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Implications of and possible responses to climate change

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Sustainable Rural Development with Emphasis on Agriculture and Food Security within the Climate Change Setting (SARD-Climate) Deliverables

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The SARD-Climate project provides report containing an analysis and policy recommendations for a development policy aiming at a Sustainable Development with regard to agriculture and rural areas, food security and climate. The project has been coordinated by Professor John Sumelius at the Department of Economics and Management, Faculty of Agriculture and Forestry, University of Helsinki. Dr Stefan Bäckman has been a project secretary. The project was carried out in cooperation with MTT Agrifood Research Finland Dr, Reimund Rötter and Dr Helena Kahiluoto

The following reports have been issued:

1. General theoretical framework (John Sumelius, Stefan Bäckman, Reimund Rötter, Helena Kahiluoto)
2. Start-up document (John Sumelius, Stefan Bäckman)
3. Investigation of the effects of increases in agricultural productivity with regard to food security, employment and rural development in general (Newton Nyairo, Tuulikki Parviainen, K.M. Zahidul Islam and Stefan Bäckman)
4 .Analysis of the relation between rural poverty, malnutrition and hunger, and the interlinks with agricultural production growth and productivity growth with special reference to Mozambique and Bangladesh (Rose A. Ingutia, K. M. Zahidul Islam and Md. Motaher Hossain)
5. Effects of land tenure and property rights on agricultural productivity in Ethiopia, Namibia and Bangladesh (Shimelles Tenaw, K.M. Zahidul Islam and Tuulikki Parviainen)
6. Effects of developing country policies on agricultural services, extension, rural infrastructure and energy, health care, water and sanitation (Md. Motaher Hossain and Shimelles Tenaw)
7. Identifying the driving forces behind price fluctuations and potential food crisis (Stefan Bäckman and John Sumelius)
8. Analysis factors affecting supply of agricultural products: market liberalization, agricultural policies, bioenergy policies, population growth, input price development, trade policies and other relevant factors (Newton Nyairo and Stefan Bäckman)
9. Rural financial services and effects of microfinance on agricultural productivity and on poverty (Shimelles Tenaw and K.M. Zahidul Islam)
10. Fair Trade coffee certification. A tool for rural development and environmental protection in Nicaragua? (Joni Valkila)
11. Implications of and possible responses to climate change (Helena Kahiluoto and Reimund Rötter)

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Sustainable Rural Development with Emphasis on Agriculture and Food Security within A Climate Change Setting

Implications of and possible responses to climate change

Task 11. The framework and implications set by climate change for all the other tasks; Main elements to enhance adaptive capacity of agrifood systems in two case countries in Sub-Saharan Africa

Task 12. Opportunities offered by carbon trade and integration of food and bioenergy systems in two case countries in Sub-Saharan Africa

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SARD-Climate

D11: Implications of and possible responses to climate change in Sub-Saharan Africa
- Impacts, adaptation options and adaptive capacity in agrifood systems
- Opportunities by carbon trading in food and energy systems

Helena Kahiluoto and Reimund Rötter

Abstract

Climate change is expected to worsen food insecurity and seriously undermines rural development prospects. It makes it harder to achieve the Millennium Development Goals and ensure a sustainable future beyond 2015. Findings from the recent 4th assessment report of IPCC, Working Group II indicate that already towards 2050 with respect to food crops yield losses between 10 and 30% can be expected as compared to current conditions in large parts of Africa, including Western, Eastern and Southern Africa. Climate change is likely to increase disparities between developed and the developing world, while many uncertainties remain. It is, for instance, estimated that developing countries would need to bear 75-80% of the costs of damages caused by a changing climate.

The prevention of such threats cannot rely alone on economic growth, but requires climate policies that combine enhancement of development with reduction of vulnerabilities and effective financing mechanisms that support the transition to low-carbon economies. The major strategies to reduce the potentially harmful effects of global changes, especially climate change are 1) adaptation of food and farming systems to climate change, 2) enhancing their resilience and adaptive capacity to changes in climate variability and extremes that are difficult to predict, and to global change more generally (including socio-economic changes), and 3) mitigation of climate change and trading the options to mitigate in low-income countries on the global carbon markets to create a substantial financial flow from the North to the South.

Key Words: Climate change, adaptation, adaptive capacity, mitigation, carbon trading, land use, agrifood systems, Sub-Saharan Africa, Ethiopia

1 Potential impacts, adaptation options and adaptive capacity

1.1 Introduction

The fragile ecosystems and communities of Sub-Saharan Africa are already burdened by poverty, high population growth rate, social and political unrests, weak institutions and unfavourable, highly variable climatic conditions, the combination of which results in food insecurity, epidemics, and environmental problems. While prices of major cereals have fallen from their recent (2008) peaks, they remain high compared to previous years. The number of hungry people has been estimated at 923 million in 2007, an increase of more than 80 million since 1990-92 (FAO, 2008). In 2008, another 40 million were pushed into hunger, bringing the overall number of undernourished to 963 million, and in 2009 it is estimated that, still as a consequence of the recent food market and financial crisis, the threshold of 1 billion hungry people will be surpassed. While several factors are responsible, the consensus is that high food prices are driving millions into food insecurity, and worsen conditions for many who were already food-insecure. The impacts of projected climate change during the first half of this century will add considerable burdens to those who are already poor and vulnerable and pose also a serious problem for development to regions in Sub-Saharan Africa that are now less affected.

Many of the impacts will be felt by agrifood systems and rural communities, which – nevertheless – will continue to play a crucial role in SSA. Agriculture through its direct and indirect impact on poverty is and will remain a basis for expanding economic growth and reducing poverty - far beyond the agricultural and rural sectors (Huq & Reid, 2005; Roetter et al., 2007; WDR, 2008, OECD, 2009, IFPRI, 2009).

There is much activity on the part of governments and development agencies to come to grips with the additional challenges imposed by climate change. Planners and decision makers could benefit from information that quantifies the impacts that may arise so that development collaboration can be targeted in appropriate place depending on the development objectives that are pursued mainstreaming climate change in poverty reduction strategies or more generally, in development cooperation. The goal of agricultural adaptation and mitigation research must be to overcome the additional threats posed by a changing climate to achieving food security, enhancing livelihoods and improving environmental management. In the sections that follow we describe outcomes of such research for cases in Sub-Saharan Africa, with focus on Eastern Africa, and give an outline of some future challenges.

Definitions of exposure to climate variability and change, sensitivity of systems, adaptive capacity, resiliency and vulnerability of agrifood systems are given in chapter 2 (Sumelius et al., 2009, Final Report).

In summary: Vulnerability = (adaptive capacity) – (sensitivity + exposure).

1.2 Potential impacts and adaptation options in SSA

Potential impacts

Climate change is expected to bring in a worsening situation of many food producing regions. Parry et al. (2004) found for most scenarios of the Special Report on Emission Scenarios (SRES)

(Nakicenovic et at., 2000) a negative impact on simulated world cereal yields from slight to moderate (0-5 %). However, with enormous regional differences (Figure 1) that very likely will increase disparities between developed and the developing world.

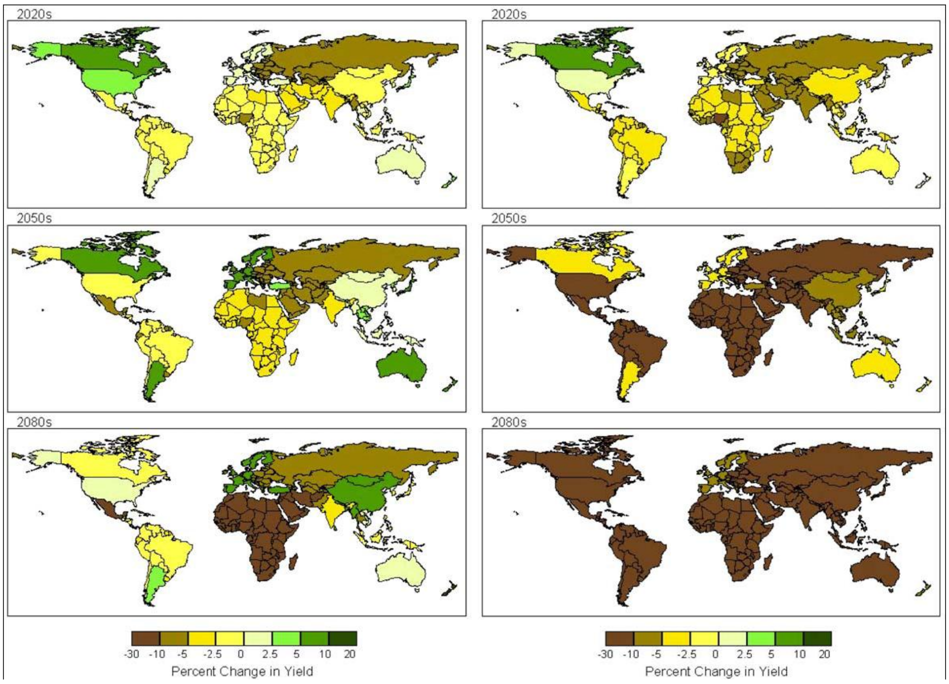

Figure 1. Potential changes (%) in national cereal yields for the 2020s, 2050s and 2080s (compared with 1990) with (left) and without (right) CO_2 effects (Parry et al. 2004).

In several reports of Working Group II of IPCC (1995, 2001 and 2007), assessments of potential impacts for agriculture in Sub-Saharan have been summarized as being generally negative, even at relatively little changes in global mean temperatures. Watson et al. (1997) already concluded that Africa is the most vulnerable region to climate change because widespread poverty limits adaptive capacity. This has been confirmed and elaborated by later studies that also emphasized the role of multiple stresses that African agricultural systems face (e.g. ILRI. 2006). Jones and Thornton (2009) report that recent climate change projections indicate with a substantial increase in arid and semi-arid lands; at the same time, there are also some regions that will get wetter. In some SSA countries yield decline in rainfed agriculture ranges between 20 and 50% by 2050. Small-scale farmers and pastoralists will need to gradually adapt to climate change and adopt and/or co-develop technologies that increase productivity, stability and resilience of production systems. When adaptation options are taken into account in climate change assessment studies, we speak of *actual* instead of *potential impact* (Easterling & Aggarwal, 2007).

According to Schmidbuber and Tubiello (2007) and Tubiello and Fischer (2007), in most climate scenarios SSA is estimated to account for 40-50 % of global hunger by 2080. In the high emission scenario A2, world-wide, as compared to unchanged climate, climate change would cause an additional 70-90 million people at risk of hunger in year 2080, depending on the climate model. This means increases by about 10-15% relative to the (A2) reference world. In terms of the absolute number of people, the bulk of the increases were in SSA (+43 to +53 million) (Tubiello and Fischer, 2007). However, it should be noted that both time course and spatial pattern of these changes was highly variable, depending on the climate model applied.

Food security must be analysed in the context of climate variability, climate change and uncertainty about future climate conditions. Although climate change is a long-term phenomenon, the actions taken over the next 10-20 years will be critical. The foundations must be set for responsive, adaptive agricultural technologies and policies that help people reduce their vulnerability to climate variability, while at the same time paving the way for enhancing adaptive capacity for the successful management of long-term changes.

Impacts of actual climate variability: findings from Ethiopia

The famine of Ethiopia in 1983-84 created world-wide awareness of the harsh realities of food insecurity in sub-Saharan Africa. Ethiopia is highly vulnerable to climate change due to its dependence on rainfed agriculture, low level of economic development, limited disaster management skills, and weak institutional capacity. A recent mapping on vulnerability and poverty in Africa (ILRI, 2006) puts Ethiopia as one of the countries most vulnerable to climate variability and change. It suffers from recurrent droughts and chronically food deficiencies. There has been no single year since 1950 where there was no drought in some parts of the country. While Ethiopia is drought-prone, the resulting famine and deaths in 1983-84 were also a consequence of policy failure on all fronts (Hellmuth et al., 2007) – however, lessons were learned from this disaster: Two decades later, the country had developed early warning systems, coupled to associated response mechanisms. This showed, for instance, to be effective in 2003: more than 13 Mio Ethiopians were affected by drought, but major famine was avoided. About 75% of Ethiopia's population is dependent on agriculture, which is almost entirely rainfed and small-scale. A further 10% earn their living entirely from livestock. The dependency of Ethiopian agriculture on climatic conditions is reflected by the remarkably high correlation between rainfall and GDP fluctuations (World Bank, 2006) (Figure 2). A similar study by Hassan (2006) also indicates that years of drought and famine (1984/1985, 1994/1995, 2000/2001) were associated with very low contributions, whereas years of good climate (1982/1983, 1990./91) were associated with better contribution to the country's total GDP. This correlation between GDP and annual rainfall is so high as, generally, there is a unimodal rainfall pattern prevailing in the important agricultural regions. Moreover, agriculture, and especially food production are heavily based on cereals (see, Table 1).

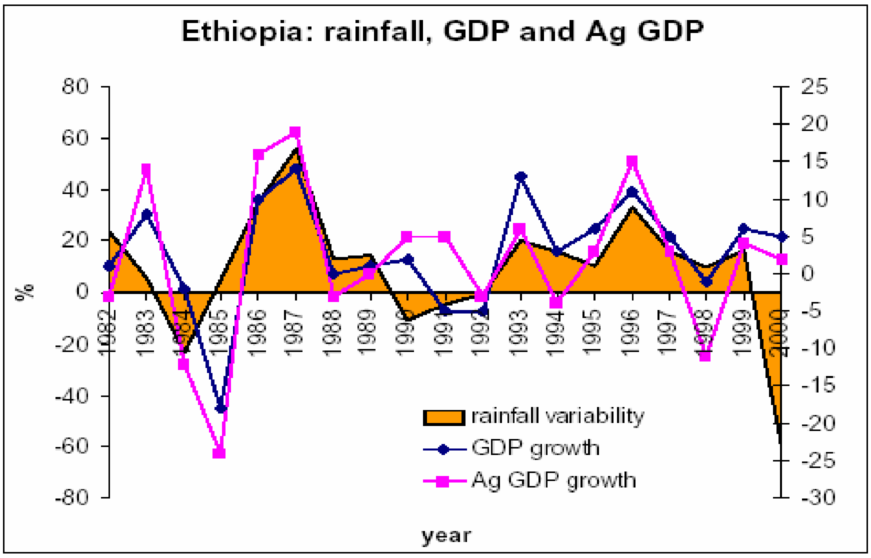

Figure 2: Relationship between annual rainfall and Gross Domestic Products (GDP) growth over Ethiopia.

The importance of cereals in Ethiopia's agriculture is reflected in the total land area allocated to cereal production. In 2007/08, 75 percent of all land under crops was used for cereal production, followed by pulses with 13 percent of the area, while all other crops were produced in 12 percent of total crop's area. Table 1 presents a summary of area, production and yields of cereals from the main production regions in Ethiopia.

Table 1. Area, production and yields of cereals in Ethiopia, 2003/04 and 2007/08

	2003/04				2007/08			
Crop	Area 1000 hectares	Production 1000 tons	Yield Kilograms/ hectare	Share (area) (%)	Area 1000 Hectares	Production 1000 tons	Yield Kilograms/ hectare	Share (area) (%)
Barley	911	1071	1,176	13.4	985	1355	1,376	11.4
Maize	1300	2455	1,889	19.1	1767	3750	2,122	20.4
Millet	303	304	1,002	4.5	399	538	1,347	4.6
Sorghum	1242	1695	1,365	18.2	1534	2659	1,734	17.7
Teff	1985	1672	842	29.1	2565	2993	1,167	29.6
Wheat	1075	1589	1,477	15.8	1425	2314	1,625	16.4
Others	35	44	1,257	0.5	55	108	1,962	0.6
Total	***6816***	***8786***	***1,289***	***100***	***8675***	***13609***	***1,569***	***100***

Source: IFPRI 2009 based on CSA data

The summary table shows that total cereal production in main production regions was 13.6 million tons in 2007/2008, an increase of 4.8 million tons compared to production in 2003/2004. Total area allocated to cereals also increased from 6.8 million hectares in 2003/2004 to 8.7 million in 2007/2008. Note, that 2003 was one of the severe drought years, with more than 13 million Ethiopians affected. Although the climatic drought was as severe as in 1983-84, a major famine was avoided. This is because Ethiopia was much better prepared (see, Hellmuth et al., 2007).

The major adverse impacts of climate variability on agricultural and rural development in Ethiopia include:

- Food insecurity arising from occurrences of droughts and floods
- Outbreak of disease such as malaria, water borne diseases associated with floods and respiratory associated with droughts
- Land degradation due to heavy rainfall
- Damage to communication, roads and other infrastructure by floods

Future climate change is expected to increase climate-induced risk, especially by more frequent extreme events (drought, floods, and high temperature waves) and changed rainfall patterns and variability (IPCC, 2007). The consequences of these environmental changes manifest themselves through declining water resources potential, reduction of productive land resources, decline in organic matter content, reduction in agricultural productivity and food insecurity threatening rural livelihoods.

In terms of studies on climate change impacts that have been several climate change impact assessments, mostly using maize as indicator crop, at different spatial scales (SSA, Eastern Africa). That may be the reason that the few adaptation options are also related to maize. On the other hand it is surprising that relatively little is known about impacts and adaptation options for teff, the traditional and still widely cultivated and consumed cereal in Ethiopia. This is the more surprising as teff is much more resistant to drought than the other cereals. It has the ability to recover, even from severe moisture stress. There seems to be a clear research gap regarding adaptation options for teff-based systems, also in terms of breeding efforts.

Adaptation options

Adaptation implies initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects, both in the short and in the long run. The adaptation measures are of various types, both private and public, and autonomous and planned ones. Examples are the rise of river or coastal dikes, substitution of temperature-sensitive plants by more resistant ones, etc. (Bates et al. 2008).

When options to adjust to future climate change are under consideration, the question is whether adaptation practices for current climate variability can be helpful? Traditional adaptation practices have included changes in cropping and planting practices, reduction of consumption levels, collection of wild foods, inter-household transfers and loans, migration in search of employment, grain storage, sale of assets (livestock, tools), mortgaging of land, credit from merchants and money lenders, use of early warning system and food aid (e.g. NAPA, 2007).

Adaptation to changing climate is happening all the time, e.g. an increasing number of croppers become livestock keepers (Jones and Thornton, 2009). Favoured adaptation options are those that enhance soil fertility (organic matter) and water availability can increase/maintain productivity in the face of climate change, and, at the same time be mitigative (such as minimum tillage and site-specific nutrient management). However, climate change poses new challenges to adaptation, asking for new strategies, new technologies and knowledge and effective agricultural extension services – especially in areas that, as a consequence of climate change will become transition areas (e.g. from cropping to livestock keeping). Enhanced infrastructure (early warning systems) has shown potential to remarkably reduce impacts of climate variability and change (e.g. in Ethiopia).

Climatic risk management

Climate variability and risk has always been a part of agriculture, and farmers have developed many ways of managing that risk. Developing adaptation strategies to adequately respond to climatic risk is an important task.for research and development. The damage of uninsured climate shocks, such as droughts or floods, to health, productive assets and infrastructure can affect livelihoods long after the stress has ceased (Dercon, 2004). Climate variability and the conservative strategies that risk-averse decision makers employ ex-ante is one of several factors that contribute to the existence and persistence of poverty – sacrificing appropriate investment, intensification and adoption of innovation in climatically favourable seasons to protect against the threat of shocks (see, Barrett et al., 2007; Hansen et al., 2007). Limited empirical evidence suggests that the cost of climate risk in rainfed farming systems can be quite large, and is borne disproportionately by the relatively poor.

Developing drought-resistant and other abiotic stress-tolerant crop varieties, and soil and water management practices for marginal areas, for example, have for a long time been core activities of agricultural research in the tropics and sub-tropics. Climate change introduces a new dimension to that problem – its unprecedented rate and magnitude presents great challenges to farmers, researchers and policymakers. Without effective intervention, projected increases in climate variability can be expected to intensify the cycle of poverty, natural resource degradation, vulnerability and dependence on external assistance. Managing current climate risk must therefore be integral to a comprehensive strategy for adapting agriculture and food systems to a changing climate. Given pressing current development challenges and a 2015 deadline for the MDG targets, management of current climate risk offers attractive win-win opportunities for developing countries to contribute to legitimate immediate priorities while reducing vulnerability to a changing climate. Goal of agricultural adaptation and mitigation research must be to overcome the additional threats posed by a changing climate to achieving food security, enhancing livelihoods and improving environmental management

In a recent modelling study by IFPRI, using the IMPACT model in combination with GTAP (Calzadilla et al., 2009), two possible adaptation options to climate change in whole SSA were analyzed (under SRES scenario B2):

- the first variant doubles the irrigated area in SSA by 2050,
- the second variant increases both rainfed and irrigated crop yields by 25%

In B2, a relatively moderate climate change scenario, without specific adaptation, climate change would have a negative impact on agriculture. Food production would fall by 2% in 2050. The number of malnourished children would increase by almost 2 million. With adaptation, results indicate that due to the limited initial irrigated area, an increase in agricultural productivity would achieve better results than doubled irrigated area. Moreover, both options were able to help lower world food prices.

Such lowered food prices making food more affordable for the poor, would lead to a decline by 0.3 million children by 2050 (for the doubled irrigated variant) and a reduction of 1.6 million children (for the increased agricultural productivity variant). Among the caveats of the study is that aspects of irrigation investment or possible constraints regarding access to water resources was not explicitly considered.

Adaptation options - findings for Ethiopia

As a concrete example Kato et al. (2009) mention soil bunds, stone bunds, grass strips, waterways, tree planting, contours and irrigation as typical soil and water conservation measures that may be used for Ethiopian farmers in order to adapt to climate change by reducing production risk. This list partly agrees with that of Rahmann (2008), who compiled the autonomous adaptation options to climate variability and change considered most important to smallholders:

- changing agricultural inputs: type, amounts and timing
- making wider use of technologies to ‘harvest’ water, to conserve soil moisture
- judicious water management to prevent water logging, erosion and nutrient leaching,
- altering the timing or location of cropping activities,
- diversifying income by integrating into farming activities additional activities,
- using seasonal climate forecasting to reduce production risk.

However, some of these measures may become insufficient in the face of accelerating climate change. A longer-term planned approach for adaptation is therefore needed. It has to incorporate additional information, technologies and investments, infrastructures and institutions and integrate them with the decision-making environment. Insurances, safety nets and cash transfers to reduce vulnerability to shocks are also part of the solution. In terms of technical options, the planned approach has to include many forms of land use and land use change, new cultivation practices, new seed varieties, etc. It must include an appropriate incentive structure, such as targeted payment for environmental services. Adaptation strategies can vary, and are usually very location-specific. Some adaptation options may increase competition for available resources – e.g. improving crop productivity may increase water demand for irrigation systems in dryland areas, which decreases the availability of water for those who have no access to irrigation schemes. Some adaptation measures may also increase the price of land, particularly in the rental market, thus affecting landless smallholders.

Integrating climate change in national policies - example Ethiopia

The main focus of Ethiopia’s national policies and sectoral strategies is to reduce poverty through advancement of rural and agricultural development. Already many current national policies include indirect adaptation options aiming to reduce the vulnerability of agricultural, water and health sectors to climate change (NAPA, 2007; pages 33-34). In national policies climate change is considered as sub-component with influence on the main development goal. Due to the cross-cutting nature of climate change, it is important that all relevant sectors participate to reduce vulnerability. Climate change adaptation goes hand in hand with poverty reduction, food security, as well as disaster prevention and management.

Ethiopia's national policies that take climate change adaptation into consideration:
* Plan for Accelerated and Sustainable Development to end Poverty (PASDEP),
* Environmental Policy of Ethiopia
* Agriculture and Rural Development Policy and Strategy
* Water Resources Management Policy
* Health Sector Development Policy and Program
* National Policy on Disaster Prevention and Preparedness
* National Policy on Biodiversity Conservation and Research
* Science and Technology Policy
* Population Policy
* National Agricultural Research Policy and Strategy)

Research challenges
Perhaps the most important research challenge is that we do not currently possess a framework to analyse the implications (both positive and negative) of human responses to the climate challenge in terms of regional food security and the preservation of important ecosystem services, upon which the long-term sustainability of global agriculture must be based. Such interactions may themselves be strong determinants of vulnerability to climate change. While the broad trends may be discernible, much more detail is required concerning localised impacts of climate change, effects on livelihood systems, and options that can increase the well-being of people dependent on natural resources for their living. The tools needed for both these tasks (assessing the impacts of climate change on systems, and assessing the impacts of interventions on the same systems) are essentially the same: a comprehensive and quantitative framework that both interrogates and pulls together what is known about the climate system, the ways it may change into the future, the associated impacts on agro-ecosystems, the livelihoods of those who depend on them, food security, and feedbacks to the earth system. While much is known about many components, no attempt has been made until recently to develop such integrated framework at (sub-) national level in Sub-Saharan Africa.

BOX 1: Research project AlterCLIMA, Ethiopia.

This Academy of Finland project is coordinated by MTT Agrifood Research Finland, and collaborates with several Ethiopian agricultural and environmental research institutes, Wageningen UR, The Netherlands, and several CGIAR institutes located in Eastern Africa. AlterCLIMA is one of a new generation of projects addressing the multi-scale aspects (local to global) of implications and responses of agrifood systems to climate change in Sub-Saharan Africa, with focus on a very vulnerable region (Central Rift Valley) in Ethiopia. Aim of the research is to develop concepts and operational tools for analysing feasible and promising adaptation options, and identify combinations of adaptation and mitigation options that can increase food security, reduce poverty and support sustainable development (especially in the vulnerable semi-arid regions in Sub-Saharan Africa) and apply it to selected sub-national case studies.

1.3 Assessing adaptive capacity of agrifood systems

Application of adaptive capacity concepts - findings for Ethiopia
Assessment of adaptive capacity of socio-ecological systems is a relatively new research field. Some recent studies that try to advance the methodology, also in terms of the agricultural sector, have been launched in Europe. Examples include AgriAdapt of the Dutch Climate Programme, Nordic project CARAVAN, and the Finnish projects ADACAPA (MTT coordinated) and MAVERIC (SYKE coordinated).

In a study of Ethiopia's vulnerability to climate change (Deressa 2008) adaptive capacity included wealth, income, technology, literacy rate and availability of infrastructure and institutions. Sensitivity included irrigation potential and frequency of drought and floods. Exposure included predicted change in temperature and precipitation by 2050. Higher values indicated lower vulnerability (Deressa, 2008).
The study was realized at regional level (11 regions); each region included different socio-economic and environmental characteristics. According to the study, vulnerability was incurred first of all by poverty. Also low level of regional development, extreme weather conditions such as drought and floods, low access to technology, institutions and infrastructure and high population rate attributed the vulnerability of farmers. Increasing adaptive capacity; through projects that reduce poverty and investing in technologies, institutions and infrastructure could again reduce vulnerability.

1.4 Enhancing adaptive capacity of agrifood systems

Enhancement of adaptive capacity reduces vulnerability, and is especially a means to be able to better respond to the uncertainties related to future climate. The adaptive capacity approach deviates fundamentally from the traditional approach of assessing impacts and adaptation in relation to a limited set of well-defined climate change scenarios. The adaptive capacity on the other hand, addresses preparedness for the uncertainties of future climate, and the flexibility to adapt to unexpected changes. Vulnerability (of socio-ecological systems) depends on the exposure and sensitivity to changes, and on the ability of the system to manage these changes, i.e. on their capacity to adapt (adaptive capacity, adaptability, coping ability) (IPCC, 2001; Smit and Pilifosova, 2003; Metzger and Schröter, 2006). Adaptive capacity on the other hand means the whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures to varied changes. Enhancing resilience increases adaptive capacity (e.g., Yohe and Schlesinger, 2002; Smit et al., 2003). Through mitigation of GHG emissions over the coming decades long run effects can be reduced.

Current means for enhancing adaptive capacity
More generally, it can be concluded that means for enhancing adaptive capacity of agrifood systems include *policy measures* that lead to:

- Diversification of livelihoods
- Poverty reduction
- Protection of natural resources
- Better education and (collective) learning
- Better infrastructure
- Strengthening of collective action.

This is very much in line with the findings of J Sachs (2005; 2008), World Bank (2007, 2009) and IAASTD (2008). In several new Nordic and Finnish methodology development projects on adaptive capacity and resilience of agrifood systems, special attention is paid to the role that diversity in agrifood systems at different scales, and diversification of agricultural/rural activities can play in enhancing adaptive capacity. Some studies (Reidsma, 2007) at sub-national scale in Europe suggest that diversification can be an important means for enhancing adaptive capacity.

1.5 Policy recommendations

Some policy recommendations with respect to adaptation options and enhancement of adaptive capacity

- To African partner countries: Engage in mapping of vulnerability (to understand its distribution and identify hot spots), resilience, adaptive capacity and carry out regional case studies to better understand causes that shape vulnerability (is in line with several initiatives of the World Bank and proposed CGIAR Challenge Programme on Climate Change, Agriculture and Food Security)
- To donors: Concentrate investments on most vulnerable regions and on effective means (infrastructure, R & E programmes) to adapt to climate change
- Carefully consider two-way relationship of climate change and agrifood systems: highly sensitive, but also high mitigation and adaptation potential
- Support development of scientific-technical means and policy measures that support more diversified agro-ecosystems, livelihoods low-carbon economy and utilize its opportunities (e.g. offered by carbon trading, see 2 below)

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2 Opportunities offered by carbon trading and integration of food and bioenergy systems in Sub-Saharan Africa

2.1 Introduction

The already unavoidable global change has severe impacts on food security, environmental sustainability and global equity. The industrialized world is in the main charge for climate change, which hits worst the poor already now suffering from food insecurity. Agroecosystems in low latitudes are estimated to suffer most, although the role of the continent in contributing to climate change is relatively small. For example, SSA's input to global greenhouse gas (GHG) emissions is approximately 6% (WRI, 2009). Climate change directly affects food production by changing agro-ecological conditions and indirectly influencing distribution of benefits (IPCC, 2007). Africa is considered to be the most susceptible region for climate change, conjoining the most food-insecure region also in the future. In most climate scenarios SSA is estimated to account for 40-50 % of global hunger by 2080 (Tubiello and Fischer, 2007).

Food security has supply and demand side aspects, and most international initiatives clearly focus on the former ones - on increasing agricultural productivity and food availability. This is important but insufficient, because hunger is often a result of poverty (OECD, 2009). Therefore, besides food availability, also access to food and affordability, linked to the socio-economic dimensions of sustainable development, such as equity, are important aspects (FAO, 2002). In addition, in the context of climate change difficult to predict, and of increasing variability of climate and socio-economic drivers, it is important to include also the fourth aspect, stability (e.g., Howden et al., 2007). This aspect implies the temporal dimension of sustainable development and thus stewardship of the resource base and ecosystem services, which agriculture relies on. Further, especially in the context of climate change, requirement of stability emphasises adaptive capacity and resilience in terms of food security.

Global carbon trading is a market mechanism to reduce greenhouse gas concentrations in the atmosphere for mitigating climate change. It offers for industrialised countries an opportunity to mitigate climate change and thus fulfil its international commitments, and to contribute to the global equity. Carbon and emission trading offers also an opportunity to build adaptive capacity, and finance adaptation to and mitigation of climate change in low-income countries. In addition, it has the potential to simultaneously contribute both to food and energy security. Trading of ecosystem services, especially carbon trading, could in fact offer for Africa a win-win-win opportunity in terms of mitigating climate change and thus providing a direct benefit to the areas worst hit, such as SSA, conserving the resource base of its food security and ecosystem services, and financing its adaptation and development.

Carbon trading offers perhaps the only realistic option to still keep the global emissions below the catastrophic limits (Figures 3 and 4) (Schellnhuber, 2009).

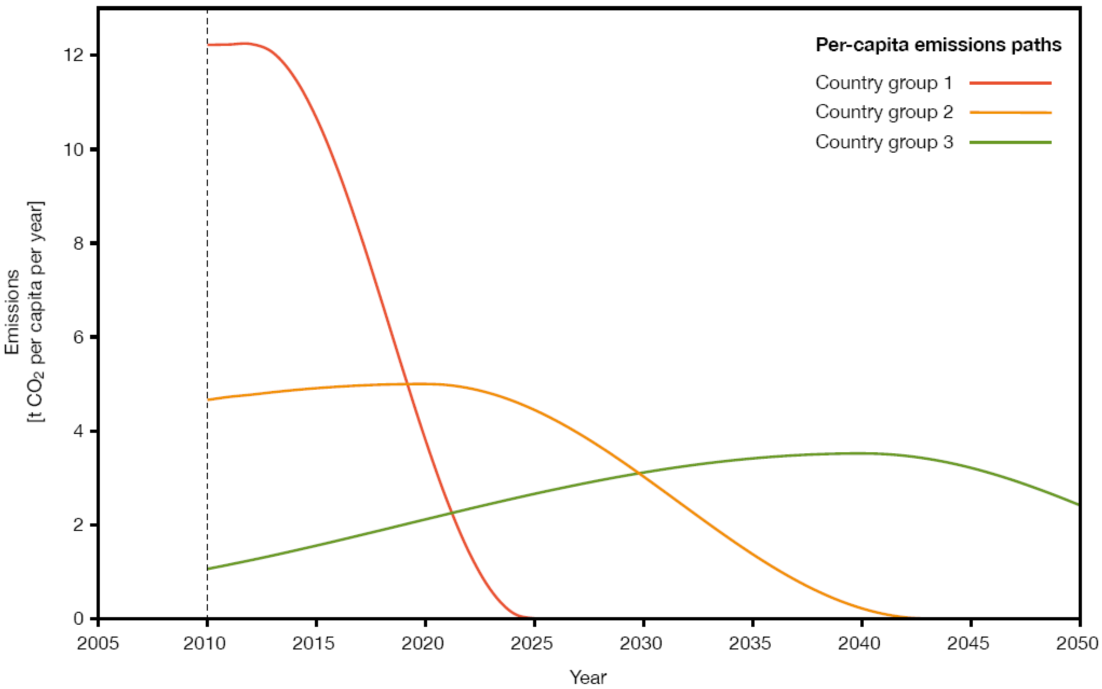

Figure 3. Reducing of GHG emissions per capita in industrialised countries quickly enough to a safe level might be too challenging without emission trading. Examples of emission paths of CO2 according to the WBGU budget approach without emission trading for countries with high (mainly industrialised countries), moderate (many newly industrialised countries) and low emissions (mainly developing countries) per capita. Source: WBGU, 2009.

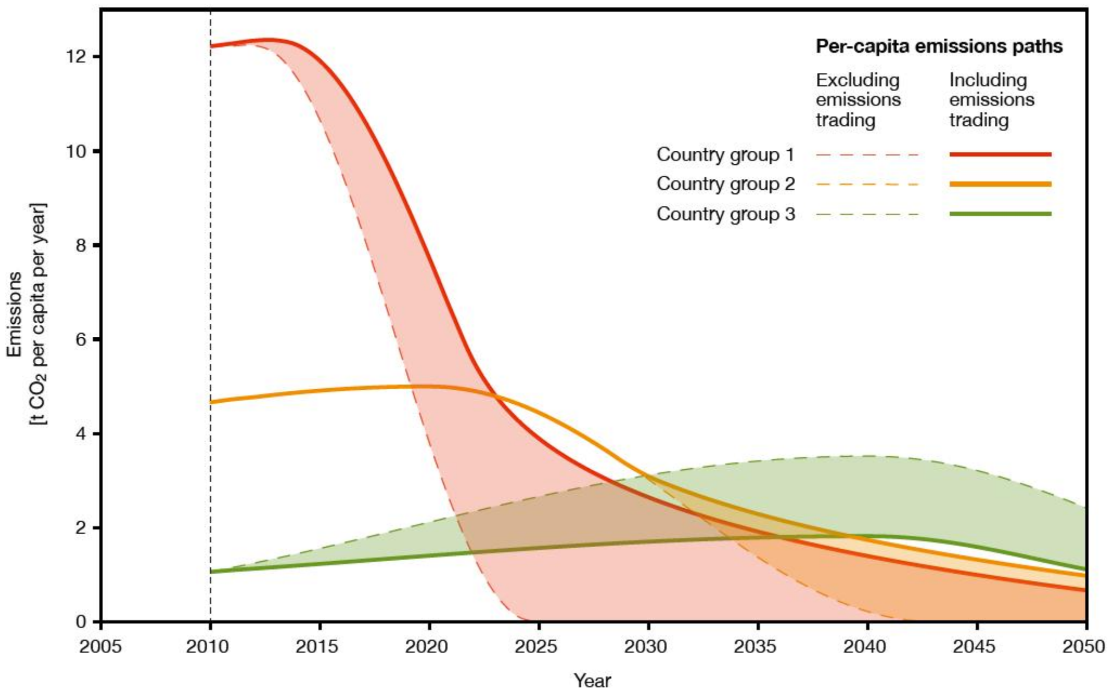

Figure 4. Emission trading between the industrialized and developing world would make the target realistic, and would imply an unequalled financial flow from the North to the South. The country groups see Figure 3. Source: WBGU, 2009.

There is available a global framework for trade of ecosystem services, most developed for carbon trading (Table 2). The global emission market is a concrete regulatory effort to mitigate climate change, hugely expanded since Kyoto protocol's entry into force and the launch of the European Union's Emission Trading Scheme in 2005 (Capoor and Ambrosi, 2006). The compliance (or regulatory) markets are based on international and regional agreements. The Kyoto protocol ratified by 184 countries (UNFCCC, 2009) underpins in some way most of these markets, even if it is directly concerned only with the biggest one. In addition to these regulated frameworks there are voluntary carbon markets.

Market-based carbon transactions are defined as purchase contracts in which one party pays another party in return for GHG emission reductions or for the right to release a given amount of GHG emissions that the buyer can use to meet its compliance or corporate citizenship objectives vis-à-vis climate-change mitigation. Buyers can be cities, companies, organizations or individuals which have interest or are required to reduce emissions. Whereas sellers can be companies which are able to reduce their emissions more than required or communities which can sequester carbon in soil or trees or avoid emissions for instance replacing fossil fuel with biofuels. Payment is made using cash, equity, debt, convertible debt or warrant, or in-kind contributions such as providing technologies to abate GHG emissions. In recent years emerging carbon market has doubled its volume and value. Restrictions on the GHG emissions have expanded market value to US$64 billion (€47 billion) in 2007 (Capoor and Ambrosi, 2008). Carbon markets, including the voluntary ones (Table 2), have a great unexplored development potential (Bayon et al., 2008).

Table 2. Classification of carbon markets

		Emission Allowances	Project-based
Regulatory (compliance market)	Kyoto compliant	Assigned Amount Units (AAUs) EU Emission Trading Scheme: EU Allowances (EUs)	CDM, JI
	US	the Regional GHG Initiative (RGGI), California's Global Warming Solutions Act (AB 32), the Western Climate Initiative and the Midwestern Regional GHG Reduction Program (MRP)	
	Australia	the New South Wales GHG Abatement Scheme (NSW GGAS)	
Voluntary markets		Chicago Climate Exchange (CCX)	CCX Over the counter markets (OTC)

Within the dramatically extending carbon markets, developing countries and especially Sub-Saharan Africa (SSA) have a marginal share. Africa (excluding North African countries and South Africa) represents a share below 1%. The value of the Clean Development Mechanism (CDM), the mechanism of Kyoto Protocol addressed for trade between industrialized and developing countries, more than doubled each year between 2005 and 2007. Still Sub-Saharan Africa (SSA) accounts for only 1.4 % of all registered CDM projects (Bryan et al., 2008). The share is roughly a tenth of

SSA's global share of emissions. Consequently, SSA has potential for greater role in global carbon market. The current technical mitigation potential through African agriculture is estimated at 17 % (economic potential 10%) and forestry 14 % of the global total mitigation potential of these sectors, and it is likely to increase due to the growing population and wealth and rising demand for livestock products with a high demand for land (Bryan et al., 2008). The potential of avoided deforestation in SSA accounts for 29% of the global total for that sector.

Based on recent literature, collaborative studies and our own surveys (see Box 1, p. 12), we analyse below, using an Ethiopian case, why the great opportunity of global trading of carbon and environmental services offered to Sub-Saharan African (SSA) agriculture and land use is not utilised, and what could be done to take the full advantage of it. We identify 1) the interrelationships of mitigation options and food security in changing climate, 2) what the mitigation options in agriculture and land use in SSA are, 3) which are the options with most potential to enhance food security and reduce poverty, 4) which are the major obstacles and bottlenecks for their utilisation set on the other hand by the Ethiopian circumstances and on the other hand by the global trading framework, 5) search for available solutions and 6) sketch options for the role, which the Finnish Ministry for Foreign Affairs could play in this effort.

2.2 Impacts of mitigation options on food security

The options to carbon offsets concern emission reductions, increasing sinks or avoiding emissions. The major agricultural mitigation options are based on soil carbon sequestration. Carbon sequestration implies removal of atmospheric CO_2 by plants and storage of fixed carbon as soil organic matter. While forestry-related mitigation options often offer higher mitigation benefits than carbon sequestration in agricultural soils, they also often compete for land with food production. Increasing carbon stocks in agricultural soils enhance soil fertility, water retention capacity and productivity, and thus improve food availability and buffering capacity against drought and other climate stresses. This is especially important in the context of climate change.

Climate change affects soil moisture and temperature, changing species composition in the ecosystem. These changes may affect soil carbon pool and soil physical properties due to changes in biomass returned to the soil (Lal, 2004a). Increased soil temperature also directly stimulates mineralisation of soil organic matter leading to a decline in the soil organic carbon pool. Decline in the SOC pool causes degrading in the soil structure, and increases erosion, crusting, compaction and runoff (Lal, 2004a). Temperature increase and decline in rainfall is estimated to shorten growing periods (Thornton et al., 2008) and to decrease net primary productivity in tropical regions (White et. al., 1999). In Africa the growing season may by 2050 be 5-20% shorter and crop yields 5-20% lower than at present (Jones and Thornton, 2003). In addition, about 5-10% of currently marginal cropland will become transition zones from cropping to livestock keeping (Jones and Thornton, 2008).

Apart from effects like increase in soil productivity and buffering capacity to climate stresses, carbon sequestration also offers an opportunity to additional income on carbon markets through mitigation. Agriculture-related mitigation options are even relatively cost-effective. Decisive for the impact of carbon trading on food security is, however, how the benefits are distributed. This concerns both the distribution of the income and the increased value of capital, e.g., soil. National and local proprietary regimes are there in a key position. In Ethiopia, the complex and locally varying proprietary arrangements could provide a negative incentive, but this was not considered a problem in terms of agricultural production and soils by the interviewed farmers.

2.3 Agriculture-related mitigation options in SSA

The agriculture-related options with most potential for mitigation in SSA are cropland and grazing land management and restoration of organic soils (Table 3). Replacement of burning dung and crop residues for energy by anaerobic digestion and recycling is one management option. Of particular relevance to smallholder agriculturalists is the potential of agro-forestry in mitigation (Rahman, 2008). The appropriateness of individual mitigation options depends on regional and local conditions, including the features of agricultural and food systems. For example, avoided deforestation seems to provide in SSA even thousand times greater, in Ethiopia 50 to 100 times greater, but in the Central Rift Valley (CRV) only a ten times greater mitigation potential than agricultural soils (e.g., Sampson and Scholes, 2000; Batjes, 2004).

Table 3. Estimated economic mitigation potential by management practice and region

	Economic Mitigation Potential by 2030 at Prices of up to US$20 per tCO_2e ($MtCO_2e$ per year)					
	Cropland management	Grazing land management	Restoration of organic soils	Restoration of degraded land	Other practices	Total
East Africa	28	27	25	13	15	109
Central Africa	13	12	11	6	7	49
North Africa	6	6	6	3	3	25
Southern Africa	6	5	5	3	3	22
West Africa	16	15	14	7	8	60
Total	69 (26%)	65 (25%)	61 (23%)	33 (12%)	37 (14%)	265

Source: Smith et al. 2008
Note: $MtCO_2e$ = mega tons of carbon dioxide or equivalent

Futher, in Ethiopia, restoration of degraded soils is the most important agriculture-related mitigation option, but in CRV, the cropland and agroforestry management were found to have the highest mitigation potential, based on land use data from ongoing collaborative studies (Jansen et al., 2007). When the future changes in land use due to the expected climate change (see above) are considered, the importance of restoration of degraded land will be emphasised relative to the other options.

Carbon sequestration can be improved by adding biomass to the soil through plant growth or recycling, through reduced soil disturbance and through specific soil and water conservation measures (Lal, 2004b) such as fertility management, diverse crop rotations, erosion control and irrigation management. The following adaptation options which offer possibilities to mitigation and carbon trading for Ethiopia, are either proposed by the synergy assessment report, the INC or the consultative workshops, or otherwise (NAPA, 2007):

- Community Based Carbon Sequestration Project in the Rift Valley System of Ethiopia
- Reforestation for Fuel in the Highlands of Ethiopia
- Promotion of Legume-based Agroforestry Systems and Home-garden Agriculture
- Stall feeding promotion and free range grazing restriction in selected regional states of Ethiopia
- Promotion of on farm and homestead forestry and agroforestry practices in arid, semi-arid and dry-sub humid parts of Ethiopia

- Undertake soil and water conservation practices for improved land husbandry in Afar, Somali and Gambella regional states and Diredawa city administration
- Community based sustainable utilization and management of wet lands in selected wet lands in Ethiopia
- Improving/enhancing the range land resources management practices in the pastoral areas of Ethiopia

Enhanced agroforestry was in our survey considered a promising option, as well as restoration of degraded land to contain more organic matter. Local conditions set, however, constraints for realizing certain practices. Fertility management appeared challenging due to lack in access to inputs, use of plant residues for feed, and burning manure for energy. No crucial problems were perceived in channelling the benefits of soil carbon sequestration to the farmers cultivating the soil. The primary barrier in access to carbon market in the case region CRV turned out to be a full unawareness of the carbon trading framework.

2.4 Opportunities in SSA for trading of ecosystem services

For trading of ecosystem services in SSA, options with most potential concern trading of carbon offsets, biodiversity conservation and water management. For carbon trading between developing and industrialised countries, the project-based trading within the Clean Development Mechanism (CDM) of Kyoto Protocol or on the voluntary carbon markets is possible, while there is no hinder in principle to launch an allowance-based voluntary carbon markets (Table 2). E.g., the World Bank Carbon Finance Unit (WBCFU) buys project-based GHG emission reductions in rural areas of developing countries and emerging economies. A wider range of projects than on other carbon markets, are eligible for inclusion in the only allowance-based voluntary scheme Chicago Climate Exchange (CCX). It also includes emission reduction in projects related to agricultural soil carbon sequestration and forestry, CCX, has developed simple, standardized rules for several types of projects: agricultural methane and landfill methane reduction, agricultural soil carbon, rangeland soil carbon management, forestry and renewable energy. Eligible projects for carbon emission reductions via agricultural soil carbon sequestration include continuous conservation tillage and grass planting, reducing deforestation and degradation, afforestation and reforestation, forest management to increase stand- and landscape-level carbon density, and increasing off-site carbon stocks in wood products and enhancing product fuel substitution (CCX , 2008).

Besides many disadvantages and uncertainties in the presently little organised and standardised voluntary carbon markets, the important advantage is that buyer can choose options with ecological and social co-benefits, such as biodiversity enhancement, local environmental improvement or greater economic opportunities in developing countries or for the poorest within them. Voluntary markets can also enhance diversity and innovativeness of options implied. The fair trade framework and private labels implying carbon foot print are examples of other options for global carbon trading.

Smith et al. (2008) estimate that by 2030 the technical potential for mitigation through world agriculture is between 5,500 and 6,000 MtCO2e and the economic potential is between 1,500 and 4,300 MtCO2e at a range of carbon prices (up to US$100 per tCO2e). They further estimate that 89 percent of this is from carbon sequestration in agricultural soils and 9 percent and 2 percent are from mitigation of CH4 and N2O, respectively. Replacing fossil fuels by, e.g., crop residues, dung, and dedicated energy crops would further reduce GHG emissions. The economic mitigation potential of biomass energy from agriculture is estimated to be up to 16,000 MtCO2e per year at

US$100 per tCO2e, respectively. Since total annual anthropogenic CO2 emissions during the 1990s were approximately 20,000 MtCO2e per year, the full biophysical potential offset by agriculture is even 30% of total annual CO2 emissions, with economic offset potentials of approximately 8 percent and 20 percent at prices of up to US$20 to US$100 per tCO2e. However, the mitigation potential of land use change and forestry is multiple to that of agriculture. Sathaye et al. (2005) estimate that by 2050, the potential from both avoided deforestation and afforestation/reforestation is 15,628 MtCO2 at a price of US$10 per tCO2 + 3 percent per year.

For Africa, according to Smith et al. (2008), the technical potential for mitigation through agriculture is 970 MtCO2e per year by 2030, and the economic potential (assuming prices of up to US$20 per tCO2e) is 265 MtCO2e (Table 3). The potential of replacing fossil fuels is additional to this. For land use change and forestry, the total economic potential in Africa is estimated to be 2000 MtCO2 per year in 2030 at US$100 per tCO2e, or roughly triple to that of the estimated agricultural options, avoided forestation having drastically higher potential than afforestation or forest management. If biomass energy is included, the potential of agriculture might be higher than that of land use and forestry. Taking into consideration the combined mitigation and food security benefits, the significance of agriculture is strongly emphasized.

2.5 Present situation and obstacles

As the largest project-based market with a focus on developing countries, the CDM provides the largest market for carbon offset projects in SSA countries. On the demand side, European buyers dominated the CDM market in 2007, with 90 percent of volumes transacted (Capoor and Ambrosi, 2008). Private sector players were the main buyers of CDM assets in 2006, with 79 percent of CDM volumes transacted in 2007. SSA (North and South Africa excluded) accounted for just over 10 MtCO2e from the total carbon market of 2 983 MtCO2e. Africa's share of the CDM market increased from 3 percent in 2005 and 2006 to 5 percent in 2007 (Capoor and Ambrosi, 2006, 2007, 2008). At the end of October 2008, 27 projects from Africa (and only 17 from SSA) were registered by the CDM, out of a total of 1,186 projects for all developing countries (ibid.). Land use and land use change and forestry (LULUCF) activities of CDM are limited to afforestation and reforestation. Large classes of LULUCF assets, including soil carbon sequestration, fire management, and avoided deforestation, are attractive opportunities to promote sustainable development in Africa and in other natural resource based economies, but are excluded from the CDM and other regulatory markets. Of the projects funded by WBCFU, SSA's share was 18% (90 projects in total, 18 of which in SSA). Two of these projects included soil carbon sequestration.

The low utilisation degree of the mitigation and carbon trading options of SSA agriculture, land use and forestry reflects several major obstacles. These obstacles are related to difficulties at least in 1) developing and implementing the mitigation options, 2) verifying their mitigation impacts, 3) access to the carbon market, and 4) distribution of benefits which is not efficient in terms of food security and poverty reduction. These difficulties are all interlinked.

So far smallholder farmer's access to most of the carbon markets is limited. The complexity of project design and implementation, and the need to comply with administrative and financial management requirements have been identified as most critical. Projects high certification costs, smallholder's high transaction costs and competition with large plantations which are more effective in emission reduction exclude small-scale projects from markets. Efforts to overcome these barriers are important in engaging small holder farmers in mitigation efforts and in making sure they benefit from the opportunities presented. One way is to expand the concept of carbon trading to include compensating rural communities for soil conservation and reforestation. Also payment for environmental services, through which poor rural people are paid for protecting biodiversity and the environment, is another option (Rahman, 2008).

Development and implementation of mitigation options is knowledge-intensive, and especially so concerning the options with most significance in SSA. Implementation of these options suffers from lacking training and empirical data to rely on. For example, low cost mitigation options based on enhancing carbon sequestration in grasslands are available. There are, however, important methodological issues to be addressed (carbon monitoring, permanence, leakage) (FAO, 2005). For many countries in SSA, a lack of technical training and support in setting benchmarks as well as poor data availability and quality are obstacles to defining an adequate baseline.

There is also lack of awareness of available and optional trading frameworks, and the necessary institutional framework for verifying multiple mitigation options for voluntary carbon markets is not in place. In our survey in an Ethiopian case region it turned out that no key stakeholder had any information about the carbon market, while they, on the other hand, considered themselves being in a key position and also eager to become responsible for building up the regional framework. The inter-linkages between the potential clients in industrial countries on the other hand, and the local suppliers and supporting actors suffer from infrastructural deficiencies also. The situation is aggravated by the fact that CDM excludes the options with most potential for SSA and for many low-income countries more generally: agriculture and avoidance of deforestation. Also, the transaction costs, relatively high in CDM (Bayon et al., 2008), cause a bias against small-holders' access to carbon markets and thus hinder pro-poor mechanisms. Finally, property regimes such as ownership of forest or fields, play a major role for the feasibility of option implementation and distribution of benefits from carbon trade.

2.6 Requirements for better utilisation of the options – policy recommendations

Deletion of above-mentioned obstacles and relief of constraints to fully exploit the potential of carbon trading in SSA, requires research and development, capacity-building and institutional infrastructures and policies. Further development of global carbon trading and policy framework (emission trading frameworks, taxes, regulations, institutional arrangements), global trade standards/labels (fair trade, C footprint, food print) and transnational and -continental partnerships are also urgently needed.

Therefore, it is necessary to implement the following improvements:

1) Develop the international carbon trading framework to respond the needs and potential of SSA. This implies, e.g., revising and simplifying the CDM rules and standards to get agriculture and avoidance of deforestation included in the CDM mechanism and to reduce the transaction costs of establishing a carbon trading project and verifying the impact lower.

2) Affiliate the multiple carbon markets and create a supportive infrastructure to enhance voluntary carbon markets. This implies, e.g., to create a third party organ with competence and credibility to standardize and certify voluntary carbon offsets. Here the following major issues should guide the offset quality: Additionality (has to add to the business as usual scenario; requires specific solutions to take into account the inequity in the baseline),

permanence (GHG mitigation over the stated time period, e.g., for carbon sequestration), leakage (mitigation here may not cause emissions somewhere else), double counting (has to be avoided through transparent inventories), ex-ante vs. ex-post accounting (the former requires stringent guarantees), co-benefits (has to be clear, which have been parcelled off) (Bayon et al., 2008).

3) Create international, national and regional participatory interlinkages in the value network for effective integration, from the global governance of carbon trading to the sectoral and micro-level design of products, markets and contracts. E.g., marketing cooperatives for mitigation options might be most relevant. Local perspectives should be permanently linked in the governance, development and assessment of carbon trading.

4) Develop appropriate climate change policies to unleash the potential for pro-poor mitigation in SSA. Such policies should focus on increasing the profitability of environmentally sustainable practices that generate income for small producers and create food security and investment flows for rural communities. Clarifying the proprietary regimes and take them into account when developing climate policies and carbon trading with synergy for food security is important.

5) Initiate empirical research on impacts of mitigation options on carbon balance, adaptation and resilience in terms of food security, and related competence and capacity building.

2.7 Options for the Ministry of Foreign Affairs of Finland

The Ministry of Foreign Affairs can promote the above-mentioned actions

- through the development collaboration, e.g., funding of CDM projects and projects for the voluntary markets, linked with agriculture

- initiating and supporting construction of local and national institutional frameworks in SSA to connect to varied carbon markets

- supporting appropriate R&D and local to national capacity building

- influencing and integrating Finnish, Nordic, EU and UN climate, food and development policies, e.g., *to take care that development of pro-poor CDM will be on the agenda and proceed in the UN Climate Change Conference in Copenhagen in December 2009.*

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