



Mitigating Greenhouse Gases in Agriculture

A challenge and opportunity for agricultural policies

Imprint

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Abbreviations

AWG-KP	Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol
AWG-LCA	Ad Hoc Working Group on Long-term Cooperative Action under the Convention
BAU	Business as usual
CDM	Clean Development Mechanism
CH ₄	Methane
CO ₂	Carbon dioxide
CO ₂ -eq	Carbon dioxide equivalents
COP	Conference of the parties
CT	Conservation tillage
ECCP	European Climate Change Programme
EU-CAP	EU Common Agricultural Policy
EU-ETS	EU Emissions Trading Scheme
GDP	Gross domestic product
GHG	Greenhouse gas
Gt	Gigaton (10 ⁹ t)
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use, land use change and forestry
MACC	Marginal abatement cost curve
N ₂ O	Nitrous oxide
NAMA	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programmes of Actions
NT	No tillage
REDD+	Reducing emissions from Deforestation and Forest Degradation in Developing Countries and supporting conservation and sustainable management of forests and enhancing forest carbon stocks in developing countries
SOC	Soil organic carbon
SRES	Special Report on Emissions Scenarios
t	ton
yr	year
/ha/yr	per ha and per year

Foreword

Food is something that most of us take for granted, yet more than one billion people go to bed hungry every night. Climate change is threatening the livelihoods of many around the world. The ACT Alliance therefore welcomes this study by ACT members on mitigating greenhouse gases in agriculture. Working to relieve hunger and ensure that people can live in peace and with dignity is at the heart of ACT's development and humanitarian work.

Since the beginning of the ACT Alliance, climate change has been a subject of great importance as it is having highly damaging effects on the global south. Some of our members are already experiencing the effects of climate change. Changing rainfall patterns, more floods and droughts, and storms that are becoming more violent, are all becoming more frequent. A predicted rise in global temperature will have even more serious impacts, the full extent of which we do not yet know.

For people who are already struggling to survive and who are dependent on agriculture for their daily needs, climate change is a huge threat. They will have to adapt their food production and agriculture techniques, all while trying to ensure they have enough food to keep their families alive. As an alliance of more than 110 churches and church-related organisations working together in over 140 countries around the world, we are proud that our members are sharing their knowledge and expertise to pursue our goal of a more just world.

John Nduna
General Secretary
ACT Alliance

Preface

Food is a basic need and a human right. However, today's world is more distant than ever from being free from hunger. While abundant food is available, almost one billion people are suffering from hunger. Prevailing hunger in a world of plenty is a clear result of lacking political will, as it has been stated by the UN Secretary General's Task Force on Hunger. Moreover, hunger is a severe breach of States' human rights obligations in international law, i.e. the International Covenant on Economic, Social, and Cultural Human Rights (ICESCR), which has been ratified by the vast majority of States.

While today's world is being characterized as a world of plenty which deprives one out of six human beings from the right to be free from hunger and malnutrition, global warming bears the enormous risk to deepen the current food crisis and to eventually lead to a future world where our children suffer from global food scarcity. Changing and less predictable weather patterns, more extreme weather events such like droughts and floods as well as coastal erosion and sea level rise are worsening the framework conditions of food production already today. This hits poor people in particular. Besides adaptation measures in agriculture, the mitigation of greenhouse gases is a precondition to keep global warming below 2°C. Once again, agriculture comes into the picture. Around 10 to 15 percent of all greenhouse gas emissions can be accounted to agriculture, not even including emissions of deforestation where agriculture again is the single most important driver.

This report was commissioned from the Research Institute of Organic Agriculture (FiBL) to shed light on the mitigation potential of agriculture. The conclusions create some hope. There is a great potential to significantly reduce emissions from agriculture – and it seems to be a potential which has only been started to be explored. However, the report also points to the fact that the increase in food production and the global shift to a more meat and protein based "westernized" diet will become a ticking bomb of boosting emissions if no corrective action is being taken.

The authors of the study argue that the two most important strategies that need to be taken within the agricultural production system are to increase soil carbon and to close the nutrient cycles in agriculture. Besides their mitigation potential, both strategies have other advantages, too, such as increased soil fertility and water holding capacity and hence an important contribution to adaptation, increased productivity and food security.

Political framework conditions are key factors to either foster or hinder necessary changes towards a more climate friendly agriculture. This is true for both industrialized and developing states. This report analyses (agricultural) policies at both national and international levels, taking the lessons from three case studies, the European Union, Brazil, and Indonesia. In none of these cases, the mitigation potential in agriculture has been systematically mobilized. In contrary, current agricultural policies in all three countries include incentives for an emission intensive agriculture. Based on their findings, the authors give policy recommendations for necessary policy changes.

But we need not wait for farmers or policy makers to move – consumers can act now: massive changes in consumption patterns towards a more regional, seasonal, environmentally sound and more vegetarian diet with less wastage will decrease emissions from agriculture, whereas continuing in the same way will lead to an increase in emissions. Civil society in general and faith based organizations in particular have an important role to play. Let's get it started.

Beat Dietschy
Bread for All

Cornelia Füllkrug-Weitzel
Brot für die Welt

Erik Lysén
Church of Sweden

Henrik Stubkjær
DanChurchAid

Executive summary

Climate change has severe adverse effects on the livelihood of millions of the world's poorest people. Increasing temperatures, water scarcity and droughts, flooding and storms affect food security. Thus, mitigation actions are needed to pave the way for a sustainable future for all.

Currently, agriculture directly contributes about 10-15 percent to global greenhouse gas (GHG) emissions. Adding emissions from deforestation and land use change for animal feed production, this rises to about 30 percent. Scenarios predict a significant rise in agricultural emissions without effective mitigation actions. Given all the efforts undertaken in other sectors, agriculture would then become the single largest emitter within some decades, and without mitigation in agriculture, ambitious goals, such as keeping global warming below two degrees may become impossible to reach.

The main agricultural emission sources are nitrous oxide from soils and methane from enteric fermentation in ruminants. In addition, conversion of native vegetation and grasslands to arable agriculture releases large amounts of CO₂ from the vegetation and from soil organic matter. The main mitigation potential lies in soil carbon sequestration and preserving the existing soil carbon in arable soils. Nitrous oxide emissions can be reduced by reduced nitrogen application, but much still remains unclear about the effect different fertilizer types and management practices have on these emissions. Methane emissions from ruminants can only be reduced significantly by a reduction in animal numbers. Sequestration, finally, can be enhanced by conservative management practices, crop rotation with legumes (grass-clover) leys and application of organic fertilizers.

An additional issue of importance are storage losses of food in developing and food wastage in developed countries (each about 30-40 percent of end products). Thus, there are basically five broad categories of mitigation actions in agriculture and its broader context:

- reducing direct and indirect emissions from agriculture;
- increasing carbon sequestration in agricultural soils;
- changing human dietary patterns towards more climate friendly food consumption, in particular less animal products;
- reducing storage losses and food wastage;
- the option of bioenergy needs to be mentioned, but depending on the type of bioenergy several negative side-effects may occur, including effects on food security, biodiversity and net GHG emissions.

Although there are many difficulties in the details of mitigation actions in agriculture, a paradigm of climate friendly agriculture based on five principles can be derived from the knowledge about agricultural emissions and carbon sequestration:

- Climate friendly agriculture has to account for trade-offs and choose system boundaries adequately;
- it has to account for synergies and adopt a systemic approach;
- aspects besides mitigation such as adaptation and food security are of crucial importance;
- it has to account for uncertainties and knowledge gaps, and
- the context beyond the agricultural sector has to be taken into account, in particular food consumption and waste patterns.

Regarding policies to implement such a climate friendly agriculture, not much is yet around. In climate policy, agriculture only plays a minor role and negotiations proceed only very slowly on this topic. In agricultural policy climate change mitigation currently plays an insignificant role. In both contexts, some changes towards combined approaches can be expected over the next decade. It

is essential that climate policy adequately captures the special characteristics of the agricultural sector. Policies with outcomes that endanger other aspects of agriculture such as food security or ecology have to be avoided. Agriculture delivers much more than options for mitigating greenhouse gas emissions and serving as a CO₂ sink.

We close this report with recommendations for the five most important goals to be realized in the context of mitigation and agriculture and proposals for concrete actions. First, soil organic carbon levels have to be preserved and, if possible, increased. Governments should include soil carbon sequestration in their mitigation and adaptation strategies and the climate funds should take a strong position on supporting such practices. Second, the implementation of closed nutrient cycles and optimal use of biomass has to be supported. Again, governments and funds should act on this. Policy instruments for nitrate regulation are a good starting point for this. As a third and most effective goal, we propose changes in food consumption and waste patterns. Without a switch to attitudes characterized by sufficiency, there is a danger that all attempts for mitigation remain futile. Finally, there are two goals for research, namely to develop improved knowledge on nitrous oxide dynamics, and on methods for assessment of multi-functional farming systems. Without this, adequate policy instruments for climate friendly agriculture and an optimal further development of it are not possible.

1 Introduction

Climate change will adversely affect hundreds of millions of people and will pose serious threats to the global food system and to rural livelihoods. To assure food security, adaptation to climate change is unavoidable.

In addition, as much climate change mitigation as possible needs to be undertaken for reducing this pressure. While clearly acknowledging the fundamental importance of successful adaptation to climate change in agriculture, the focus of this report is on mitigation in agriculture. Adaptation is thus mentioned repeatedly, but it is not in the focus of the following analysis.

Agriculture contributes significantly to global GHG emissions and thus to anthropogenic climate change. But agriculture has also a huge potential to contribute to climate change mitigation. Moreover, agriculture is strongly affected by climate change. The direct contribution of agriculture to total global greenhouse gas emissions is about 10-15 percent. Counting indirect emissions from land use change (viz. deforestation and cultivation of peatlands) and input production as well, this share rises to more than 30 percent (Smith et al. 2007, 2008; Belarby et al. 2008).

Currently, national and international climate policy and discussions of their future development focuses on mitigation in the energy, industry and transportation sectors, and also in reducing deforestation. The mitigation potential of agriculture, however, has yet received little attention in these policy discussions. Climate policy should harvest this mitigation potential, and, with a similar aim, agricultural policy should put more emphasis on climate change aspects.

Mitigation in agriculture has to be achieved in a sustainable way. Furthermore, other outputs from agriculture such as various ecosystem services have to be duly accounted for. Mitigation is only one among many parameters of sustainable agriculture. In particular, mitigation in agriculture must not compromise food security for a growing population.

Many intergovernmental and national governmental bodies and NGOs deal with these aspects, some with a more science-based approach while others are more policy-based. This report supports the work towards optimal climate change mitigation in agriculture by assessing it in the context of agriculture as an emitter, as a sector with considerable mitigation potential, and as a sector of crucial relevance for all aspects of sustainability including food security and livelihoods for many of the poorest people on earth. Thereby, it accounts for both the science and policy aspects.

The report is divided into four parts. Following the introduction, including the background and context of this study, section 2 provides some methodological remarks. The next part includes section 3 to 6. It begins by providing a global picture of agricultural greenhouse gas emissions and their sources within the agricultural sector. Next, carbon sequestration in agricultural soils is described in more detail, as this has a substantial mitigation potential and has become a topic of rapidly increasing interest. In order to further illustrate the relevance of agricultural mitigation, the report continues by presenting trends and future climate scenarios. All this information sums up to the fact that considerable potential for climate change mitigation exists in the agricultural sector and that realizing this mitigation potential is essential for reaching stringent mitigation goals such as the two-degree goal. This leads to the need for a new paradigm for agricultural development: climate friendly agriculture. Different possibilities to actualize climate friendly agriculture are then presented in the following section.

All this factual information serves as a scientific basis to understand the relevance of the agricultural sector in climate change mitigation policies. In section 7 and 8, we describe and analyze global (UN), regional (EU) and country policies (Indonesia, Brazil) with regard to their support for agricultural mitigation. Both climate and agriculture focused policies are considered. The choice of the country policies was driven by the specific interest in case study based assessments of climate policy of an important rice producer (Indonesia) and of a meat, fodder and biomass producer (Brazil). This part thus as-

sesses both climate and agricultural policies at different levels.

The report concludes in section 9 by providing concrete policy recommendations, aimed at harvesting the potential of the agricultural sector to mitigate climate change in a sustainable way.

We want to acknowledge the very valuable input of Bread for all, "Brot für die Welt", Dan Church Aid, Church of Sweden, APRODEV, Urs Niggli and Jørgen Olesen who reviewed the whole or parts of the report.

2 Methodological Remarks

The information in section 3 to 6 of the report is based on a literature review drawing on scientific databases and the expert knowledge of the authors. (Inter-)governmental (e.g. UNFCCC, FAOSTAT, EU Commission), some NGO and academic sources were considered.

For the assessments and comparisons of greenhouse gas emissions and soil carbon sequestration, those are usually expressed in CO₂ equivalents (CO₂-eq). We also adopt this approach in this report. Each greenhouse gas contributes to a larger or smaller extent to the greenhouse effect. In order to be able to compare the effects of different greenhouse gases, they are all converted to the amount of carbon dioxide (CO₂) that would create as high a greenhouse effect as the gas in question. Considering (as usually done) a 100 year global warming time horizon, methane (CH₄) has a global warming potential of 25, and nitrous oxide (N₂O) of almost 300.

When analysing emissions and sequestration, it is important to point out that the respective data is always afflicted with uncertainties and faces data gaps. Thus, figures must be regarded with care (Mayo and Sessa 2010; Steenblik and Möisé 2010). Reasons for this include that:

- Methods to determine emissions rely on many estimated and uncertain values, such as average crop harvests, irrigation levels and livestock numbers (Baumert et al. 2005).
- Local conditions play a strong role in agriculture. Local ecosystems, soil parameters, available labour and commonly used production techniques vary strongly from place to place. This is of particular importance for nitrous oxide emissions, and less so for methane; cf. e.g. the assessment given in Muller and Aubert (forthcoming).
- Many important processes behind agricultural emissions are not yet fully understood, e.g. the soil processes behind nitrous oxide emissions and

their interaction with soil carbon sequestration. In consequence, many potential mitigation options in agriculture are neither fully understood nor fully developed.

- As a consequence, compiling data on greenhouse gas emissions from the agricultural sector is a challenging task, especially for developing countries (Mayo and Sessa 2010).
- Different sources use different categorizations for agricultural and other emissions, and accounting of emissions can be done in different ways. The life cycle assessment approach, for instance, tries to capture all emissions that are related to the production, trade, consumption and disposal of a specific product expressed as a functional unit (for example for 1 kg milk). This approach is also used for calculating the so-called “carbon footprints” of agricultural products (Steenblik and Möisé 2010). An approach focusing on single farming practices, on the other hand, may be based on data covering on-farm emissions only and not indirect emissions from inputs. Thus, system boundaries need to be taken into account when assessing and comparing different agricultural emission data.
- The different sectors overlap and interact, complicating the picture even more. For instance, energy production by the agricultural sector (“biofuels”) produces interactions with the transport sector: Due to biofuels, emissions from the transport sector are reduced, while at the same time emissions from land use change and agriculture are increased.

A literature review was also the basis for section 7 and 8, and the relevant literature was gathered in the same manner as for the previous part. Given the topic, the emphasis was naturally stronger on (inter-)governmental documents. Besides scientific policy assessments, nonscientific sources (NGO reports and policy briefs) were considered as well. In fact, scientific peer-reviewed publications assessing policies with regard to agricultural mitigation were rather scarce. This is due to the nature of the topic. The fast dynamics of the

policies, their ever changing contents and form and the debates surrounding them necessitate a strong involvement of civil society and governmental agencies, while scientific analysis is adequate for certain specific aspects of this process only. Besides the sources mentioned, one climate policy and agriculture expert was interviewed and some authors were contacted by email and commented on specific aspects.

Based on these sources, on the factual background provided in the report's first part and on their individual expertise, the authors draw conclusions in the section 9, which correspondingly also depend on the authors' individual judgements. These conclusions comprise recommendations on how to improve, change or implement new policies in order to exploit agriculture's potential to contribute to the global challenge of climate change mitigation. In drawing these conclusions due account is paid to not compromise food security, poverty alleviation or various ecosystem services and climate change adaptation. It is crucial to emphasize that mitigation in agriculture is only feasible if it supports the important contributions of agriculture regarding other aspects of sustainable development.

Throughout the report, we use the term "agricultural sector" when referring to the narrow IPCC categorization: According to that, the agricultural sector corresponds to the so-called "Source/Sink Category 4" and comprises emissions from six broad subsectors (IPCC 1996):

- emissions from enteric fermentation in ruminants;
- emissions from livestock manure management;
- methane emissions from flooded rice fields;
- emissions from fertilized agricultural soils;
- emissions from field burning of biomass waste and
- emissions from burning of savannas (for pest, weed and vegetation growth control and nutrient cycling).

Not covered under this definition of the agricultural sector are 1) Sewage emissions (covered under the waste sector); 2) CO₂ emissions and sequestration due to land conversion, e.g. deforestation to gain/expand agricultural land are counted under the land use, land use change and forestry sector – LULUCF – which is the number one cause of deforestation; 3) Emissions from agrochemical productions, which are covered under the industrial sector; 4) Emissions related to energy consumption – e.g. machinery, irrigation, buildings, etc. – which are covered under the energy sector.

When we refer to "agriculture" we mean all agricultural emissions as just described, including both the emissions of the IPCC's "agricultural sector", which we call "direct emissions (from agriculture)" and the above-mentioned additional four emissions sources, which we subsume under "indirect emissions (from agriculture)".

3 Greenhouse gas emissions from agriculture

This section discusses global greenhouse gas emissions from agriculture, using the common metric of CO₂-equivalents (cf. section 2). We present the share of agricultural emissions to total emissions and then further differentiate in three complementary ways, namely by gases (nitrous oxide, methane, carbon dioxide), sub-sectors (e.g. rice production, livestock), and regions (e.g. developed versus developing world, EU). More details on the EU and details on Brazil and Indonesia are given in section 8, where this region and the two countries are presented as case studies. Emission trends over time are presented in section 5.

3.1 Share of agricultural to total emissions

According to the narrow UN definition of the agricultural sector, it causes 10 – 15 percent of global anthropogenic GHG emissions (Baumert et al. 2005; Smith et al. 2007; Bellarby et al. 2008; EC 2010a). Including the indirect sources, this percentage increases to more than 30 percent (Bellarby et al. 2008). This makes agriculture the second largest emitter after fossil energy use (US-EPA 2006a). Agriculture is also the largest producer of both methane and nitrous oxide, which together make up about 22 percent of global emissions (Baumert et al. 2005).

3.2 Emissions by regions

On a regional level, the shares of the different greenhouse gases in the total and the contributions of various sectors to it are different than on the global level. In the EU-27, for instance, about 9 percent of total GHG emissions originate from the agricultural sector (Figure 1). This can be explained by the fact that agriculture plays

a less prominent role (if measured in GDP shares) in Europe than globally. Again, this figure must be considered a low estimate, as indirect emissions are accounted for under other sectors (Schulze 2010). In Brazil, for example, shares are much higher, with direct emissions from the agricultural sector at more than 20 percent and emissions from LULUCF at about 60 percent (cf. section 8.3).

Figure 2 shows the total and per capita agricultural emissions by country for the 25 most emitting countries worldwide. Together, they are responsible for 72 percent of all agricultural emissions worldwide (Baumert et al. 2005). There is a clear distinction between total emissions – e.g. 1.1 Gt CO₂-eq /yr in China – and per capita emissions – e.g. less than 1 tCO₂-eq per capita and year in China.

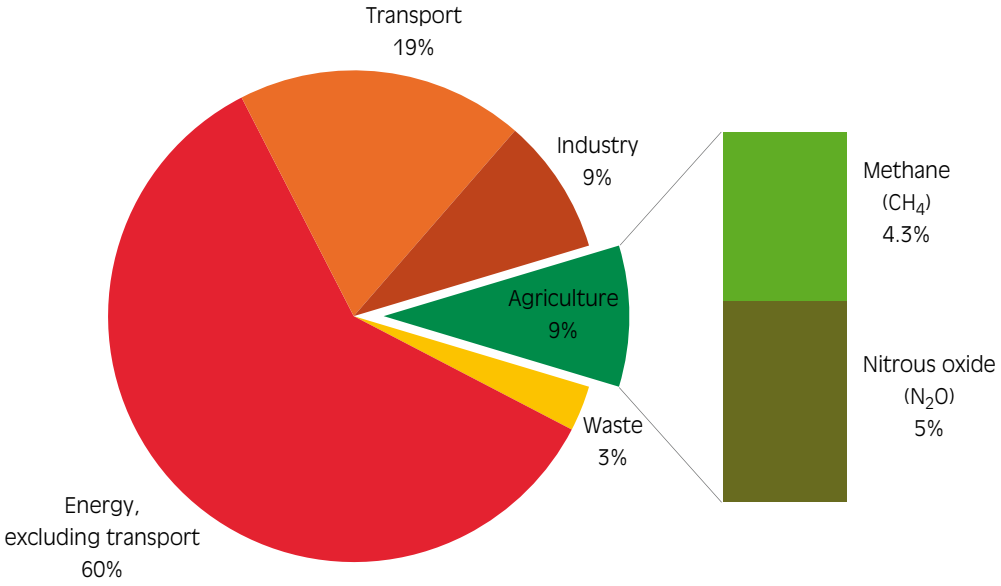
3.3 Emission sources by agricultural sub-sectors and by gases

Agricultural practices are each associated with certain emissions. Typical direct emissions are methane and nitrous oxide. In addition, CO₂ is directly released as a result of agricultural activities. Counted as direct agricultural emissions under the IPCC categorization are only CO₂ emissions from microbial decay or burning of plant litter and soil organic matter, and not the emissions from fossil fuel use in machinery and input production (IPCC 2006). Indirect emissions occur also in the form of methane, nitrous oxide and CO₂.

The most important source of nitrous oxide emissions are fertilized soils. A certain part of the nitrogen applied to soils via organic and mineral nitrogen fertilizers or green manure and other forms of plant residues is emitted as nitrous oxide, which is generated through soil microbial processes. These nitrous oxide emissions account for more than 40 percent of the sector's overall emissions (cf. Figure 3). Nitrous oxide emissions are par-

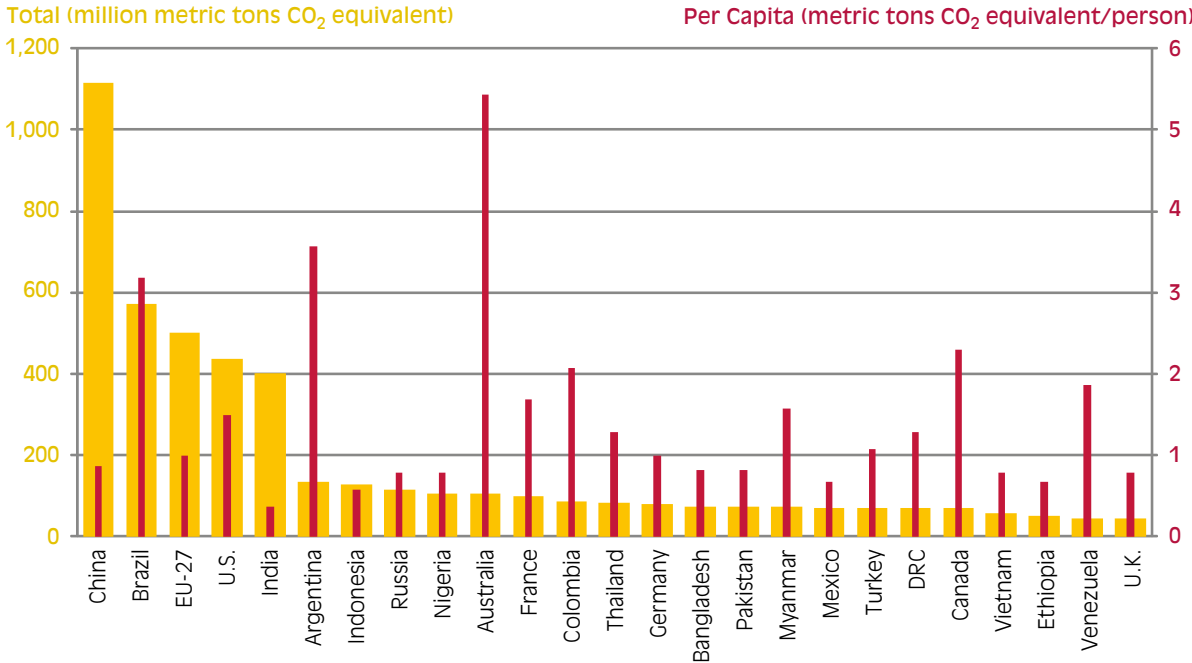
¹ Values vary slightly between different years: most recent globally aggregated numbers are given in Smith et al. 2008, referring to model results from 2005 that base on underlying data from 2000. Recent numbers for 2009 are available for industrial countries from their national inventories.

Figure 1: Share of the GHG emissions of the agricultural sector in total EU-27 emissions in 2007 (CO₂-eq)



Based on EEA databases (on the basis of EU Member States greenhouse gas inventories and projections) (EC 2009a)

Figure 2: CO₂-eq emissions from agriculture, total and per capita, 2000: Top 25 GHG emitters



Sources and notes: WRI, based on CAIT and IEA 2004a. CO₂ emissions include direct fossil fuel combustion only. (Baumert et al. 2005). Wide bars (yellow/bright) are total emissions, narrow bars (red/dark) are per capita.

ticularly difficult to quantify, as they are highly dependent on many factors such as the local small-scale weather conditions as well as on the particular fertilizer type used, soil and crop characteristics, management techniques and so on (see e.g. the brief review in Muller and Aubert, forthcoming). Not only do many factors play a role, but also knowledge on how exactly they influence emissions is incomplete (Bouwman et al. 2002).

A robust finding is that reduced nitrogen inputs result in reduced nitrous oxide emissions. This effect is particularly strong for shifts from very high to medium nitrogen fertilization levels (Bouwman et al. 2002). However, figures of nitrous oxide emissions must always be regarded with special care.

Methane is produced mostly by enteric fermentation in ruminants and in rice production. About a third of all agricultural emissions are from the enteric fermentation in ruminants. Most of the world's rice is produced as wetland rice in so called rice paddies under flooded conditions, which leads to methane emissions from anaerobic processes. Other sources of methane are manure management and biomass burning.

The animal sector is a good illustration on how different approaches for allocating emissions to different sectors can influence an assessment. In its 2006 report "livestock's long shadow", the FAO used a life cycle analysis, accounting for all direct and indirect emissions along the livestock value chain (Steinfeld et al. 2006). They found that 18 percent of all anthropogenic greenhouse gas emissions are caused by the livestock sector if assessed in such an encompassing manner. Considering direct manure and livestock emissions only, the share is about 5 percent.

Not only ruminants, but livestock in general are an important source of emissions, as feed production is often associated with carbon dioxide emissions from large-scale deforestation and corresponding biomass and soil carbon losses, e.g. for soy and maize production. In fact, land use change is the most important source of carbon emissions associated, at least indirectly, with the expanding agriculture. Estimates are very uncertain, but

it accounts for about 5.9 +/- 2.9 Gt CO₂-eq/yr globally. This is slightly more than total global emissions from the agricultural sector (Bellarby et al. 2008). Besides from land use change, CO₂ is also released from fossil fuel use for irrigation, agricultural machinery and the heating of greenhouses. This corresponds to about 10 percent of direct agricultural emissions although not counted in the agricultural sector by the IPCC categorization (Bellarby et al. 2008).

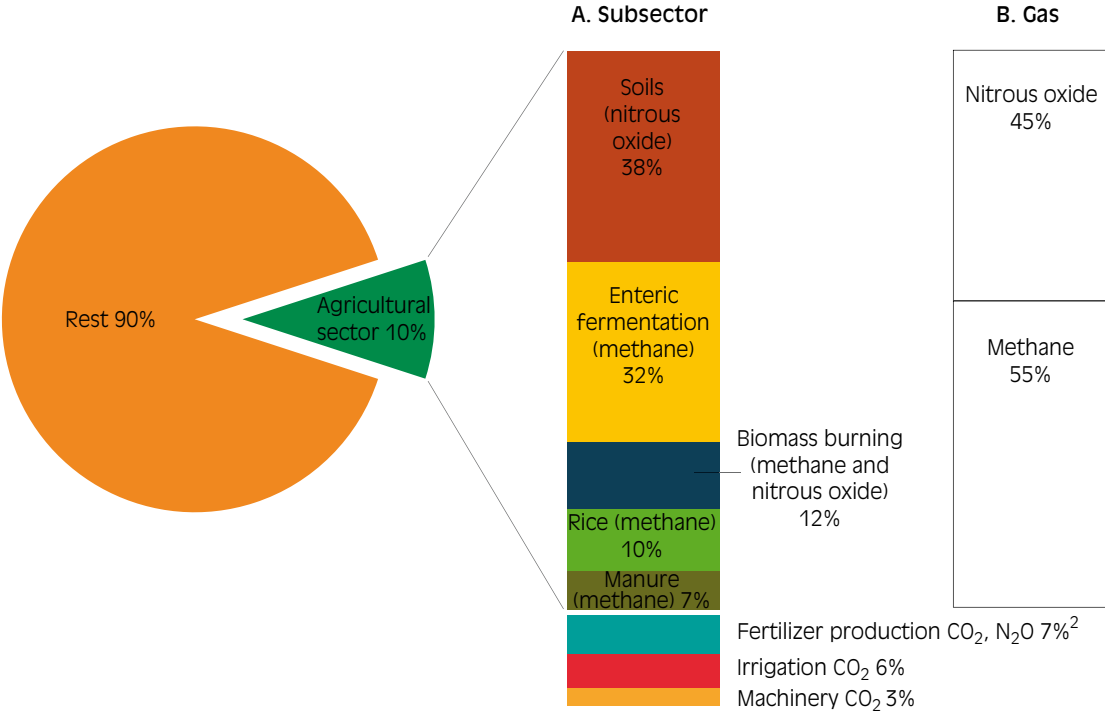
Overall global agricultural emissions, for which are counting direct agricultural emissions plus input production and energy use, but land use change is disregarded, are composed of about 41 percent nitrous oxide, 49 percent methane and 10 percent carbon dioxide according to Bellarby et al. (2008) (Figure 3).

In relation to total global emissions of each of these gases, the agricultural sector causes about 50 percent of methane emissions, and 60 percent of nitrous oxide emissions worldwide (Smith et al. 2007). With regard to total global anthropogenic greenhouse gas emissions, methane accounts for about 15 percent, and nitrous oxide for about 8 percent of total emissions (US-EPA 2006a).

About 38 percent of annual direct global agricultural sector emissions are derived from fertilizer use (2.1 Gt CO₂-eq; in relation to an average of 5.6 Gt CO₂-eq; Bellarby et al. 2008), followed by enteric fermentation (32 percent, 1.8 Gt CO₂-eq), biomass burning (12 percent, 0.7 Gt CO₂-eq), paddy rice (11 percent, 0.6 Gt CO₂-eq) and manure handling (7 percent, 0.4 Gt CO₂-eq). Fertilizer production emissions, not accounted for in direct agricultural emissions, are also of the order of 7 percent if put in relation to these direct emissions.

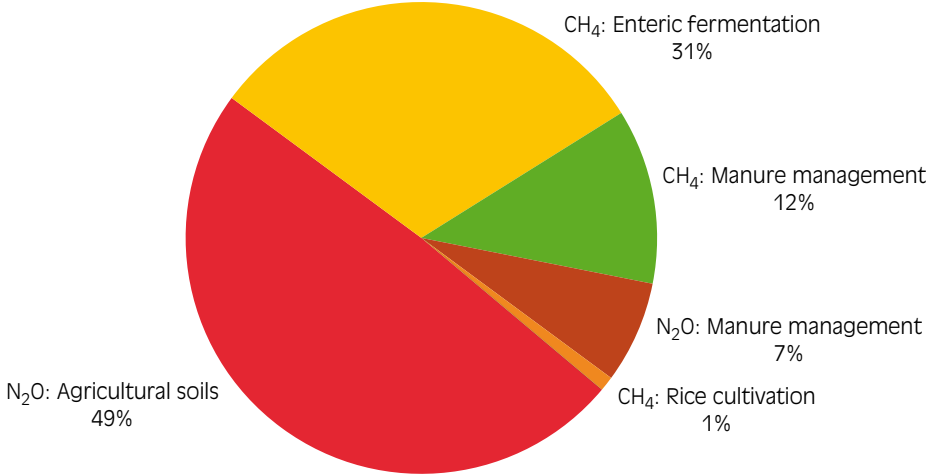
Emissions from energy use are again lower with 0.37 Gt CO₂-eq for irrigation (6 percent) and 0.16 Gt CO₂-eq for farm machinery (3 percent, again put in relation to direct emissions). For Europe, this distribution is slightly different. Rice cultivation does not play a role here (only about 1 percent), and fertilized soil accounts for almost half of the total agricultural emissions (cf. Figure 4).

Figure 3: GHGs from agriculture counting direct agricultural emissions plus input production and energy use, disregarding land use change



Adapted from Bellarby et al. 2008

Figure 4: GHG emissions of the agricultural sector for EU-27



Based on EEA databases on the basis of EU Member States greenhouse gas inventories and projections (EC 2009a)

² These percentage values are in relation to the direct emissions of the agricultural sector.

4 Carbon sequestration – agricultural land and top soil as carbon sink

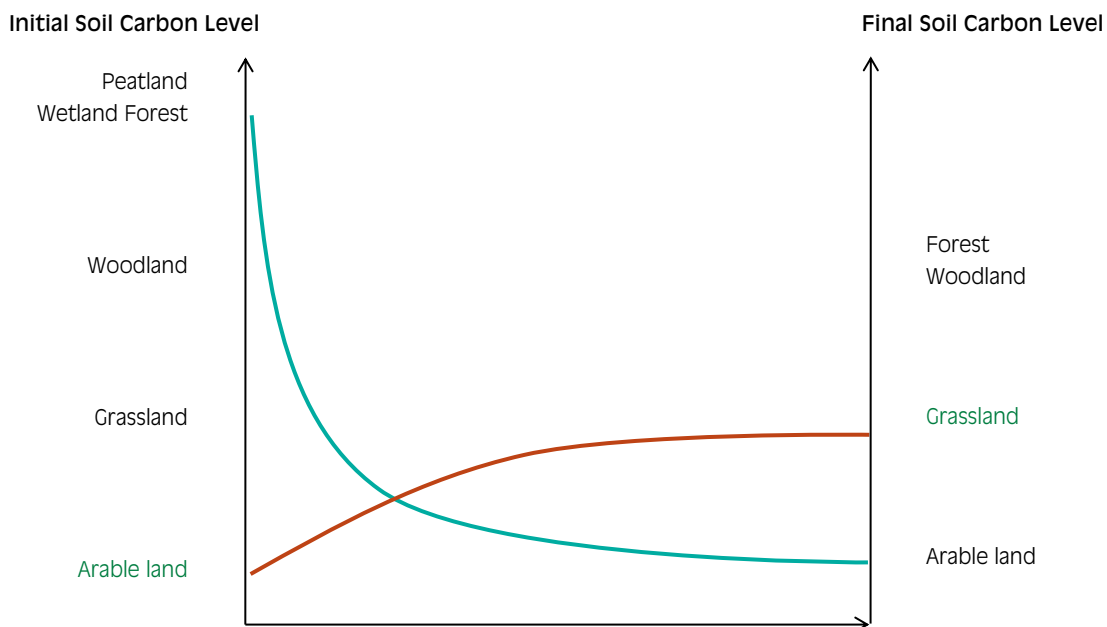
Carbon sequestration in soils implies transferring atmospheric CO₂ into long-lived pools and storing it securely so it is not immediately reemitted. Thus, soil carbon sequestration means increasing soil organic carbon and soil inorganic carbon stocks through judicious land use and recommended management practices (Lal 2004). Although soil carbon sequestration does not mean avoidance and reduction of the formation of greenhouse gases it is considered as a significant mitigation strategy because of the soils' potential to store large amounts of CO₂ at a global scale (IPCC 2007).

The global soil carbon pool is about 9,200 Gt CO₂-eq, thereof about 5,700 Gt CO₂-eq are soil organic carbon and 3,500 Gt CO₂-eq soil inorganic carbon (e.g. Lal 2004). The soil carbon pool is 3.3 times bigger than the atmos-

pheric pool (2,800 Gt CO₂-eq) and 4.5 times bigger than the biotic pool (2,000 Gt CO₂-eq) (e.g. Lal 2004). High soil carbon levels have also other beneficial effects, as they improve soil structure, fertility and soil life, thus contributing to improved plant health, water holding and retention capacity, resistance against drought and extreme weather events. The main reason for high soil carbon levels are high organic matter inputs, crop rotations with grass-clover/forage legumes leys and/or little disturbance of protected soil organic matter. Particularly high soil carbon levels are found in wetlands, where anaerobic conditions prevent degradation of the organic matter. Conservation of high soil carbon levels is achieved in undisturbed, permanent systems such as forests, grasslands and wetlands.

In this section, we assess soil carbon levels and their development, including losses of soil carbon. We differentiate findings about soil carbon levels and developments according to regions/vegetation/soil types, crops, and management techniques/fertilizer types. While soil car-

Figure 5: Changes in carbon stock from peat land to arable land and from arable land to grassland



Changes in carbon stock from peatland to arable land (blue/light line) and from arable land to grassland (red/dark line). Each Eco-system and agroforestry management crop system has a soil carbon equilibrium. Time constant of exponential change depends on climate change but averages around 33 years (Adopted from Bellarby et al. 2008)

Table 1: Global carbon stocks in vegetation and top one metre of soils

Biome	Area M km ²	Carbon Stocks (Pg CO ₂ -eq)			Carbon stock concentration (Pg CO ₂ -eq M km ²)
		Vegetation	Soils	Total	
Tropical forests	17.60	776	791	1,566	89
Temperate forests	10.40	216	366	582	56
Boreal forests	13.70	322	1,724	2,046	149
Tropical savannas	22.50	242	966	1,208	54
Temperate grasslands	12.50	33	1,080	1,113	89
Deserts and semideserts	45.50	29	699	728	16
Tundra	9.50	22	443	465	49
Wetlands	3.50	55	824	878	251
Croplands	16.00	11	468	479	30
Total	151.20	1,706	7,360	9,066	60

Source: Bellarby et al. 2008

bon sequestration is a promising mitigation option, it has to be emphasized that it is difficult to quantify the corresponding mitigation potential, due to the difficulties in measurement, data uncertainties and gaps mentioned in the introduction. It should also be mentioned that besides sequestering soil carbon, the most important issue is probably to protect the existing stocks of soil carbon, since the increase in large-scale arable agriculture to produce more cereals and protein feed will in many cases reduce soil organic matter levels.

Soil carbon levels follow a saturation dynamics (cf. Figure 5). This means that undisturbed soils in temperate climates are in equilibrium with relatively high carbon levels. This is found for example in forests, or grasslands. A land use change then usually leads to a decrease in soil carbon levels, e.g. in the case of deforestation for cropland development. This decrease is slowed and halted at low carbon levels again.

Similarly, soil carbon sequestration comes to a halt at high carbon levels, when equilibrium is reached again. This dynamics extends over several decades, depending on the climate conditions. While conventional agriculture led to huge soil carbon losses on a global level over the past decades (Lal 2004), with correspondingly adverse effect regarding soil fertility, erosion and pro-

ductivity, there are management practices that can halt soil carbon losses and even reverse them, thus leading to sequestration. Examples are use of organic fertilizers, crop rotations with grass-clover leys improved residue management and reduced tillage practices (cf. section 6).

4.1 Regions, vegetation and soil types

Soil carbon stocks are distributed unevenly. Generally, intensively managed land will have lower carbon stocks than natural vegetation (Table 1). Croplands have the lowest carbon stock concentration of all terrestrial ecosystems, except for deserts and semi-deserts. Wetlands have by far the greatest carbon stock concentration, being more than eight times that of croplands. Wetlands cover only a small percentage of land, but they still contribute twice as much to the global carbon stock than croplands do (Table 1).

As a result, the conversion from a more natural type of land use to croplands can have a pronounced negative effect on carbon stocks (Figure 5). The drainage of peatlands and the deforestation of woodlands prior to land use change are the actions with the most detrimental impact on CO₂ release. With drainage of peatlands the previously anoxic and methane emitting peat horizons

Table 2: Benchmark values for crop-specific changes in soil organic carbon stocks expressed in CO₂-equivalents (t CO₂-eq/ha/y)

Crop	t CO ₂ -eq/ha/y Loss (-) or Gain (+)	
	Lower range	Upper range
Sugar beet	-2.8	-4.8
Potatoes	-2.8	-3.7
Maize (silage)	-2.1	-2.9
Cereal crops, oleiferous crops	-1.0	-1.5
Grain legumes	+0.6	+0.9
Alfalfa grass/Clover grass	+2.2	+2.9
Stubble crops	+0.3	+0.4
Interrow crops	+0.7	+1.0

Negative values show the required humus demand. Within crop rotations positive and negative changes can be partially or totally compensated (Redrawn from VDLUFA 2004; this is a study from Germany and data on other crops, in particular from the South (rice, yams, etc.) is not available. As the reason behind these numbers lies in the cropping and tillage practices and less in species characteristics themselves, one may assume that other root-vegetables will have a similar range of losses as potatoes and dry rice would be similar to wheat. No indication for wet rice can be derived from this data, though).

become oxic and the aerobic decomposition of organic matter to CO₂ starts subsequently and will turn the peatland from a previous CO₂ sink to a CO₂ source (e.g. Minkinen et al. 1999). Thereby, CO₂ emissions are that high that they offset the methane emission reductions from drainage. The lowland peatlands of south-east Asia represent an immense reservoir of fossil carbon and are reportedly responsible for 30 percent of the global CO₂ emissions from Land Use, Land Use Change and Forestry (Couwenberg et al. 2010). These authors conservatively estimated emissions of at least 9 t CO₂-eq/ha/yr for each 10 cm of additional drainage depth.

With forest clearance it is not only the soil carbon stock but also the vegetation biomass, which is transformed into CO₂ to a large extent. In some areas, like in Brazil, land use change by deforestation is a significant source of GHG emissions (cf. section 8, about 60 percent of total emissions from Brazil).

Grasslands, although they are often used for agriculture show higher soil carbon stocks than the croplands because of their permanent vegetation cover and the

underlying undisturbed soil horizons. With the conversion to cropland, this carbon reservoir is turned to CO₂ gradually because of tillage-induced disturbances initiating aerobic decay of the organic matter.

4.2 Crop selection

Crop species and the corresponding crop specific management differ widely with respect to their effects on soil carbon levels (cf. Table 2). Maize for example is planted in late spring in Mid Europe in width larger than 50 cm allowing significant areas of bare soil prone to wind and water erosion. Furthermore, maize does not express intensive rooting within its short vegetation period. Such management related factors and less the specific characteristics of the crops themselves are mainly behind the carbon balance of individual crops as shown in Table 2.

Legumes which were part of crop rotations of Mid European agriculture for centuries were replaced in recent decades by maize varieties as with progress in plant breeding maize cultivation was also possible in disad-

vantaged cropping areas with lower temperatures, less sunshine and poorer soil qualities, where legumes were standard fodder crops before. But this replacement of the fodder crops red clover and alfalfa by maize for silage leads to changes in soil organic carbon stocks, mainly due to the management differences. Whereas clover and alfalfa cultivation lead to significant soil organic carbon accumulation, maize for silage depletes the humus stocks of up to $-3 \text{ t CO}_2\text{-eq/ha/yr}$ (Table 2) (VDLUFA 2004).

A cropping system of particular interest is agroforestry, which can lead to high soil carbon levels due to the forestry part of the cultivation system. Agroforestry is the production of livestock or food crops on land that also grows trees for timber, firewood, or other tree products. It includes shelter belts and riparian zones/buffer strips with woody species (Bellarby et al. 2008). The standing stock of carbon above ground is higher than the equivalent land use without trees, and planting trees may also increase soil carbon sequestration (e.g. Nair et al. 2009).

The perceived potential is based on the premise that the efficiency of integrated systems in resource capture and utilization (nutrients, light, and water) is greater than in single-species systems and therefore will result in greater net carbon sequestration (Nair et al. 2009). Estimates of the carbon sequestration potential of agroforestry systems are derived by combining information on the above-ground, time-averaged carbon stocks and the soil carbon levels.

The amount of carbon sequestered in any agroforestry system will depend on a number of site-specific biological, climatic, soil, and management factors. Nair et al. (2009) compiled data from 16 sites worldwide and found a large variation in the above- and belowground carbon sequestration potential of agroforestry. The lowest sequestration rates were found in a fodder bank in Mali ($1.1 \text{ t CO}_2\text{-eq. ha/yr}$; 7.5 years runtime) and the highest in mixed species stands, Puerto Rico ($55.8 \text{ t CO}_2\text{-eq./ha/yr}$; 4 years runtime) (Nair et al. 2009).

There are methodological difficulties, however, in estimating carbon stocks of biomass and the extent of soil

carbon storage under varying conditions. Also there is a lack of reliable estimates of area under agroforestry. Nair et al. (2009) estimate that the area currently under agroforestry worldwide is about 1 million ha.

4.3 Management and fertilizers

Reduction of soil disturbance and improved residue management has also a significant impact on soil carbon sequestration (Bellarby et al. 2008). Soil disturbance by tillage aerates the soil enhancing microbial decomposition along with the release of CO_2 and the loss of carbon. The traffic by machinery or livestock and the tillage can also lead to compactions and poor drainage. These disturbances can be reduced through no-till practices and less intensive grazing. No-till is a controversial subject, though, due to its promotion by agribusiness in combination with GMO crops and adequate pesticides with the correspondingly adverse effects on smallholders' livelihoods and independence.

In addition the higher GHG emissions from increasing reliance on herbicides and machinery needed for weed control may reduce the carbon benefits from no-till agriculture (Bellarby et al. 2008). Most importantly, however, the mitigation potential of no-till itself is also contested. A recent most encompassing review on the available literature on no-till agriculture concludes that this practice does not lead to increased soil carbon sequestration (Gattinger et al. 2011). A crucial study hereby is Luo et al (2010) who analysed global data sets from 69 paired experiments and found a SOC enrichment in the uppermost 10 cm of a soil and a depletion in the 20-40 cm horizon for no-till. Overall, adopting no-till did not enhance SOC stock down to 40cm. Luo et al. (2010) assumed the combination of diverse crop rotations aiming at continuous vegetation cover with reduced tillage practices might be a more efficient strategy to sequester Carbon in agro-ecosystems making use of reduced soil disturbance. This strategy is now introduced into organic farming systems and first results from Switzerland show a clear SOC benefit after 5 years (Berner et al. 2008).

The importance of complex crop rotations is illustrated by the meta-study of West and Post (2002), for exam-

ple. They report increased soil carbon sequestration by about 0.8 t CO₂-eq/ha/yr in comparison to monocultures.

Diacono and Montemuro (2010) investigated the effect of regular organic fertilisation on SOC levels by reviewing long term experiments lasting between 3 and 60 years. They found that long-lasting application of organic amendments such as compost or crop residues increased SOC levels by up to 90 percent versus unfertilized soil, and up to 100 percent versus chemical fertilizer treatments.

Despite these general trends, that seem well established, uncertainties and knowledge gaps prevail. It has to be mentioned, for example, that there could be trade-offs of high soil carbon contents and organic fertilizers with higher nitrous oxide emissions (e.g. Bouwman et al. 2002), but more research on this is needed. Unexpected findings can always occur, as the following example illustrates. Research on European croplands based on the observation of five crop rotations and two monocultures for 4 years at 7 different sites show carbon losses, in average of 3.5 ± 3.2 t CO₂-eq/ha/yr (Kutsch et al. 2010). These results challenge current good practice guidelines, as even at sites where farmer applied organic manure and increased residue incorporation a neutral carbon balance could not be achieved. According to Kutsch et al. (2010) humus loss in spite of good practice is most pronounced in soils with high carbon concentrations, which are not in equilibrium. The authors assumed that it may also be a result of an already ongoing climate change as this leads to increased soil microbiological activity due to higher average temperatures.

5 Agriculture and mitigation – current trends and future scenarios

The previous two sections addressed current agricultural emissions and soil carbon sequestration. This section addresses the future development of these emissions and sequestration based on emission scenarios.

We shortly depict the current trends in agricultural emissions and sequestration and subsequently assess the most important and widely used emission scenarios and how they picture future agricultural emissions and carbon sequestration. We add some methodological and concluding remarks.

5.1 Current Trends

Assessing current trends gives a first description on how agricultural emissions may develop. This does not take into account systematically any driving forces or interactions with other sectors. Current trends suggest a differentiation between developed and developing countries, as in the latter agricultural production is becoming more industrialized with correspondingly higher greenhouse gas emissions, while agriculture loses importance in most developed countries.

Globally, agricultural methane and nitrous oxide emissions have increased by nearly 17 percent from 1990 to 2005 (Smith et al. 2007). During that period, developing countries showed a 32 percent increase, and were, by 2005, responsible for about three quarters of total agricultural emissions. Developed countries showed a decrease of 12 percent in the emissions of these gases (Smith et al. 2007).

Thus, current agricultural GHG emissions are rising and reasons for the upward trend include:

- Greater demand for food in general due to population growth, which leads in particular to higher total use of nitrogen fertilizers and expansion of cropland areas (Smith et al. 2007).

- Increasing meat demand associated with changing diets and consequently more livestock and animal feed demand (Smith et al. 2007; Bellarby et al. 2008; Smith et al. 2008).

Further regional differentiation is necessary to understand the trends. Declining emissions in the developed world resulted from averaging an increasing trend for North America and Canada, and a decreasing trend for most of Europe and Russia. In Russia, e.g. emissions from the agricultural sector have decreased by 55 percent from 1990 to 2008, in the EU-27 by 20 percent. During the same time span, emissions have increased by 10 percent in the United States and by 29 percent in Canada (UNFCCC 2011a).

In the EU, the decline in nitrous oxide and methane emissions over the last two decades was due to a decline in nitrogen input (Nitrate directive) and a reduction in animal numbers (cf. section 7). Australia also showed a decline in emissions. This was mainly due to drought conditions over the past decade with correspondingly reduced number of animals. The end of this drought in 2010 is expected to result in correspondingly increasing emissions again (Australian Government 2010). This illustrates how the stories behind the development of emissions are very different for different regions.

Current trends in agricultural emissions are also reflected in soil carbon losses from land use change due to growing demand for food and feed. From 1961 to 2002 the global agricultural production area has increased by 10 percent (Smith et al. 2007, based on FAOSTAT 2006). This figure is composed of a 2 percent decrease of agricultural land in developed countries and a 19 percent increase in developing countries during the mentioned time span. This land use change and agricultural production resulted in huge soil carbon losses and corresponding CO₂ emissions. A very gross estimate of this can be based on the annual loss of 0.6-2.8 GtC/yr as reported for the 1980 (Houghton 2003, table 4), and the fact that these carbon losses increased over the last decades (Houghton 2003), arriving at 40 GtC for these 40 years, when assuming an average of 1GtC/y. Lal (2004) reports estimates of this for the last 150 years, providing a range

of 44-537 GtC for this period, with a common range of 55-78 GtC. These are very uncertain numbers and may serve only as an indication of order of magnitudes.

5.2 The IPCC SRES Scenarios and Amendments

The most important and most widely used climate change emissions scenarios are the so-called SRES scenarios from the IPCC, which were developed in the Special Report on Emission Scenarios SRES published in 2000 (IPCC 2000). This report contains 40 scenarios covering the development of emissions till 2100, grouped in four "scenario families" based on 4 storylines. These storylines are differentiated along the key aspects of a globalized vs. a regionalised world and a strong economic growth focus vs. a strong environmental focus. For a short description of the storylines see e.g. the Summary for Policymakers of the SRES (IPCC 2000, SPM, p.4).

Several criticisms have been forwarded against these scenarios and specific aspects of the underlying modelling approaches (see e.g. the discussion in Girod et al. 2009). Important for this report here is Strengers et al. (2004) who address the shortcomings of the SRES scenarios with regard to land use, land use change and forestry (LULUCF). They mainly criticise that LULUCF is represented poorly in these scenarios and partly inconsistent, due to use of models that are not built to capture LULUCF. They point out that not only population dynamics mainly drives LULUCF and agricultural emissions (as concluded in the assessment of most SRES scenarios, in combination with technological progress and dietary preferences), but also the temporal and spatial dynamics of greenhouse gas sources and sinks, and systemic feed backs and interactions in the climate system that influence deforestation and forest re-growth. They provide improved assessments of LULUCF in the scenarios based on an improved and more adequate model.

This criticism was taken up in the section on agriculture of the IPCC Fourth Assessment Report from 2007 (Smith et al. 2007), which bases the analysis of aspects related to LULUCF on these improved calculations of Strengers et al. (2004). These improved SRES scenarios provide

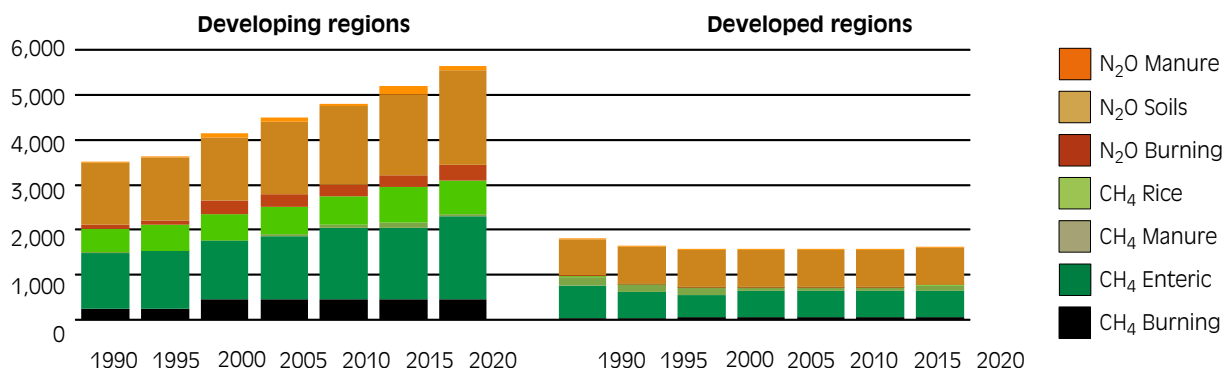
LULUCF emissions and sequestration for the period till 2100.

There are however no numbers for the other agricultural emissions from the improved SRES scenarios. We thus only state some general and robust findings. A general pattern is that population dynamics, technological progress and dietary preferences (amount of meat consumption, i.e. size of the animal sector) have a strong effect on agricultural emissions. Depending on the relative strength of these drivers, emissions may increase, stagnate or decrease. The storyline with strong growth, peaking population numbers, globalisation and technological progress (A1) leads to rather flat aggregate agricultural emissions, while the storyline with a strong emphasis on environmental concerns (B1) has a tendency for reduced emissions. The storyline with ongoing population growth, an economic focus but no globalisation and correspondingly low technological progress in developing regions (A2) leads to the highest emissions, and the storyline without globalisation but some emphasis on environmental concerns (B2) also leads to some, but less high increases in emissions (IPCC 2000, ch.5). These results are intuitive but incomplete, as pointed out above.

In addition, we report emission scenarios from other sources that were also used in Smith et al. (2008) and IPCC (2007). These are the FAO World Agriculture: Towards 2015/2030 forecasts on a global level (FAO 2003), resp. the US-EPA (2006a) forecasts till 2020 on a regional level. The trends identified are largely similar for both of these sources. Nitrous oxide emissions will increase by 35-60 percent by 2030, resp. by 50 percent by 2020, mainly due to increased synthetic fertilizer use and manure management.

Methane emissions will increase up to 60 percent by 2030, mainly due to increased animal numbers. There, US-EPA (2006a) has lower estimates of 20 percent by 2020. Methane emissions from rice increase by 4.5 percent till 2030 according to FAO (2003) and by 16 percent till 2020 according to US-EPA (2006a), mainly due to increased rice cropping areas. On the whole, emissions are expected to increase about 10-15 percent per dec-

Figure 6: Estimated historical and projected nitrous oxide and methane emissions in the agricultural sector of developing and developed countries during the period 1990-2020



This reference also provides detailed charts on emission trends for further differentiated regions. (Smith et al. 2007, p. 504)

ade, and aggregated emissions from agriculture would thus contribute 8.3 GtCO₂-eq/yr to total greenhouse gas emissions in 2030. Compared to a mid-value for total global emissions in the SRES scenarios in 2030, which also largely show increasing emissions by then, this would be about 15 percent.

As with the above mentioned current trends of emissions, it makes sense to differentiate between developed and developing countries and by different world regions, as the projections for 2005 till 2020 from US-EPA (2006a) look very different for these different countries and regions (cf. Figure 6).

The two assessments discussed above are based on more simplistic modelling approaches than the SRES scenarios. The FAO (2003) model, as described in their appendix, uses exogenous values for population and GDP growth and heavily relies on expert judgements for more detailed regional and crop specific aspects and conditions. As they state in Appendix 2, p 380,

“The end product may be described as a set of projections that meet conditions of accounting consistency and to a large extent respect constraints and views expressed by the specialists in the different disciplines and countries.”

The US-EPA report, on the other hand, is based on compilation of a huge number of country reports and projections are mainly based on country specific national communications. These projections depict business as usual development including mitigation policies only if a well-established programme for those is in place. The methodological details of the country specific projections are thus very diverse and such combination of different approaches is in fact problematic. All these scenarios thus describe “business as usual” developments, not capturing increased mitigation actions, as e.g. necessary to reach the two-degree goal by 2100.

5.3 Mitigation Potential

Based on the assessments reported above, Smith et al. (2008) calculated the technical mitigation potential in agriculture for the year 2030 and the mitigation potential that is economically feasible at various carbon prices by the same year, based on cost estimates for the various climate friendly practices in agriculture. Mainly based on the marginal abatement cost curves (MACCs) as provided by US-EPA (2006b, ch.7), they find that about 90 percent of the total mitigation potential in agriculture as identified in Smith et al. (2008) would be realised by increased soil carbon sequestration, 9 percent by methane and only 2 percent by nitrous oxide emissions reductions.

Concretely, the measures behind these mitigation potentials are a) improved cropland management such as tillage, nutrient and water management; b) improved grazing land management; c) reduced soil GHG emissions from bioenergy crops; d) improved rice management; e) restoration of cultivated organic soils; f) restoration of degraded land; g) improved livestock management; and h) improved manure management (cf. also section 6). Measures beyond agriculture, e.g. changes in consumption patterns, are not assessed here. The respective mitigation potential by 2030, which is economically feasible at prices of 30, 50 and 100\$/tCO₂-eq are 1.5-1.6, 2.5-2.7 and 4.0-4.3 GtCO₂-eq/yr and can be put in relation to total emissions from the agricultural sector of 5.1-6.1 GtCO₂-eq/yr. Interestingly, the different storylines, resp. marker scenarios, did not translate into dramatically different mitigation potentials, or into dramatically different areas for cropland and grassland, which drive these emissions. The variations around these representative values within each scenario family are huge, though, illustrating the importance of specific modelling details.

A drawback of this assessment is the fact that the MACCs used in the above analysis do not capture several practices that are central to organic agriculture and have a big mitigation potential, such as the mitigation potential of switching from synthetic to organic fertilizers (manure and compost), increased use of grass-clover leys, avoiding deforestation by restricting concentrate feed for animals or increasing the longevity of dairy animals. Also, options that go way beyond the agricultural sector such as a reduction in the number of ruminants, resp. in meat and dairy product consumption and reduced storage losses and food wastage are not systematically captured in these mitigation potential scenarios.

Another drawback is that the storylines of the SRES scenarios deliver the grassland and cropland areas in 2030, mainly in the absence of specific agricultural climate policy, while the implementation of the climate friendly practices is not linked to the storylines driving the LU-LUCF development. However, implementation of the climate friendly practices clearly necessitates the presence of some specific agricultural climate policies. Thus, this assessment is based on inconsistent combination of dif-

ferent modelling approaches. Furthermore, the MACCs used are based on other than the SRES scenarios (US-EPA 2006b). Similarly, the bioenergy assessment in Smith et al. (2008) is based on literature that is not based on the SRES scenarios.

A thorough assessment of the mitigation potential of these issues would need additional model development. A first indication can be developed along simple extrapolation of the mitigation potential per area or animal combined with some assumptions on the future development of area and animal numbers. The drawback of this approach clearly is the absence of any interactions with or linkage to other developments and key drivers or boundary conditions.

Another approach would be to assess regional or country specific and agricultural sub-sector projections in detail. Such an approach lacks the global or whole-sector scope but can capture regional or sub-sector developments. A systematic assessment of such approaches is beyond the scope of this report.

6 Climate friendly development in agriculture as blue-print – a new paradigm

The previous sections have shown that agriculture is a large emitter of greenhouse gases, but also has a large mitigation potential, mainly through soil carbon sequestration. Calls for mitigation in agriculture have become louder in recent years. Climate friendly techniques and practices could serve as a blueprint for a re-design of the agricultural sector.

Considering the profound importance and urgency to mitigate global climate change, climate friendly agriculture must become the new paradigm. As already pointed out in the introduction, this must not compromise food security and other sustainability aspects of agriculture. This approach is thus related to the “climate-smart agriculture” as defined in FAO (2010, Footnote 1):

“[...] agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals.”

The new paradigm we present here is even broader, as it covers aspects of consumer behaviour and dietary change as well.

6.1 Practices of climate friendly agriculture

Many practices leading to mitigation are already well known. Now it is of primary importance to develop policies that help putting into practice the solutions that we already have. Furthermore, research must continue to look for further improvements and for new solutions of climate friendly agriculture while maintaining food security.

This section presents the options for climate friendly agriculture. The policy aspects are addressed in section 9 below. A high mitigation potential can in principle be re-

alized through four broad fields of action in agriculture directly and in its wider context (cf. above):

- reducing direct and indirect emissions from agriculture;
- increasing carbon sequestration in agricultural soils;
- changing dietary patterns towards more climate friendly food consumption;
- reducing waste throughout all food chains.

Producing biofuels to replace fossil fuels is a fifth mitigation option that needs to be assessed. Implemented in a sustainable manner, it may be of only local and marginal importance for overall agricultural mitigation, though. The overall mitigation effect and sustainability of this option is highly contested and we shortly take up this controversy in section 6.2.3.

On a first level of analysis, these mitigation options can be described by single practices and measures that can be implemented on various levels, from rather specific field management (1. and 2.) to more systemic approaches (3. and 4.). Table 3 at the end of this section gives an overview of these mitigation practices and their effects, focusing in detail on direct agricultural practices (i.e. 1. and 2. from above). The more systemic approaches and bioenergy are addressed in further detail below, in section 6.2. The suggested practices vary in type and extent of effect, which is in addition not always known and often variable. For many practices, exact effects are still unclear, or strongly dependent on local factors. Often, interactions between different practices also play an important role (cf. also the assessment in sections 3, 4 and 5).

6.2 Principles of a new paradigm

On a second and more important level of analysis than the level of single practices, a new paradigm for climate friendly agriculture should be developed based on these practices. Single climate friendly practices can be applied in many contexts and often without much change in

the overall system. To develop a truly sustainable climate friendly agriculture, though, more concerted action is necessary. This means, that some guiding principles for climate friendly agriculture and the related policies have to be derived. From the table of practices and the discussion in the previous sections, five guiding principles can be derived. A new paradigm for climate friendly agriculture needs to

- account for trade-offs and choose system boundaries adequately;
- account for synergies and adopt a systemic approach;
- account for aspects besides mitigation (e.g. adaptation, food security and biodiversity);
- account for uncertainties and knowledge gaps;
- account for the context beyond the agricultural sector: in particular consumption and wastage patterns.

6.2.1 Trade-offs and system boundaries

Trade-offs have to be considered most prominently in no-till agriculture, animal husbandry, bioenergy production and some nitrous oxide dynamics. As one purpose of tillage is to decrease weed pressure, this is compensated through increased pesticide use and correspondingly higher emissions from inputs in no-till systems. No-till systems are often also tailor-made for certain combinations of GMOs and pesticides with the corresponding dependence of farmers on the corporations that supply those.

In addition, pesticides and herbicides are potentially deposited in ecosystems and food chains. Trade-offs also exists for certain mitigation proposals in animal husbandry, where increasing productivity and feed additives have some potential for reducing methane emissions from enteric fermentation but mostly have adverse effects on animal health as well, which also reduces the mitigation potential due to a reduced productive lifespan of animals (cf. section 6.2.3 below).

Bioenergy production faces considerable trade-offs, and there are still controversies regarding its net energy and greenhouse gas balance, and regarding its impact on food security (for this latter point, see also 8.2.3 below) (Muller 2009, Berndes 2010).

Cropping legumes and using organic fertilizers reduces the need for external nitrogen input and thus avoids corresponding emissions. With regard to nitrous oxide emissions, there are indications that organic fertilizers produce higher emissions than synthetic fertilizers (Bouwman et al. 2002), though. Single cases can also point in the opposite direction (e.g. Alluvione et al. 2010). Improvements regarding nitrous oxide emissions may be realised by biogas fermentation or composting of legume biomass and not mulching it (Möller and Stinner 2009; Heuwinkel et al. 2005), and by adding bulking material such as biochar or sawdust for optimal compost production (see e.g. Dias et al. 2010). As already pointed out above, figures of nitrous oxide emissions need always to be regarded with great care, since they are affected by management and environment in complex ways.

Also related to nitrous oxide emissions is the trade-off that higher soil carbon levels can correlate with higher nitrous oxide emissions, thus offsetting part of the mitigation potential from soil carbon sequestration (Bouwman et al. 2002; Li et al. 2005). It has to be considered that nitrous oxide emissions and carbon sequestration differ regarding permanence, as the latter is non-permanent only, while the emissions, once realised, cannot be undone.

The most prominent example illustrating system boundaries is the feed for ruminants. While concentrate feed may reduce methane emissions from enteric fermentation by about a third compared with roughage rich feed (Shibata and Terada 2010), the production of the concentrate feed often causes heavy land use change and deforestation in particular. This is the case for soy cake, for example (see also the case study on Brazil, section 8.3). The losses in soil and biomass carbon following land use change and deforestation and the nitrous oxide emissions from the fertilized crops for concentrate

feed production can offset the reduced methane emissions from concentrate feed. Employing global system boundaries, concentrate rich feed thus has higher emissions than a roughage rich diet. An optimized mixed system based on grassland and livestock can in some cases even be climate neutral (Soussana et al. 2010).

Similarly, the proposal to switch from ruminants to monogastric animals such as pigs and poultry may not lead to reduced emissions under global system boundaries. Those animals do not emit much methane, and they are much more efficient in transforming plant protein into animal protein than ruminants. They do however mainly eat concentrate feed with the above-mentioned drawbacks and the competition with humans for valuable grain commodities. The favourable performance of these animals regarding methane emissions can thus partly be offset by CO₂ emissions from concentrate feed production.

6.2.2 Synergies and systemic approach

Synergies most prominently arise in the context of soil and nutrient management. Using organic fertilizers such as crop residues or compost not only reduces emissions from production of synthetic fertilizers but also increases soil carbon sequestration. Higher soil carbon contents in turn reduce energy use for tillage, due to a less dense soil structure, and for irrigation, due to higher water holding capacity. A higher soil carbon content has positive effects beyond mitigation as well as it improves soil structure and thus water holding and retention capacity, reduces soil erosion and improves soil biodiversity and soil health in general (e.g. Niggli et al. 2009).

Related is the optimal synergy between animals and grassland. An optimal stocking rate allows producing animal products in a basically carbon neutral system, as the grasslands involved can build up soil carbon level and thus have a high soil carbon sequestration potential (e.g. Freibauer et al. 2004, Soussana et al. 2010).

This already points to the importance of systemic approaches, where not only single practices for mitigation are considered, but a whole system of interlinked prac-

tices is implemented and optimized, duly accounting for other aspects than mitigation. The prime example of such a systemic approach is organic agriculture. Organic agriculture does apply most of the climate friendly practices proposed by the IPCC 2007 (Niggli et al. 2009) in a well-designed systemic context. This is important, as the various trade-offs and synergies between different climate friendly practices necessitate the implementation of an encompassing systemic approach to fully harvest the mitigation potential. Merely implementing climate friendly practices as independent pieces of mitigation actions, e.g. in the context of an otherwise unchanged conventional farming system, are likely not to achieve this.

The main building blocks of the mitigation potential in organic agriculture are a lower nitrogen input per ha (up to 60-70 percent less input, Niggli et al. 2009), the use of organic fertilizers and grass-clover/forage legumes leys, the absence of biomass burning, the absence of emission and energy intensive inputs such as synthetic fertilizers, pesticides and herbicides (Nemecek et al. 2010, in press), and the focus on soil fertility and soil health, i.e., among others, on soil carbon build-up. These aspects are integral part of the organic standards (IFOAM 2011). The systemic aspects are realized by a systemic approach to pest, disease and weed management, with a strong basis in plant and soil health, by closed nutrient cycles, e.g. by optimal combination of animal and crop farming in mixed farming systems, and by using crop and animal varieties adapted to local conditions and climate friendly management practices. It is still subject to ongoing research whether organic pest and disease management are compatible with reduced tillage and non-permanently flooded rice cropping practices such as the System of Rice Intensification SRI.

Organic agriculture and agroecology have been championed as most sustainable forms of agriculture also with regard to soil carbon sequestration (e.g. De Schutter 2010a, El-Hage Scialabba and Müller-Lindenlauf 2010). Leifeld and Fuhrer (2010) analysed a total of 68 data sets from 32 peer-reviewed publications comparing conventional with organic agriculture. On average, soil organic carbon (SOC) contents in organic agriculture increased by 2.2 percent annually, while in conventional agriculture,

SOC did not change significantly. As analysis of conventional systems with organic fertilizers shows, this difference is less due to the farming system as such than due to the use or absence of organic fertilizers. However, detailed carbon sequestration values for organic farming cannot be gained from their analysis as SOC stocks are often missing as well as SOC values determined at the start of farming system comparison. More scientific research is needed to evaluate the specific carbon benefits of these practices due to organic farming. This is particularly important for organic farming practices in developing countries. In a current literature review Gättinger et al. (in preparation) found no reliable comparative data on the SOC development under organic and conventional management from Africa and Mid and South America. This is one important reason why the Research Institute of Organic Agriculture (FiBL), Switzerland initiated 3 years ago farming system comparison trials (organic vs. conventional) in Kenya, Bolivia and India representing regionally important cropping systems.

A very gross and preliminary estimate of the mitigation potential from conversion to organic agriculture from Niggli et al. (2009) is a reduction by 40 percent of the world's agricultural greenhouse gas emissions, and by 65 percent if combined with reduced tillage techniques. This would reduce yields in intensively farmed regions under the best climate conditions by one third but could significantly improve yields under low-input situations (Niggli et al. 2009). This illustrates that productivity differences have to be seen in such a broader context.

Maeder et al. (2002) reported an increased efficiency of input use of organic agriculture. Fertilizer inputs were lower by 50 to 60 percent in comparison to conventional management, while the crop yield reduction was less than 20 percent. It is also important to mention that such increased input efficiency has direct positive economic effects as it lowers input costs per unit output.

We emphasize that the general, aggregate estimates given above are of very gross and preliminary nature, while numbers from single experiments, field trials and comparisons can be very accurate for the case in consideration, but cannot be generalised to a global estimate.

6.2.3 Aspects besides mitigation

A new paradigm for climate friendly agriculture must account for other sustainability aspects than mitigating climate change. Agriculture has multiple functions in society and mitigation is not the most important goal. This means, that mitigation measures in agriculture must not only be evaluated according to their mitigation potential, but also according to their effects on other sustainability indicators such as food security, adaptive capacity, rural livelihoods, various ecosystem services, nutrient and water management and impacts on soil, water and air quality.

A focus on soil fertility, i.e. on soil carbon sequestration performs well regarding such aspects, as it improves soil structure and thus water holding and retention capacity, thus making agriculture more resilient against extreme weather events such as heavy rains and droughts and it avoids water logging. Improved soil fertility also improves plant health and correspondingly increases the capacity to deal with pest and diseases, which is crucial in the context of adaptation to climate change, where increased pest and disease pressure is expected. This advantageous performance of an agricultural system focusing on soil fertility is further improved by choosing optimal crop rotations and locally adapted varieties. Similarly, optimal nutrient management and recycling plays a role, as increasing soil organic matter contents depends on organic fertilizer inputs. Composting, legumes and avoiding biomass waste burning are crucial for these aspects. Furthermore, a smallholder focus is often seen as crucial for food security in developing countries (Lal 2009).

These options are largely in line with organic agriculture and are also in accordance with the approaches described in the FAO report on "Food Security and Agricultural Mitigation in Developing Countries" (FAO 2009) and of other governmental and NGO documents with a similar focus (e.g. Soil Association 2009 or FAO 2010). FAO (2009), for example, finds that many climate-friendly farming practices at the same time promise economic gains for developing country farmers and they conclude that

„[t]he potential for synergies is particularly high for changing food production practices such as adopting improved crop varieties; avoiding bare fallow and changing crop rotations to incorporate food-producing cover crops and legumes; increasing fertilizer use in regions with low N content (as in much of sub-Saharan Africa), and adopting precision fertilizer management in other regions; seeding fodder and improving forage quality and quantity on pastures; expansion of low energy-intensive irrigation; and, expansion of agroforestry and soil and water conservation techniques that do not take significant amounts of land out of food production.“ (FAO 2009, p.24)

Using organic fertilizers is absent in this list, but it is mentioned as advantageous at various other places in this report (e.g. footnote no. 7, p20). In the context of food security, Badgley et al. (2007) showed with a review of 293 studies on productivity that organic agriculture can meet the food security challenge on a global basis (see also El-Hage Scialabba 2007).

The main points of debate between organic agriculture and these similar other suggestions as mentioned in the previous paragraph refer to the use of synthetic fertilizers, to pest and disease control, and the use of GMOs. Using organic fertilizers has many advantages, but there is no need to exclusively use those. Some synthetic fertilizer application can make much sense, in particular in nutrient-deficient regions, and where biomass and residues for composting and other organic fertiliser is scarce. Similarly, avoiding pesticides and herbicides would be optimal, but in some cases moderate use of some substances is very effective without overly burdening the environment. This mainly depends on the types of chemicals used and their toxicity.

GMOs, finally, are most controversial. GMO technology may help to considerably hasten plant breeding, but it is connected with potentially huge ecological as well as socioeconomic risks that need to be managed based on the precautionary principle. Another important ques-

tion is whether locally adapted traditional breeding techniques may not perform similarly or better. More detailed discussion of GMOs is however beyond the scope of this report.

A second broad area besides soil fertility where an in depth discussion of aspects besides mitigation is needed is the animal sector. Animal welfare and health are the crucial topics. There are many proposals to mitigate methane emissions from ruminants, either by feeding practices, by feeding additives to inhibit methanogenesis or by breeding programmes. Many of these affect animal health adversely, though, as they go counter physiological characteristics of the ruminants. Concentrate feed reduces methane emissions considerable with regard to roughage (reduction by one third) (Shibata and Terada 2010).

Various feed additives are tested with the goal to (further) reduce methane emissions from enteric fermentation. Some feed additives such as fatty acids or tannins seem promising (4-5 percent of lipids added to the feed reduce emissions by 15-20 percent) (Martin et al. 2010) but more research is still needed (Sejian et al. 2010). Feed additives with characteristics of antibiotics and other drugs are highly problematic. A short overview on some feed additives is given in Smith et al. (2008). Although clearly reducing emissions per unit output, increasing the productivity of animals towards higher milk yields and faster growth (for meat), also increases their health problems (e.g. mastitis) and reduces their lifetime performance.

A third area where a critical discussion is crucial is bioenergy and biofuel production in particular. One problem is the fact that agricultural land dedicated to bioenergy production is lost for food production. In addition, increasing bioenergy production may lead to indirect land use change, as it shifts agricultural production into forest areas with corresponding deforestation. There are strong indications that the recent food price rises were at least partly driven by the expansion of energy crops (e.g. Mitchell 2008). Besides this competition for land, there is also a competition for water and for biomass (see e.g. Muller 2009). This latter point is particularly

important for the context of climate friendly agriculture and the important role of organic fertilizer for it. Particular attention has to be paid to the local situation of subsistence farmers, as bioenergy strategies may exclude certain groups from their traditional land use with correspondingly adverse consequences for local food security of these groups, in particular in contexts of informal property and use rights. A clear statement on whether and to which extent bioenergy can be produced in a climate friendly agriculture and compatible with food security is currently not possible, but when reforming agriculture – and the energy system – these aspects and trade-offs clearly need to be kept in mind. For this, the emissions and energy balance of bioenergy and biofuels in particular need to be assessed on an encompassing life-cycle basis. Depending on the production system and its management, the net emissions gains from biofuels can be nil or even negative (e.g. DeLucchi 2010).

In summary, there are strong synergies between many mitigation and other ecological sustainability objectives and food security, while there are concerns regarding some mitigation approaches and animal welfare, and also regarding mitigation based on bioenergy.

6.2.4 Uncertainties – knowledge gaps

As already pointed out repeatedly in the previous sections, there are still many uncertainties and knowledge gaps regarding the potential effects of specific mitigation options, their adverse or synergistic interaction, and underlying processes. This situation considerably influences the monitoring, reporting and verification approaches that are related to quantification in climate friendly agriculture. Whether quantification of some mitigation potential is possible on a detailed, single farm level, on a more aggregate level and in form of a rough tendency only, or whether it is not possible at all depends on these uncertainties and knowledge gaps and policies supporting climate-friendly agriculture. This challenge needs to be taken into account explicitly.

A particular case where a cautious approach regarding quantification is important is the assessment of produc-

tivity in organic agriculture and the assessment of the mitigation potential per unit output (e.g. crop yield) or per area. Any comparison of systemic agricultural approaches with complex crop rotations, high on-farm diversity, etc. with conventional systems based on mono-cropping faces considerable challenges as assigning emissions to units of a certain output is very difficult or even impossible.

The potentially lower yields for some crops under organic management can reduce the mitigation potential of organic agriculture. The carbon footprint of organically grown potatoes for example, if measured on a per kg output basis, is higher (Nemecek et al. 2010, in press) whereas for organically grown wheat the carbon footprint was lower than for the corresponding conventional crops (Hirschfeld et al. 2008).

In summary there are not only direct uncertainties and knowledge gaps regarding emissions and sequestration of certain practices, but also “procedural” uncertainties regarding how to correctly quantify mitigation in multi-functional contexts.

6.2.5 Broader context – Consumption patterns

Addressing consumption patterns is the most visionary guiding principle for climate friendly agriculture. It makes clear that successful mitigation in agriculture must deal with issues well beyond the core issues of this sector. This is so, as the most effective way to reduce methane emissions from ruminants is a reduction in the number of animals (cf. e.g. Stehfest et al. 2009 for an assessment of the mitigation effects of reduced meat consumption). This clearly is viable only when the consumption of animal products and of meat in particular decreases correspondingly.

A certain number of animals is necessary for rural livelihoods, food security (as many areas are not suitable for crop production but still can produce animal protein if used extensively), nutrient management and the production of fuel and fibre. A high and increasing number of animals however negatively affects food security, as it directly competes for land with food production and as

the efficiency for nutrient protein from animals is much lower than from plants (Carlsson-Kanayama and Gonzalez 2009). An optimized grassland/animal farm system can even be climate neutral, at least for some period of time (Soussana et al. 2010).

Besides changing the quantities of certain food consumption, consumer aspects are relevant for all the measures that involve changes in types and varieties of food. Examples are the promotion of new (or old and currently not used) pest-resistant varieties, of seasonal/regional food (if grown without fossil heated greenhouses) and of meat from monogastric animals (if fed with sustainably grown feedstuff). All these measures crucially hinge on consumer acceptance.

Reducing food wastage, finally, has a big potential, as in developing countries much food is lost due to poor storage facilities (30 to 40 percent) and in developed countries food is wasted in final use, i.e. thrown away in retailers, restauration and households (again 30 to 40 percent) (Godfray et al. 2010). This could be changed with improved infrastructure in developing countries. In developed countries, it would need a change in attitudes and expectations of consumers and suppliers (on immediate availability, freshness, look of the food, etc.).

Table 3: Mitigation measures in agriculture and their indicative mitigation potential

	Measure	Mitigation effect	Sources
Crops and farming system management	Improve crop varieties and productivity	Reduces direct (and indirect) emissions per kg yield	IPCC recommendations Smith et al. 2007; Muller and Aubert, forthcoming
	Improve residue management e.g. avoid biomass burning	Reduces direct emissions	
	Reduce reliance on external inputs (e.g. include nitrogen fixing plants into crop rotations)	Reduces direct and indirect emissions	
	Introduce legumes into grasslands (to enhance productivity)	Reduces direct nitrous oxide and indirect emissions	IPCC recommendations Smith et al. 2007
	Optimized Rice management (e.g. System of Rice Intensification SRI – not flooded)	Reduces methane (but may increase nitrous oxide; - more research needed)	Sass 2003; Neue 1993; US-EPA 2010, ch. 6; Wassmann et al. 2000, Wassmann and Dobermann 2006
	Well-managed combined animal-grassland systems	Can be climate neutral	Soussana et al. 2010
Fertilizer, manure and biomass management	Reduce use and production of synthetic fertilizers	Reduces direct and indirect emissions. (1 to 10 kg CO ₂ -eq per kg N)	Wood and Cowie 2004; Snyder et al. 2007
	Reduce fertilizer (N) input (only 20% of all N produced in synthetic fertilizers is finally used by plants in conventional agriculture)	1-2% of the N applied are emitted as nitrous oxide	Bouwman et al. 2002
		Additional CO ₂ emissions from urea due to its chemical properties: 0.7 t CO ₂ -eq per t urea applied	Alluvione et al. 2010
	Avoid leaching and volatilization of N from organic fertilizers during storage and application	Reduces nitrous oxide emissions	IPCC recommendations Smith et al. 2007
	Optimize fertilizer application management (e.g. fertilizer application adjusted to crop needs (no surplus-N applications), including right timing for optimum uptake through crops); Use slow-releasing fertilizers	Reduces emissions by 1/3 to 3/4	Pattey et al. 2005; IPCC 2006; Smith et al. 2007; Vanotti et al. 2008
	Optimize compost production (by addition of bulking material)	Reduces nitrous oxide emissions	Dias et al. 2010
	Avoid burning of biomass residues	Avoids 0.08 t CO ₂ -eq / t residue which is not burned	IPCC 2006, vol.4, ch.2
	Biogas production (methane capture)	No emissions besides physical leakage	
	Improve storage management of manure (prevent methane emissions from manure heaps and tanks)	Reduces direct methane emissions	IPCC recommendations Smith et al. 2007
	Compost manure	Reduces direct nitrous oxide emissions	IPCC recommendations Smith et al. 2007

	Measure	Mitigation effect	Sources
Soil management	Use organic fertilizers (production emissions from organic fertilizers have to be accounted for e.g. compost production)	Increases soil organic carbon; Reduces emissions from synthetic fertilizer production	Diacono and Montemurro 2010, FiBL ongoing research
	Optimize crop rotations e.g. use perennials in crop rotations	Increases soil organic carbon: 0.8t CO ₂ -eq/ha/y	West and Post 2002; Smith et al. 2008
	Use of legumes (to fix nitrogen); use cover crops and intercropping; avoid bare fallows	Increases soil organic carbon, reduces emissions	Smith et al. 2007; Smith et al. 2008; ADAC 2009
	Reduced tillage		
	No tillage	Increases soil organic carbon:: 2 t CO ₂ -eq/ha/y	West and Post 2002; Smith et al. 2007
	Avoid soil compaction (e.g. by avoiding heavy machinery)	Reduces nitrous oxide emissions	Bouwman et al. 2002; Bhandral et al. 2007
	Agroforestry	Increases soil organic carbon:: 3-8 t CO ₂ -eq/ha/y	Albrecht and Kandji 2003; Mutuo et al. 2005
	Plant hedges		
	Permanent grass cover (e.g. in vineyards and orchards)		
	Pasture instead of cropland (has to be seen in a larger context of changed production patterns (e.g. fewer animals, cf. below, and those on pastures without concentrate feed)		
	Plant deep-rooting species		
Biochar			
Animal husbandry	4-5% of lipids as feed additives	Reduces methane emissions by 15-20% or more	Martin et al. 2010
	High concentrate instead of roughage (assure absence of indirect emissions from concentrate feed production from land use change/deforestation and absence of competition with crop production)	Reduces methane emissions by 1/3	Shibata and Terada 2010
	Avoid use of concentrate feed	Reduces indirect emissions: Avoids deforestation/land use change and corresponding soil carbon losses	
	Breed and manage dairy cattle for lifetime efficiency (increase longevity of dairy cows)	Minus 13% emissions by doubling the number of lactations	O'Mara 2004; Smith et al. 2007
	Increase productivity: higher milk yields per animal	Potential for emission reductions, but trade-off with animal welfare	
	Increase productivity: faster growth of meat animals		
	Monogastric animals inst. of ruminants	Reduces methane emissions per kg meat (but due account has to be given to the origin of the feed used)	
	Use dual-purpose cattle races (which deliver both milk and meat)	Reduces emissions per kg output by increasing output per animal (as both meat and milk can be used)	

	Measure	Mitigation effect	Sources
Energy use	No heated greenhouses	Reduces fossil emissions	
	Energy efficient machinery		
	Optimized machinery use		
	No use of synthetic biocides		
	Pest-resistant varieties with less spray cycles		
	Provision / use of bioenergy (cf. the critical discussion in the text)		
Restoration of degraded land, maintenance of fertile land	Re-vegetate: improve fertility by nutrient amendment	Increases soil carbon	Smith et al. 2007; Smith et al. 2008
	Apply substrates such as compost and manure		
	Halt soil erosion and carbon mineralization by soil conservation techniques		
Systemic	Changed consumption patterns (reduced number of animals, regional/seasonal food, etc.)	Reduces emissions	Carlsson-Kanayama and Gonzalez 2009
	Reduction of food wastage and storage losses	Reduces emissions through reduced demand (currently 30-40% product output losses)	Godfray et al. 2010
	Switch from ruminants to monogastric animals (Pigs, poultry)	2-5 more efficient feed protein in meat protein conversion	
	Switch to organic	Increases soil organic carbon: 2-4 t CO ₂ -eq/ha/y (this is a very gross and preliminary assessment); reduced input use and emissions	Niggli et al. 2009; Soil Association 2009

7 Assessing UNFCCC and FAO policies – what are the adequate measures for climate friendly agriculture?

This part of the report assesses the status of agriculture in UN climate change mitigation policies and in the climate policy negotiations. First, the UNFCCC and its policies are described in brief. Then, past policy performance and current negotiations are critically assessed. The section then gives an overview over the on-going discussions on future UN policies for mitigation in agriculture and draws some conclusions.

7.1 Introduction to UN climate policies

In its narrow sense, the UNFCCC provides the UN framework on multilateral action to mitigate and adapt to global climate change (UN 1992). The Kyoto protocol, an addition to the UNFCCC, sets legally binding targets for climate change mitigation (UN 1998). In its wider sense, the UNFCCC stands for the UN institutions through which international negotiations and agreements regarding climate change mitigation and adaptation are managed (www.unfccc.int). It is important to carefully distinguish between the convention and the Kyoto protocol. The USA, for instance, is party to the convention, but not to the protocol and has thus not committed to legally binding emissions reduction goals.

The UNFCCC has a permanent secretariat situated in Bonn, which supports all institutions involved in the climate change process. Member states to the UNFCCC (parties) meet regularly at the so-called Conferences of the Parties (COPs), where the course for global climate policy is set. The 16th and most recent COP took place in Cancún, Mexico, in November/ December 2010, the next will take place in Durban, South Africa, November/ December 2011.

The UNFCCC obliges countries to “mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases” (UN 1992, article 4). Article 2 of the Kyoto protocol says

that in order to achieve emission reductions, each party to the convention shall implement certain policies and measurements, among others “Promotion of sustainable forms of agriculture in light of climate change consideration” (UN 1998, article 2.1 a (iii)). The Kyoto protocol sets reduction targets for developed countries (the so-called Annex I or Annex B countries, according to the list provided in Annex I to the Convention and Annex B to the Kyoto Protocol) and allows carbon emissions to be offset by demonstrated removal of carbon from the atmosphere, for instance through “removals by sinks in the agricultural soils” (Article 3.4). Two important bodies to the convention are the “Ad Hoc Working Group on Long-term Cooperative Action under the Convention” (AWG-LCA), which was established in the context of the Bali Action Plan 2007 at COP 13 (UN 2008) and the “Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol” (AWG-KP), established in 2005. These groups negotiate the framework for future global climate policy beyond 2012, when the first commitment period of the Kyoto-protocol ends.

The UNFCCC and the Kyoto protocol introduced several mechanisms and institutions that shape the international climate change mitigation activities: First, there are the so-called “flexibility mechanisms” of the Kyoto Protocol, i.e. emission trading, joint implementation and the clean development mechanism (CDM). Second, there are the national greenhouse gas inventories of the nations subjected to binding emission targets (Annex I parties) that report national emissions and sequestration on an annual basis, in order to assess and document achievement of the Kyoto targets. Third, there is REDD+ (Reducing emissions from Deforestation and Forest Degradation in Developing Countries and supporting conservation and sustainable management of forests and enhancing forest carbon stocks in developing countries). While the rules are clear for the flexibility mechanisms and the inventories for the current commitment period of the Kyoto Protocol, rules for subsequent commitment periods and for REDD+ are still to be decided and institutionalised. Finally, NAMAs (Nationally Appropriate Mitigation Actions) are gaining increasing importance as a future mitigation institution. Currently, they are not defined at all and discussions on concrete

tisation are ongoing. All this will also affect the standing of agriculture in the UN climate policies, as there is an ongoing discussion on whether and how agriculture should be covered in these contexts in the future.

Although the awareness in the UNFCCC for the potential role of agriculture in mitigating climate change and in particular of soil carbon sequestration is reflected in the relevant documents, agriculture is not playing a prominent role in UN climate policies as shown below.

7.2 The role of agriculture in UNFCCC policies in the past

Agriculture and land use, land use change and forestry (LULUCF) played a minor role in mitigating emissions in the past (IATP 2010 for a detailed overview, see also Benndorf et al. 2007; Murphy et al. 2009a). The clean development mechanism (CDM) excludes soil carbon sequestration from agriculture, which represents 90 percent of agriculture's mitigation potential (FAO 2010). Regarding agricultural sink activities, the CDM is restricted to afforestation and reforestation. According to the rules on national GHG inventories, agricultural sector emissions have to be reported on. From LULUCF, only reforestation, afforestation and deforestation have to be reported on, while GHG emissions and sequestration due to cropland and grassland management are not mandatory for the inventories.

The reasons for the exclusion of agriculture date back to the negotiations that led to the Kyoto Protocol and subsequent amendments (e.g. the Marrakech Accords (UNFCCC 2002), where the detailed rules for LULUCF were resolved and agreed on. The FAO (2008) notes that agriculture is considered difficult and that it has therefore been neglected, despite the fact that it is clearly acknowledged that the agricultural sector has the potential to contribute substantially to greenhouse gas emission reduction (Metz et al. 2007).

The difficulties mainly refer to huge heterogeneity in the sector, i.e. the large number and variety of farming systems, agro-ecosystems and farmers, the complexities of the agricultural sector with regard to measurement, re-

porting and verification of emissions and sequestration potentials and the perceived lack of and expense associated with robust methodologies for this (FAO 2008). Further challenges stem from leakage (displacement of emissions), financial barriers, and non-permanence (carbon sequestration in agricultural soil is non-permanent) (Murphy et al. 2009b).

An additional barrier is the recognition of the fact that food production will have to be increased to feed a rising world population (e.g. Lal 2010). Thus, as many argue, it plays a special role and should not be pressurized by carbon reduction targets. Many countries regard agricultural production as a sovereign right directly linked to food security. They do not wish this sector to be under the influence or control of an international body (Murphy et al. 2009b).

Although agriculture played a limited role in past UN climate negotiations and has been approached "in a fragmented manner" only (Murphy et al. 2009b), action has taken place on the ground, with many countries having included agriculture in their national agendas (Murphy 2011). This is reflected in the Nationally Appropriate Mitigation Actions (NAMA), which list mitigation policies and activities of developing countries. Some countries are quite detailed on those and some include agricultural projects, such as massively increasing compost and organic fertilizer use in Ethiopia and Ghana, no tillage in Brazil or increased soil carbon sequestration in Indonesia (Fukuda and Tamura 2010, UNFCCC 2011g).

Action has also been taken on adaptation in agriculture. It is widely acknowledged that agriculture faces considerable threats from climate change over the next decades and that successful adaptation is of paramount importance for food security and poverty alleviation for hundreds of millions of people (Lal 2009, 2010). Adaptation and related policies are less institutionalised than mitigation. The National Adaptation Programmes of Action NAPAs are an – albeit very heterogeneous – pool collecting envisaged and planned national policies and activities for adaptation, in a similar spirit as NAMAs collect such envisaged and planned mitigation activities (UNFCCC 2011b).

7.3 The role of agriculture in current UNFCCC negotiations

While agriculture played a minor role in the past, there has been a shift in recent negotiations: Prior to 2010, only minimal progress has been made to capitalize on opportunities in the agricultural sector, while observers from 2010 claim that agriculture's role is increasing significantly.

"Agriculture (...) is one of the areas that made greatest progress within the formal UNFCCC negotiations over 2009 and in early 2010"

say Murphy et al. (2010b). The question if agricultural soil carbon sequestration should be included in emissions and removals accounting, was for instance discussed at the COP in Copenhagen in 2009.

Other indicators that mitigation related to the agricultural sector is gaining in profile in the UNFCCC negotiations (Murphy et al. 2010b) include the work of the AWG-LCA. This working group has written a technical paper on the challenges and opportunities for mitigation in the agricultural sector (UNFCCC 2008). A lot of the general progress with regard to the inclusion of agriculture was made due to this working group. A draft text "Cooperative sectoral approaches and sector/specific actions in agriculture" (ADAC 2009) was produced at COP 15 in Copenhagen (Dec. 2009). No decisions were taken concerning this draft, though, and the COP agreed to continue the work of the group.

No big changes have been made in the draft LCA text about agriculture during 2011. In the meeting of the AWG-LCA in April negotiations did not move at all, and agriculture was not discussed. In June parties met again, and this time agriculture created debate. However, not so much about the content, but about the placement of agriculture within the negotiations. In preparation of the meeting, intergovernmental organisations (e.g. the FAO) and NGOs (e.g. ITAP) submitted comments on market-based and non-market based mechanisms to enhance mitigation actions and claimed that such mechanisms

need to account for agriculture's characteristics (UNFCCC 2011f). The other working group – the AWG-KP – has also contributed to strengthening agriculture's role by submitting a request that describes modalities and procedures for possible additional LULUCF activities under the CDM (e.g. revegetation, cropland management, grazing land management, wetland management, soil carbon management in agriculture) (Murphy et al. 2010a).

In October a third session took place in Panama. Again the discussion focused on how agriculture, as well as other sectors, should be treated within the negotiations, rather than how agriculture as a sector could be linked to the climate change agenda. However, the debate about the text was also reopened and it now includes various options (e.g. about the link between agriculture and trade) which needs to be resolved before a text about agriculture can be adopted in Durban (ENB 2011).

The FAO appears as a stakeholder with own interests in the UNFCCC negotiations. For instance, the FAO prepared a report in advance of the COP in Cancún (FAO 2010). This report advocates for a stronger financial support of agriculture, arguing that agriculture needs substantial investments to become "climate-smart", meaning to be able to cope with adaptation, while utilizing its full mitigation potential and still increasing yields. The FAO generally emphasizes in their publications how deeply involved agriculture is with climate change and acts upon this through several efforts and initiatives related to climate-friendly agriculture.

The increasing importance of agriculture in climate change mitigation is also reflected beyond the UNFCCC, e.g. in the rapidly increasing number of agricultural off-setting methodologies for the voluntary carbon market (T-AGG 2009; Coren 2010) or in the upcoming discussions on the inclusion of agriculture in existing or planned emission trading schemes (IETA 2010).

Despite the fact that some progress was achieved at the COPs in Copenhagen and Cancún, discussions on many details are continuing. It is argued that agriculture is a main cause of deforestation and should therefore also

be considered in REDD+ mechanisms, which is not the case so far (Parker et al. 2009; Arens et al. 2010; Murphy et al. 2010a). Without a substantial change in policies, greenhouse gas emissions from agriculture could rise by 40 percent by 2030, the UN Special Rapporteur on the right to food warned, urging negotiators at the Cancún Climate Summit to “consider climate and agricultural policies together” (De Schutter 2010b).

It is discussed whether reporting on LULUCF emissions beyond forestry, in particular sequestration in and emissions from agricultural soils, should be made obligatory for developed countries for the post-2012 period, so that it would count towards overall greenhouse gas reduction targets. There is also some discussion to cover agriculture under future REDD+ regulations (“REDD++” as it is sometimes called, IATP 2010; see also Arens et al. 2010 and Parker et al. 2009).

To summarize, discussions are shifting towards a broader inclusion of agriculture and there are (internal) texts that can serve as a basis for further discussion (e.g. the one presented in the AWG-LCA on June 17, ENB 2011). The question on how to shape the future role of agriculture in UNFCCC policies remains important.

7.4 The potential role of agriculture in UNFCCC policies the future

Given the recent policy developments and the progress of science regarding uncertainties and costs in reporting and monitoring of emission reductions and carbon sequestration in agriculture, soil carbon sequestration and other agricultural mitigation options likely will play a more important role in the future (Murphy et al. 2010b). Stakeholders in favour of such a development, such as the FAO, claim that finances are needed for agriculture to become climate friendly.

“Through ambitious programmes and policies, a ‘Green Marshall Plan’ for agriculture would scale up agro-ecological approaches towards more sustainable modes of agriculture which are sensitive to the needs of vulnerable communities,”

said the UN Special Rapporteur on the right to food at the beginning of the Cancún conference (De Schutter 2010b).

Those who argue in favour of increasing agriculture’s role emphasize the positive side-effects that an inclusion would have – for instance on smallholder livelihoods dependent on agriculture, especially in Africa (Murphy et al. 2010b). Also, sustainable agricultural practices deliver benefits such as increased soil fertility, enhanced drought and flood resistance and thus better adaptation capacities in a changing climate (Metz et al. 2007). Growth of emissions from agriculture and deforestation activities (with agriculture being their major cause) occurs mainly in developing countries, where most of the global agricultural production takes place (Nabuurs et al. 2007; Smith et al. 2007). Thus, according to proponents, including agriculture more into UNFCCC policies might be a key factor for success in broader sustainable development, while missing this chance would mean that poor, agriculture-based countries remain largely excluded from accessing the different types of climate change mitigation financing (Murphy et al. 2009b).

The choice of policy instruments for a potentially increased role of agriculture in UNFCCC policies is crucial for the sustainability of mitigation policies in agriculture. Many NGOs point at the risks of addressing mitigation policy in agriculture with market-based mechanisms: Additional money entering agriculture in such ways might support large-scale and “business as usual industrial agriculture” as well as landgrabbing, rather than supporting truly sustainable, environmentally friendly agriculture (Jordan 03.02.2011; Econexus 2009; IATP 2010). As the International Federation of Organic Agriculture Movements IFOAM (03.02.2011) argues, organic agriculture accounts only for a few percent of the total agricultural production area – thus, only a tiny share of the carbon financing would be dedicated to organic production. Instead, the policy instruments might be abused for greenwashing conventional agricultural practices.

Those criticisms are partly linked to a general rejection of market-based policy tools such as emission trading. Some NGOs advocate for abolishing the CDM and related

market mechanism completely. According to them, off-setting provides loopholes so that emission reductions only appear on paper. Instead of being allowed to shift the burden of mitigation to poor countries, the developed countries should be required to do so domestically (e.g. Third World Network 2010).

While part of the NGOs emphasize the potential role of mitigation in agriculture, other NGOs argue also that adaptation and food security and not mitigation should be the focus of climate policy in agriculture. The Third World Network (2010), for example, claims that expanding the CDM to include soil carbon sequestration projects would be “a dangerous distraction from the more urgent needs of agricultural adaptation”, and would allow developed countries to continue emission intensive agriculture domestically. It argues that most importantly, money must be provided for developing countries for agricultural adaptation to climate change, in order to ensure food security. This money shall be provided without conditions.

It seems generally agreed that mitigation through land-use measures in agriculture and forestry has a large potential to contribute to the goal of the UNFCCC – especially with regard to contributions from developing countries. However, the question remains how to best utilize this potential in the context of climate policies, in particular, whether offset mechanisms such as the CDM or emissions trading are adequate for this, and how to deal with associated risks.

7.5 Concluding remarks

It is likely that agriculture will play an increased role in the climate change regime after 2012. However, whether this inclusion will succeed in facilitating the urgently needed global turn towards climate-friendly, sustainable agriculture, or whether it will instead support the opposite, depends on the details.

First, the detailed design of the institutional framework for broader inclusion of agriculture in climate policy is decisive. It is alluring to call for more money for agricultural investments, but this is clearly not enough. The

numerous concerns, but also ideas of NGOs, should be heard and included into UNFCCC policy debates to find ways to ensure that a shift to truly sustainable agriculture is supported. Important aspects relate to the livelihoods and rights of smallholders and indigenous people, and to food security. These aspects have to be considered when analysing the potential of offsets and other market based mechanisms in particular. There is a danger to reduce agriculture to its carbon sink effects disregarding broader sustainability aspects. That market-based instruments are vulnerable to these problems can be seen from the negative experiences in the EU-ETS (registry frauds), the CDM (lack of additionality) and REDD related projects (indigenous peoples rights).

This links to a second concern, namely that climate change mitigation is only one aspect of sustainability and others of equal or even more importance must not be neglected when supporting mitigation in agriculture. Examples are primarily adaptation, but also water and soil resources, nutrient management, biodiversity, etc.

Third, reliable measurement, reporting and verification (MRV) of emission reductions and sequestration will remain an important issue. In particular offset mechanisms such as emission trading and the CDM rely on high standards of MRV to make sense. Here, caution is advised on which types of mitigation actions may meet the necessary standards (soil nitrous oxide emissions, for example, are still very difficult to quantify).

Fourth, and related to this, is the fact that setting strict boundary conditions can help increase MRV standards, but may be incompatible with systemic agricultural practices, such as organic agriculture, where complex crop rotations and organic fertilizers make it difficult to compare the system to a baseline to calculate emission reductions. Approaches based on standardisation and quantification are biased towards industrialised, large-scale agricultural systems based on monocultures and chemical fertilizers. Mitigation in agriculture thus must not be achieved at the expense of sustainable cropping systems.

8 Assessing national policies – case studies

In this section, we present three case studies. They cover EU policies and the country cases of Indonesia and Brazil.

8.1 The EU Common Agricultural Policy (CAP)

8.1.1 Greenhouse gas emissions from the European agricultural sector

EU agriculture (Agriculture, forestry and fisheries) is responsible for 534.8 million tonnes CO₂-eq in GHG emissions which is 10.6 percent of total EU emissions in 2007 (EC 2010c) (cf. section 3). The by far largest emitter of GHG in the agricultural sector is France with 104.6 million tonnes CO₂-eq followed by Germany (57.4 CO₂-eq), Spain (56.6), United Kingdom (54.1) and Italy (45.9). These five largest emitters of agricultural GHG account for 60 percent of the EU total of the agricultural sector.

Because of differences in the agricultural structure among EU countries, also the GHG sources differ in their importance. In 2008, whereas in France agricultural soils and rice production account for 50.2 percent respectively 0.1 percent (UNFCCC 2011c) of the domestic agricultural GHG emissions, in Italy agricultural soils emit 46.8 percent and rice production 3.9 percent (UNFCCC 2011e) of the domestic agricultural GHG. Agricultural soils account for 62.6 percent of the German agricultural GHG emissions (UNFCCC 2011d) with a significant release of CO₂ and nitrous oxide from cultivated organic (peat) soils. These cultivated organic soils play an important role even if compared to total and not only agricultural emissions, as they account for ca. 4 percent of the total GHG emissions in Germany (Flessa 2010).

In the following paragraphs, we describe the European Union's Common Agricultural Policy (CAP) and its planned reforms, with a focus on its considerations with regard to climate change, and we critically assess the implications of the CAP concerning the contribution

of European agriculture to climate change and climate change mitigation.

8.1.2 The EU CAP

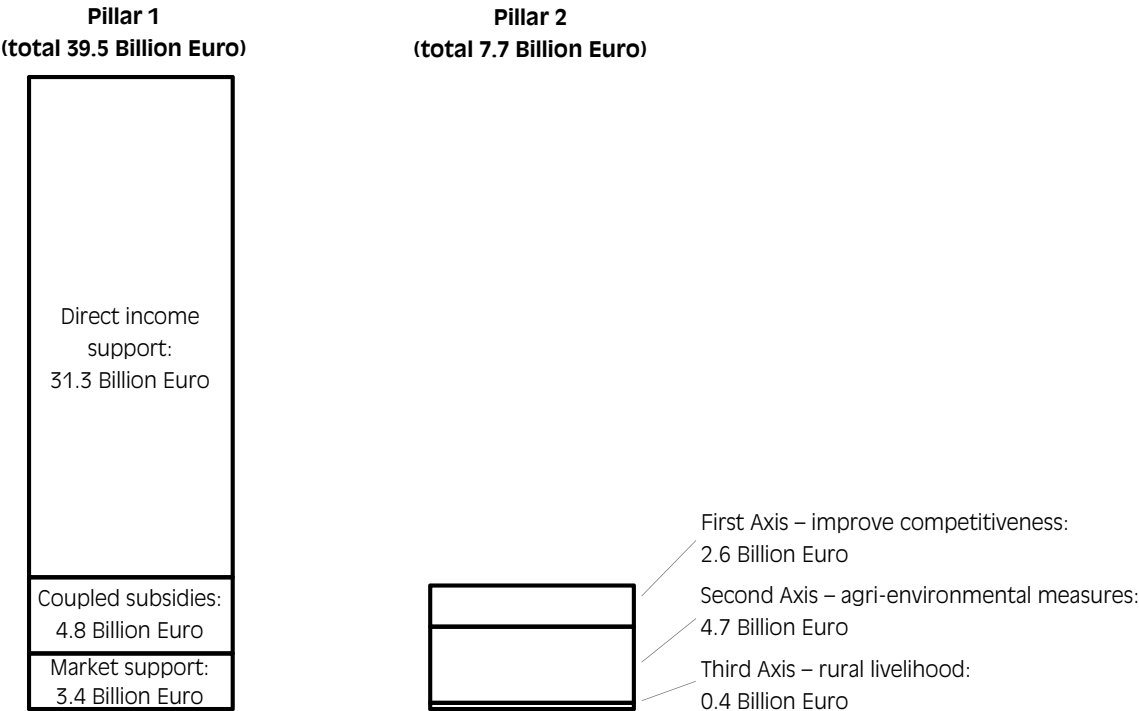
The CAP, with a yearly budget of about 50 billion Euro, which is about 40-50 percent of the total EU budget, is the most important policy framework with strong influence on land use management across the EU. It has therefore a large potential to influence the scale to which European agriculture delivers public goods, such as a contribution to climate change mitigation (Cooper et al. 2009).

Currently, the CAP is broadly structured in two "pillars" of policies (see Figure 7). The first pillar, accounting for 75 percent of all EU agricultural payments, consists in annual direct payments and market measures, viz. subsidies, to farmers. The second, smaller pillar covers multi-annual measures for "rural development". This second pillar is organised along three axes. Two of those can also be seen as subsidies to improve competitiveness on sectoral and territorial level, while one is targeted at payments for public goods of mainly environmental character. The agricultural expenditure is financed by two funds, the European Agricultural Guarantee Fund for pillar 1 and the European Agricultural Fund for Rural Development for pillar 2.

The initial objectives of the CAP at the time of its creation in 1957 were mainly economical, with some social aspects: 1) to increase agricultural productivity; 2) to ensure a fair standard of living for the agricultural community; 3) to stabilise markets; 4) to assure the availability of supplies and 5) to ensure that supplies reach consumers at reasonable prices (EEC, 25 March 1957, article 39).

During the last decades, the CAP has undergone several reforms, and today its targets differ significantly from the original ones mentioned above. Environment-related issues such as resource depletion, biodiversity, and climate change have been increasingly considered. The last reform was the so-called "Health Check" (EC Agriculture and Rural Development 2010), implemented from 2009 onwards, based on the rapid international develop-

Figure 7: The structure of the CAP with budget numbers as of 2009



Reform the CAP 2010b

ments since the reform in 2003, in the context of the financial crisis and increasingly volatile agricultural prices and costs. The current policy framework of the CAP is confirmed until 2013. Negotiations on a fundamental reform of the CAP potentially affecting the details of all funding institutions for the next EU budget period from 2013 onwards are currently under way and several policy documents in preparation of legislative proposals of the post-2013 CAP have recently been published (Bureau and Mahé 2008; Adinolfi et al. 2010; EC Climate Action 2010) (see also the web resources: Capreform 2010; IEEP 2010; Reform the CAP 2010a). As this section was written before the Resolution of the European Parliament (EP 2011) as well as the legislative proposals made by the European Commission (EC 2011b), these are not reflected in the following analysis.

Most important in this process is the European Parliament Resolution of 8 July 2010 (EP 2010b) and the European Commission Communication from November 18 2010 (EC 2010b). The EP Resolution dedicates a section

to the challenges to which the post-2013 CAP must respond (Paragraphs 10 to 20). It highlights, among other issues, the importance of climate change (Paragraphs 13 and 14). The EP Resolution also defines the new CAP priorities for the 21st century in line with the new EU 2020 Strategy (Paragraphs 37, 48): It is stated that agriculture is well placed to make a major contribution to tackling climate change (EP 2010b). The EC (2010b) names climate change and environmental challenges as one of three key challenges in agriculture, the others being food security and territorial imbalances, and it describes three corresponding main objectives for a post-2013 CAP. These statements are based on a range of recent official EC and EP documents that specifically address climate change mitigation and adaptation in European agriculture and on the global IAASTD report emphasizing the crucial and pressing importance to address climate change in agricultural policy (Bureau and Mahé 2008; EC 2009a, b; IAASTD 2009; EP 2010a). Three options are proposed for the post-2013 CAP in the EC communication which were also subject to public consultation on the

CAP impact assessment (EC 2010b). These options were chosen to reflect the main directions of ongoing debates. The three options will have to be evaluated with regard to economic, environmental and social impacts before being considered for the basis of the legislative proposals on funding instruments in 2011.

Option 1 would consist in gradual adjustments only to the current CAP. Option 2 is a balanced CAP reform increasing spending efficiency and effectiveness and making the CAP more sustainable. Option 3 breaks up with the current CAP philosophy and adopts a strong focus on rural development and agri-environmental public goods. Those options are however not further specified and complemented with concrete suggestions for implementation (Adinolfi et al. 2010). Finally, simplification of the CAP is also a general aim of the reform. Formal legislative proposals for the post-2013 CAP are expected for mid-2011 or September 2011.

8.1.3 Financial Subsidies and non-financial support measures and the CAP

Financial subsidies and non-financial support measures are both powerful instruments through which the CAP influences European agriculture and land-use. They are also the most controversial instruments: Hailed by the European Commission as essential to ensure the economic viability of European farmers, and reward the provision of public goods, subsidies are strongly criticised by many NGOs and other stakeholders for being inefficient, distorting and ineffective (Jambor and Harvey 2010; Reform the CAP 2010a). Major reforms or even total abolishment of subsidies is seen as one of the most important issues for the reformed post-2013 CAP. The EC acknowledges the need to shift subsidies such that

“[...] the future CAP should contain a greener and more equitably distributed first pillar and a second pillar focussing more on competitiveness and innovation, climate change and the environment.” (EC 2010b, p.3)

Subsidies under the first pillar are a) direct income payments that reward farmers based on historic support

entitlements via single farm and area payments, b) coupled subsidies to increase and support the production of certain specific goods via production premiums and area payments, and c) market interventions to raise and stabilize prices via intervention buying and export subsidies. Direct income support is largest with 31.3 billion Euro in 2009, coupled subsidies were at 4.8 billion and market support at 3.4 billion. Parts of pillar two measures also count as subsidies. Those are the payments under the first axis, that aim at improving the competitiveness of agriculture and forestry via modernization, infrastructure provision and adding value to products (2.6 billion), and of the third axis, aiming at improving livelihood in rural areas via village renewal, basic service provision and business development (0.4 billion; Source: Reform the CAP 2010b).

Since 2005, direct payments are subjected to fulfilment of compulsory requirements, the so-called cross compliance requirements. Those are based on 18 standards, referring to environmental, public, animal and plant health, and animal welfare aspects (EC 2003, article 3 and 4, Annex III). None of those criteria is linked to climate change mitigation, though, but this is now addressed in the CAP reform process, see below. In addition, member states shall ensure that agricultural land is “maintained in good agricultural and environmental condition” (article 5), according to the standards set out in Annex IV. These standards aim at reducing soil erosion, maintaining soil organic matter and soil structure, and avoiding deterioration of habitats. Due to the focus on soil organic matter, these standards are of some climate relevance.

Despite recent reforms, such as the abolishment of support for livestock on a per head basis, thus reducing incentives to increase and maintain high livestock numbers, or a decoupling of direct payments from specific production under the “Health Check”, climate change mitigation plays almost no role under the current CAP pillar one measures. The situation is somewhat better for rural development under pillar two. There, several measures have a clear mitigation benefit, although they were not aimed at mitigation in the first place (EC 2009a). Farm modernisation support (Axis 1) can, for example,

improve the efficiency of energy use and fertilizer application, and manure management. Also possible under farm modernization is support for renewable biomass energy and local biogas production in particular. Under Axis 2, payments for improved soil management and fertiliser application are available, thus increasing soil carbon sequestration and reducing nitrous oxide emissions from soils. Providing training and advisory services for climate friendly agricultural practices is another option for improvement.

Some of these measures are programmed for some national Rural Development Plans for 2007-13 (EC 2009a, p. 44-45). Nevertheless, climate change mitigation is not yet a specific target under the CAP and implementation of measures to support mitigation and the choice of adequate policy instruments remains at the discretion of the member countries. The whole discussion on those then also remains somewhat hypothetical or optional, as reflected in the document EC (2009a), Annex 2, for example.

8.1.4 Public Good Provision

Payments for the provision of public goods are an important aspect of the CAP. They are provided via the agri-environmental measures under pillar 2 (Axis 2). In 2009, 4.7 billion Euro were allocated to this axis (Reform the CAP 2010b). Typical public goods provided by agriculture are related to environmental quality, such as biodiversity, water quality, water availability, soil functionality, air quality, resilience to flooding and fire and climate change mitigation (greenhouse gas emissions, carbon storage) (Cooper et al. 2009). Public good provision may play a much more important role in a reformed post-2013 CAP with a particular focus on climate change mitigation (Jambor and Harvey 2010). Most notably, there are the agri-environmental measures under pillar two (Axis 2) that have the potential to support environmental public good provision.

While such public good provision may have slowed down environmental degradation, there is evidence of undersupply of most key environmental public goods in agriculture (Cooper et al. 2009). Current levels of spend-

ing on environmental public goods are insufficient to meet societal demands and EU targets. The undersupply of agricultural public goods is due to the low importance of environmental aspects in the CAP. There are also trade-offs between general goals and policies for increased efficiency and productivity in agriculture and environmental goals and corresponding policies.

Many farming systems and practices have considerable potential to provide public goods. For climate change mitigation services, most important practices are those that increase soil organic matter, such as use of organic fertilizers, reduced tillage, and optimized crop rotations, and those that reduce soil nitrous oxide emissions, i.e. practices with reduced external nitrogen inputs. Methane reduction in the livestock sector can primarily be achieved by improved manure management and a reduction in the number of animals (e.g. Smith et al. 2008; EC 2009a).

It is important to note that reduction of methane emissions from ruminants by feed additives is controversial, due to adverse effects on animal welfare, and that the relatively lower emissions from concentrate feed than for roughage have to be evaluated in relation to the higher emissions from concentrate feed production, in particular if deforestation in the south is involved. It must also be noted that many agri-environmental programmes like the support for organic farming depend strongly on regional policies and budgets as such programmes are subjected to 50 percent co-financing by the EU Member States, i.e. their region. That means no funding of such agri-environmental is possible if the Member State does not want to or cannot contribute a sufficient share.

In principle, supporting these mitigation practices under the CAP would be possible and has in part already been done (Cooper et al. 2009; EC 2009a), and some aspects are a recurrent topic (e.g. maintaining soil organic matter and soil structure), but a much stronger emphasis on this topic is needed to achieve any significant results. Even, some adverse development can be seen. The "Health Check" from 2009, for example, abolished the requirement for 10 percent set-aside land. This is done

with the aim to allow farmers maximise their productive potential, but it will lead to soil carbon losses when changing from set-aside fallows to crop production.

At the same time, direct premiums for energy crop production were abolished as well. This will likely have a negative effect on energy crop production but it increases efficiency of the combined food/energy crop production as a distorting measure is abolished. Compared to the three options proposed for the post-2013 CAP (cf. above), achieving significant mitigation by measures from the CAP would require a fundamental shift such as proposed by the third option mentioned previously.

8.1.5 Relation to EU climate policies

Under the Kyoto Protocol, the EU-15 has agreed to reduce GHG emissions by 2012 by 8 percent compared to 1990 levels. In 2008, total emissions of the EU-15 were 6.5 percent below 1990 levels and for the whole EU-27, they were 11.3 percent below 1990 levels. The agricultural sector contributed about 10 percent to the total emissions of the EU-27 in 2008 (11 percent in 1990), excluding emissions and sequestration from land use, land use change and forestry (LULUCF). LULUCF sequestered 8.3 percent of the total EU-27 emissions in 2008 (6.2 percent in 1990) (EEA 2010). We also note that emissions from fertilizer, pesticides and animal feed production and fossil energy use in farming machinery, equipment and buildings are not covered under "agricultural sector emissions".

Over the last two decades (1990-2008), agricultural sector emissions in the EU-27 fell by about 20 percent, mainly due to a reduction in the livestock numbers (by 25 percent), more efficient fertilizer application (a decrease of 25 percent in fertiliser use) and due to improved manure management (EC 2009a). These reductions were partly due to CAP reforms, e.g. the shift from production based support to area payments or the rule for set-aside land in force until 2009, but other policies such as the Nitrates Directive were equally important (EC 2009a). Identification of the detailed mitigation contribution of specific policies and market developments is rarely possible.

Current expectations for future emission reductions from agriculture in the EU 27 are almost nil with respect to today (about -1 percent by 2020; EEA 2009). Expected reductions for the EU 15 by 2020 are -4 percent. In any case, those expectations are the lowest among all sectors. According to the "Effort Sharing Decision" of EU climate policy, the sectors not covered by the EU Emission Trading Scheme (transport, buildings, agriculture and waste; cf. below) need to reduce about 10 percent by 2020 (EC Climate Action 2010a). This percentage was defined as the sector's contribution to the EU's present commitment to reduce overall emissions by 20 percent to 2020. According to recent negotiations, this target might be raised to 30 percent (EP 2010c).

To stabilise global warming below two degrees, reduction targets of 80-95 percent by 2050 for developed countries are needed (Allen et al. 2009; Meinshausen et al. 2009). All this illustrates that enhanced action on mitigation in agriculture is needed and that agriculture will have to achieve even larger emission reductions in the future. This is, however, not necessarily reflected in policy proposals. The EU Roadmap 2050, for example (EC 2011a), which aims at emission reductions of 80 percent by 2050, foresees no dramatic change in agricultural emissions. Agriculture is thus projected to be the single most emitting sector in 2050, accounting for about a third of total EU emissions.

The EU has many policies addressing climate change. Since 2000, most important is the European Climate Change Programme (ECCP), which identifies and develops all the measures necessary to implement the Kyoto Protocol. It entered a second phase in 2005. The ECCP provides an EU-wide comprehensive package of mitigation policy measures, which is complemented by national policies that also build on the ECCP (EC Climate Action 2010b). However, agriculture plays a minor role in climate policy only.

Although the mitigation potential of agriculture and soil carbon sequestration in particular has been assessed by specific working groups under ECCP (ECCP 2001, 2003, 2006), no specific climate policies for agriculture were derived from that (see section 7 on UNFCCC policies).

A directive on soil has been proposed in 2006, but the decision-making process has been blocked since 2007 (EC Environment 2010). Such a directive has to explicitly address and support the mitigation potential of soil carbon sequestration, which is not the case in the current proposal (EC 2006).

Thus, agriculture is still not part of EU climate policy. Inclusion of agriculture in the third phase (2013-2020) of the most prominent EU-wide mitigation policy, the EU Emissions Trading Scheme EU-ETS, has been discussed, but the uncertainties regarding measurement and verification of mitigation in agriculture lead to the decision against its inclusion (EC 2008, 2009c).

In contrast, inclusion of agriculture in the EU-ETS is seen as a promising option by some stakeholders, as it would put a price on the mitigation potential in agriculture with corresponding effects on incentives to provide such mitigation (e.g. Reform the CAP 2010c). According to a recent literature review on the CAP reform, most authors, however, do not discuss concrete policy measures for mitigation in agriculture besides the general suggestion of putting a price on carbon (Jambor and Harvey 2010).

A large mitigation potential is seen in measures linked to land use, land use change and forestry (LULUCF). Soil carbon sequestration in cropland (e.g. via use of organic fertilizers and reduced tillage) and pastures and in organic soils (reduced use and restoration of peatlands) is an important part (EC 2009a). 90 percent of the mitigation potential in global agriculture lies in LULUCF, namely in soil carbon sequestration (this share is assumingly of a roughly comparable size in the EU, e.g. judged on the basis of Freibauer et al. 2004 and the Roadmap 2050, EC 2011a). LULUCF is however not part of mitigation commitments of the EU and it is only marginally covered in the CAP. Forestry covers almost as much land as agriculture in the EU. Despite this, only 1 percent of the CAP budget is dedicated to forests (CEPF 2010). To overcome this situation of neglect, the European Commission has to assess ways to include emissions and sinks from LULUCF in the community reduction commitments by mid-2011 (EP 2009).

8.1.6 Concluding remarks

Although mitigation increasingly gains importance in the CAP and plays an important role in the discussion on the post-2013 CAP reform, much remains to be done to achieve significant mitigation results in agriculture, especially considering the additional emission reductions the EU will have to achieve in the coming years to contribute reaching the 2°C goal.

First, targeted measures should be taken to support the most effective mitigation actions. This could be achieved by strengthening the payments for public good provision resp. by tying direct payments via mitigation aspects in the cross compliance. For this, cross compliance criteria need to be changed to also account for mitigation. A thorough reform of the CAP that changes its current form is needed (i.e. option 3 of the reform).

Most relevant are various measures for increasing soil carbon sequestration, sustainable peatland management, forestry management, optimized fertilizer use and an optimized livestock sector. In particular measures to address the latter have to be assessed in a global context, as the production emissions of imported concentrate feed and consumer behaviour need to be taken into account. Eating less meat and other animal products, resp. the corresponding reduction of livestock numbers is a most effective mitigation measure.

Second, harmonization of mitigation aspects in the CAP and of coverage of agriculture in climate policy, in particular regarding LULUCF, is of primary importance. The relevance of LULUCF is acknowledged in both the CAP and climate policy, but in both, LULUCF is only marginally addressed. The discussion on full inclusion in both is, however, ongoing.

Finally, mitigation is only one aspect of a sustainable agriculture. While strengthening mitigation policy, accounting for adaptation and other co-benefits of agriculture is of crucial importance.

The CAP has a broader coverage with regard to these topics than climate policy and in the course of harmo-

nization, a balanced mix must be achieved. This means, for example, that monetary incentives must not be given primarily for most effective mitigation measures only, but also for the most important adaptation activities. Given the globalized agricultural markets, this should also be reflected by complementing the five objectives of the CAP as referenced above with a sixth one, focusing on global responsibility, such as suggested in APRODEV (2011), for example. For further conclusions and proposals for action, see also section 9.3.1.

8.2 Rice production and climate change – Country case Indonesia

By Friedhelm Göldenboth

8.2.1 Introduction and general situation concerning emissions from paddies

Rice is planted to approximately 154 million ha worldwide in 113 countries of the tropics and subtropics. It occupies about 11 percent of the world's cultivated land. India and China together account for more than 50 percent of the world rice production of about 300 million t per year. Rice is used as staple food and is the first cultivated crop in Asia at least the last 10,000 years.

Perhaps even today there is no food as widely eaten as rice. It is estimated that about 3 billion people are dependent on rice for their daily consumption, about 1 billion of the poorest people of the world included. And presently about 960 Million people do not have enough means to sustain themselves with sufficient food on a daily basis. The majority of these people do live in countries where rice is the daily staple food (Wassmann et al. 2000a-c; Zhang et al. 2010).

About 160,000 rice varieties are still existing (Wassmann et al. 2000). These varieties derive from originally two species of rice: *Oryza sativa* in the Indo-Chinese region and *Oryza glaberrima* in the African region. The breeding of rice varieties just under the aspect of quality and quantity is neglecting the aspects of multiresistance and stress tolerance highly needed for adaptation processes due to climate change.

It is further well established that rice production contributes to climate change. While this contribution can be rather substantial on a national scale, on a global scale it is still a minor contribution compared to the contributions of the industrialized nations.

As a general rule, with every 75 ppm increase in carbon dioxide concentration, rice yield might increase by 0.5 t/ha but yield will decrease by 0.6 t/ha for every 1°C increase in temperature particularly through higher respiration losses and sterilization processes. The decrease in rice production in Indonesia by 2025 could then reach 1.8 Mio t annually (Anonyma 2010). But the projected decrease in rice production due to agricultural land conversion is much greater than the decrease due to increasing temperatures (Boer et al. 2008, Mitra et al. 2005, Ortiz-Manasterio et al. 2010, Wassmann et al. 2004).

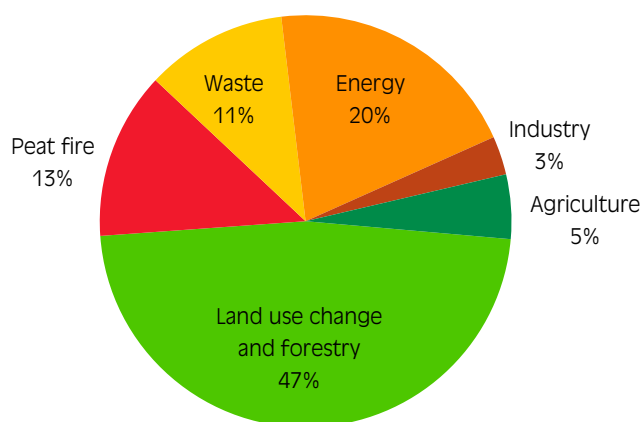
All the presently used rice strains do flower at the same time of the day between 10-12 o'clock in the morning. They are then extremely sensitive to heat impact. Further, a month delay in wet season onset due to El Nino events would decrease wet season rice production by approximately 65 percent for West and Central Java (Naylor et al. 2007).

8.2.2 Specific situation in Indonesia and Indonesia's national agricultural policies addressing climate change

Indonesia is the largest archipelagic state of the world with a landmass of about 1,919,270 km² encircled by about 3.3 million km² of territorial seas (Rigg 1996). It has five large islands (Kalimantan, Sumatra, Java, Sulawesi and West Papua) and about 17,503 small islands, 7 percent permanently inhabited. Of the about 20 million ha of arable land about 40 percent are wetlands, mainly paddies, about 40 percent are dryland and about 15 percent is under shifting cultivation. The archipelago is part of the monsoonal regime and is experiencing the so-called El Nino-Southern Oscillation impacts with sometimes torrential rains followed by extended dry spells.

Based on the occurrence of disasters recorded in the International Disaster Database (in Anonyma 2007), the

Figure 8: Emission contributions in Indonesia by sectors in 2000



After Anonyma 2010

ten biggest disaster events in Indonesia over the period 1907-2007 occurred after 1990 and most of these are weather-related. The number of deaths because of climate-related disasters has increased 50 percent per decade in Indonesia. Economic losses from these ten biggest disasters are estimated with 26 billion US\$ (Anonyma 2007).

The signals are well understood by the Indonesian Government as expressed in the National Action Plan (NAP) (Anonyma 2007): The Indonesian Government does realize that economic management without consideration of its social and ecological implications contributes to the loss of human safety and social security. The national action plan addressing climate change, issued by the Ministry of Environment, is in effect since November 2007 (Anonyma 2007). This plan has been followed by the Second National Communication under the United Nation Framework Convention on Climate Change (UNFCCC) (Anonyma 2010).

The Indonesian Government stresses the following fields of action and placed the respective actions and considerations high on their agenda in relation to climate change issues:

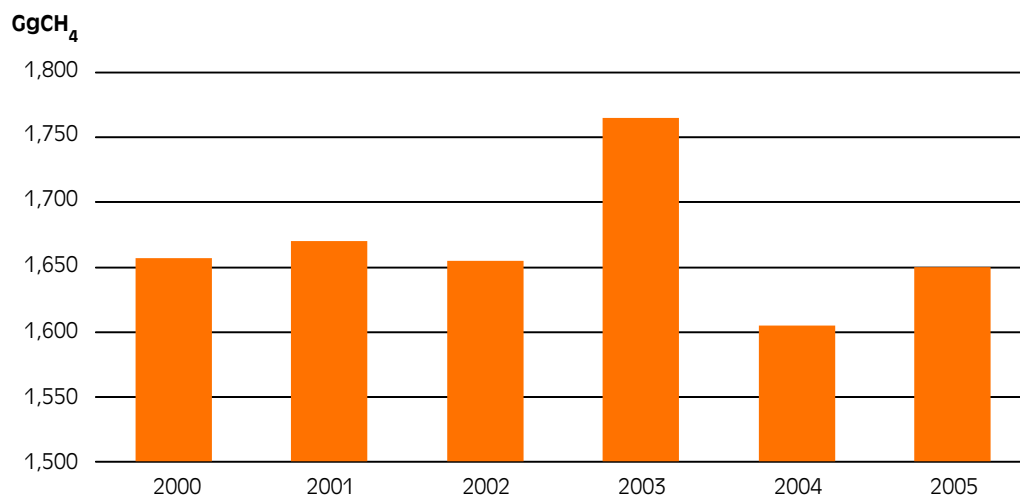
- Agricultural land conversion to non-agricultural land results in a development of public activities that do

not have a community economic historical base, and this has apparently accelerated ecological damage on a national and global scale.

- The availability of water, for various needs of the domestic settlement sector, agriculture, fisheries, animal husbandry, industry and environment is very dependent on the climate. The supply of clean water through the piping system only covers about 37 percent of the urban population and about 8 percent of the rural population. The number of critical water catchment areas has increased in recent years due to forest clearings, inappropriate land management practices and pollution. None of the Indonesian Rivers satisfy the first or second class of quality standard.
- The management of the economic performance and quality of life is linked to the reduction of GHG emissions and the reduction of energy consumption.

The adaptation to climate change is a key aspect of the national development agenda, just as effective climate change mitigation and the development of a system that is resilient to long-term climate change impacts. The implementation of adaptation activity should be parallel with poverty alleviation efforts and economic development targets for poor communities, which are the group most vulnerable to the impact of climate change.

Figure 9: Estimation of Methane emissions from rice cultivation in Indonesia from 2000-2005



After Anonyma 2010

In 2005 the total GHG emission in Indonesia for the three main greenhouse gases (carbon dioxide, methane, nitrous oxide) was estimated with 2.3 Gt CO₂e (1 Gt = 1 billion t). The main contributing sectors were land use change and forestry followed by energy, peat-fire-related emissions, waste, agriculture and industry (Anonyma 2010; www.unfccc.int/ghg_data/ghg_data_unfccc/time_series_annex_i/tems/3814.php) (Figure 8). This makes Indonesia the third largest GHG emitter of the world after the USA and China.

GHG emissions in Indonesia are expected to grow by 2 percent annually reaching about 2.8 Gt CO₂e in 2020 and 3.6 Gt CO₂e in 2030 under business-as-usual (BAU) conditions.

The total area of paddies in Indonesia is given with about 8 million ha. The monitoring of rice cultivation between 1993 to 2002 revealed that 190,000 t of dried grain were lost due to drought and 177,000 t by flooding. Further, different rice cultivars do have different root and above ground biomass besides different yields/ha. The cultivar Cisadane for example, used in Central Java, is the reason for much more methane (CH₄) emissions with potentially up to 142 kg per ha than other cultivars like Memberamo, Way Apo Buru or IR 64 (Setyanto et al. 2009).

The total emissions from the agricultural sector are calculated with 139 Mt CO₂e in 2005. The methane emissions from Indonesian paddies in 2005 are given with 51.4MtCO₂e (Anonyma 2010; <http://forestclimatecenter.org/files/2009-08-27%20Fact%20Sheet%20-%20Indonesia%20Greenhouse%20Gas%20Emission%20Cost%20Curve%20by%20Indonesia%20National%20Council%20on%20Climate%20Change.pdf>) (Figure 9).

The reduction of 3.1 percent in 2004 can be attributed to an El Nino event during that year (Anonyma 2010).

Under the assumption that all paddies are continuously flooded and inorganic fertilizer is applied, e.g. for the Cisadane variety of rice, it is expected that methane emissions in 2030 would be about 38,804 Mt CO₂e (Anonyma 2010).

Anticipated fields of actions addressed in the Indonesian National Action Plan concerning Climate Change

The Indonesian Government stresses in its National Action Plan (NAP) the following fields of action and attention (Anonyma 2007):

- The utilization of environmental friendly organic fertilizer and pesticides and efficient machinery needs to be encouraged.
- The regulation of the height of the water puddle, minimal land processing (TOT), direct seed spreading (TABELA) and integrated plant management (TPT) is mentioned.
- The System of Rice Intensification (SRI), based on findings that the sitting of the seedlings in the seedlings-bed can be reduced to just one week instead of about four weeks and therefore the entire waterlogged period in the paddy can be reduced by about 3-4 weeks, is also recognized.
- The rehabilitation of the irrigation network for paddies is a part of the planned activities.

An institutional improvement is planned by forming working groups for climate change, flood and drought disaster, water consumption and weather forecasts, besides advocacy and socialization to establish the right understanding to climate change and its impacts on the agricultural sector.

Also the necessity of food diversification, agriculture development policies with considerations on eco-systems, reduction of emissions of GHG's on all levels and avoidance of pollution is clearly seen and in the focus of attention. The integration of sustainable environment and natural resources issues and climate change issues into the national curricula are also part of the NAP.

The following actions are planned and underway since the issue of the National Action Plan in 2007 and several initiatives to integrate mitigation and adaptation to climate change issues into the national development planning agenda are actively persuaded.

The required instruments with their institutional support of the NAP are on their way to be institutionalized according to the commitment made by the Indonesian Government at the COP 15 Meeting in Copenhagen to reduce the carbon emissions by 26 percent from the

present Business-As-Usual (BAU) situation reaching a reduction of about 41 percent of GHG or about 1.2 Gt CO₂e by 2020 (Anonyma 2010) .

A financing management system for supporting and accelerating the implementation of climate change programs called the Indonesian Climate Change Trust Fund (ICCTF) is operational since 2009. At the initial phase, the ICCTF will be dominated by public funding and at a later stage will draw predominantly on private funds (Anonyma 2010) (Figure 10).

Until the end of the first commitment period of the Kyoto Protocol in 2012, the implementation of NAP in each of the mitigation and adaptation priority sectors will be measured.

It is understood that the reduction potential for GHG emissions lies mainly in the forestry, peatland and agriculture sector.

A total of about 2 Gt CO₂-eq is anticipated in 2030 for all of Indonesia. It is expected that the forest sector will produce about 850 Mt CO₂-eq or 38 percent of the total expected emissions by 2030. A reduction of about 1,100 Mt CO₂-eq could be reached by halting deforestation and forest degradation (REDD). Afforestation and reforestation efforts could account for an additional 230 Mt CO₂-eq.

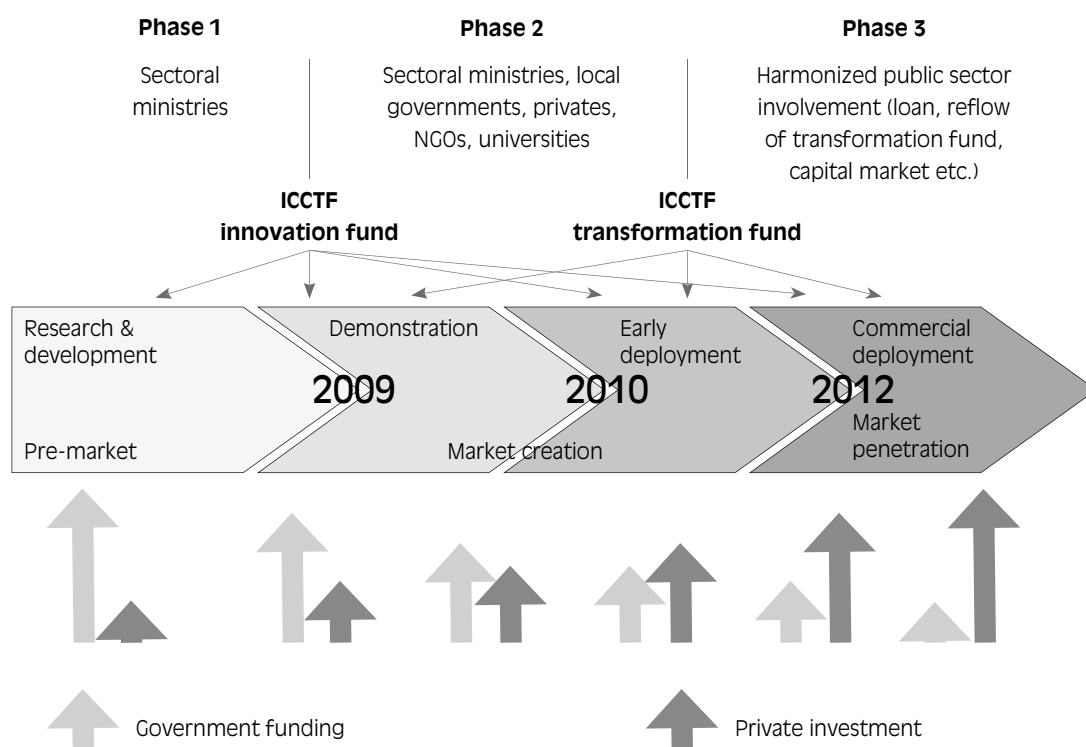
Through appropriate peatland management a reduction of 700 Mt CO₂-eq could be reached.

The agricultural sector contributed in 2005 about 139 Mt CO₂-eq. Up to 63 percent could be avoided through improved water and nutrient management for rice cultivation and restoration of degraded agricultural land (see: <http://forestclimatecenter.org>).

Aspects of politics concerning subsidies in Indonesia

Discussions and demands for subsidies are playing always a very crucial role when it comes to decisions concerning mitigation of climate change impacts. Subsidies

Figure 10: Responsibilities and development of the Indonesian Climate Trust Fund (ICCTF)



After BAPPENAS 2009

for fertilizer, pesticides and seeds have always been a part of the governmental policies for rural improvements and support for the agro-business sector.

However, officially no special considerations are given by the Indonesian Government to specific subsidies for the agricultural sector under the aspects of climate change issues presently, but through cross sector funding dedicated specifically for adaptation and mitigation of climate change impacts, the needed funds could be made available. It is admitted that due to limited funding capacities through the national budget the Government of Indonesia will try to create various funding schemes, from domestic sources to bilateral and multilateral sources, including funding via REDD-related external compensation funding (Anonyma 2010).

A first sign of a concrete step in the right direction can be seen in the reported action of the GOI (Jakarta

Post, January 2011, <http://www.thejakartapost.com/news/2010/08/26/letter-the-failed-rice-field-project.html>) to ban the further conversion of e.g. peatland to other land uses in Kalimantan and Sumatra.

But this came only after massive protests by local communities and international organizations like the World Bank and after having implemented the One Million Hectares Peatland Project in Central Kalimantan during the last 10 years (so-called Mega Rice Project).

If the Central Government of Indonesia will adhere to its commitment to reduce carbon dioxide emissions up to 26 percent by the year 2020 about half of this target can be achieved just by re-adjusting this Mega Rice Project.

For some further concrete policy recommendations, see section 9.3.2.

8.3 Meat, fodder and biomass producers and Climate Change – Country Case Brazil

By Jørgen Olesen

8.3.1 Introduction

With an area of 8.5 million km², Brazil is the largest country in South America. It had 186 million inhabitants in 2008 and an average population growth rate of 1.15 percent per year. Most of the population (85 percent) lives in urban centres. The GDP growth was 2.6 percent per year thus exceeding the population growth.

However, a large proportion (30 million) of the population still live in poverty, and eradicating poverty, improving health care, combating hunger, ensuring housing etc. is therefore a priority that ranks equal to environmental and climate change concerns (MCT 2010).

Brazil is an emerging economy that in economic terms is ranked eighth in the world. It is to a large extent an industrialised economy, but with a large agricultural sector that has food exports as its main export commodity (about 35 percent of the country's exports).

Brazil is the main global exporter of sugarcane, beef, chicken, coffee, orange juice, tobacco and alcohol, it comes second in soybean and maize exports, and it is ranked fourth in pork exports. Agriculture employs about one-quarter of the labour force. However, in terms of the total economy, agriculture only has a share of 5.5 percent. On a value basis, production is 60 percent field crops and 40 percent livestock.

In 2005 the total greenhouse gas (GHG) emissions from Brazil amounted to 2,189 million ton CO₂-eq. (MCT 2010). The major source of GHG emission is land use change (primarily deforestation) that contributed to 58 percent of total GHG emissions. Methane emissions from livestock contributed to 11 percent of the total GHG emissions, and nitrous oxide emissions from agricultural use of fertilisers accounted for 7 percent of total GHG emissions.

8.3.2 Land use and agriculture in Brazil

Brazil is home to an extremely rich flora and fauna, and it hosts over a third of the Earth's tropical forests. In addition to the rainforest in the Amazon basin, Brazil has several other major ecosystems, such as savannah in the Cerrado as well as coastal wetlands. The climate of Brazil ranges from wet tropical in the rainforest over semi-temperate in the south to very dry and warm in the Northeast.

Brazil has a very large agricultural area, which is located in different parts of the country. The southern half of the country has a semi-temperate climate and adequate rainfall, good soils, access to technology and inputs (seeds, fertilisers, agrochemicals, etc.), adequate infrastructure, and experienced large-scale farmers. It produces most of Brazil's grains and oil seeds and export crops. A more subsistence type of farming is located in the drought-affected northeast region and in the Amazon basin, where rainfall is not well distributed, soils are poor, and infrastructure and capital for agricultural development is lacking.

However, the Amazon region is increasingly becoming important as a source of exports of forest products, cocoa, and tropical fruits. Central Brazil contains substantial areas of savannah with trees covering 3 to 30 percent of the area (the Cerrado). The mixture of grass and deep-rooted trees provides good vegetation cover in both the wet and dry seasons. This area is increasingly being used for raising cattle and producing crops (e.g. soybean) for exports. These new systems are less capable of utilising resources than the native ecosystem.

Brazil's cattle and soybean production are concentrated in the Legal Amazon and Cerrado grasslands regions, and have resulted in considerable biodiversity loss, deforestation, water pollution and displacement of indigenous peoples. In 2007, about 74 million cattle, or 40 percent of Brazil's herd, were living in the Legal Amazon. Almost one million km², or nearly half of the Cerrado, have been burned and are now cattle pasture, or cultivated for soybeans, maize (both primary for livestock feed), and sugarcane for ethanol production. At least

one quarter of Brazil's grain is grown in the Cerrado region. Eucalyptus plantations are increasingly being planted for bioenergy purposes, often with negative impacts on water availability due to the high water consumption of Eucalypt.

8.3.3 Biofuel production

Brazil was the world's second largest producer (after USA) of bioethanol in 2007 with a global share of 37 percent (Fischer et al. 2009). The country exported 3.5 billion litres in 2007, 20 percent of Brazilian production, and about 50 percent of global ethanol exports. Whereas the ethanol production in USA is based on maize, in Brazil it is based on sugarcane. The supply of sugarcane in Brazil is mainly based on large farm mono-cropping (up to 100,000 ha), with intensive use of machines and agrochemicals (WWF 2006).

Following restrictive environmental legislation in the 1990s, burning crops before harvest has been prohibited in the state of Sao Paulo, which accounts for the largest share of Brazil's sugarcane production. The abolition of pre-harvest field burning should have significant environmental benefits, such as the elimination of air emissions and a reduced risk of forest fires (Pinto et al. 2003; Galdos et al. 2010). However, this clearly depends on the efficiency with which this is enforced. The effect on soil carbon also depends on whether the leftover straw is harvested for energy purposes (e.g., incineration). There is no common practice of post-harvest burning of the straw.

It has been estimated that the production of one ton of sugar results in emission of 241 kg CO₂-eq., of which 44 percent results from residue burning, 20 percent from use of synthetic fertiliser and 18 percent from fossil fuel use (Figueiredo et al. 2010). It is also the agricultural phase that dominates the GHG emissions from ethanol production (Galdos et al. 2010). It is particularly the burning of the crop residues that contributes to GHG emissions.

Sugarcane has expanded onto more degraded or poor areas (mainly previously extensive pastures). It con-

tributes to soil recovery by adding organic matter and chemical-organic fertilizer, thus improving soil structure and making it possible to use it for agriculture again. Sugarcane production in Brazil today causes relatively little soil loss through erosion.

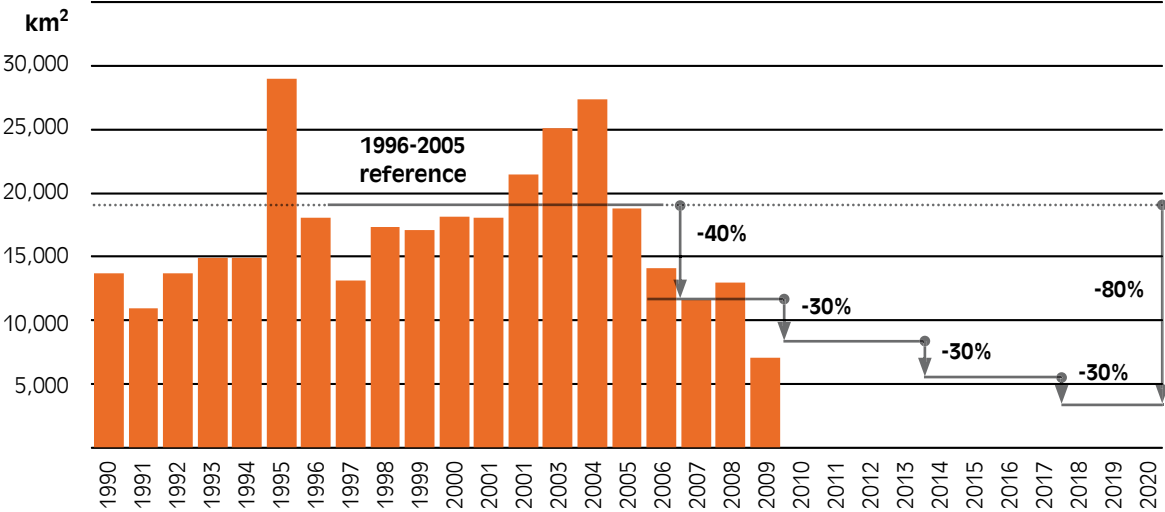
This situation is improving as a result of the progressive increase in harvesting without straw burning and the use of reduced soil-preparation techniques, leading to very low erosion losses compared to those obtained by direct plantation in annual crops. There may still be some problems related to the use of agrochemicals in the production. Since sugarcane is not irrigated in Brazil, environmental problems caused by irrigation to water quality, nutrients inflow and erosion are low.

Direct biodiversity loss from sugar-cane production is generally low, since sugarcane is largely cultivated on degraded or poor land, and mainly on "recycled" extensive pasture – but not extensively on new, uncultivated land. There are, however, indirect negative effects on biodiversity since the expansion of sugarcane onto grasslands will be a driver for expansion of grasslands and cultivated soybean into forested areas in other regions of Brazil. A major consequence for biodiversity could happen if cultivation expanded to the Cerrado or forest land as a result of extreme demand for sugar and bioethanol (Kaltner et al. 2005). To maintain a sustainable bioethanol production in Brazil, sustainability standards or certified production will most probably be required (Smeets et al. 2008).

8.3.4 Greenhouse gases from land use change

In many tropical countries, the majority of deforestation results from the actions of poor subsistence cultivators. However, in the Amazon, these farmers contribute only to about 30 percent of deforestation, while the majority (60-70 percent) of the deforestation can be attributed to cattle ranches (Butler 2008). The direct contribution of large-scale farming (i.e. soybeans) to total deforestation in the Amazon is currently relatively small. Most soybean cultivation takes place outside the rainforest in the neighbouring Cerrado ecosystem and in areas that have already been cleared. However, car-

Figure 11: Reported deforestation rates (bars) in the Amazon and levels of reduction (lines) proposed by the National Plan on Climate Change in reference to the 1996-2005 baseline



Redrawn after Cerri et al. 2010, based on data from MCT 2010

bon emissions from cultivating the Cerrado can also be quite large.

Soybean expansion is not the primary direct driver of deforestation of rainforests in South America (Batlle-Bayer et al. 2010). It is rather grasslands and savannahs (Cerrado that also has a large tree cover) that are converted to soy plantations, since these areas can readily be used for growing soybean. As cattle farms and the land of some subsistence farmers are converted to soybean cultivation, cattle and subsistence farmers turn to forest clearing in order to obtain new land. In this sense soybean expansion becomes the main indirect driver of deforestation. Additionally, studies have shown a close correlation between logging and future clearing for settlement and farming. When land is cleared for cultivation, charcoal producers remove the trees.

The rest of the vegetation is gathered into piles by tractors or bulldozers and burned. After clearing, the soil is ploughed and prepared for sowing. The development of the soybean area is largely driven by exports to Europe and other industrialized countries, where it is currently used as animal feed. In the future, though, soy oil could also be extracted and processed into biodiesel, and this

is already now being pushed by the national biodiesel policy. This would further increase the area of soybean and increase the pressure on native vegetation.

In the agricultural frontier state of Mato Grosso croplands doubled from 2001 to 2006 to cover about 100,000 km², and new intensive double cropping systems occupied more than 20 percent of croplands (Galford et al. 2010a).

During the period 1996-2005 there was a reported average deforestation rate of 11,720 km² per year, which, however, has declined to half this rate in recent years (Figure 11). This reduction is likely a response to governmental actions for reducing deforestation.

During land clearing carbon is lost as CO₂ and partly methane by the slash and burn process. It can be assumed that about 1 percent of the carbon lost is emitted as methane (Galford et al. 2010b). Since methane is a more potent greenhouse gas than CO₂, its importance for the GHG balance cannot be ignored. After the land clearing there are substantial losses of soil organic carbon (SOC). However, estimates of emissions from changes in SOC are quite variable, because of uncertain-

Table 4: Emissions from agriculture and land use change and forestry, and sinks from land use change and forestry expressed in million ton CO₂ equivalents for 1990 and 2005, and the relative change from 1990 to 2005, expressed in percentages of the 1990 values

Source	1990	2005	Difference 1990-2005 in % of 1990 values
Agriculture			
Enteric fermentation in livestock (CH ₄)	184,9	248,4	34%
Manure storage and management (CH ₄ , N ₂ O)	13	16,1	24%
Rice cultivation (CH ₄)	5	5,4	8%
Field burning of crop residues (CH ₄ , N ₂ O)	4,4	4,6	5%
Agricultural soils and fertilisation (N ₂ O)	132,1	192,9	46%
Total	339,4	467,4	38%
Land use change and forestry			
Forest and grassland conversion (CO ₂ , CH ₄ , N ₂ O)	919,8	1074,2	17%
Emissions and removal from soils (CO ₂)	110,2	65,1	-41%
Total	1030	1139,3	11%
Sinks (change in biomass and land abandonment)			
Total (CO ₂)	-234,4	-230,2	-2%
Net emissions (sources - sinks)	795,6	909,1	14%

Cerri et al. 2009

ties in estimated carbon stocks in the natural ecosystems, surveys on state of grassland conditions, and the management data for grasslands and croplands (Maia et al. 2010a).

There are currently activities ongoing in Brazil for afforestation and reforestation. The planted forests in Brazil were estimated to cover 66,000 km² in 2009 (Cerri et al. 2010). More than two thirds of the planted forest are with Eucalyptus species. The planted area with Eucalyptus has since 2004 shown an average annual increase of 7.4 percent, whereas the area with other species was rather constant. These plantations are designed to deliver high outputs of biomass for bioenergy.

However, they will do little to deliver other ecosystem goods and services, since these monocultures will not support biodiversity, and the Eucalyptus species generally have a high water consumption, which can threaten local water supply. In some cases Eucalyptus plantations will also impact on small-scale farmers that lose access to their land, largely because of poor land entitlement.

8.3.5 Greenhouse gases from agriculture

Agriculture releases significant amounts of CO₂, methane and nitrous oxide to the atmosphere (Cerri et al. 2007). The expansion of agriculture in Brazil means that agricultural GHG emissions are also increasing, primarily from the livestock (Table 4).

However, the emissions from agriculture is still overshadowed by emission from land use change, which leads to the fact that agricultural soils are also a considerable source of CO₂.

8.3.6 Mitigation of agricultural emissions

For arable land the most important greenhouse gases are nitrous oxide and CO₂ (Six et al. 2004), and management practices highly affect the emissions. For livestock systems major emissions stem from the methane from enteric fermentation and from methane and nitrous oxide from manure management. These emissions can in general best be reduced by improving the efficiency

of the entire production system (Olesen et al. 2006), although there are also specific measures that can be taken to further reduce emissions.

Below is a list of particular measures that have been found suitable in Brazil and for which evidence has been provided for their applicability in Brazil. Some of these measures are best applied in large scale farming, e.g. no-tillage. However, other measures that involve agro-ecological techniques are equally well suited for smallholder farming. However, in many cases the issue of making smallholders more climate-friendly would be that of better empowering them in terms of knowledge and skills and in terms of access to necessary implements and finance. Some of these barriers can be overcome through community-based approaches such as establishing water user associations (IWMI and SIC ICWC 2003), community-based agricultural extension services (Coupe 2009) and organisation of micro credits.

Restoration of degraded pastures

Grassland management can greatly affect SOC contents, and a range of practices to improve SOC content in degraded grasslands have been proposed, including irrigation, improved grazing, improved grass species and introduction of legumes. Maia et al. (2009) compared traditional grassland management that typically leads to degradation with improved grassland management involving moderate grazing pressure combined with at least one improvement such as fertilisation, lime, irrigation, seeding legumes or planting more productive grass species. They found that the improved pastures led to SOC increases of about 20 percent.

Elimination of field burning of crop residues

Field burning of residues is a major source of CO₂ and methane emissions. In traditional cropping of sugar cane, it was burnt a few days before harvesting in order to facilitate manual cutting by removing leaves and insects (Thorburn et al. 2001).

However, since May 2000 this practice has been progressively prohibited by law in some areas of Brazil. In addi-

tion to GHG emissions, other air pollutants are emitted during burning causing respiratory problems and ash fall over urban areas. Even though the law will not be fully implemented before 2030, it has led to rapid adoption of mechanical harvesting, which also leads to more soil organic matter accumulation.

No-tillage

No-tillage is an arable crop production system, where the soil is left undisturbed from harvest to planting. This causes less soil disturbance, which often results in significant accumulation of soil C (Carvalho et al. 2009; Boddey et al. 2010; Maia et al. 2010b). There is controversy on the extent to which no-till really sequesters SOC, especially when the whole soil profile is considered (Baker et al. 2007).

The quantity of residues returned, variations in practices implemented and perhaps climate and soil type are likely to affect the soil carbon sequestration obtained. Results from no-tillage in Brazil have generally showed significant carbon accumulation in the top 30 cm of the soil profile. This also has positive effects for soil fertility and crop yields (Cerri et al. 2007).

The Brazilian Ministry of Environment has a goal of increasing the extent of no-tillage from currently 28 million ha to 40 million ha in 2020 (Cerri et al. 2010). The adoption of no-tillage involves changes in farming practices, which is coupled to changes in machinery, residue management and often also changed systems of weed and pest control that for economic reasons often involve use of GMOs that enable simpler management schemes to be introduced, which lowers labour costs in large-scale farming systems.

Agroforestry systems

Agroforestry systems offer possibilities for improving productivity and sequestering carbon in dry environments by providing a better use of soil moisture. These systems are particularly relevant in the dry regions of north-eastern Brazil, where rural poverty is widespread (Maia et al. 2007). Not all agroforestry systems are equal-

ly efficient in delivering both climate change mitigation and increased productivity. Maia et al. (2007) found that a silvo-pastoral system was the most favourable in terms of carbon sequestration. In this system trees provided a 38 percent soil cover and the rest of the area was in grazed grassland.

Rice cultivation

Rice is not a dominant crop in Brazil, but the emissions in 2005 did amount to 5.4 million ton CO₂-eq. Since about a third of this rice cultivation is managed as permanently flooded rice there is a potential for reducing methane emissions by reducing the duration of the flooding period by using intermittent flooding systems.

Integrated crop and livestock systems

Recently there has been a trend in parts of Brazil for conversion of pasture and agriculture to integrated crop-livestock systems, where the grasslands are in rotation with the arable crops (Carvalho et al. 2010). This system has been found to be a sink of carbon that is larger even than permanent pastures, perhaps due to maintenance of a higher soil fertility.

Improved manure management

Manure can be stored either wet (slurry) or dry (e.g. farm-yard manure). Methane emissions occur primarily when the manure is stored in the liquid form. In contrast to the global situation, most intensive livestock systems in Brazil apply drylot based manure management systems, which means that methane emissions may be relatively low. On the other hand this could mean that nitrous oxide emissions are high, although this would greatly depend on the local environmental conditions.

For the future development of livestock systems in Brazil there is a need to consider which manure management systems are put into place. To the extent that there is an increase in slurry-based systems, this should be coupled with use of anaerobic digestion (biogas) to avoid increase in methane emissions (Cerri et al. 2010).

8.3.7 Policies affecting agricultural greenhouse gas emissions

Agricultural policy

Brazil's agricultural sector has grown rapidly since government abandoned policies for import substitution (favouring domestic production over competing imports, e.g. high import tariffs), and recently agriculture has been largely liberalised. This has led to a large growth in production of the agricultural sector in Brazil, and much of this can be attributed to increased productivity and lower prices of imported inputs, and also to an increase in agricultural area.

Brazil provides a relatively low level of government subsidy for agriculture. It amounted to about 6 percent of farm income in 2005-07, compared to 12 percent in USA and 29 percent in the EU (Economist 2010). Producer support is supplied mostly through preferential credit to the sector (MAPA 2008). This support is justified to offset high market interest rates and to support income generation for the rural poor.

The agricultural policies are primarily directed towards improving economic and social conditions in rural areas and in increasing the global competitiveness of the Brazilian agriculture. There are, however, two government programmes that are relevant for climate protection. This concerns the Prolora programme that promotes commercial forestation, forest preservation in areas of legal reserve, and wood production for burning in the drying of grains. It also concerns the Produa programme that supports recovery of degraded soil and pastures, and support to the use of environmentally sound practices, in particular through providing funding for soil preservation, improvement of pastures and agroforestry.

Climate and energy policies

Brazil as an emerging economy so far has no reduction commitments under UNFCCC and the Kyoto Protocol. Despite this, there is an array of programmes in Brazil to promote reduction in GHG emissions. Some of these

programmes contribute to “clean” energy, while other measures are targeted at reducing deforestation (MCT 2010).

In 1975 following the first oil crisis, the Brazilian government launched the National Ethanol Program (ProAlcool), creating conditions for large-scale development of the ethanol industry based on sugar cane. This program was further developed in 1979 after the second oil shock by introducing a number of tax and financial incentives. The economic incentives for the industry was largely dismantled during the late 1990s and replaced with mandatory blending targets.

In the beginning of the 2000’s, the Federal Government started incorporating biodiesel as part of reducing the dependency on fossil fuel. The intention of the Probiodiesel program was also to add to the creation of jobs and income in the poorer parts of the country.

Brazil is now among the largest producers and consumers of biodiesel with an annual production of 1.6 billion litres in 2009. The production is based on a mix of different oil crops (including beans and palm). There is an expectation in Brazil that there will be a considerable expansion of bioenergy production based on use of agricultural residues. Policies to increase biodiesel production include a special scheme (Social Fuel Seal), where biodiesel producers who buy feedstocks from small family farms in poor regions pay less federal income tax.

Experience with the Proalcool program gathered in the 1980s shows that rapid expansion of biofuel production can lead to the devastation of ecosystems. Potential risks to biomass energy resources also include deforestation and the degradation of other conservation land. Monocrop cultivation reduces biodiversity and soil fertility and degrades land. There is also a risk of competition for land between food production and biomass resources.

Bioenergy is not necessarily carbon-neutral, and additional, often fossil energy is required for crop cultivation and fuel transportation (Galdos et al. 2010). In addition, increasing international trade in bioenergy and biomass

will create further competitive pressure to expand unsustainable production. Yet with improved legislation and environmental enforcement and significant expertise in improving land-use management, some of the problems faced in the early days of the Proalcool program have been reduced, e.g. through prohibition for preharvest straw burning.

Brazil adopted a National Plan on Climate Change in 2008 with the aim to identify, plan and coordinate actions and measures that can be undertaken to mitigate GHG emissions generated in the country, as well as actions for adaptation to climate change. In 2009, the National Policy on Climate Change was put in place, and this policy aims to reconcile social and economic development with protection of the climate system through reductions of GHG emission and enhancement of CO₂ removals through sinks. It also includes measures to promote adaptation to climate change, particularly for the most vulnerable segments of society. The aim is to reduce projected emissions by 36-39 percent in 2020 (MCT 2010).

Half of Brazil is covered by forests, which includes both the Amazon rain forest and the Cerrado. Recent migrations into the Amazon and large scale burning of forest areas have placed the international spotlight on this source of greenhouse gas emissions and biodiversity loss. Much progress has been made in recent years to combat deforestation, particularly in the Amazon. This has been done through reduced incentives for activities leading to deforestation, implementation of an ambitious environmental plan, and adoption of an Environmental Crimes Law with serious penalties for violations. This also includes the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon. These measures reduced the rate of deforestation by 73 percent, from 27,772 km² in 2004 to 7,464 km² in 2009.

Much of the success in the implementation of these measures is due to the fact that Brazil has advanced systems for monitoring forest areas (MCT 2010). This includes a remote sensing-based monitoring system for the Amazon run by the National Institute for Space Research. Brazil has further developed a remote sensing

system for monitoring burning activities. This resulted in creation of a Program for the Prevention and Control of Burnings and Forest Fires (Proarco).

Brazil also has a large number of Federally Protected Areas covering 449,000 km². When both state and federal protected areas are added, the total is 2,386,000 km², accounting for 28 percent of the country's territory. The government further has a policy to double the planted forest area in Brazil. This planted forest will primarily be Eucalyptus for paper and bioenergy production.

A number of activities have been undertaken under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Some of these CDMs have also been applied to reduce GHG emissions from agriculture, in particular by reducing methane emissions from manure management in large scale pig farms in Brazil. There have also been CDM activities to reduce methane emissions from many small-scale pig farms.

For some further concrete policy recommendations, see section 9.3.2.

9 Conclusion: Policy recommendations – how to achieve a climate friendly agriculture

Policy recommendations for the achievement of climate friendly agriculture have to be developed in the context of the new paradigm for climate friendly agriculture as presented above in this report, and in the context of both agricultural and climate policy. We repeat the five guiding principles for climate friendly agriculture (section 6): it has

- to account for trade-offs and choose system boundaries adequately;
- to account for synergies and adopt a systemic approach;
- to account for aspects besides mitigation (adaptation, food security);
- to account for uncertainties and knowledge gaps; and
- to account for the context beyond the agricultural sector: consumption and waste patterns.

Policy recommendations have to fulfil criteria of their own as well: They basically need to answer what has to be done, who has to do it and how it can be done. They thus need

- to be given in relation to clearly defined and concrete goals;
- to address clearly named agents;
- to clearly define the actions these respective agents should take.

In addition, we propose that they should

- be in part pragmatic and in part visionary – but not only the latter alone and preferably not only the former alone.

In this context, we recommend concrete policy goals, agents and actions. This is done in a pragmatic way, i.e. purposely not covering all important aspects, but being selective by focusing on the most important, most effective and most realistic aspects. And it should be done with visionary ideas in mind, following new paths, where appropriate.

9.1 Goals

From the previous sections, we identify five main goals, which policies for climate friendly agriculture should focus on. These are soil carbon, closed nutrient cycles, consumption and waste patterns, nitrous oxide dynamics and assessment of multi-functional farming systems.

9.1.1 Increase soil carbon

Increasing soil carbon levels has a huge mitigation potential. It is not permanent and has saturation dynamics, but it could considerably contribute to gain time for stringent and permanent mitigation options in agriculture and other sectors.

Increasing soil carbon levels is of paramount importance for increased soil fertility, soil and plant health and thus for climate change adaptation, securing rural livelihoods and food security. The non-permanence is not crucial in this regard, as past achievements (e.g. food security in the previous year) are not lost from a change in management practices today. The saturation aspect is not problematic either, as a certain high soil carbon level also allows for adaptation and food security if no further increase of soil carbon contents takes place.

9.1.2 Realise closed nutrient cycles in agriculture

Increasing soil carbon levels strongly depends on the input of organic matter through crop residues and organic fertilizers and also on the presence of grass-clover/forage legumes leys in the crop rotation. Nutrient recycling has to take into account the biomass exported from the farms as well. This is an issue when agricultural goods are not processed at the production site and thus

contribute to nutrient deficits there and nutrient over-supply in the areas where the processing occurs. This is an issue in the context of urban hot-spots of organic waste generation and can even have a global dimension when production in the South and processing in the North lead to unsustainable nutrient outflows from South to North.

Closed nutrient cycles have several advantages regarding nitrogen (e.g. avoidance of the energy intensive synthetic fertilizer production and generally reduced nitrogen losses resulting in reduced negative environmental impacts), but they are even more important regarding non-renewable nutrients such as phosphorus.

In the context of the emerging “peak-phosphorus” discussion, saving use and recycling of this nutrient is of significant importance. Fertilisation strategies have to be developed for the agricultural sector on regional and national levels aiming at a resource-efficient utilisation of organic and synthetic fertilisers.

Therefore large carbon and nitrogen surpluses in farm balances in intensive livestock regions have to be balanced out with carbon and nitrogen deficits in areas with only little livestock. This would have to be achieved by transporting manure or nutrients from processed manure (e.g. pellets) on a regional level, as far as this transporting and processing makes sense, and – especially important – by structural policy, to set incentives for mixed farming systems, so as to have livestock production integrated with the production of the feed for the livestock.

9.1.3 Change consumption and waste patterns

Without changes in consumption patterns, climate friendly agriculture will never be possible. The primary goal is a considerable reduction of ruminant meat consumption. But also changes towards increased acceptance and consumption of resistant and locally adapted varieties are important. Finally, consumer changes directly influence energy use. Choosing seasonal and in addition local products as well as reducing food waste would reduce corresponding emissions.

Another big potential for increased mitigation lies in avoiding current food wastage. In developing countries, storage losses could be avoided with improved infrastructure. A totally different strategy is needed in developed countries where food waste occurs for the end product. Unrestricted availability of fresh food, expectations regarding freshness and clean look are drivers of this wastage. Attempts to change this have to address consumer behaviour directly.

9.1.4 Improve the scientific knowledge on nitrous oxide dynamics

Although many aspects of methane emissions from ruminants and manure still need more research, the situation with regard to nitrous oxide from soils is even more complex. A robust finding is that lower nitrogen application rates correlate with lower nitrous oxide emissions, thus reducing nitrogen inputs is key for a climate friendly agriculture. But the details of nitrous oxide emissions are still only partly understood. Of particular importance is a better understanding of the emissions from various types of organic fertilizers and green manures and how to optimally apply them to keep emissions at a minimum. Furthermore, improved understanding on the influence of site-specific parameters on emissions is necessary. Also the trade-off between carbon sequestration through carbon and nitrogen containing humus built up at the one side with the release of nitrous oxide on the other side needs further scientific investigation at an international level.

9.1.5 Develop methods for the optimal assessment of complex, multi-functional farming systems

Quantification of emissions and sequestration in the context of climate friendly agriculture is necessary. Although uncertainties prevail and knowledge gaps hinder thorough assessment of the exact mitigation potential of many practices, trends can often be identified and it is also necessary to do so. Quantification however needs to be done in such a way that no bias is introduced. There is a danger that easily quantifiable solutions win over truly sustainable solutions simply because the lat-

ter might be more difficult to quantify. There is still a need for conceptual work on how to best assess agricultural systems with various outputs and services in the context of mitigation. How this assessment is done will be influential on the type of agriculture that will be supported as climate friendly and also on which importance other sustainability aspects will have.

9.2 Agents and Actions

We frame the discussion in this section according to the goals identified above. We aim at identifying the relevant agents and the necessary actions, and provide some suggestions for promising policy instruments. Thereby, we aim to be as concrete as possible. Also, we indicate the level where appropriate policies should be executed (regional/national/international). Although we would like to, it is impossible for us to recommend a single policy instrument as the instrument of first choice to reach a certain goal. Such an optimality assessment of various policy instruments is beyond the scope of this report and needs to be done for each case in its specific sectoral and regional or country context separately.

Of general importance is the inclusion of the paradigms for climate friendly agriculture in the relevant policy documents, such as legislative texts for the CAP reform of the European Union, texts for UNFCCC Ad-hoc Working Group meetings and also the IPCC 5th Assessment Report. NGOs and other stakeholders should be ahead of these drafting processes and provide relevant and concrete formulations to the respective writing bodies early in the process to allow for critical discussion and adequate consideration of these aspects.

9.2.1 Increase soil carbon

For this goal, most important is action on national levels and on the level of the UNFCCC. Governments of non-Annex I countries should incorporate the increase of soil carbon levels both in their Nationally Appropriate Mitigation Actions (NAMAs) and in their National Adaptation Programmes of Actions (NAPAs), thus accounting for the strong synergies between mitigation and adaptation in soil carbon increases. This has to go well beyond

mere declaration of intents. Concrete measures need to be formulated in the NAMAs and NAPAs, such as support for the various practices that increase soil carbon levels via tax- or payments for environmental services schemes or some prescription of certain management practices.

As said, the decision on which of these policy instruments is most appropriate also depends on local conditions and further analysis is necessary for each concrete case. There is a window of opportunity now with regard to NAMAs, as their institutionalisation is currently under discussion, but it is not yet defined. NGOs should thus work towards adequate coverage of sustainable agriculture therein.

Governments of Annex-I countries should incorporate soil carbon sequestration (or losses) in their national inventories and in their adaptation strategies. This would make it visible to policy makers and put it on the agenda for interventions. The UNFCCC should make accounting for soil carbon in inventories mandatory, as this would urge nations to include it and as it would also establish a level playing field between nations regarding this mitigation aspect.

On the level of EU and national policies, all countries should change their subsidy schemes for agriculture towards payments for environmental services, thus also covering increased soil carbon levels.

Similarly, financial funds for mitigation and adaptation (as the Adaptation Fund) should take a strong position on supporting practices that lead to increased soil carbon levels. Clearly, financing also needs to support related dissemination and extension activities.

It is important to emphasize that support schemes need to account for the systemic character of sustainable agriculture. Techniques focussing on no-till only, for example, are not sufficient, as they are not well adapted to other soil fertility increasing strategies such as diversified crop-rotations, use of organic fertilizers and the reduction of herbicide and fungicide use. Effective strategies need to optimally combine nutrient recycling,

soil conservation and increased agro-biodiversity. It is a task for state research to also focus on such systemic strategies.

9.2.2 Closed nutrient cycles

As for soil carbon, incorporation of nutrient recycling and optimal use of biomass should be covered in NAMAs, NAPAs and agricultural policy on all levels. This would parallel a development of reduced synthetic fertilizer use. Policies setting maximum allowed rates for nitrogen inputs, such as the EU Nitrate Directive, or avoiding use of inorganic fertilizers, such as area payments for organic farming can be very successful in this.

Especially in areas with marginal soils and nutrient-deficiency, optimal combination of organic and synthetic fertilizers should be promoted. Governments need to assure that any policy aiming at closed nutrient cycles is developed in close interaction with bioenergy policies, to avoid incompatible proposals due to lack of biomass for both strategies.

Information provision and skill development on how to optimally produce and use organic fertilizers (e.g. compost) play an important part for achieving this goal. The corresponding extension services have to be established and trained by governments and NGOs.

A dialogue with the fertilizer industry needs to be sought; it could be inspiring to learn from electricity producers, where promoting energy efficiency, superficially going against their business of selling electricity, becomes a new, profitable business field. Initiatives in this spirit are already under way in the US and Canada (VCS 2010, GoA 2010), covering reduction in fertilizer use, but not nutrient cycling, though. In regions where mixed farms are economically and socially still viable, this type of farms should be encouraged by advisory services.

As an alternative, policy actions should heavily focus on giving preference to small-scale cooperations of farms in order to combine the positive effects of former mixed farming with the economic gains of specialisation and economy of scale.

9.2.3 Change in consumption and waste patterns

Changes in food consumption and waste patterns are the most difficult, but at the same time the most effective measures. First, an honest dialogue on consumption and waste patterns needs to be started in our liberal societies, where the core-value of individual freedom conflicts with prescribing life-styles to individuals. Starting such a dialogue lies in the responsibility of politicians. Ultimately, changing consumption patterns is not about prescribing life-styles but about rising awareness for the impacts of our actions in a globalized world. Not restricting the freedom of others by our actions is also a core value in liberal societies. In contrast to most other policy instruments, it has to be seen in the time frame of several decades or generations rather than of a few years.

Changing consumption and waste patterns clearly also lies in the responsibility of individuals. Individuals must develop an understanding of themselves as citizens in a globalized world and not merely as consumers. This can be supported by information provision, but ultimately, a discussion about values and preferences and about notions of what constitutes a good life and about the virtues of prudence and moderation cannot be avoided. The key is to involve a broad public in this discussion and do so in an official policy frame, avoiding unpopular labels such as "alternative", "esoteric", "deep-green" or other approaches lacking general acceptance.

There are a number of official governmental and related reports pointing in this direction, but they have never achieved much attention (e.g. UNEP 2001; Kaenzig and Jolliet 2006; IPCC 2007; ECEEE 2006; moderately, but nevertheless pointing out the key role of consumers: World Bank 2010). It is especially the role of NGOs to support politicians and governmental agencies to developing this topic to a level, where it can become a legitimate topic in policy debates.

The interdependence of eating and food waste habits with the quality of our landscapes, with the attractiveness and ecological soundness of our farms and with the health and well-being of citizens should become the

major content of the campaigns of all NGOs for years in order to change public awareness.

Although a totally different dynamic is behind wastage from storage losses in developing countries, we shortly cover this here as well. Improved infrastructure, logistics and training are necessary to reduce these losses. This and the respective financial means should be promoted and provided by governments.

NGOs should also implement such projects. Part of these projects will be of comparatively low complexity and have big effects with few means (e.g. provision of simple household or community storage facilities).

9.2.4 Nitrous oxide dynamics

Knowledge on factors that affect nitrous oxide emissions are still scarce, in particular when it comes to technologies and management measures that can control and reduce these emissions. Here, research institutes and, in consequence, institutions financing research (governmental agencies, but also large NGOs and private funds) need to take action.

More research on nitrous oxide emissions from fertilized soils is needed, in particular differentiating for different organic fertilizer types and green manuring strategies. For this, ideally, a well-designed global initiative for continuous measurements in various climate zones, and for various soil types and farming systems should be established. Besides fertilizer types and site-specific characteristics, this research should also cover interactions of nitrous oxide emissions with soil carbon sequestration in particular. Although the situation is somewhat better regarding understanding methane emissions, more research is needed there as well.

9.2.5 Assessment of multi-functional farming systems

Additional research is needed on the role of multi-functional farming systems, too, thus pledging the same agents as above. Also, large retailers and other agents along the value chain should provide means to reach

this goal, as they increasingly demand such assessments in the context of carbon footprints for single products, etc. This endeavour can draw on a rich body of knowledge in both life cycle analysis for agricultural products and in multi-criteria analysis.

Policymakers and governmental institutions also play an important role, as they need to communicate that a reliable assessment and comparison of multi-functional farming systems and quantification of key sustainability aspects of those is not yet established, thus avoiding bias for preliminary and incomplete solutions with corresponding biases towards certain unsustainable, but easily quantifiable systems.

9.3 Policy recommendations in detail

We close this report with an attempt to provide some policy recommendations in further detail and on a more specific level of concreteness. This has illustrative character only, as providing very concrete policy recommendations for specific contexts such as certain sub-sectors of agriculture or regions in the EU, in Brazil or Indonesia needs to be based on a much more in-depth analysis of the current situation for each specific case and its local context. This clearly is beyond the scope of this report. Nevertheless, this attempt of more concreteness may inspire such additional work. We structure this part according to the three case-study regions and countries EU, Brazil and Indonesia.

9.3.1 EU

In the cross compliance regulations of the EU common agricultural policy (CAP) attention is already paid to maintaining and increasing soil carbon levels, via the humus content, but the current practice is not very effective. In Germany for instance, a humus balance is not compulsory, when the farmer cultivates at least 3 different crops (each crop must cover at least 15 percent of the agricultural land) or cultivates predominantly humus "neutral" or "positive" crops. But if the farmer does not follow these two options, only a farm-gate balance or soil sampling for humus analysis has to be conducted.

The required farm gate balance, however, is too un-specific as it doesn't show the humus dynamics of the various fields. To allow for effective action the future EU-CAP should regulate a field-specific humus balance. With this more detailed balance the message should be transferred, that humus is not just a criterion of the cross-compliance catalogue, it is also an agronomic and environmental good!

In the same direction goes the proposal of the German peasant association AbL (Arbeitsgemeinschaft bäuerliche Landwirtschaft) (AbL 2011). In their opinion farmers should qualify for getting full support from the first pillar of the EU-CAP when a crop rotation is realized and 20 percent of the cultivated crops are legumes such as grass clover leys known to be effective in humus accumulation. If a farmer does not take this option he will get 30 percent less direct payment and this withdrawn money is used for agri-environmental measures in the 2nd pillar.

The commitment to grow grain legumes in Europe would also influence land use in North and South America, where soybean monocultures exert negative impacts on greenhouse gas balances especially when land use change is involved.

Another effective measure is the EU-wide promotion and support of tillage practices preventing soil erosion. In some member states these options are part of the current agricultural subsidy schemes already, but there is still a substantial part of agricultural land, which is prone to erosion because of slope exposition and poor soil aggregation (e.g. sandy texture) and not managed adequately.

A framework of good tillage practices including cover crops on EU level is urgently needed and basic measures e.g. to prevent soil and nutrient loss at hillside situations should be part of direct payment schemes (cross compliance) and additional measures e.g. plough avoidance can be supported through 2nd pillar programmes.

The recycling of organic refuse from households (kitchen refuse, green waste from gardens, lawns, etc.)

needs to be further developed EU-wide. Some regions and countries have recycling activities ongoing where these organic materials are separated from municipal solid waste, collected separately and processed at composting facilities and brought back to agricultural soils. Composts however have not the best reputation among farmers and need promotion. As composts are also valuable phosphate fertiliser a strategy needs to be developed to enable humus increase, general soil improvement and phosphate fertilisation at the same time.

Besides increasing soil carbon, action is needed on closing nutrient cycles. Closing nutrient cycles does imply to develop fertiliser strategies at national level. This fertiliser strategy should aim at prioritising manure/fertiliser types. At the moment (arable) farmers are not obliged to make use of organic manures (slurries, solid wastes, composts, etc.), which are at surpluses in some areas.

Often they do not know about the multiple benefits of organic manures (humus built-up, C-sequestration, N, P, K fertilisation, etc.) and just go for the established mineral fertilisers. An organic manure network needs to be developed at national levels, which run an organic manure exchange (internet) platform where seller and buyer of organic manures meet. Such an exchange platform exists for fermented slurries and composts in Germany (www.kompost.de) but needs to be further developed for solid manures and unfermented slurries.

Such manure exchanges enable the reduction of synthetic N-fertiliser in agriculture (reduction of nitrous oxide from fertiliser industry and cultivated soils) and soil organic carbon increase at the same time. Making use of organic manures at least for the basic fertilisation (Humus, N, P and K content, lime) before applying mineral fertiliser should be implemented into the cross-compliance catalogue of EU-CAP. In that context farmers should indicate that they check availability of regional organic manure suppliers and make use of manures (or not) depending on availability.

Nitrogen surpluses well above 50 kg/ha exist in many EU countries/regions (<http://www.eea.europa.eu/data-and-maps/figures/estimated-nitrogen-surplus-across->

europa-2005): e.g. Bretagne, Netherlands, Belgium, Northwest Germany, Denmark, Northern Italy. The EU farmers, however, are not obliged for effective nitrogen control, as they are only obliged to calculate annual farmgate balances for nitrogen and phosphorous. As for humus (see above) also an area-specific nutrient balance should become compulsory for farmers in the EU and payments should be tied to performance regarding nitrogen efficiency, inputs and runoff.

Renaissance of leguminous crops: Nitrogen-fixing legumes should become integral parts of European agriculture. As outlined above maize displaced legumes in Mid European agriculture along with soil carbon losses and other effects. The already mentioned proposal by the German peasant association AbL (Arbeitsgemeinschaft bäuerliche Landwirtschaft) (AbL 2011) appears to be effective to stimulate the cultivation of N-fixing legumes in the EU along with a reduction of synthetic nitrogen.

The further promotion and financial support of organic farming has many climate-related and environmental benefits. It is a systemic approach and targets many sustainability criteria including the closed cycle principle at the same time. European and national governments should dedicate a substantial part of their budgets for research and development of organic farming systems as it also offers great potential to developing countries because of low-external inputs requirements. The continuation of supporting the conversion and perpetuation of organic farming through payments of the second pillar of the EU-CAP is necessary in that respect.

Animal numbers need to be limited and livestock units (= number of animals/ha of agricultural land) similar to the one of the EU organic regulation (EG-Öko-Verordnung Nr. 889/2008) have to be introduced into the EU legislation. This will help to avoid the questionable concentration of large animal units in the Central and Eastern European countries like East Germany, Czech Republic and Poland where investors established poultry, pig and other factories in the past with insufficient linkage to the available agricultural land and the corresponding excess of nitrogen of animal excrements at farm surroundings.

9.3.2 Indonesia

A number of programs and recommendations are initiated or considered by the Indonesian Government to reach the proposed emission reductions (Las et al. 2008, BAPPENAS 2010).

- Technical Recommendations: Major areas of action include the implementation of no-burning technology for land clearing and land preparation, in food crop, horticulture, and in the plantation sub-sectors. Furthermore, new low methane emitting technologies for bioenergy and composting and improved feed and optimization of the productivity of existing agricultural lands will be supported. Through introduction of carbon efficient farming technologies and the increasing use of organic fertilizer and bio-pesticides emission avoidance strategies are supported.
- Weather related recommendations: Based on Data from the Badan Meterologie Klimatologi dean Geofisika (BMKG) the monsoon onset has changed in many parts of Indonesia . It is e.g. delayed in Java and the wet season has tended to shorten almost by a month (Sofian 2010). It is further forecasted that the rainfall pattern will change under increasing GHG emissions and most Indonesian regions will experience much higher rainfall than under the current conditions from 2025 onward (Anonyma 2010). Therefore, farmers need proper weather forecasts to optimize the water-logged period of the paddies.
- Recommendations for rice cultivation: Introduction of low emitting rice varieties like Ciherang, Cisantana, Tukad Belian and Way Apo Buru is recommended besides preparation of seed stocks for accelerated planting. A modified cropping pattern, improved nutrient supply, seed and seedbed management, ecology-based pest management and smart management of rice residues is also recommended. The incorporation of appropriate fallow periods and mulching of rice straw is seen as a highly efficient measure to reduce methane emissions. The employment of the SRI method is supported because up to 60 percent of the methane emissions could be avoided. Further, by

turning rice straw and husks into “biochar” or ashes, emissions can be reduced by up to 85 percent from the respective paddies.

Establishment of efficient irrigation and water saving techniques like optimizing irrigation patterns for rice and non-rice crops, distinct drainage periods within the season to reduce methane emissions, intermitted and pulse irrigation is compared to the conventional continuously flooded system reducing CH₄ emissions up to 62 percent and therefore highly recommended (Setyanto 2004).

- Tentative time table for implementation of recommended policies for emission reduction from paddies (Anonyma 2007, Anonyma 2010, Naylor et al. 2007, Boer et al. 2005, 2009):

By 2015

Planning and discussion with all stakeholders of the respective National Action Plan (NAP) and establishment of the required instruments with the cross-sectoral support of all agencies involved. The different sources for funding the activities to reduce the emissions need to be established including the so-called Indonesian Climate Trust Fund (ICCTF).

The recommendations concerning rice cultivation, including cropping pattern, crop management, and irrigation efficiency must be transferred into respective activities in the field.

By 2030

The recommendation to ban the conversion of rice-fields to other use and the expansion of the rice growing area must be fulfilled.

The forest cover must be maintained and increased and food consumption must be diversified.

9.3.3 Brazil

Brazil has a huge potential for production of food and bioenergy. However, any expansion of the agricultural

area into native areas have large negative consequences for biodiversity and also leads to large emissions of CO₂. It is therefore essential from a climate perspective to preserve the carbon in the native vegetation by avoiding further expansion of the agricultural area. To ensure that the agricultural activities are sustainable from both economic, environmental and social perspectives, policies should ensure that emphasis is given to maintaining soil fertility and to growing high yielding crops in crop rotations that add resilience to climatic and biological threats.

The further expansion of agricultural land into native forests and savannah regions can most likely only be prevented through strong federal legislation against deforestation with severe penalties coupled with local enforcement and social programmes that offer alternative livelihoods to the rural poor.

The sustainability of large-scale farming systems can be improved through legislation and adoption of sustainability criteria (e.g. based on cross-compliance for financial support) that are then controlled by federal or regional agencies. Such sustainability criteria should be incorporated into the agricultural and/or environmental policies and legislation. Elements of such sustainability criteria could be:

- requirements for recycling of animal manure, household waste and urban organic waste onto the agricultural lands;
- elimination of burning of straw or any other organic materials in the field;
- avoidance of intensive soil tillage;
- use of crop rotations and cover crops to retain nutrients and increase soil organic matter;
- Use of integrated crop and livestock systems (mixed farming);
- improved manure management to reduce emissions during manure storage;

- restoration of degraded pastures and introduction of agroforestry systems in pastures;
- use of dryland rice or intermittent flooding systems in rice cultivation.

For smallholder systems it may not be feasible to adopt strict legislation that will require extensive control systems. However, many of the measures that are listed for the intensive large-scale farming systems will in principle also apply in smallholder systems. In addition many agroecological techniques that make use of more complex combinations of special plant and crop-livestock systems can also be used here. Some of these systems will typically be classified as organic farming systems, and the certification of smallholders within an organic farming scheme may be one way forward. In many cases the most efficient way of improving the sustainability for smallholders is via improving their knowledge and skills and their access to the necessary equipment and to finance. There is a particular need for setting up community-based programmes that can provide a range of services to overcome current barriers. This may include

- Education within climate-friendly farming,
- Agricultural extension services,
- Micro-credits for financing investments in new techniques,
- Common management of woodlands or grazing lands to avoid degradation, and
- Establishing market access for products that may also be certified.

Such approaches should be supported through the agricultural policy, but may also be targeted by NGOs.

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