide emissions. The important points are:

- No synthetic nitrogen fertilizer is used, which clearly limits the total nitrogen amount and reduces emissions caused during the energy demanding process of fertilizer synthesis.
- Production in tight nutrient cycles aims to minimize losses;
- Animal stocking rates are limited. These are linked to the available land and thus excessive production and application of animal manure is avoided.
- Dairy diets are lower in protein and higher in fibre, resulting in lower emission values.

Organic Agriculture thus serves an important function to avoid nitrous oxide emissions.

4.4 Biomass as a Substitute for Fossil Fuel

The use of biomass as a substitute for fossil fuel represents a high potential for the avoidance of GHG emissions. Although the various concepts and technologies for using biomass for energy production are not exclusive to organic farms, the development of the underlying ideas as well as the technical equipment and facilities have mainly been driven by the Organic Agriculture sector. Moreover, as explained below, when biomass is cropped organically instead of conventionally, GHG emissions (e.g. N_2O) are lower.

One possibility is the production of biomass explicitly for energy purpose. Various technical options to produce and convert biomass into energy are available. Solid biomass and even fresh biomass may be used directly for combustion or converted (e.g. pyrolysis, fermentation) to liquid or gaseous compounds. Wood, straw, oil, ethanol and biogas are only some of the sources of energy that can be produced.

A second opportunity is associated with the processing of slurry, by which means biogas is obtained. The latter produces energy and at the same time reduces methane emissions, which result from inadequate handling of animal manure.

The production of organic sugar cane combined with improved technologies to produce energy from biomass represents another important potential. A large factory in the State of Sao Paolo, Brazil reports that the cogeneration of thermal energy and electricity from burning bagasse (instead of using fossil fuel) makes the high energy demand sugar mill self sufficient. In addition it produces a considerable surplus of electricity (Native 2004).

According to Lal (2002), carbon sequestration through bio fuel production cannot be overemphasized. The author estimates that bio fuel production on degraded soils could yield a sequestration of around 129,7 Pg/50 years and make two thirds of the overall potential (soil sequestration and biomass production for fuel). The author also mentions that a real mitigation of GHG is only achievable if the biomass is produced in equilibrium with the carbon cycle. In other words, as long as the production itself does not produce additional GHG emissions. Intensively fertilized annual crops, for instance, typically cannot be included because they require and remove large quantities of nutrient from soils.

Organic Agriculture is well positioned in this sector. It has the advantage that inorganic N-fertilizers are not applied, an input causing significant emissions of N_2O. These emissions partly offset CO_2 savings (see rape seed oil in table 7) and contribute in high degree to ozone depletion

(Reinhardt & Zemanek 2000). Synergies may also result from new management options to target problems of pest and weed management and the physical restoration of soils including carbon sequestration in deeper soil layers. Perennial energy crops in a short-term rotation like Miscanthus or Willow may be of particular interest.

In the following (table 7) an example from Germany is given, presenting the various options of net CO_2 avoidance through biomass production. It is calculated on a 1 ha basis and assumes that mineral oil for heat generation and car gasoline are replaced. It further takes into account the emissions throughout the whole life cycle (LCA approach) including the production, consumption and disposal of goods. Similar energy yields can be expected in tropical countries where enough water is available and where energy crops may contribute to improved land husbandry at the same time offering opportunities for decentralized low emission energy production in rural areas.

Table 7: Net carbon emission reduction potential of energy crops (Germany)

Source of energy	Yield assumed dry matter t/ha+y	Emission reduction kg CO_2 only	Emission reduction[1)] kg CO_2e
Wheat (whole plant)	10.0	11,121	8,796
Poplar (short term rotation)	9.9	10,795	10,371
Wheat straw	1.8	6,845	6,616
Miscanthus grass[2)]	--	10,954	10,289
Grass (meadow extensive)	2.3	2,561	2,497
Ethanol from sugar beet [3)]	14.8	9,029	7,322
Rape seed oil	2.8	2,759	1,221
Rapeseed RME[4)]	2.8	3,794	2,280

1) Biomass versus mineral oil, discounts for CH_4 and N_2O
2) recent developments suggest even higher net gains (Müller-Sämann et al 2003)
3) substituting car gasoline
4) Rape seed oil or -methyl ester substituting diesel fuel

Source: (Reinhardt & Zemanek 2000)

As can be seen from data presented in table 7 perennial, low external input energy crops like Miscanthus or poplar not only have a large potential, but also low discounts for other greenhouse gases (CO_2e reduction vs. CO_2 reduction) resulting from extensive fertilizer and energy consumption for production.

The possibilities to reduce CO_2 emission through fuel-wood production in tropical agroforestry systems are discussed in chapter 5.2.

5. Improved Carbon Sequestration through Organic Agriculture?

A second pathway to mitigate GHG emissions consists in sequestering carbon dioxide in soil and vegetation.[5] The key principle of tight nutrient and energy cycles through organic matter management in soils gives Organic Agriculture a particular sequestration potential. It mainly follows these principles in applying improved or alternative practices in cropland management and in agroforestry. The evidence of their performance is reviewed in the next paragraphs.

5.1 Cropland Management

Worldwide, the conversion of natural systems to agriculture resulted in losses of soil organic matter (of which around 50% is soil organic carbon) with two major consequences: enormous amounts of carbon dioxide were released into the atmosphere and soil productivity decreased drastically. These losses are particularly high immediately after land clearing. They then show a typical exponential decline with a continuing loss over many years if no systematic measures are applied to replenish soil organic matter (Nye and Greenland 1960, Rasmussen et al. 1998, Sanchez et al. 1982, Siband 1972, Young 1976).

With on-going cultivation, soil organic matter stabilizes at a rather low level. Total losses of 70-75% are not exceptional. On a global basis, the cumulative loss of carbon from agricultural soils has been estimated to be as high as 55 Gt C (IPCC 1996) - almost one third of the total losses from soils and vegetation together.

This trend can be stopped, and even reversed, if appropriate measures are taken. There is widespread consensus that rising organic matter levels can be achieved through systematic application of organic manure from animal and crop residues, through crop-legume rotations and green-manure practices as well as ground covering legumes (Coleman et al. 1997, Kätterer and Andren 1999, Leigh and Johnston 1994). All of these help to replace organic matter losses due to oxidation. A second, and sometimes complementary option is to reduce the oxidation process through reduced soil tillage methods such as minimum tillage, conservation tillage and no tillage (Heenan et al 2004 and others).

Organic manure

There is ample evidence from various long term trials that the regular addition of organic materials to the soil is the only way to maintain or even increase SOC and soil productivity (Powlson et al. 1998, Nyamangara et al. 2001). Under permanent cropping this can be achieved through organic manures, addition of plant residues, mixed cropping, legume based crop rotations or agroforesty (Drinkwater et al 1998). It has also been proven that an enrichment of soil organic matter cannot be achieved through mineral fertilizer alone (Leigh and Johnston 1994, Jenkins et al. 1994, Raupp 2001 and many others). On the contrary: the sole use of synthetic nitrogen fertilizer often contributes to increased oxidization of organic matter thus increasing soil organic carbon losses.

[5] There is no significant sequestration potential for other greenhouse gases. N_2O has to be avoided and methane either to be avoided or oxidized in the soil.

The systematic development and application of organic fertilization technologies has been the domain of Organic Agriculture for many decades and outstanding results have been achieved so far. Key issues of technology development have been:

- To optimise quantity and application of organic manure. A close integration of crop with animal husbandry and systematic recycling of organic waste are basic elements.
- To improve organic waste processing techniques to obtain high quality manure. The composting of animal and plant residues has become a key technology to minimize losses in the humification process and to achieve a high proportion of the solid humus fraction (but this may lead to higher methane emissions).

A basic source of recent scientific evidence in temperate climates is the DOK trial, a long-term systems comparison between "dynamic" (bio-dynamic), "organic" and "conventional" carried out in Switzerland. Raupp (2001) found that after a period of 18 years soils under different manure treatment contained 3-8 t /ha more C than those with mineral fertiliser treatment.

According to Bachinger (1996), Raupp (1995), Fließbach and Mäder (1997), and Gehlen (1987), microbial biomass and the Cmic/Corg ratio is distinctly higher in long term organically fertilized plots. At the same time, the metabolic quotient (an indicator of the energy requirement of soil organisms) is lower. Reduced metabolism is particularly low under biodynamic treatment, soil properties improved and root development increased (Reganold 1995). This is of significant importance to carbon sequestration because root biomass contributes more to carbon accumulation in soils than aboveground biomass (Sisti et al 2004).

Crop rotations

Long and diversified crop rotations are a characteristic of Organic Agriculture and legume cropping forms an indispensable part. A systems comparison conducted by Haas and Köpke (1994) revealed that organically grown crops sequester less carbon in the upper biomass of crops but more in the root biomass. Secondly, the sequestration potential given as the output/input ratio was twice as high under Organic Agriculture (42:1 compared with 21:1 for conventional, see table 8).

Studies of organically managed grass-legume mixtures in Denmark revealed that only small proportions (0.1-0.25%) of the biologically fixed nitrogen were lost and losses decreased with pasture age (Ambus 2002). Grass-clover mixtures as part of the crop rotation are common practice in Organic Agriculture and seem to yield a double benefit: As an alternative to mineral nitrogen they help to reduce N_2O emissions, and as a means to accumulate soil organic matter they contribute to carbon sequestration, not to mention other benefits such as improved soil structure, provision of animal feed etc.

Table 8: Carbon sequestration by organic and conventional farming systems

	Organic	Conventional	Difference
		-- t CO_2 / 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 & Köpke (1994)

Conservation tillage

Conservation tillage is a term that embraces zero- and minimum tillage combined with the use of organic soil covers. Legume crops maintain a permanent or semi-permanent organic cover partly combined with a growing crop or dead organic matter in the form of mulch.

Little or no tillage of the soil reduces the carbon losses by oxidization, cover crops protect the soil from sun, rain and wind, increase soil organic matter and feed microorganisms. The result is a higher content of soil organic carbon, increased soil productivity and reduced soil erosion. Conservation tillage practices are applied mainly in North America, Brazil, Argentina and Paraguay and are increasingly recognized by farmers as one of the most promising agronomic interventions as it helps to reduce production costs and, at the same time, to invest into soil fertility. On top it has a significant carbon sequestration effect. Conservation tillage is mostly dependent on using herbicides and often combined with herbicide resistant GMO crops, both representing components that are unacceptable for Organic Agriculture.

An example from USA comparing mouldboard ploughing and zero-tillage with and without cover crops is presented in Table 9 (Pretty & Ball 2001).

Table 9: Carbon losses and gains under ploughing and zero-tillage (USA)

System	Rotation	Gains or losses of carbon (t C / ha+yr)
Mouldboard plough	Continuous maize or wheat	- 0.105 to - 0.460
	Mixed rotations and cover crops	- 0.033 to - 0.065
		-
Zero Till	Continuous maize or soybeans	+ 0.330 to 0.585
	Mixed rotations and cover crops	+ 0.660 to 1.310

Source: Pretty & Ball (2001) adapted from Reicosky et al. (1995), Langdale et al. (1992), Edwards et al. 1982, 1992)

Conservation tillage is less frequent but also expanding in Europe. Research findings from Germany, the UK and Spain suggest similar sequestration rates. Zero tillage yields 0.10 – 0.77 t C /yr (Smith et al. 1998, Edwards et al. 1992, Lal et al. 1998, Tebrügge and Düring 1999, Tebrügge 2000). Pretty & Ball (2001) conclude that, in combination with cover crops, a general estimate of 0.66 – 1.3 t C/ha+yr can be given. There is, however, no evidence of how carbon sequestration will develop over time. With increasing carbon saturation, sequestration rates will have to decrease. This has to be considered when calculating total gains over longer time periods.

In Organic Agriculture, ground-covering legumes are widely applied, minimum tillage is basically supported, but barely practiced. The reason is that these technologies are mostly based on using herbicides, either to control weeds or to kill cover crops before planting maize or other cereals. Chemical herbicides are not allowed in Organic Agriculture, and weed control is still dominated by tillage practices. Hence further technology development is needed to integrate conservation tillage in Organic Agriculture systems.

However, recent research results revealed that gains in soil organic carbon are sometimes less or non-existent if the whole profile depth is considered[6] (Vanden Bygaart et al. 2002, Rücknagel et al. 2003). Six et al (2000) also show that with minimum tillage gains in soil organic carbon are partly or completely offset by increased N_2O emissions. Thus it can be concluded that minimum tillage combined with mineral fertilizer application compares less well with Organic Agriculture if the focus is on GHGs in general rather than considering carbon sequestration alone.

5.2 Agroforestry

Agroforestry is a management system that integrates trees on farms and in the agricultural landscape. It leads to a more diversified and sustainable production system than many treeless alternatives and provides increased social, economic and environmental benefits for land users (Sanchez 1995). Agroforestry is practiced in all agro-climatic zones but is most prevalent in the

[6] depending on slope position and clay content of the soils.

tropical belt and holds a particular potential in the humid tropics. The performance of agroforestry practices for the main climatic zones is summarized in Table 10 (Schroeder 1994).

Table 10: Above ground carbon storage and annual growth rate for agroforestry practices in different eco-regions

Ecozone	Carbon storage t C / ha	Growth rate t C / ha+yr	Cutting cycle (years)
Semi-arid	9	2.6	5
Sub-humid	21	6.1	8
Humid	50	10.0	5
Temperate	63	3.9	30

Source: Schroeder (1994)

Agroforestry succeeding slash and burn systems

In the humid tropics, agroforestry is seen as a viable alternative to slash and burn agriculture. Comprehensive research under the ASB Programme[7] (Palm et al. 2000) suggests that after the clearance of forests carbon sequestration rates are highly negative with - 92 t C / ha+yr during the first two years. But carbon sequestration becomes positive with secondary forest fallows producing 5-9 t C / ha+yr, or with complex agroforests contributing 2-4 t C / ha+yr. Simple agroforests with one species such as oil palm or rubber can yield 7-9 t C / ha+yr. As a consequence, such agroforestry systems can regain 35% of the original carbon stock of the forest (three times more than cropland and pastures). The time averaged additional carbon stock in the vegetation increases by 50 t C ha^{-1} plus 7 t ha^{-1} SOC over a period of 20-25 years. The findings further suggest that this potential for short to medium term carbon sequestration in the humid tropics is mainly above ground (Palm et al. 2000).

[7] Alternatives to Slash and Burn Programme, Nairobi

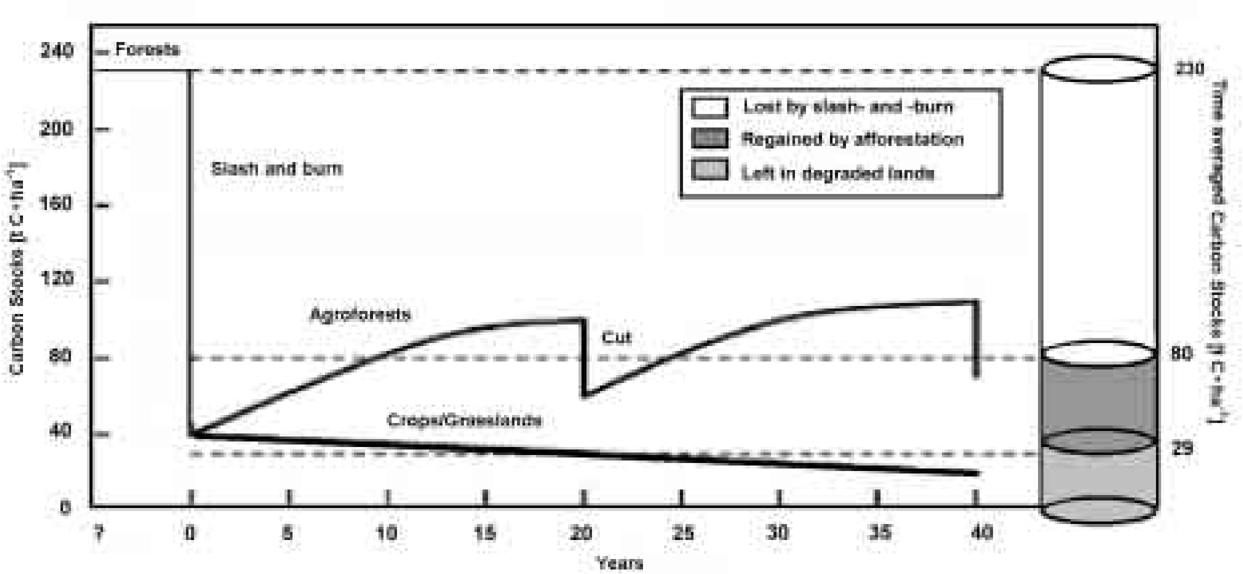

Figure 2: Time course of system carbon stocks (biomass and soil, solid lines) and time-averaged carbon stocks (dotted lines) in agroforestry systems vs. crops followed by grasslands at margins of humid tropical forest. IPCC (2000)

Conversion of low productive cropland

Another major option is the conversion of low productive cropland. This applies mainly in the sub-humid tropics. In this climatic belt, carbon stocks (above ground biomass and soil organic carbon) have decreased dramatically. Associated nutrient depletion renders grain yields (maize, sorghum) in smallholder agriculture mostly below 0.5 t/ha. One of the many examples researched (Table 11) illustrates the performance of various agroforestry practices in Central America (Kürsten and Burschel 1993).

Table 11: Performance of agroforestry practices (above ground) under sub humid conditions

Agroforestry systems in Central America	CO_2 mitigation t C /ha+yr
• Shade trees in coffee, cacao (Gliricidia, Inga densiflora, Mimosa scarabella)	0.7 – 2.0
• Fuel-wood plantations (Leucaena leucocephala, Eucalyptus saligna)	2.0 –3.6
• Secondary forests	0.3 – 2.0
• Trees in corrals and annual crops	0.1
• Living fences (Gliricidia sepium)	1.4
Source: Kürsten and Burschel (1993)	

Extensive research on the current situation and on the potential impact of agroforestry has been undertaken by ICRAF for East and Southern Africa. Improved short rotation fallows of 1-2 years with fast growing tree species such as Sesbania, Crotalaria, Calliandra and Leucaena, combined with 1-3 consecutive years of cropping are the first step to replenish soil organic carbon and soil productivity. In a second step more trees are integrated on the farmland. In doing so an average of 1.2-5.1 t C /ha+yr with a modal value of 3.1 t C /ha+yr can be sequestered (Sanchez 2000). As illustrated in Figure 3, over a period of 25 years carbon stocks can be tripled from 23 to 70 t C ha^{-1}, out of which an estimated 16% are sequestered as soil organic carbon, whereas the main carbon stock is in above ground biomass (IPCC 2000). Similar results can be assumed for sub-humid West-Africa and sub-humid South-America, but there is little researched evidence.

Similar processes can be assumed for the in semi-arid areas. The carbon sequestration potential however will be much lower but the impact on soil fertility improvement may be equal or even higher (FAO 2001).

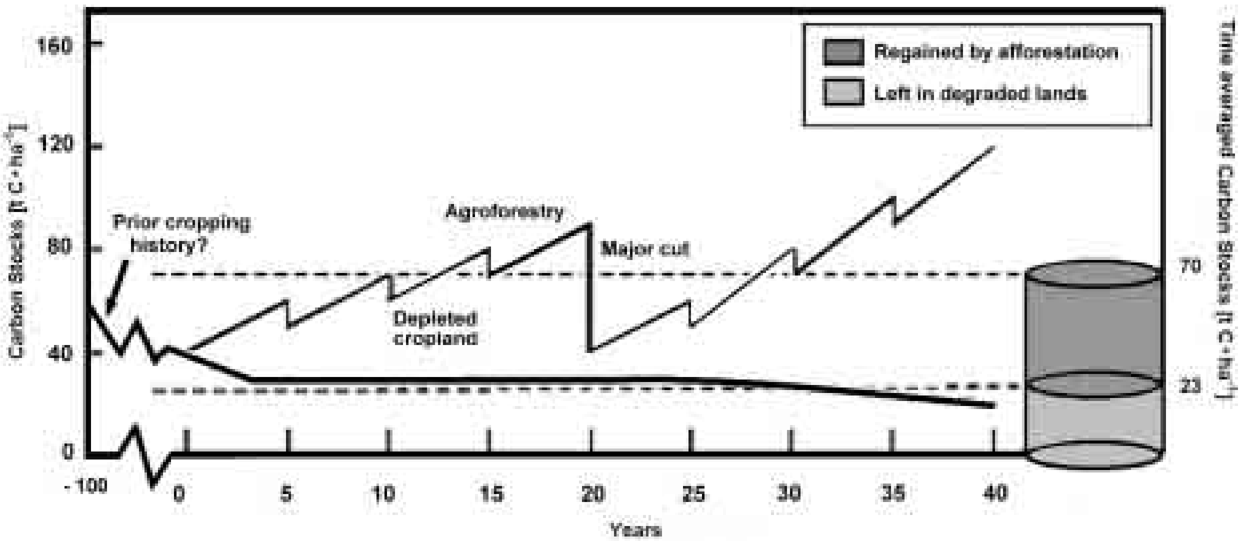

Figure 3: Project time course and system carbon stocks (biomass and soil) and time-averaged carbon stocks in sequential agroforestry systems based on soil fertility replenishment and intensification with high-value trees in sub-humid tropical Africa. IPCC (2000)

Improvement of existing agroforestry systems

A third option is the improvement of already existing agroforestry systems. This is relevant to all tropical areas from humid to semi-arid sites. Various techniques such as higher tree density combined with various agronomic and sylvicultural practices (pruning, pollarding, use of rock phosphate, enhanced germplasm of trees and shrubs) contribute to an overall estimated gain in carbon storage of 0.02 – 1.0 t C / ha+yr, and a modal value of 0.22 t C / ha+yr is assumed (IPCC 2000).

5.3 Global Estimates

The global estimates for future carbon sequestration follow the logic of the Kyoto Protocol. They distinguish between forestry[8] (Article 3.3) and "additional human induced activities" (Article 3.4), the latter addressing agriculture and agroforestry (see also chapter 8).

[8] Afforestation, Reforestation and Deforestation

The following estimates for "additional human induced activities" are based on the physical potential of land and vegetation, and the technical feasibility of sequestration technologies. Both are comparatively easy to assess. However, it is quite difficult to predict political, institutional and regulatory frameworks as well as financial resources, all of which favour or constrain large-scale implementation of carbon sequestration. The definition of adoption rates is based on expert opinion and vary considerably. Two estimates are reported here as follows.

The most comprehensive calculation (IPCC 2000) is presented in tables 12 and 13. According to the Kyoto Protocol, a distinction is made between Annex I countries, which are almost identical to the industrial countries, and Non Annex I countries that represent the developing countries. Taking both groups together, it is estimated that a global quantity of 1.3 Pg C / yr can be sequestered by 2010. This amounts to 16% of the global annual emission rate of 8.0 Pg C / yr from fossil fuel combustion. According to the authors the amount may increase beyond 2010 due to growing adoption rates.

Table 12: Potential net carbon storage through improved land use or land use change in Annex I countries (IPCC 2000) [9]

Activity / practice	**Area 10^6 ha**	**Adoption/conversion % of area**		**Rate of Carbon Gain**	**Potential Mt C / yr**	
		2010	2040	t C / ha+yr	2010	2040
a) Improved management in land use						
Cropland	589	40	70	0.32	75	132
Paddy cultivation	4	80	100	0.10	>1	>1
Agroforestry	83	30	40	0.50	12	17
Grazing land	1297	10	20	0.53	69	137
Forest land	1898	10	50	0.53	101	503
Urban land	50	5	15	0.3	1	2
b) land use change						
Agroforestry	~0	~0	~0	~0	0	0
Restoration of severely degraded land	12	5	15	0.25	>1	1
Grassland	602	5	10	0.8	24	48
Wetland restoration	210	5	15	0.4	4	13
c) Other	n.a.	n.a.	n.a.	n.a.	210	210
Total					497	1063

[9] Increases in carbon storage may occur via (a) improved management within a land use, (b) conversion of land use to one with higher carbon stocks, or (c) increased carbon storage in harvested products. For (a) and (b), rates of carbon gain will diminish with time. Potential carbon storages are approximations, based on interpretation of available data. For some estimates of potential carbon storage the uncertainty may be as high as 50% (IPCC 2000 p. 184).

Table 13: Potential net carbon storage through improved land use or land use change in Non-Annex I countries (IPCC 2000)[9]

Activity / practice	Area 10^6 ha	Adoption/conversion % of area		Rate of Carbon Gain	Potential Mt C a^{-1}	
		2010	2040	t C ha^{-1} a^{-1}	2010	2040
a) Improved management in land use						
Cropland	700	20	50	0.36	50	126
Paddy cultivation	149	50	80	0.10	7	12
Agroforestry	317	20	40	0.22	14	28
Grazing land	2104	10	20	0.80	168	337
Forest land	2153	10	30	0.31	69	200
Urban land	50	5	15	0.3	1	2
b) land use change						
Agroforestry	630	20	30	3.1	391	586
Restoration of severely degraded land	12	5	10	0.25	3	7
Grassland	855	2	5	0.8	14	34
Wetland restoration	20	1	10	0.4	0	1
c) Other	n.a.	n.a.	n.a.	n.a.	90	90
Total					805	1422

Another calculation presented by Lal (2003c) states that of the total emission of 8.0 Pg C a^{-1} due to fossil fuel combustion, 1-2 Pg C a^{-1} can be sequestered in world soils through conversion to an appropriate land use, restoration of degraded soils and ecosystems and adoption of "recommendable management practices" on agricultural and forestry soils (Lal 2003c). The largest share comes from Asia with approximately 30%, followed by Africa with around 23%. This calculation assumes a 50-75% adoption of recommended management practices by the year 2050. Above surface biomass has to be added.

According to estimations from Cole et al. (1996), appropriate management practices could increase carbon sinks by 0.4 to 0.9 Pg C/yr, or a cumulative carbon storage of 24 to 43 Pg C over 50 years. Energy efficiency improvements and production of energy from dedicated crops and residues would result in a further mitigation potential of 0.3 to 1.4 PgC/yr, or a cumulative carbon storage of 16 to 68 PgC over 50 years.

6. Conclusions

Land use is an important sector within an overall strategy for the mitigation of atmospheric greenhouse gases. This concerns the avoidance of greenhouse gases (CO_2, N_20 and CH_4) as well as the sequestration of CO_2. Though sinks in vegetation and soils have a high potential to mitigate increases of CO_2 in the atmosphere, they are insufficient to compensate for heavy inputs from fossil fuel burning. Even if historic changes in land use could be reversed completely, estimates of CO_2 reduction in the atmosphere would not be higher than 40-70 ppm (IPCC 2001).

The contribution of the land use sector to climate change mitigation has therefore a limited impact. The long-term solution lies in developing alternatives to fossil fuel. Yet this contribution buys time during which alternatives to fossil fuel can take affect.

On a global scale, forestry and agriculture (including animal husbandry and agroforestry) represent an equally large potential for carbon sequestration). In agriculture, with the often quoted “recommendable management practices” a significant impact can be achieved. This is valuable knowledge, but the question of how they can be applied in an optimal way remains. Single technologies may have an impressive physical performance, what matters, however, is the challenge to integrate as many as possible of them into farming systems in a way that the overall economy of the farm is improved.

In this respect Organic Agriculture has a unique position. It offers an agricultural strategy, which systematically integrates most of them and creates continued technological innovation through research and development (R&D) in the context of farming systems. Secondly, and equally unique, Organic Agriculture is the only strategy that offers a comprehensive and transparent framework aiming at more sustainability in land use and climate management. Its principles are in line with climate protection. The standards set are superior in their impact on climate protection and instead of being informal as under conventional agriculture, the standards are compulsory. Last, but not least, there is a well functioning mechanism of inspection and certification that guarantees compliance of principles and standards.

In valuing single measures, an overview of the benefits of Organic Agriculture is given in Table 14. It comprises technologies that either reduce emissions or sequester carbon or do both. It also includes consumer behaviour, which may contribute to emission reductions from agriculture.

On the avoidance side, Organic Agriculture has a significant impact on reducing CO_2 and N_2O. A potential to reduce CH_4 exists but it is less pronounced.

On the CO_2 sequestration side there is a huge potential but it is different for tropical and temperate countries. The Non-Annex I Countries (Developing Countries, mostly in the tropical belt) have a 30-60% higher carbon sequestration potential than the Annex I Countries (industrial countries, mostly in the temperate climate regions).

On agricultural land in industrial countries improved management of cropland and grazing land are equal in potential, but sequestration rates per ha are higher for grazing land. Options for land use change are of minor importance.

On agricultural land in the predominantly tropical and developing countries, land use change through the introduction of agroforestry has the highest sequestration potential. It has rather low sequestration rates but addresses vast areas of degraded lands and smallholder agriculture. Second in relevance is improved land use management, which mainly addresses cropland and grazing land.

Table 14: 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)			

Sound technologies to sequester additional carbon have been developed in cropland management and in agroforestry and they are systematically applied and improved in Organic Farming systems. Evidence of their performance does exist, but it is fragmentary as it does not allow regular comparison and quantification for the various agro-climatic regimes and socio-economic patterns. A third vast potential for sequestration in both country groups is rangeland management. In this sector, Organic Agriculture has little to offer.

As a summary conclusion, Organic Agriculture contributes significantly to reduce GHG releases and to sequester carbon in soils and biomass. Secondly, the evidence – although fragmentary – is sufficient to state clearly that Organic Agriculture is superior to mainstream agriculture.

The capacity of Organic Agriculture to contribute to the mitigation of climate change can be considered as an ancillary benefit to its primary goal of sustainable land use. This primary goal is achieved by gains in soil productivity, consecutive food security, biodiversity conservation and many other benefits.

Part II The Framework to Combat Climate Change

7. Conventions and the Kyoto Protocol

The discussion in the preceding chapter on the impact of land use on climate change illustrates that our world climate is a common resource pool at the global level. Accordingly, the protection of this resource can only be attained through international efforts. There are three international conventions related to issues of climate change and biological diversity. These are:

- The Convention on Biological Diversity (CBD)
- The United Nations Convention to Combat Desertification (UNCCD)
- The United Nations Framework Convention on Climate Change (UNFCCC)

These conventions are often referred to as the Rio Conventions as all three are associated with the 1992 Rio de Janeiro "Earth Summit". Although each convention has its own particular mandate, it has been recognised that there are issues and concerns common to all three. In response to these commonalities, the Joint Liaison Group (JLG) was established in 2001 to facilitate and enhance cooperation among the three secretariats of the "Rio Conventions". Through this apparatus the secretariats share information on the work of their conventions, identify possible joint activities and any potential conflicts.

The Kyoto Protocol is the culmination of years of negotiation among the parties to the UNFCCC to establish a commitment regime by which industrialised countries would limit their carbon emissions at negotiated and agreed upon levels. The impetus for the Kyoto Protocol and before it the UNFCCC, was the growing public concern for issues related to global climate change. This movement coalesced as intergovernmental organisations and scientists indicated that the threat of climate change was indeed real. Accordingly, in 1990, the United Nations responded to these calls and formally launched negotiations on a framework convention on climate change. The UNFCCC was adopted on 9 May 1992, and was opened for signature on 4 June 1992 at the UN Conference on Environment and Development in Rio de Janeiro, Brazil, and came into force on 21 March 1994. Since this time, the Conference of the Parties (COP) have met on an annual basis to monitor the implementation of the convention and further discuss the best possible measures to respond to global climate change. The Berlin Mandate, a decision to launch a new round of talks to decide on stronger and more detailed commitments for industrialised countries, was established at the first COP (1995). In 1997, the Kyoto Protocol was adopted at COP 3 in Kyoto, Japan.

By now (November 2003), 84 parties have signed and 120 parties have ratified or acceded to the Kyoto Protocol; and parties that have not yet signed the Kyoto Protocol may accede to it at any time.[10] The web-site further states:

> *The Protocol is subject to ratification, acceptance, approval or accession by Parties to the Convention. It shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55 % of the total carbon dioxide emis-*

10 http://unfccc.int, 26 Nov 2003

sions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession[11].

The Annex I countries[12] are members of the OECD and represent more or less the industrial countries which committed themselves to quantified emission limitations or reductions (for Instance the European Community agreed on a cap of 92% of the 1990 baseline). The Annex I countries are further grouped into Annex II countries, which are the wealthier nations among the entire Annex I countries. These countries were members of the OECD in 1992, while the other Annex I countries include the Russian Federation, the Baltic States, and other Central and Eastern European states. All other countries, called thereafter Non-Annex I countries, comprise mainly the developing countries.

The Kyoto Protocol is the only international treaty that negotiated limits or caps on total GHG emissions of the Annex I countries. Currently, the treaty has not yet entered into force. The COP 9 took place from 1 - 12 December 2003 in Milan Italy. A decision on modalities and procedures for afforestation and reforestation (activities under Article 3.3) under the clean development mechanism in the first commitment period of the Kyoto Protocol was finally made. Otherwise, little progress has been achieved.

8. The LULUCF Sector under the Kyoto Protocol

The acronym LULUCF stands for Land Use, Land Use Change and Forestry. Articles 3.3 and 3.4 of the Kyoto Protocol define how Annex I Countries must take account of the LULUCF sector as an anthropogenic source and a sink of greenhouse gas emissions in their first commitment period (2008-1012).

Article 3.3 addresses afforestation reforestation and deforestation:

- *"The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human induces land–use change and forestry activities, limited to afforestation, reforestation and deforestation (…) shall be used to meet the commitments…"*

Article 3.4 concerns:

- *"…The Conference of the Parties (…) as soon as practicable thereafter, decide upon modalities rules and guidelines as to how, and which additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to or subtracted from the assigned amount for parties included in Annex I, taking into account transparency in reporting, verifiability…"*

Agriculture ranges under paragraph 3.4 and as an "additional human induced activity". Whereas article 3.3 clearly states that forestry shall be used to meet the commitments, the whole sector of agriculture is kept open and further specification is demanded. However, up to now, the Conference of Parties (COP) with the support of the International Panel on Climate Change (IPCC) has

[11] At present the percentage of total emissions represents 44.2%
[12] Annex I to the UNCCC and almost identical with Annex B of the Kyoto Protocol.

not succeeded in specifying the inclusion of agricultural land use and land use changes as part of the commitment of the Annex I countries. The sector may be accountable within the first commitment period (2008-2012), if an appropriate decision has taken place and in due course.

IPCC (2000) proposed the following categories for LULUCF activities (Table 15; compare with Tables 13 and 14). The categories are based on FAO's land use types (FAO 1986, 1995, FAO/UNEP 1999). They serve to define a baseline for national inventories (1990) but also a baseline for an emissions reduction project. Basically, the Kyoto Protocol permits any certified emission reduction from the year 2000 (which is 8 years prior to the first commitment period). Such reduction could be used to achieve compliance (of the industrial countries) during the first commitment period (2008-2012).

Table 15: Land Use Categories as suggested by IPCC

a) Improved management within a land use		
• Cropland	-	reduced tillage, rotations, and cover crops, fertility management, erosion control and irrigation management
• Rice paddies	-	irrigation, chemical and organic fertilizer and plant residue management
• Agroforestry	-	better management of trees in croplands
• Grazing land	-	herd, woody plant, fire management
• Forest land	-	forest regeneration, fertilization, choice of species, reduced forest degradation
• Urban land	-	tree planting, waste management, wood product management
b) Land use change		
• Agroforestry	-	conversion from unproductive cropland and grasslands
• Restoring severely degraded land	-	to crop grass or forest land
• Grassland	-	conversion from cropland to grassland
• Wetland restoration	-	conversion of drained land back to wetland
c) Off site carbon storage		
• Forest products		

Many methodological questions remain unresolved and need to be answered before the system can be put in place. A few aspects of particular importance may illustrate the problem.

Baseline: The baseline is the scenario that reasonably represents the anthropogenic emission by sources of greenhouse gas (GHG) that would occur in the absence of the proposed project activity. A baseline shall cover emissions from all gases, sectors and source categories listed in Annex A (of the Kyoto Protocol) within the project boundary.

Additionality: Under this issue, it is argued that carbon sink projects would have happened anyway for other reasons apart from climate change and, therefore, would be the “business as usual” and not add anything to reduce GHG emissions. Once additionality has been demonstrated, a baseline and a projection of the business as usual scenario has to be defined. The difference in carbon balance between the business as usual and the mitigation option would represent the carbon value (Chomitz 2000).

Permanence: The question of which degree of permanence should be achieved is unresolved. Concerns exist because of the risk that the sequestered carbon could be released back to the atmosphere either through natural events (e.g. fires or hurricanes) or anthropogenic events (e.g. non-enforcement of contracts, policy changes). Some are therefore proposing to acknowledge carbon sinks as a temporary measure, as a means to buy time until other technologies have been found to abate climate change (Brown et al. 2002).

Leakage: Leakage can be defined as the unanticipated change of emission reduction (increases or decreases) outside a project’s accounting area. This can occur, for example, through relocation of energy intensive production to non-constrained regions, or through a situation where tree planting as a carbon sequestration activity induces another activity, which increases carbon emission and counteracts the sequestration efforts.

Ancillary impacts: are other effects or side effects of policies or measures aimed at climate change mitigation. Carbon sink projects may provide considerable benefits to soil productivity, to biodiversity, to income generation, employment and food security. The question is how these impacts, whether beneficial or detrimental, are to be accounted.

9. Implementation Mechanisms

Greenhouse gas emissions are a cost to society. Under the Kyoto Protocol their value is defined globally by a limit on the total emissions. The total emissions are then broken down to emissions allowed for single countries and, within such countries, to the various sectors and finally to companies or sub sectors. In the Kyoto Protocol they are named “Assigned Amount Units (AAU)”. This framework in its totality does not yet exist but is the pre-condition for the implementation mechanisms which are discussed in the following paragraphs.

Annex I countries are committed to reduce their GHG emissions. This has to be achieved mainly by domestic efforts. In addition however, the Kyoto Protocol provides three so-called flexibility mechanisms to allow the Annex I Countries to fulfil their emission reduction commitments as cost efficient as possible. The principle is that measures for the reduction of GHG (up to a certain percentage) can be applied outside the country at a place where they are least costly.

Annex I countries can apply “Joint Implementation (JI)” within their own country or in another Annex I country and in cooperation with another member of this group. They can also undertake “International Emissions Trading (IET)” and, thirdly, the “Clean Development Mechanism” (CDM) allows Annex I countries to achieve emission reductions in Non-Annex I countries and in cooperation with them.

There are different types of credit depending on the implementation mechanism applied:

- RMUs — Removal Units, credits from part of a party's assigned amount generated from domestic sinks activities within Annex 1 countries,
- ERUs — Emission Reduction Units, credits from a JI project,
- CERs — Certified Emission Reductions, credits from a CDM project.

All three types may contribute to the Assigned Amount Units (AAU) of an Annex I country, but each requires different procedures and methodologies for approval as accountable credits.

9.1 Joint Implementation (JI)

The Joint Implementation (JI) mechanism allows Annex I Countries to invest into emission reduction projects in other countries within the Annex I group in order to obtain reduction credits, named Emission Reduction Units (ERU). Joint Implementation focuses mainly on projects in CIS States. These countries generally have a lower level energy use efficiency. The assumption is, therefore, that options for emissions reduction can be achieved more easily and with lower cost. In addition, the CIS States will require foreign funding for emission reduction.

JI Projects can start already in 2000 but ERUs are given only from 2008 onward. For the period in between there is the possibility to negotiate "Forward of Assigned Amount Units" (AAUs). Such units would be reimbursed later on through a transfer. ERU´s can be transferred from one commitment period to the next, however on a limited scale; only 2.5% of the assigned amount of a country can be transferred.

9.2 The Clean Development Mechanism (CDM)

CMD is a compensation mechanism. It allows industrial countries to obtain emission reduction credits with emission reduction projects in developing countries. The credits are called Certified Emission Reductions (CER). An Annex I country invests in a Non-Annex I Country and cooperates with private or public institutions. The accounting of such reduction credits starts retroactively from the year 2000 onward.

In contrast to Joint Implementation, this mechanism has a double objective: a) to produce CER and b) to include developing countries in a global effort of climate protection and to contribute to sustainable development in these countries. In doing so, CDM has an exceptional position in comparison to the other two mechanisms.

So far, however, there is an important limitation in using CDM. Eligible activities as established by the Kyoto Protocol (Article 3.3) include:

- Afforestation;
- Reforestation; and
- Deforestation.

Additional eligible activities (Article 3.4) were specified in the Marrakech Accords. These include:

- Forest management;
- Cropland management;
- Grazing land management; and,
- Re-vegetation

In other words: All LULUCF projects (afforestation, reforestation, and/or deforestation, re-vegetation, cropland management, grazing land management, and forest management projects) are eligible sink activities for JI projects. Currently, this is not the case for CDM projects. Only afforestation and reforestation are eligible CDM projects during the first commitment period[13].

9.3 International Emissions Trading (IET)

The trading of GHG emission permits is based on a liberalised market approach. It assumes that industries and other emission sources are encouraged to reduce their emissions to a point where the marginal cost of reduction equals the marginal benefit of reduction. And, if the costs are less than the benefits, there is even scope to reduce emissions further and to improve global welfare. The optimal reduction for a company is therefore where the costs equal the benefits and if there was a completely liberalized market this level would represent the price for trading emission permits.

Economists consider emissions trading as a very efficient instrument to achieve an environmental goal with smallest possible cost, provided there is a functional market. Emissions trading as such does not reduce emissions, but it may create incentives for innovative research and development to make accessible additional reduction potentials.

There are four types of carbon emission units that can be traded according to International Emission Trading as defined in Article 17 of the Kyoto Protocol. These are: AAUs (assigned amount units), CERs from CDM activities, ERUs from JI activities, and RMUs from the domestic LULUCF sector.

10. Carbon Markets, Prices and Trends

Markets for trading GHG emissions are emerging around the world irrespective of uncertainties regarding the Kyoto Protocol and trusting on the likelihood of an international regime. According to Lecocq & Capoor (2002), "there is no single carbon market [their emphasis], defined by a single commodity, a single contract type or a single set of buyers and sellers … [more accu-

[13] Tier 4: For projects under the clean development mechanism, only afforestation and reforestation activities are eligible, and greenhouse gas removals from such projects may only be used to help meet emissions targets up to 1 % of a Party's baseline for each year of the commitment period (UNFCCC Climate Change Secretariat. *A Guide to the Climate Change Convention and Its Kyoto Protocol*. Bonn, 2002. p 25.).

rately] … the carbon market is a loose collection of diverse transactions through which quantities of GHG emission reductions are exchanged".

Lecocq & Capoor (2002) provide the following break-down of the carbon market:

a) By commodity traded

- Project-based GHG emission reductions, created and exchanged through a given project or activity (*most transactions to date, e.g. by PCF, Oregon Trust Fund, etc)*

- GHG emission Allowances, as defined, or expected to be defined under international, national, regional, or firm-level regulations (*UK trading system, BP or Shell internal trading)*

b) By volumes

- Wholesale: Large transactions, usually > 1 Mt CO2e (m*ost projects to date)*

- Retail: Deals in the '000s of tons (*carbon-neutral events, non-carbon intensive corporations, etc.)*

c) By types of contracts (e.g. spot, forward, options, swaps),

d) By timeframes (most contracts: 10 – 14 years, some >50 years).

There is a pluri-lateral regime of carbon trading. Furthermore, there are various types of emission reductions that can be traded and various systems for trading. Currently, the largest volume of market trading is in project based emission reduction purchases; however, carbon allowances are beginning (particularly in the UK and in Denmark) to be traded as confidence increases that a system will be put in place. Additionally, many different trading systems have been developed including both national and regional trading systems for allowance trading as well as pre-compliance trading for emission reductions. In summarizing it can be said:

- The carbon market is firming up, data show that it is growing as more buyers enter the market and as contracts become more diverse.

- Price signals are uneven. ERU prices from JI projects have ranged from \$3.00 – \$8.10 (for PCF and ERUPT deals). CERs from CDM projects have ranged from \$1.48 – \$3.50. Trades between Annex II countries have ranged from \$0.40 – \$7.30. However, higher prices (\$5 – \$10) are being paid for small volumes of emission reductions from small-scale sustainable development projects producing under 10,000 tons (Lecocq & Capoor 2002).

- Non-carbon attributes of emission reduction have become increasingly important to both buyers and sellers. This includes: enhanced water quality, health and education facilities, job creation, reversal of soil erosion, habitat creation, enhancement of conditions for biodiversity, capacity building and technology transfer.

Other sources indicate similar price fluctuations as the market continues to mature. According to de Connick and van der Linden (2003), the average price of a credit for the ERUPT[14] 2000 tender was US $8.3 per t CO_2e reduction, this dropped to US $ 4.8 per t CO_2e reduction for 2001. Further, they indicate that the average price of CDM credits is in the range of US $3-4 per t CO_2e.

All these prices have developed in anticipation of the first commitment period (2008-2014) and for reduction activities, which will be credited retrospectively. And they neither reflect real benefits of GHG reduction nor costs of additional emissions.

Various working groups have tried to assess the external costs of carbon emitted to the atmosphere (Frankhauser 1994, Eyre et al 1997, Holland et al. 1999, Pearce et al 1996). Their calculation models are based on estimates of damage caused through climate change as well as on the assumed mitigation costs. Figures vary between 20 and 95 US $.

11. Carbon Funds

11.1 World Bank Funds

The Prototype Carbon Fund (PCF) is a US $180 million fund designed to invest in CDM and JI projects that generate GHG emission reductions that could be registered with the UNFCCC. The PCF was established in 1999 as a public-private initiative consisting of six governments and seventeen private sector companies. Guidelines concerning regional distribution of PCF funds (as of June 2002) are:

- No more than US $35 million allocated to CDM projects in Latin America
- US $25 million allocated to CDM projects in East Asia and the Pacific
- US $25 million allocated to CDM projects in Central and South East Asia
- US $20 million allocated to CDM projects Africa
- US $75 million allocated for JI projects

Further objectives concerning the mix of projects in the portfolio include:

- Up to US $15 million can be allocated to LULUCF projects.

PCF should increase efforts to identify and develop energy efficiency projects. The goal is a 3:2 ratio between renewable energy and energy efficiency projects.

The Community Development Carbon Fund (CDCF) is managed jointly by the World Bank and the International Emission Trading Association (IETA). The CDCF is designed to link small-scale projects seeking carbon finance with companies, governments, foundations, and NGOs wanting to improve the livelihood of local communities and to achieve verified emission

[14] The Emission Reduction Unit Purchasing Tender (ERUPT) programme was set up by the Dutch government with the aim to purchase carbon credits through the implementation of JI projects.

reductions. This fund emphasises renewable energy, energy efficiency, methane capture and agro-forestry projects. Such small-scale CDM projects are often overlooked because of the higher risks and business costs of establishing such projects in LDCs.

The size of the fund is approximated to be between US $50 and 100 million. The CDCF, like the PCF, is a public-private initiative. The Bank plans to work closely with local intermediaries to lower transaction costs and other associated risks.

The following text provides the criteria for projects seeking funding from the CDCF. This is an excerpt from the CDCF web-site.

> *The Fund Manager will develop a project portfolio with the intention that during the term of the Fund:*
>
> - *CDCF projects will be located exclusively in developing countries that are Parties to the UNFCCC and are not included in its Annex I (non-Annex I Parties). The CDCF will not support projects in Annex I Parties.*
> - *No more than 10 percent of the first tranche of the CDCF capital will be committed to projects located in the same country.*
> - *A distinct criterion for CDCF project selection will be the generation of benefits for poorer communities in developing countries. The development outputs that are expected to generate such community benefits will be documented by entities independent from the CDCF.*
> - *The CDCF management will work to achieve the goal of placing at least 25 percent of the first tranche of funds in projects located in LDCs and other poor developing countries.*
> - *For the purpose of the CDCF, "LDCs and other poor developing countries" are defined as follows:*
>   - *Countries listed in the World Bank's International Development Association or "IDA" list of countries;*
>   - *Countries commonly referred to as "IDA blend", including those IDA countries that have a population of less than 75 million; or*
>   - *Countries designated as LDCs by the United Nations.*
>   - *The CDCF will also endeavour to support small-scale projects in countries other than LDCs and other poor developing countries, so long as these projects will directly benefit poorer, rural communities of such countries.*
>   - *Up to approximately 10% of the CDCF capital may be committed to small-scale projects in the afforestation and reforestation areas.*
>   - *CDCF projects will comply with the criteria for CDM project activities under Article 12 of the Kyoto Protocol and provisions adopted there under, in order to be eligible to generate certified emission re-*

ductions under the CDM. Preference will be given to projects that are compatible with the definition of “small-scale CDM project activities” in accordance with decision 17/CP.7. Adopted by the Conference of the Parties to the UNFCCC at its seventh session and concerning the modalities and procedures for a clean development mechanism and the facilitation of its prompt-start. See http://unfccc.int/cdm/cop.html.

- *CDCF projects will conform to policies and guidelines set by the World Bank Group for development projects. They will also comply with all Safeguards Policies of the World Bank Group.*[15]

The first step in a project proposal process is the submission of a Project Idea Note (PIN).

The BioCarbon Fund aims to demonstrate and test the use of carbon finance to generate emission reductions from LULUCF projects in developing countries and economies in transition. This fund will utilize two different lending windows. The first will generate Kyoto-compatible (potentially verifiable) emission reductions from LULUCF activities and the second will generate reductions from carbon sequestration and conservation projects that can be used in emerging carbon management programs or in voluntary markets.

Apart from measuring carbon emission reductions, the BioCarbon Fund could also measure biodiversity, watershed management, community development and other sustainable development benefits, in anticipation of the potential development of traded markets in these environmental goods.

The BioCarbon Fund is a public-private initiative, and is expected to become operational in autumn 2003. The size of the fund is approximated to be US $100 million. The following text provides the criteria for projects seeking funding from the BioCarbon Fund. The web-site clearly states that the criteria are still under review and subject to change. This is an excerpt from the BioCarbon Fund web-site.

Climate and Environment

- *Will there be real gains in carbon sequestration or net greenhouse gas emission reductions (considering all greenhouse gases); what amount and at what cost?*

- *Does the project meet the likely requirements of the CDM? A project can still be considered even if it does not fulfil this requirement, as the Fund will have CDM compliant and CDM non-compliant windows.*

- *Does the project clearly meet sustainability criteria and contribute to the goals of the major environmental conventions such as The Convention on Biological Diversity (CBD), The Convention to Combat Desertification (CCD) and the Ramsar Convention on wetlands?*

[15] http://communitycarbonfund.org/router.cfm?Page=Criteria 11 August 2003.

Poverty Alleviation

- *Will the project improve the livelihoods of a significant number of local/low-income people?*
- *Will the World Bank's Safeguard Policies be met?*

Project Management and Learning

- *Is the project cost effective?*
- *What learning opportunities does the project offer? Can we learn about, and address, design, finance, institutional arrangements, implementation, monitoring, leakage and permanence issues?*
- *Is there an adequate enabling environment in place? (Factors to consider here include the general political/security situation, a national climate change policy framework, etc.)*
- *Do appropriate institutions exist to serve as intermediaries between the BioCarbon Fund as a buyer and local communities as sellers?*

Portfolio Balance

- *How replicable (transferable) is the experience and knowledge gained from this project?*
- *Does this project add to the range (project type, economic situation, geographic distribution, social environment) and learning experience in the portfolio?*[16]

The first step in a project proposal process is the submission of a Project Idea Note (PIN) which will be used as a means of screening projects and providing feedback. The submission of a PIN does not entail any legal obligation for either party.

11.2 Other Funds

ERUPT and CERUPT. Senter is the Dutch Government agency responsible for the execution of projects in the fields of energy, environment, technology, exports and international cooperation funded by the ERUPT and CERUPT programmes. This agency was initiated by several Dutch Ministries. Senter buys emission reductions, on behalf of the Dutch Government, these carbon credits are realised by the financing made available from Senter investors, and which would not otherwise have occurred. Senter pays approximately EUR 3-5 per carbon credit; prices are realised by a process of competitive bidding.[17] Senter has a total of EUR 1 billion at its disposal.

[16] http://biocarbonfund.org/router.cfm?Page=Criteria 8 August 2003.
[17] http://www.senter.nl/asp/page.asp?id=i001003&alias=erupt 11 August 2003.

ERUPT is a tender-based program designed to encourage JI projects in Eastern Europe and produce verifiable emission reductions for carbon market trading. The ERUPT programme has already launched three tender processes, the last one ending 30 January 2003. Expressions of Interest may be submitted during the tender process, prospective tenders are short-listed and invited to submit a proposal. The ERUPT project must supply at least 250,000 t CO_2e during the term of the crediting period. Several small projects may be initiated to achieve the necessary reductions; however, they must all take places in the same country. The following excerpt from the Senter web-site describes the ERUPT submission process in more detail.

1. *You have an investment plan, the feasibility of which has been more or less demonstrated. (If this is not the case, the PESP (for Dutch companies only) may be of assistance to you).*
2. *You submit your idea to the host country's government and assess whether commitment for your investment can be obtained. The host country expresses is commitment in a Letter of Endorsement.*
3. *You submit your idea with an Expression of Interest to Senter during the ERUPT submission period, which depends on the location of your investment.*
4. *Senter assesses the ideas that have been submitted on the basis of the financial strength of the business and the feasibility of the investment. Senter then selects a number of companies and invites them to submit a detailed proposal.*
5. *If you are invited to submit a detailed proposal, you draw up a baseline that you have had validated by an independent and qualified validator. You also obtain a Letter of Approval and submit both documents to Senter. It is advisable not to wait until Senter officially selects you before you do this. This is because you then only have limited time to submit your complete proposal. It is better for you to proceed with obtaining the necessary documents. You will receive reimbursement from Senter for the costs you have incurred in relation to this baseline.*
6. *Senter assesses the detailed proposal on the basis of the price at which carbon credits are being offered, the feasibility of the investment and its sustainability. Senter also checks the validation and the Letter of Approval and contracts a number of companies. The proposals that comply to the requirements are ranked by price (EUR/CO_2e). Contracts are awarded to the lowest price proposals.*
7. *During the term of the contract Senter provides if needed advances on the basis of the progress of the investment. They may amount to 50 percent of the total amount of carbon credits. The remainder of the payment follows annually on delivery. In the case of CDM this happens as soon as actual reduction is achieved. In the case of JI the project must be verified twice before the end of 2008 (once after the start of the investment and once during the course of the investment) and thereafter annually on delivery.*

The CERUPT programme is similar to the ERUPT programme; however, funds are targeted at CDM projects (hosted in Non-Annex I Countries) in the area of renewable energy, energy efficiency, fuel switch and waste management. According to de Connick and van der Linden (2003), CERUPT was established in parallel with the ERUPT tender and has many characteristics in common in terms of procedural matters.[18] Importantly, the CERUPT programme tender was launched in 2001; in March of this year, the Dutch Ministry of Environment declared that no new CERUPT round would be opened.[19]

The **Government of Finland**'s Ministry of Foreign Affairs (Development Cooperation) is currently exploring the feasibility of acquiring CERs from small-scale CDM projects. An invitation to submit project proposals has been submitted; however, according to de Connick and van der Linden, it remains unclear as to how many and what kind of proposals will be granted funding.[20]

Asian Carbon Fund 2003. This fund seeks to target investment in small-scale projects in Asia, which can deliver real, measurable and long-term reductions of GHGs. The fund is scheduled to be a 5-year closed-end investment vehicle with the objective of achieving a target of 10% IRR in US dollar terms. It is important to note that the closing date for Expressions of Interest to Invest was 21 March 2003.

The **Global Environment Facility (GEF)** is the operating entity of the Climate Convention and the Protocol's financial mechanism. GEF activities are focused in six areas: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs). The GEF is responsible for two funds (established during the Marrakech Accords) under the Convention and another under the Kyoto Protocol. These funds are: the **Adaptation Fund** (under the Kyoto Protocol), and the **Special Climate Change Fund** and the **Least Developed Countries Fund** (under the Convention). The **GEF Small Grants Program** (SGP) supports activities of non-governmental and community-based organizations in developing countries towards climate change abatement, conservation of biodiversity, protection of international waters, reduction of the impact of persistent organic pollutants and prevention of land degradation while generating sustainable livelihoods.

The **Special Climate Change Fund** will finance projects relating to capacity building; adaptation; technology transfer; climate change mitigation; and economic diversification for countries highly dependent on income from fossil fuels (OPEC countries).[21]

The **Least Developed Countries Fund** will support a special work programme to assist LDCs.[22] This fund was fast-tracked as a priority by the COP. Thus far, the COP decided to request the speedy release and disbursements of funds and timely assistance for the preparation of National Adaptation Programs of Action (NAPAs) and the organization of four regional workshops on the advancement of the preparation of NAPAs set for this year.

At the COP 9 The European Union, Canada, Iceland, New Zealand, Norway and Switzerland renewed an earlier pledge to contribute 410 million US$ annual to developing countries through these two funds and other avenues.[23]

The **Adaptation Fund** will support projects that contribute to climate change adaptation activities.[24] This fund, like the special climate change fund, was not administered as urgently as the

[18] de Connick H.C. and van der Linden N.H. *An Overview of Carbon Transactions: General Characteristics and Specific Peculiarities*, March 2003. p 11
[19] Ibid, p11.
[20] Ibid, p11.
[21] http://unfccc.int/issues/financemech.html, 12 August 2003.
[22] Ibid
[23] UNFCCC Press Release: Milan Conference concludes as ministers call for urgent and coordinated action on climate change. December 2003

Least Developed Countries Fund and as such is expected to be dealt with once the Kyoto Protocol comes into force.

Monitoring and Evaluation: GEF projects are monitored and evaluated annually. This process yields the Project Performance Report. This is part of the wider GEF monitoring and evaluation process, which includes thematic reviews and independent evaluation.[25]

Trees for Travel and Climate Ticket: clients pay an additional charge for their air travel tickets. The money from this additional charge is directed for investment in climate change activities. Trees for Travel funds are directed toward sustainable forestry projects in developing countries (CDM projects in non-Annex I countries like Ecuador and Uganda), whereas, Climate Ticket funds are directed towards small-scale renewable energy and energy efficiency projects (small-scale CDM projects).

[24] Ibid
[25] http://gefweb.org/What_is_the_GEF/what_is_the_gef.html, 12 August 2003.

12. Implications for Organic Agriculture

Within the LULUCF sector under the Kyoto Protocol, all agricultural projects are eligible for Joint Implementation (JI) in the industrial countries. But, unlike forestry, agriculture cannot be accounted in the Clean Development Mechanism, which is implemented to stimulate cooperation between industrial and developing countries. The next important step in the Kyoto process will be, therefore, to make CDM accessible for agriculture.

It can be assumed that in the future all three flexibility mechanisms will become applicable for agriculture. Therefore, in anticipation of the first commitment phase (2008-2012), it is important to develop methodologies to make agriculture accountable for JI and CDM and also to make it part of International Emissions Trading (IET). In this process, many methodological questions are still to be resolved. The main issues are: the assessment of a baseline, additionality, permanence, leakage and ancillary impacts of standard practices in Organic Agriculture.

As a strategy Organic Agriculture has the key potential to mitigate GHG within the LULUCF sector but is, so far, hardly an issue of discussion, neither in the national processes of formulating national inventories nor in the international panel on the mitigation of GHG.

Both avenues should be pursued by the Organic Agricultural movement with equal effort:

- Lobbying initiatives in various countries at national level, to make Organic Agriculture an explicit part of LULUCF in their national GHG inventories; this is an important step to ensure that Organic Agriculture as a strategy can participate in the Joint Implementation Mechanism.
- A broad initiative, by which Organic Agriculture Projects in Developing Countries tap and utilize financial support from the various existing carbon funds; such an initiative can help to develop suitable instruments for the assessment of carbon sequestration and for the monitoring of project implementation.

At present, a number of carbon funds offer the opportunity to explore and to elaborate a methodological framework for implementation and monitoring of agricultural projects, which sequester carbon. Examples and experiences from the forestry sector may serve as a guide to elaborate this methodology. This is a very important step to make Organic Agriculture accountable within the LULUCF sector.

However, Organic Agriculture in competition with other strategies is disadvantaged. Unlike conservation agriculture for instance, which offers one technology only (minimum tillage combined with ground covering legumes, herbicide application and perhaps GMO crops), Organic Agriculture follows a site specific farming systems approach with a whole set of technological changes. Monitoring activities and the assessment of their impact with respect to carbon sequestration (or GHG avoidance) are therefore expected to be quite complicated and costly.

Organic biofuel- and energy production are however options of particular interest. The sequestration potential per unit of land is relatively high and the impact is easy to assess and monitor.

For the organic movement there is a great task ahead. IFOAM's role could be to provide a forum for information management, to coordinate research projects and to initiate lobbying in this field. As the "accounting mechanism" of the LULUCF sector is fully in process of elaboration, it is important to step in as soon as possible.

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