



Summary

Carbon Baseline Sumbawanga

Tanzania

Prepared by: Ferko Bodnár

Date: 8 May 2008

Background

EPOPA supports the Sumbawanga Organic Peanut Project, in Southwest Tanzania, from 2005-2008. The conversion to more sustainable farm practices creates opportunities to reduce greenhouse gas emissions by reducing deforestation and land degradation, and to sequester carbon in soil organic matter and tree biomass. These effects could be 'sold' as voluntary carbon credits.

As a pilot project, EPOPA wants to attach a 'carbon project' to the 'peanut project', testing the possibility to support farmers with improved practices using voluntary carbon credits. A first step in such a carbon project is the baseline study: assessing current carbon stocks and current farm practices, and estimating trends in carbon stocks under recommended farm practices.

This reports summarises the main findings from the baseline study. More details are found in the four reports produced. – see references.

Objective of this baseline study

The main objective was to describe a baseline scenario for carbon stocks against which a project scenario can be compared. Secondary objectives were to investigate current and potential farm practices and to simulate the impact of improved practices.

The specific objectives were to:

1. Describe the project area, current farm practices and climate trends.
2. Discuss farmer perception of climate change, coping strategies, and improved farm practices.
3. Evaluate current carbon stocks in the soil.
4. Evaluate current carbon stocks in the vegetation.
5. Simulate the expected trends in soil carbon stocks under the baseline scenario and under different project scenarios.
6. Simulate the expected trends in vegetation carbon stocks under the baseline scenario and under different project scenarios.
7. Make recommendations for the carbon project.

General development of the project

Besides this baseline survey, activities have been limited to training farmers in some improved farm practices and supplying farmers with some tree seed and seedlings and the basic ingredients of an agricultural conversion project. The Sumbawanga peanut project has had some problems and it is only in 2008 that the first export of organic peanuts is expected. Once organic peanuts

are exported, it will be easier to find interested partners to fund the ‘climate project’ and secondly to market ‘climate neutral peanuts’.

EPOPA Support to the baseline study

Ferko Bodnár was Project Leader in the Netherlands and Bernie Hewett was Project Consultant in Tanzania. The baseline study consisted of two periods of fieldwork plus tree periods of analysis and reporting in the Netherlands.

- From November 2005 to March 2006, fieldwork in Matai was undertaken by Janneke van Dijk, Junior Advisor, and Marleen de Blecourt, MSc Student from Wageningen University. They made observations and took soil samples on 100 geo-referenced cultivated fields and 68 fallow fields, and did interviews with 100 farmers about current farm practices and field history.
- From April to August 2006, soil samples were analysed at Uyole Agricultural Research Station in Tanzania and by BLGG laboratory in the Netherlands. These results, together with the farmer interview results, were analysed by Marleen de Blecourt. She wrote one report about the current farmer practices: “Baseline survey – Tanpro groundnuts Tanzania” and one about current carbon stocks and expected changes: “Soil carbon stocks and the potential for soil carbon sequestration through organic agriculture, a case study in southwest Tanzania”, both in English.
- In July 2006, farmer group discussions were held in 9 villages about their perception of climate changes, and farmers were taken to on-farm trials managed by Uyole Agricultural Research Institute to discuss options for adaptation, by Beatrice Riche, MSc Student from Oxford University. In August 2006, she wrote a report “Linking climate change, soil carbon sequestration, and food security in the Southern Highlands of Tanzania”, in English.
- In September and October 2006, simulations of soil carbon stocks, under baseline and project scenarios, were done using the Rothamsted model by Anneke van de Boer, Veranique Geerts, Gerdien Penninkhof and Inge Regenink, BSc students from Wageningen University, supervised by Jeste Stoorvogel. They wrote a report: “Interactions between land use history, sustainable agriculture and climate change in Matai Ward. Tanzania”, in Dutch.
- From February to April 2007, field work observations on the tree and shrub vegetation, which had not yet been analysed, were analysed by Byjesh Kattarkandi, MSc student at Wageningen University. He looked at carbon stocks and tree planting scenarios, using the tree growth simulation model CO2Fix. He wrote a report: “Baseline study on vegetation biomass in different land use types in the smallholder farming system in southwest Tanzania”, in English.

Project input

The expenditure was a little less than what was budgeted (see Table 1). This project falls under ‘Tanzania Learning and Sharing’, part of ‘Institutional Development and Capacity Building’.

Table 1. Budget and expenditure of Sumbawanga Carbon Baseline in Swedish Kroner (SEK)

	Budget	Expenditure
Fees	79,327	63,335
Reimbursable	234,615	223,203
Total	313,327	296,538

Project results

Description of the area and current farm practices

The project area consists of 9 villages (Kalalasi, Kisungamile, Kizombwe, Matai A, Matai B, Mikonko, Myunga, Mbuza and Singiwe) in Matai Ward, located in the Sumbawanga District in the southwest highlands of Tanzania, between 8°16' and 8°27' south latitudes and 31°35' and 31°37' east longitudes (Figure 1).

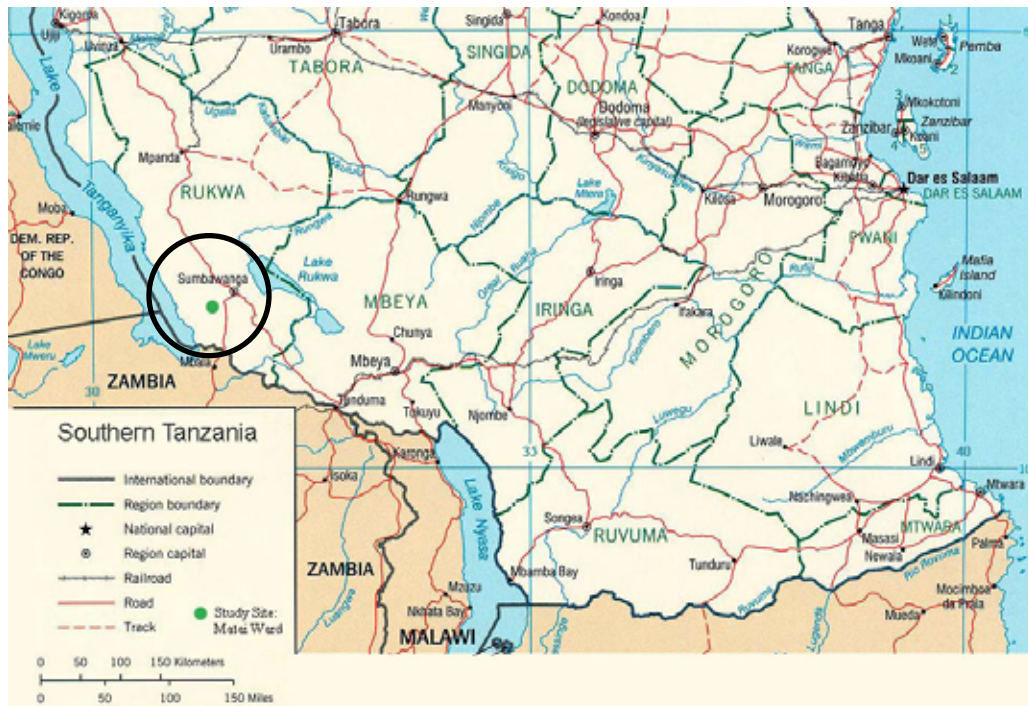


Figure 1. Map of Southern Tanzania. In the Southwest: the project area Matai Ward, Sumbawanga district, Rukwa Region.

The climate in this area varies from dry sub-humid to semi-arid, with a unimodal rainfall of about 1500mm, between December and May. The mean altitude is 1700 meters above sea level.

The average land holding is about 15 ha per family, of which about 7 ha are cultivated and 8 ha are under fallow (grass, shrubs, and open woodland). The main crops grown are maize, sunflower and beans. Other crops grown include (in order of descending acreage): groundnuts, finger millet, wheat, sorghum, sugarcane, soybean, tomato, potatoes, and cabbage.

Climate change in the past was evaluated using rainfall data from 1925 to 2005. According to the data from the Sumbawanga Meteorological Station, total rainfall did decrease between 1975 and 2005, especially in the month October (see Figure 2). There is no significant linear change in rainfall over a longer period, from 1925 to 2005.

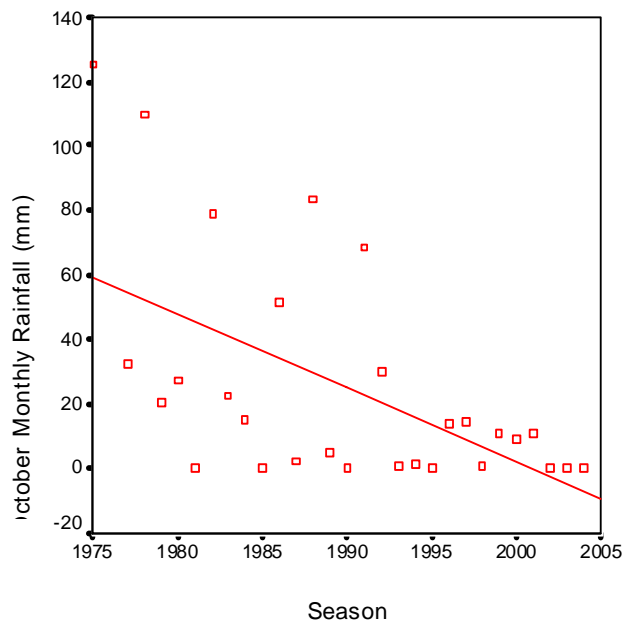


Figure 2. Regression of the rainfall in October, the start of the rainy season, between 1975 and 2005.

Climate change in the future was simulated. Averaging the outcomes of six different global climate models, simulations showed that in the coming 20 years temperature is expected to rise with 0.45 – 2.98 °C in Southwest Tanzania. The rainy season is expected to start about 2 weeks later, followed by more intense rains, and end as usual, resulting in a shorter rainy season. A simulation with a crop growth model predicted that yields would decrease by 15-25% for maize, 10-20% for beans and 5-10% for peanuts.

In the project area, most arable land is situated in the valleys. In the valleys about 40% of the available land is under crops. Fields under cultivation in 2005 have been on average 6 years under cultivation; fields under fallow in 2005 have been on average 9 years under fallow. Current farm practices are presented in Table 2.

Table 2. Current farmers' practices in Matai in (Interviews 2005)

Animal Manure	Compost	Mulching	Crop rotation	Burning	Green manure	Improved Fallow	Erosion control
23%	2%	1%	89%	59%	0%	0%	31%

- Tillage is done by hand hoe and ox-plough.
- Most farmers don't apply animal manure, if manure is applied this is only applied on fields nearby villages. Lack of transport is the main reason why not to apply animal manure. None of the farmers apply artificial fertilizers.
- Almost none of the farmers apply compost, green manures or improved fallow. The main reason why these practices are not applied is lack of knowledge.
- 59% of the farmers burn crop residues. Farmers burn to remove crop residues prior to tillage, to prevent diseases, weeds and pests, and to increase the availability of nutrients for plant uptake. Farmers who are not burning their crop residues, either leave them in the field and mix them with the soil or collect them to use as fodder. None of the farmers leave crop residues as mulch on the soil surface.
- Most farmers rotate crops but none of the farmers has a fixed rotation schedule. A field is left fallow when crop yield is decreasing. However farmers who have a shortage of land or a shortage in labor may continue to cultivate the same field.
- About 31% of the farmers apply erosion control, often with vegetation barriers on field boundaries. Other farmers either don't have problems with erosion or have lack in know-how.

Farmer perception of climate change and coping strategies

All farmers confirm a change in the climate. Most farmers noticed a recent change, since 1997-1997, i.e. since the last El Niño; some farmers noticed a change since a longer time ago. Most farmers state that the rainy season has shortened, by about two months: it used to start in October, but now starts in December. Some farmers also state that the rains now stop earlier than before. Farmers have different views about the rainfall intensity, but the majority find the rains at the start of the rainy season more intense. Besides, farmers state that it has become hotter, especially at the end of the dry season. Farmers state that as a result, droughts have become more frequent, the water table in rivers and wells have dropped, and crop yields have declined.

The increased temperature has increased the incidence of pests and diseases in crops and livestock, according to farmers.

Farmers judge that climate change is the main contributor to reduced crop yields, followed by declining soil fertility (by reduced fallow, increased livestock, deforestation, bush fire, chemical fertiliser destructing soil structure, lack of crop rotations, lack of transport to apply manure, and plants to fertilise the soil. After climate change and declining soil fertility, increased pests and diseases is considered the third cause for declining crop yields. Farmers estimate that maize yield has dropped drastically from 3,5 tons per ha to 1 ton per ha. Bean yield would have decreased from 1,1 ton to 0,2 ton per ha. As a result of declining food production, farmers now eat once a day, instead of twice a day.

Farmers perceive the following causes for climate change: a decrease in vegetation cover, using too much water and cultivating too close to water sources. The vegetation cover is reduced by agricultural expansion necessary for the increased population and declined crop yields, charcoal and wood use, bush fires, and lack of tree planting and tree maintenance by a lack of knowledge. Deforestation has also increased the wind, which dries out the land and results in wind erosion. Only few farmers had heard about the relation between fossil fuel burning and climate change.

So far, farmers have coped with climate change by a number of changes in farm practices. Some practices are applied by most farmers, while some practices have recently been introduced and are applied by few farmers (statements are farmers' views):

- Increased weeding: weeding once a month increases soil moisture.
- Choice of crops: more sweet potato, sorghum and cassava, which are drought resistant.
- Planting date: planting in December instead of October because of the later start of the rains.
- Choice of fields: planting more in swamps and along water sources; less in high, dry areas.
- Area under crops: larger areas are cultivated to compensate for lower yields.
- Crop rotation: farmers use more rotations to maintain soil fertility, reduce erosion and increase production.
- Irrigation: some farmers use gravity irrigation near water sources.
- Erosion control: few farmers started with *Vetiver* grass and contour ridges, and plough across the slope.
- Cover crops: few farmers started with various cover crops as green manure.
- Mulching: in one village few farmers leave mulch to conserve moisture.
- Tree planting: to reduce erosion and conserve moisture.
- Alternative income: making charcoal, keeping livestock, starting small businesses, constructing house, carpentry, making cooking pots.

Farmer perception of potential improved farm practices

Some farmers have already experience with some of the new, recommended farm practices, and other farmers have visited demo fields organised by the Agricultural Research Institute. Generally, farmers see good opportunities for the recommended practices.

- Conservation farming, combining reduced tillage with mulching. One way is to plough only once every crop rotation; subsequent crops are then planted on last-year's ridges. Another option is to make annually planting lines, using an ox-pulled 'ripper', leaving the soil between the planting lines undisturbed and covered with mulch. Farmers mention as constraints: the lack of equipment (ripper) and a lack of knowledge.
- Improved fallow. This can be done with annual green manures (*Mucuna*, *Crotalaria*, *Canavaria*, *Lupinus* and Soya) and with perennial green manures (*Tephrosia*, *Cajanus*, *Sesbania*, *Tithonia*, *Calliandra*). Constraints are the lack of seed of these new species, and the lack of knowledge.
- Tree planting. Constraints are the lack of knowledge on tree planting and tree management, lack of seeds, lack of water, and the costs of polythene tubes.
- Manure use. There is manure available in the cattle pens. The constraint is the lack of carts to transport the manure from the cattle pens to the fields.
- Organic farming. This includes many different farm practices that also reduce emissions and sequester carbon, including: not burning but recycling of crop residues; erosion control; no use of chemical fertilisers; reduced tree cutting and more tree planting; using manure. These practices can be monitored using the Internal Control System, set up for organic certification. Farmers would like more training and training materials about organic farming.

From all different practices mentioned above, farmers were interested most in 1) carts to transport manure, followed by 2) tree seed and seedlings, 3) tools for reduced tillage, and 4) seeds to improved fallow and green manures.

Soil carbon stocks and expected changes

Based on the total soil organic carbon stocks and field history, the different soil carbon pools were estimated. The average carbon content of all fields is 1.25% (0-30 cm deep), which is not too bad for tropical soils. Soils are still relatively fertile because of the fallow included in the crop rotation. Based on the 167 soil samples, a map could be made showing the gradient of soil carbon, see Figure 3. Soil carbon content is lower in fields closer to the village, where fields have been cultivated more intensively. Soil carbon content was – surprisingly - higher in fields with steeper slopes, perhaps due to more recent clearing for cultivation. The high-altitude fields (>1800 m) have a higher carbon content, probably because these fields were cleared for cultivation more

recently.

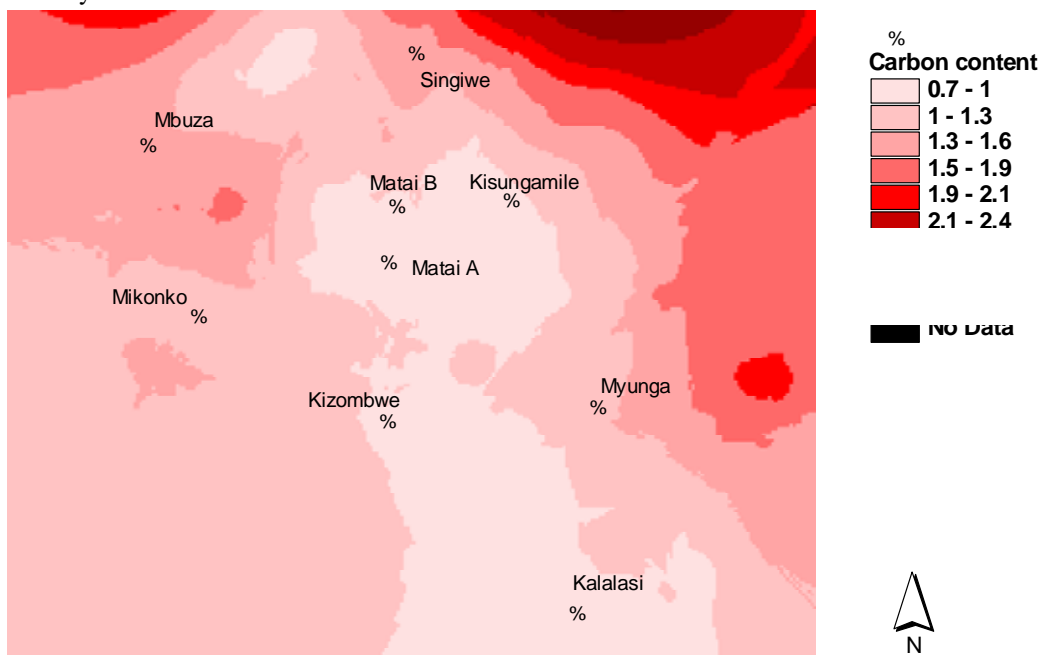


Figure 3. Soil carbon stock map of Matai Ward (% C, 0-30cm depth, soil samples 2005)

Subsequently, we simulated trends in carbon stocks under different scenarios with a soil carbon model (Rothamsted), see Table 3. Carbon stocks decline under the current farm practices, due to burning of crop residues, limited use of compost and manure, annual ploughing and no use of improved fallow or green manures. The effect of recycling more crop residues and manure alone was insufficient to reverse this trend. The scenario including an improved fallow as part of the crop rotation (2 years fallow with *Tephrosia* every 6 years) showed a net soil carbon sequestration.

Table 3. Simulated soil carbon stocks (total organic carbon C / ha in upper 30 cm), under the baseline scenario and the improved scenario, between 2005 and 2015

	2005		2015		Difference	
	% C	t C/ha	% C	t C/ha	% C	t C/ha
Current land use	1.25	47.6	1.17	44.3	-0.08	-3.3
Improved fallow	1.25	47.6	1.35	51.8	+0.10	+4.2
Difference			0.15		+0.18	+7.5

Vegetation carbon stocks and expected changes

The shrub and tree vegetation (we excluded grass from our observations) is scarce, even fallow fields. Figures 4 and 5 present the vegetation density as observed in cultivated and fallow fields. Different height and diameter classes are distinguished. As expected, the number of shrubs and trees per ha is much higher in fallow fields than in cultivated fields.

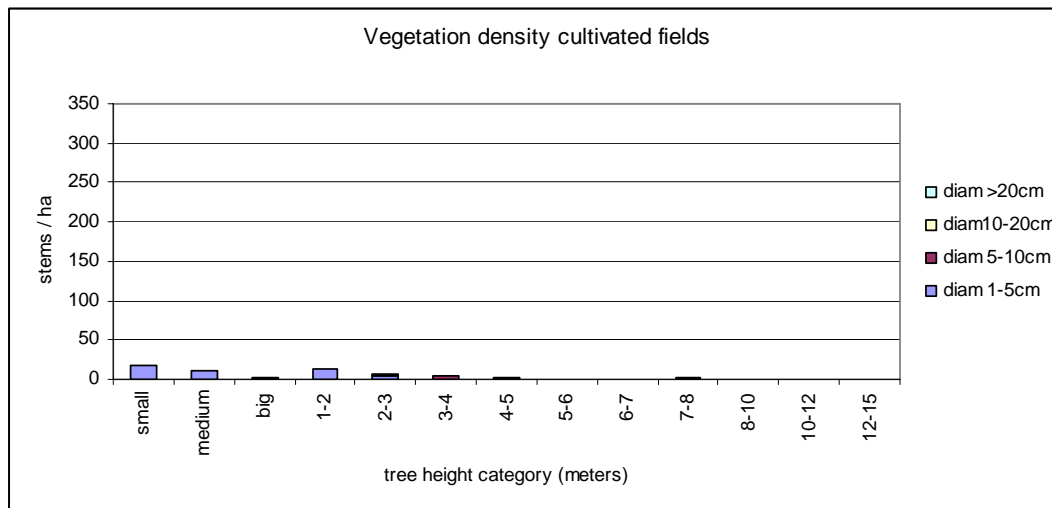


Figure 4. Shrub and tree density in cultivated fields, distinguishing different height and diameter classes.

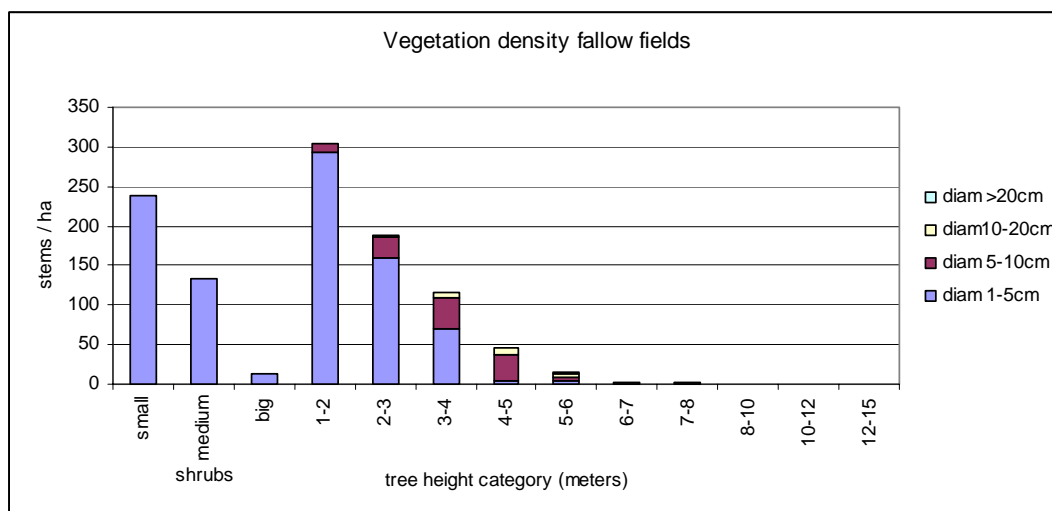


Figure 5. Shrub and tree density in fallow fields, distinguishing different height and diameter classes.

However, the amount of vegetation biomass is small, due to the small size of shrubs and trees. On average, cultivated fields have 0.7 ton carbon per ha (st dev 1.3), while fallow fields have 3.7 ton carbon per ha (st dev 6.8) in the vegetation biomass. Most carbon is present in trees (not in the shrubs) from 1 to 8 meters tall. The vegetation, even in fallow fields, is scarce because of the continuous and uncontrolled grazing and woodcutting, and annual burning.

The amount of carbon in vegetation biomass is very small compared to the amount of carbon in the upper 30 cm of soil. Only about 2 to 8 percent of the total (soil and vegetation) biomass is in the vegetation.

The current stock of vegetation carbon is low, but the potential to store carbon by planting new trees is very high. Tree growth was simulated with a model (CO2Fix), taking a pure stand of 1 ha Pinus and Eucalyptus trees as examples (see Figure 6).

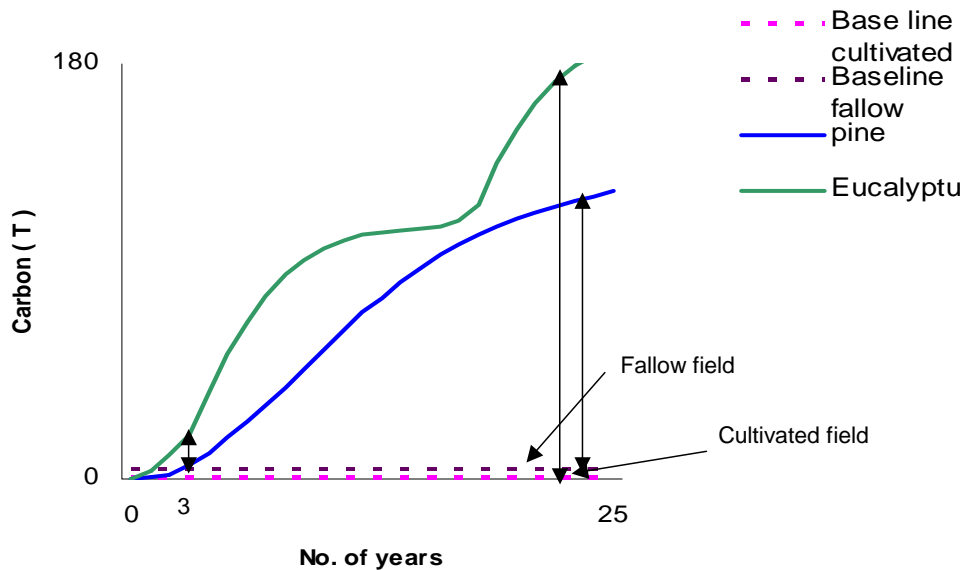


Figure 6. Simulated growth of pine and eucalyptus in 25 years, expressed in tons carbon per ha pure stand. (The dip in Eucalyptus growth in year 20 is caused by felling and replanting)

Although these simulations take the local climatic conditions into account, we should count on much more modest tree growth. Farmers may prefer other tree species above pine and eucalyptus, and may prefer to plant trees along field boundaries or around the homestead, rather than in pure stands. Nevertheless, considering the very low carbon stock in the current vegetation, it will be easy to increase the vegetation carbon stock with tree planting.

Lessons learnt

The main lesson learnt from this study is that it will be difficult to monitor a significant increase in soil organic matter in a few (3-5) years, because of the high variability between fields and the small change in one year. Soil organic matter remains a very relevant indicator for climate change mitigation and for climate change adaptation, which will need a long period of at least 10 years between baseline and impact survey to find a significant increase.

Conclusions

The project area, current practices and climate trends

In Matai Ward, farmers rotate a period of cultivation with a fallow period. The current farm practices are not sustainable. Farmers use very little inputs, under-utilise manure, burn crop residues and fallow vegetation, and have not yet adopted green manures, improved fallow or compost. This results in a steady deforestation and land degradation. Farmer experience that crop yields decline. Meteorological data for the period 1975 and 2005 show a later start of the rainy season, although the total amount of annual rainfall has not declined.

Farmer perception of climate change

Farmers have experienced climate change and reduced crop yields, which they mainly attribute to local mismanagement of land and water, and not to global warming. They are coping by planting later, planting more drought-tolerant crops, planting in low-lying areas, and planting larger areas to compensate the reduced yields. Besides, they try to earn off-farm income from e.g. charcoal burning, which in turn aggravates the poor land and water management. Farmers are eager to learn more and experiment with improved practices that can sequester carbon and improved yields at the same time. Farmers need support with training, seed and seedlings, and tools and equipment.

Soil carbon stock

The average soil carbon stock in cultivated fields and fallow fields, up to 30 cm depth, is 1.25%, or 47 tons C per ha.

Vegetation carbon stocks

The current vegetation carbon stock in cultivated fields is 0.7 ton C per ha. In fallow fields this is 3.7 ton C per ha. These amounts are very small compared to the soil carbon stocks.

Soil carbon trends

Under the current farm practices, soil carbon stocks are declining. This implies that the farming system is losing resilience to the effects of climate change (more frequent droughts, extreme rainfall events). By recycling crop residues and manure, the soil carbon stocks will still decline, although at a lower pace than under the baseline scenario. In order to reverse this trend and to increase carbon stocks, the introduction of a rotational improved fallow is needed. Although not simulated in the model, the introduction of conservation farming will improve the carbon balance even more.

Vegetation carbon trends

Vegetation biomass is declining in this crop-fallow rotation, partly due to the uncontrolled burning, grazing and woodcutting. The current carbon stocks in the vegetation are very small (2-8%) compared to the soil carbon stocks. Nevertheless, there is a high potential to sequester carbon by tree planting. There is land available for tree planting, but measures need to be taken to protect newly planted trees from fire, grazing and woodcutting.

Recommendations and Further Development of Project

A project aiming to improve the soil carbon balance can not only claim carbon sequestration from increasing soil organic matter but also claim emission reduction from *avoided soil degradation*. The current discussion to include avoided deforestation in the post 2012 regulations, following up the current CDM rules, applies also to avoided soil degradation: it makes much more sense to reverse the current trend of destruction (deforestation and soil degradation) than to neglect this and build up carbon stocks elsewhere.

In the 4-year carbon project we propose, we aim to work with about 750 farmers, who will each choose one or several of the recommended practices. In our estimations we taking into account that the number of farmers and area under improved practices increase gradually. We expect to

'gain' 18,000 tons CO₂ compared to the non-project scenario. Assuming a price of €10 per ton CO₂, this corresponds with €180,000, or €240 per farming family. Most of this will be used for the investments in the first years: seed, tree seedlings, carts, rippers and improved fuel stoves, and for annually pre-financed carbon payments to farmers (for more details, see project proposal). This support and incentive will bridge the gap between the costs of farmer investments and the benefits of increases production after several years. (for more details, see project proposal)

This baseline study and the proposed carbon project are complex and beyond the methodologies currently accepted by the formal Clean Development Mechanism. Therefore, the future carbon project will aim at delivering voluntary emission reductions to be sold at partners interested in sustainable and organic farming, and climate change adaptation. Although the project is complex and relatively costly compared to the carbon credits that could be issued after 4 year, this novel methodology is a great challenge that could potentially benefit many farmers in the South. The combination with an already existing Internal Control System for organic farmers is unique, as there is already a monitoring, certification and payment mechanism in place.

If organic peanuts are going to be exported in 2008, we should take this opportunity to try to sell the peanuts as 'climate neutral'. Already we can do a light impact study looking at a change in farmer practices, compared to the situation in 2005. However, it will be too early to measure a change in soil carbon within 3 years. Therefore, we could make publicity about the farmers adopting improved, climate-friendly practices, referring to a real carbon impact study to be done in several years from now.

With the publicity about farmers already adopting climate-friendly practices, we should continue to seek funding to support farmers more with these practices: with training, seed, seedlings, tools and equipment, and with annual payment of pre-financed voluntary carbon credits for farmers applying the improved practices.

References

- De Blecourt, Marleen. 2006. Baseline survey – Tanpro groundnuts Tanzania. EPOPA.
- De Blecourt, Marleen. 2006. Soil carbon stocks and the potential for soil carbon sequestration through organic agriculture, a case study in southwest Tanzania. EPOPA / Wageningen University.
- Beatrice Riche. 2006. Linking climate change, soil carbon sequestration, and food security in the Southern Highlands of Tanzania. Agro Eco / Oxford University.
- Van de Boer, Anneke; Veranique Geerts; Gerdien Penninkhof; Inge Regenink. Interactions between land use history, sustainable agriculture and climate change in Matai Ward. Tanzania (in Dutch). Agro Eco / Wageningen University
- Agro Eco. 2007. Climate change and organic farming. Using carbon credits to improve incomes and the sustainability of smallholder farming, pilot Tanzania. Project proposal. Agro Eco, Bennekom.