Resilience to a changing climate: carbon stocks in two organic farming systems in Africa

Koopmans[1], C.J., Bos[1], M. M. & Luske[1], B.

Key words: Climate change mitigation, adaptation, biodiversity, ecosystem services

Abstract

Our changing climate poses challenges to sustainable agriculture. Here we present two case studies on climate change mitigation of agricultural systems. In Egypt, desert soils were reclaimed for arable land through a combined approach of irrigation and compost application. The use of organic fertilizers is inherent to organic agriculture and builds upon soil quality with high water-holding capacity. In Congo, cocoa farmers adopted agro forestry practices promoted by organic premiums, which included shade management. Shade management is a tool for biodiversity conservation and contributes to higher resilience through less soil erosion and better soil fertility. In Egypt, the use of compost lead to a total carbon sequestration of almost 30 t C/ha in the course of 30 years of land use. In Congo, shade management increased the amount of stored carbon from 17 t C/ha in poorly shaded plantations to over 60 t C/ha in more densely shaded plantations. These studies illustrate the multifunctionality of sustainable agricultural practices and underline the benefits of organic principles, in particular for regions that are vulnerable to the adverse effects of climate change.

Introduction

The changing climate leads to increased fluctuations in rainfall and drought, which poses a serious threat to the food security in vulnerable regions (Adger et al. 2003). Regions that are particularly vulnerable are those where adverse effects of climate change intensify environmental threats that result from existing socio-economic and environmental processes. Examples are arid and semi-arid regions where desertification as a result from land-use intensification accelerates through increased drought severeness (Lal 2004), and rainforests where the negative effects of deforestation and forest degradation are worsened by increased rainfall that results from climate change (Verchot et al. 2007). Adapting agricultural production systems to such changes is one of the major challenges of sustainable agriculture.

In arid and semi-arid regions, soil fertility is low and needs high investments that make soils suitable for agriculture. The application of compost is a means of soil improvement to enhance soil structure and soil organic matter. Thus, the production of compost is one of the agricultural methodologies approved by the UNFCCC for emission reduction projects as part of the Clean Development Mechanism.

The effects of climate change in the humid tropics are more extreme and less predictable fluctuations in drought and rainfall. In agro forestry systems, perennial tree

[1] Louis Bolk Institute, Department of Agriculture, Hoofdstraat 24, NL-3972 LA Driebergen, The Netherlands, c.koopmans@louisbolk.nl

crops are in varying degrees intercropped with shade trees, such as fruit and timber trees. Shade trees contribute to resilient production systems through the facilitation of more efficient nutrient cycling, natural pest control, and income diversification for smallholder farmers. In addition, such systems are an adaptation to climate changes in that soils are less vulnerable to erosion and desiccation.

In this paper we present the results from two studies on the role of resilient agriculture in climate change mitigation in two vulnerable regions of Africa. First, the effect of compost application on soil carbon sequestration is quantified for an arable production system on reclaimed desert soils in Egypt. Second, the effect of different types of shade management on carbon storage in organic cacao agro forestry systems is quantified in the Democratic Republic of Congo. Shade management is promoted by organic certification, but can vary strongly between certified cacao farms. The results are discussed in the context of multifunctional agricultural resilience in food-insecure regions.

Materials and methods

Climate change mitigation through compost production and application on desert soils

This part of the study took place at the Sekem farm in Egypt, which is the first certified organic farm in the Arabic region. Since the start in the 1970s, a combination of compost, green manures and irrigation is being used to turn desert soils into fertile agricultural soils. Over the years, the farm expanded in size and created a mosaic of arable fields with different ages. The annual average compost application rate amounts to 47 m^3 per hectare. Sekem developed a large scale windrow composting site which turns organic waste fractions into compost. The organic waste consists of chicken and cow manure, rice straw and green waste from Sekem itself, nearby farms and irrigation canals.

To investigate the effect of organic farming on carbon sequestration in desert soils, soil properties of eight fields (3 desert sites and 5 arable fields) were analysed in 2009. The arable fields were similar in terms of crops and compost application, but differed in age (1, 4, 5 and 2 fields of 30 years old). The fields and desert locations were sampled in three line transects. Each transect consisted of five sample locations where samples were taken at three depths (0-10 cm, 10-30 cm and 30-50 cm) and analysed for chemical and soil physical characteristics.

Climate change mitigation in organic cacao agroforestry

In the province of North-Kivu, eastern Democratic Republic of Congo, the ESCO company assures that all farmers have access to training in cacao agroforestry and shade management. Shade tree and cacao seedlings are distributed as part of the programme. In 2010, over 100 randomly selected cacao farms were visited to estimate the carbon stored in these agroforestry systems. Based on field experiences by field officers, shade management was a priori categorized into 5 different levels of shade tree density (see table 2). In each cacao plantation, trees were counted and measured in marked quadrates. In a 10x10m quadrate, the circumference of all trees smaller than 100cm circumference at breast height (CBH) were measured. In a 25x25m quadrate the circumference of all trees larger than 100cm CBH were measured. From the CBH measurements, the Above Ground Biomass (AGB) was calculated using the allometric equation recommended by the UNFCCC for carbon stock estimations in broad-leafed humid tropical forests (UNFCCC, 2009). For carbon stock estimations, the UNFCCC recommends using a 0.3 root:shoot ratio for

estimating belowground biomass (BGB) and a 50% carbon content to calculate carbon stocks from AGB and BGB.

Results

The soil in the desert surrounding the Sekem farm contained 3,9 tons C/ha in the upper 50 cm. The carbon stocks in the arable fields of the Sekem farm were for all ages (1, 4, 5 and 30 years) significantly higher (table 1). The one year old agricultural soil contained 7,2 tons C/ha, the 4 and 5 year old fields 18,1 and 16,9 tons C/ha, and the 30 year old fields 28,3 tons C/ha. This increase in carbon stocks over time represents a carbon sequestration potential of 3,2 t/ha/year of CO_2 equivalents.

Table 1. Carbon stocks (tons C/ha) in a desert site and nearby organically managed arable fields of different ages in Egypt.

Land use	Years in use	0-10	10-30,	30-50	Total
Desert	**0**	**1.0**	**1.7**	**1.2**	**3.9**
Arable field	**1**	**4.2**	**2.0**	**1.1**	**7.2**
	4	**7.4**	**8.1**	**2.6**	**18.1**
	5	**10.0**	**6.1**	**0.8**	**16.9**
	30	**17.5**	**9.3**	**1.5**	**28.3**

The 100 agro forestry systems differed widely in the shade management category assigned by the field officers (table 2). As expected by the categorization, agro forestry systems of category V had highest density of adult shade trees, whereas category I had lowest density of adult shade trees. Cacao tree density was highest in category IV. The total carbon stocks were highest in the agro forestry systems of category V and lowest in agro forestry systems of category I.

Table 2. Carbon stocks (tons C/ha) in cacao agro forestry systems with different types of shade management in the eastern Democratic Republic of Congo.

Shade management category*	Adult shade trees (n/ha)	Carbon stock in aboveground tree biomass (tons C/ha)
I. Scarce shade trees.	**16**	**17**
II. young, heavily pruned shade trees.	**25**	**22**
III. young pruned as well as in tact shade trees.	**26**	**34**
IV. large in tact shade trees that remain from previous rainforest cover.	**29**	**30**
V. large in tact shade trees that remain from previous rainforest cover and smaller, younger shade trees.	**49**	**60**

***Shade management categories were *a priori* defined based on field experience of the field officers.**

Discussion and conclusion

In the Egyptian desert, the organic farming practice of applying organic fertilizers lead to fertile arable soils, and additionally sequestered almost 30 tons of carbon per hectare over a 30 year time-span. At the moment mitigation and carbon credit generation due to soil carbon sequestration is discussed internationally, as the permanency of the sequestration is insecure. Also within the organic sector it is discussed, as it may only be effective on large scale farms, which may have the side effect that small scale farmers are excluded. However, raising carbon stocks in soils also have multiple benefits, such as resilience to droughts and heavy rains, soil biodiversity and in general, improved soil fertility. The composting site of the Sekem farm already generates carbon credits as windrow composting is an acknowledged method to reduce greenhouse gas emissions.

The eastern Democratic Republic of Congo is currently undergoing rapid deforestation and forest degradation, followed by agricultural expansion. Our study shows that shade management is a form of resilient agro forestry that can preserve carbon stocks that amount to a multitude of that in more intensive forms of land use, such as arable land. To date, there are no economic incentives available for farmers to preserve the valuable shade tree stands on their land. Although agro forestry and shade management are widely acknowledged practices that can be used as tools in biodiversity conservation, climate change mitigation and overall land use sustainability, the trees preserved in shade management are as yet underappreciated by carbon markets and international climate negotiations. Current shade management in the study area exceeds all shade requirements by certification schemes. Organic farming standards only recommends shade management, without concrete guidelines for tree density and management. Other payment mechanisms (e.g., Payments for Ecosystem Services, Voluntary Carbon Standards) should be considered to support cacao farmers in their shade management.

The two case studies illustrate the mitigation potential of two important means of resilient farming in two very different African regions. Linking climate change mitigation to agricultural resilience, including climate change adaptation, can be a valuable multifunctional approach for sustainable and organic agriculture, particularly in sensitive regions.

References

Adger W.N., Huq S., Brown K., Hulme M. (2003): Adaptation to Climate Change in the Developing World. Progress in Development Studies 3: 179-195.

Lal R. (2004): Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science 304: 1623-1627.

Luske B. & Kamp J. van der, (in press): Carbon sequestration potential of reclaimed desert soils in Egypt. Louis Bolk Institute & Soil and More International, The Netherlands.

Luske B. (2010): Reduced GHG emissions due to compost production and compost use in Egypt; Comparing two scenarios. Louis Bolk Institute, The Netherlands.

United Nations Framework Convention on Climate Change (UNFCCC), (2009): Simplified baseline and monitoring methodology for small-scale agroforestry – afforestation and reforestation project activities under the clean development mechanism. UNFCCC, AR-AMS0004 / Version 02. Sectoral Scope: 14, EB 47.

Verchot L.V., Noordwijk M. van, Kandji S., Tomich T., Ong C., Albrecht A., Mackensen J., Bantilan C., nupama K.V. & Palm C. (2007): Climate change: linking adaptation and mitigation through agroforestry. Mitigation and Adaptation Strategies for Global Change 12: 901-918.