Factors influencing farmers' decisions-making regarding soil management in Thuti village, Nyeri South District, Kenya, and the effects of their decisions on soil fertility

Anne Damgaard Møller, Pernille Spangsberg Nielsen, Pin Pravalprukskul and Tanja Lübbers,
28th of March 2014
Interdisciplinary Land Use and Natural Resource Management
Faculty of Life Sciences, University of Copenhagen

Supervisors:
Christian Pilegaard Hansen, Department of food and Resource Economics, University of Copenhagen
Ebbe Prag, Department of Environmental, Social and Spatial Change, Roskilde University

Preface

This study is part of the Interdisciplinary Land Use and Natural Resources Management (ILUNRM) course of the University of Copenhagen. This report is a result of two month of intensive studies, including two weeks of field study in Thuti village located in the Central Highlands of Kenya.

This group work has been an interdisciplinary experience; we have been exposed to new approaches and different ways of working due to our different backgrounds, as well as a variety of methods. Further, it helped us to recognize not only our own strengths but also the strengths of our group members and the different disciplines. This has been an important and inspiring lesson in order to get a holistic understanding of the farming management in rural areas, farmers decision making processes regarding their farming practices and a study of a different culture in general.

Length of the report: 10,645 words.

Anne Damgaard Møller, Agricultural Development, University of Copenhagen

_____

Pernille Spangsberg Nielsen, Geography and International Development, University of Roskilde

_____

Pin Pravalprukskul, Sustainable Development in Agriculture (Agris Mundus), University of Copenghagen

_____

Tanja Lübbers, Agricultural Development, University of Copenhagen

_____

Abstract

This study aims to assess the factors influencing farmers' decision-making regarding soil management practices and how their decisions affect soil fertility in Thuti village, Nyeri South District, Kenya. To characterize the influencing factors and evaluate soil fertility a variety of interdisciplinary methods were carried out. The social science methods we used were questionnaires, semi structured interviews and participatory rural appraisal tools. Additional quantitative methods in terms of soil sampling and analysis were incorporated to relate applied soil management practices to the state of soil fertility. The findings show that factors influencing decision-making regarding soil management practices are: financial constraints, land fragmentation and access to knowledge. The role of gender is found to be ambiguous and calls for further investigation. Soil analysis shows that despite numerous restrictions faced in performing soil management, the current status of the soils studied is relatively fertile compared to previous studies for suitable for agricultural production.

Acknowledgements

The field-based part of the course was a collaboration between the Wangari Maathai Institute for Peace and Environmental Studies at University of Nairobi, Roskilde University and University of Copenhagen. The inputs and efforts of Prof. S. G. Kiama, Prof. R. G. Wahome, Dr Thenya Thuita, Dr Cecilia Onyango and Dr Catherine Kunyanga from Wangari Maathai Institute, Christian P. Hansen from University of Copenhagen and Ebbe Prag from Roskilde University are highly appreciated. This field work and design of the project was collaboratively done by students from Wangari Maathai Institute, University of Copenhagen and Roskilde University: Akotsi Erick F. Nyalwali, Nyamai Rhoda Mutono, Kinyori Grace Nyamweru, Pernille Spangsberg Nielsen, Tanja Lübbers, Pin Pravalprukskul and Anne Damgaard Møller. The community of Karima hosted the students and freely contributed to the information in this report through several interviews and informal communications. Their contribution is acknowledged and much appreciated. We thank our interpreters Wambugu Mbatia, Grace Macharia and our guide Joseph Mburu Mureithi for their assistance during the fieldwork. We are grateful to Chief Stephen Githaiga Mukiri and the community leaders in Karima for all the logistical support in the implementation of the training.

Table of Authors

Section	Authors
Abstract	All
Introduction	All
Field description	All
Methodology	All
Results and analysis	All
Discussion	All
Conclusion	All

List of acronyms

AC	Assistant Chief
AEO	Agricultural Extension Officer
CAN	Calcium Ammonium Nitrate
C/N	Carbon / Nitrogen
CoE	Chairman of Elders
DAO	District Agricultural Officer
DAP	Diammonium Phosphate
EM	Effective Microorganism
FGD	Focus Group Discussion
MnoxC	Permanganate Oxidizable Carbon
NPK	Nitrogen Phosphorus Potassium (K)
RFM	Resource Flow Mapping
SMP	Soil Management Practice
PRA	Participatory Rural Appraisal

Table of contents

List of Figures:

List of Tables:

Introduction

As a high agricultural potential area with fertile soil types and favourable rainfall conditions, the Central Highlands are important for Kenya's food production (Ekbom et al., 2013). Major land use changes with the introduction of coffee and tea as cash crops, combined with population pressure and subsequent land fragmentation, have greatly intensified agriculture in the area, which includes Nyeri district. The agricultural pressure has resulted in severe land degradation problems, threatening agricultural production of cash crops and food security in the area, especially since 82% of the population of Nyeri South District are dependent on agriculture as their main source of income (Jaetzold et al., 2006; Owuor et al., 2009; Westerberg and Christiansson, 1999).

Soil fertility is the ability of the soil to support the growth of plants on a sustained basis. It requires a balanced amount of nutrients and other important factors necessary for proper plant growth, such as soil moisture, pH, texture, organic matter and biological activity (Gachene and Kimaru, 2004). One of the major sources for declining soil fertility in the sloping East African highlands is soil erosion (Blanco, H and Lal R., 2010; Zöbisch, 1983). The loss of nutrients, topsoil, soil organic matter and rooting depth due to soil erosion are highly dependent on agricultural management. Although many studies in Kenya have shown that farmers are aware of soil fertility decline due to agricultural intensification and environmental factors, not much adoption of soil management practices (SMPs) has been shown (Kiome and Stocking, 1995; Odendo et al., 2010; Okoba and De Graaff, 2005; Wenner, 1989).

To identify SMPs that are both effective and feasible, it is crucial to evaluate the success of different practices in improving soil fertility and conservation, as well as understand the factors that affect a farmer's choice of practice. In doing so, key challenges to effective soil management can be brought to light, and concrete steps can be taken to target soil degradation.

There are many studies evaluating the effects of SMPs on soil fertility in Kenya (Guto et al., 2012; Kabubo-Mariara et al., 2006; Ngome et al., 2011). Numerous studies have also been conducted on the determinants of a farmer's adoption of SMPs, especially in areas with increasingly degraded soils such as the Central Highlands. These determinants include economic factors, such as assets, income, farm size, access to labour, and access to credit (Marenya and Barrett, 2007; Omamo et al.,

2002); institutional factors, such as land tenure security (Kabubo-Mariara, 2007; Mackenzie, 1989; Oostendorp and Zaal, 2012) and extension (Pretty et al., 1995); social factors, such as the influence of networks and collective action (Andersson and Gabrielsson, 2012; Fischer and Qaim, 2012; Willy and Holm-Müller, 2013); and individual characteristics, such as gender, education and age (Bekele and Drake, 2003; Fischer and Qaim, 2012; Gezon, 1996; Mackenzie, 1989; Marenya and Barrett, 2007; Omamo et al., 2002). Gender has been a particular area of research focus, as farming in the Central Highlands, according to the literature, is mostly done by women (Ekbom et al., 2013). Studies have also examined the effects of farmers' perceptions of soil fertility on their behaviour in adopting SMPs (Mairura et al., 2008; Murage et al., 2000; Odendo et al., 2010; Okoba and De Graaff, 2005; Okoba and Sterk, 2006; Tittonell et al., 2013).

Several of the studies mentioned above utilize data from large-scale surveys to model regressions relating determinants of interest with the adoption of certain management practices (Bekele and Drake, 2003; Omamo et al., 2002; Oostendorp and Zaal, 2012). However, few studies incorporate qualitative methods to delve into how multiple determinants influence the decision-making process.

There also seems to be a lack of studies that analyze the effect of farmers' soil management decision-making on soil fertility. In addition, there is a distinct lack of research on farmers' soil management decisions in Nyeri district compared to neighbouring districts in the Central Highlands, particularly Murang'a district.

This study aims to explore how factors influencing perceptions and implementation of effective SMPs affect decisions made by farmers, and evaluate the implications for soil fertility. We focus on farm-level decision-making processes, integrating qualitative analysis of factors examined in previous studies with quantitative measurements of the effects of the resulting practices.

We aim to answer the following research question:

What factors influence farmers' decision-making regarding soil management practices in Thuti Village, Nyeri South District, Kenya, and how do their decisions affect soil fertility?

Field site description

The fieldwork was carried out in Thuti village and is located in Thuti sublocation, Karima location which belongs to the Nyeri South District in the Central Highlands of Kenya. Nyeri South is situated at an elevation of 1,100-2,400 m above sea level (Hilhorst and Muchena, 2000). The rainfall is bimodal with a long rain period from mid-March to the end of May and a shorter period from October to mid-December which supports the medium long growing seasons of the cultivated crops in the area. The mean annual rainfall in the areas ranges between 1,200 and 2,000 mm (Hilhorst and Muchena, 2000). Central areas of Kenya with a humid climate including Nyeri District have a daily mean temperature of about 15° (Ojano and Ogendo, 1988). From our calculations[1] there are 1,120 households in the 6.8 km² area of Thuti sublocation, giving a density of 592 people per km².

Furthermore, the average farming size is 1.32 acres and farms are often located on steep slopes. Thuti is located in the upper midland zones and the dominant agricultural elements in the village are cash crops: Coffee (85% of the farmers grow coffee); staple crops which are sometimes sold at the market: maize (81%), banana (76%), beans (67%), kales (52%), Irish potato (52%), pumpkins (38%), cabbage (24%); for fodder crops: napier grass (62%). This is combined with a wide range of fruits and less common vegetables (Questionnaire and RFM). The dominant soil for the farms in Thuti village is the Nitisol, which occur on volcanic steep slopes, are usually reddish-brown and have more than 30 percent clay. These are weathered soils but more productive than most other tropical soils (FAO, 2001).

[1] Assuming that the 9 villages in Thuti sublocation are of equal size, as according to the District Agricultural Officer (DAO), and that density and population decrease rates are the same in all of Karima location between 1999-2009. Source: Ministry of Agriculture, 2006 and data provided by the DAO (2009)

Methodology

We used methods such as key informant interviews, participatory rural appraisals (PRAs), focus group discussions, questionnaires, and soil sampling. In addition, any relevant observations during the field study were recorded and included as data for the analysis. During our time in the field, some of our methods were adapted to the given conditions and our data collection was modified as we became more knowledgeable about the area and how to accommodate farmers' daily activities into our data collection schedule. Guides for each method can be found in Appendices A-G.

Key informant interviews

Three key informant interviews were done with four persons with extensive knowledge of the village and agricultural matters in the area: the Assistant Chief (AC) of Thuti sublocation, the Chairman of Elders (CoE) in Thuti sublocation, the Agricultural Extension Officer (AEO) in Karima location, and the District Agricultural Officer (DAO). All informants spoke English, which meant that a translator was not needed, which may reduce the chance of misinterpretation.

The interview with the AEO was conducted in his centrally-located office, which caused the interview to be interrupted several times, disrupting some of the informant's comments. At one point the AC entered, which resulted in the informant's effort to include the AC in the interview. By doing this we lost the opportunity to examine the AEO's knowledge and opinions regarding some issues.

The interview with DAO was not planned. Originally a visit to his office in Othaya was planned to obtain reports and documents, but because the office did not have the reports, we improvised an interview, which created an unstructured situation. Despite the preliminary confusion, the interview gave us most of the information needed.

PRA Session 1: Transect walk

The first day in Thuti village we did a transect walk with the CoE and the son of the AC. We combined the walk with an open interview prepared beforehand. The purpose of doing a transect walk was to gain an overview of the topography, different cropping systems, farm management and soil fertility conditions as well as general knowledge about the society. Along the way, our informant became aware of what we were interested in seeing and knowing about the village and were very motivated to tell us everything concerning the farming in Thuti village. The transect walk

was also a good way to establish rapport with our translators and informants. Having two guides with different ages provided different perspective and types of information. One initial idea was to observe potential households for the questionnaire survey, which turned out to be difficult since we did not see the entire village due to limited time.

Introductory questionnaires

Prior to the field trip we designed an introductory questionnaire which was tested on and discussed with translators before starting the survey. We wished to stratify our selection of respondents according to different wealth levels. In order to do this, we did a wealth mapping exercise with our village guide, where he sketched a map of three closeby roads and marked all households. The households were categorized into three wealth groups: below average, average and above average. We picked out seven households from each category attempting to get as much spatial variation as possible, creating a sample population of 21. The questionnaire targeted household heads in charge of farming. If the responsibility was shared between two persons in the household, the person available responded. Whenever we encountered that some chosen respondents were not at home, we would choose the nearest household within the same wealth group.

After testing the questionnaire, we decided to remove sensitive questions concerning marital status and details about family members following advice from our guide and translators.
From the survey we received both quantitative and qualitative information about the farmers. We got a general overview of the farm characteristics, crop types, farming patterns as well as perceptions of their soils, which helped us select households and farming plots for further data collection methods.

PRA Session 2: Identification and ranking of management practices and factors that influence implementation

A preference ranking PRA was conducted to investigate preferred practices, reasons that farmers prefer certain SMPs over others, and the challenges they face in implementing SMPs. We selected participants from our questionnaire results by inviting three men and three women for gender balance, and one from each of three age groups for each gender. One of the women did not show up, which reduces women's representation in the responses.

We divided the exercise into two sessions. In the first session and asked participants to rank their preferences for soil fertility management practices, and in the second session soil conservation practices, using practices mentioned in the survey. We invited the farmers to propose additional practices to rank.

One of the difficulties consisted in making understandable signs for all the participants, since according to our guide, not all of the participants were literate. Another difficulty consisted in making all the participants understand the ranking concept; for example, some participants were confused when asked to rank the "least best option". During the exercises we felt that the two women influenced each others' decisions, which could have an effect on our results. These issues caused difficulty in interpreting data. The whole exercise was carried out in a church that was a neutral and centrally-located meeting place.

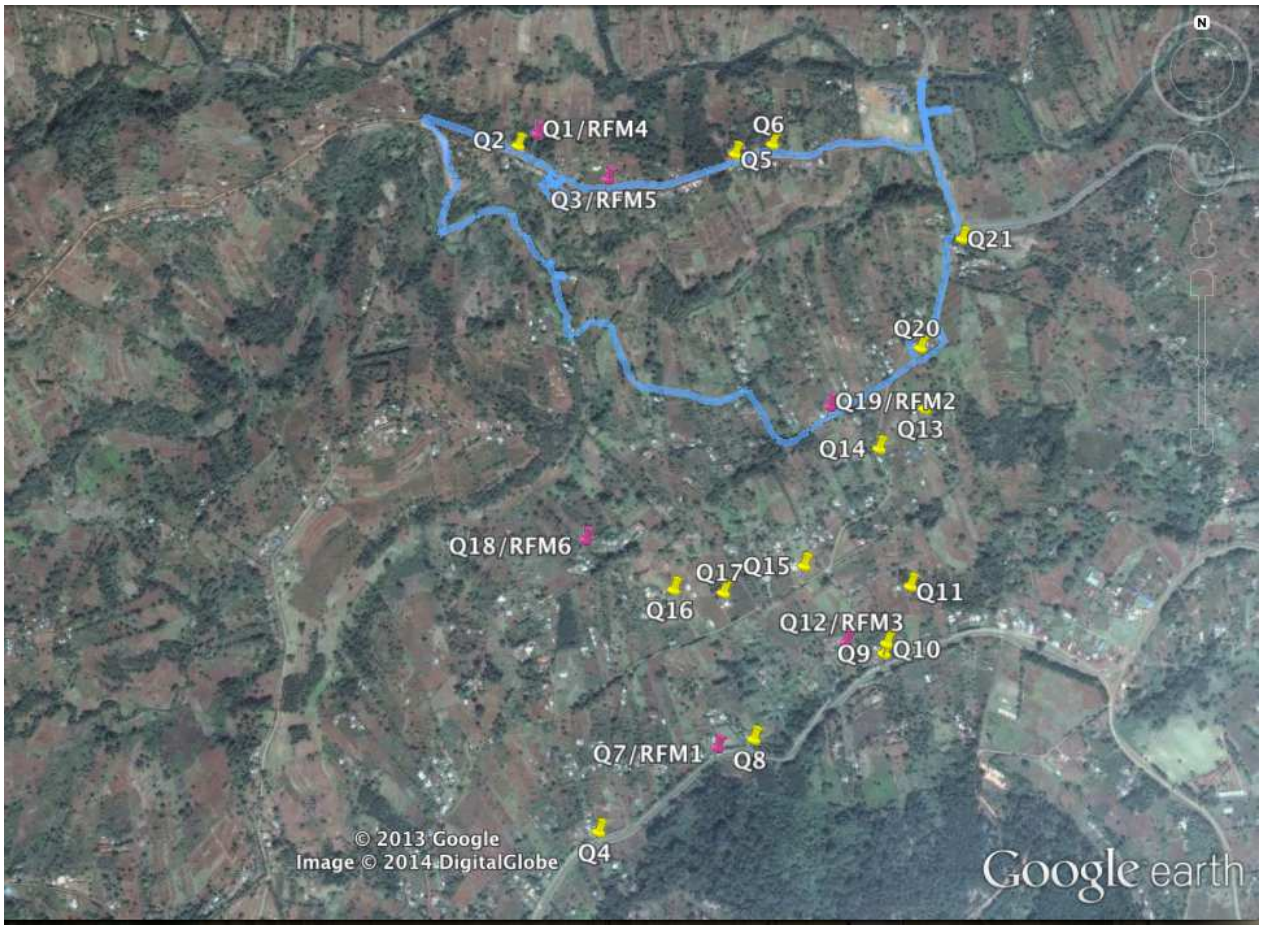


Figure 1: Map of field site, with transect walk (blue line), questionnaire (pink pins) and resource flow mapping locations (yellow pins). Sources: GPS data and Google Earth.

PRA Session 3: Resource flow mapping on farm scale (RFM)

The purpose of the method was to get a fundamental understanding of the soil management practices performed on the farms and to map the flows of resources to, from and within the farm that may affect soil management. In addition to that, a goal was to learn about prioritization and decision-making on the farm and challenges to implementing SMPs. The RFM was also used to identify plots for soil sampling.

The six participants were selected among the questionnaire respondents based on the steepness of the farming land according to the farmers' perceptions to account for possible variations in SMPs due to slope differences. We picked two farms on very steep land, two on average steep land and two on land that was a little steep. We chose not to stratify by gender, and ended up with having a participant selection of two men, three women and one couple who wished to be present at the same time.

The sessions were conducted as individual interviews where the facilitator sat down with the head(s) of farming and asked him or her detailed questions about their farm and the management practices they perform. Ideally the informant would take control in drawing a sketch of the farm including boundaries, benchmarks, plots and different crops. Flows of manure and fertilizer applied and yields harvested were attempted to be quantified and illustrated by arrows. In reality it was not always possible to convince the participants to hold the pen and in three cases the facilitator had to draw for them following their descriptions. We conclude that the method was more appealing to some than others for reasons such as age, mobility, education and shyness. This implied that we got more data from some respondents than others. However, the mapping still acted as a useful discussion tool.

As an extension of the interview, we asked questions about the seasonal farming activities and recorded them in the form of a seasonal calendar. After the mapping, a tour was done of the farm to verify the items on the map and add more details if necessary. We experimented once with having the tour of the farm prior to the interview and mapping, but the procedure seemed more natural when ending with the tour.

Figure 2: Picture of RFM session

Soil Sampling

To learn about the actual nutrient content and soil fertility we took samples from the six RFM farms, choosing to focus on a maize plot within the farm, as maize was found to be a main food crop on all farms. We had expected that the steepness of the maize plots would correspond to the farmers' perceptions of general steepness from the questionnaires. However, we learned the RFM farmers tend to plant maize on the flattest part of their land; the selected plots therefore turned out to have similar slopes with an average of 11% slope steepness. This did not allow us to explore the potential impact of variation in SMPs due to slope differences, but we decided to stick with the farms due to time limitations.

For nutrient analysis in the lab in Denmark we took samples including replicates in 0-15 cm, two from the top and two from the bottom of the field, therefore we used a composite sampling strategy, where the samples were mixed to get average conditions for the top and the bottom site and to keep the sampling number low due to resource and time restrictions. We analysed following parameters: total carbon (C) and nitrogen (N) content after Kjedahl (1883), bulk density after Blake and Hartge, (1986), pH after Black (1965) and permanganate oxidisable C (MnoxC) after Blair et al. (1995). For the bulk density we collected 3x2 samples with 100cm^3 soil cores again from the top and bottom of the plot, air dried the samples for 48 hours and weighed them afterwards. In the field we analysed

one profile per plot and described physiography, texture and structure type of the soil. All field testing was conducted using FAO's guidelines for soil description (2001).

Focus group discussions

Two focus group discussions (FGDs), one with men and one with women, were held toward the end of our field study to discuss aspects of soil management from our findings that we wanted to clarify and explore in greater depth. We invited six men and six women from our questionnaire participants and from the AC's contacts for concurrent sessions at the same church as the Ranking PRA. Each FGD had a facilitator and translator of the same gender as the participants to create an open atmosphere for potentially gender-sensitive topics. We aimed to discuss intercropping, soil conservation, youth, agricultural extension, and farmers' most significant challenges, especially when related to gender.

Many of the participants either did not show up or were very late, likely because the sessions were during the time-sensitive land preparation and planting period before the rains, which we had not considered and had limited time to adjust to. Two men cancelled last-minute, so we conducted the men's FGD with four participants. We shortened the planned sessions because the farmers had to return to their farms, which reduced the depth of discussion. The women did not show up within 1.5 hours, and were therefore expected them not to show up. However, three women did arrive eventually, although not at the same time. Each of them was interviewed separately, so we were less able to generalize our findings for women

The FGD was the most challenging method in terms of translation. We did not want to stop the flow of the men's discussion for verbal translations, and therefore relied on the translator to play a significant role in facilitation, and the village guide to communicate discussion points to observers via writing. The men's FGD facilitator was less active and had difficulty following the discussion, and so was unable to ensure that all important discussion points were covered adequately. We therefore did not obtain some of the information we desired, and expect that some points were lost in the continuous translation process.

Results and Analysis

Section 1 describes the current soil management practices and farmers' preferences of these found in our study. Section 2 analyses the effects of certain factors on SMP implementation and preference. Finally, section 3 presents and analyses soil parameter results.

1. Soil management practices

1.1 Current practices

When asked what SMPs the farmers used to improve soil fertility and conserve soil, 95% of the households surveyed reported that they use manure, and 76% fertilizer. Other practices mentioned by survey participants include mulching, terracing and grass strips (Figure 3).

Figure 3: Percentage of households surveyed that report implementing various soil management practices (use of manure, use of fertilizer, mulching, terracing, grass strips). Source: Questionnaire data (n=21).

These SMPs were also identified in the RFMs:

- All RFM participants use manure and fertilizer on their farms.
- In RFM 3, mulching is done by leaving pruned branches and leaves in the coffee fields; RFM 4 also mentions using mulching.
- All of the RFM farmers use terracing; in RFM 3, the farmer commented that the terracing was not maintained, even though it was stated as a preferred soil conservation practice.

- Grass strips are used in RFMs 2, 3 and 4, and the men's FGD participants mention growing grass on the edges of terraces to support the soil.

In the Ranking PRA, cover cropping was added by one of the participants as an option for soil conservation. In RFM 6, the farmer says he uses cover cropping when preparing for heavy rains. The men's FGD mentioned the use of cover crops, mostly sweet potatoes, as a soil conservation practice.

In addition, participants in the men's FGD included agroforestry as a soil conservation practice that they implement. One of the trees used in the area was identified during the transect walk as *Grevillea Robusta*, (Kikuyu: Mukima) which the CoE said is used for shading, mulching, firewood, timber and as a windbreaker. However, the CoE and the AC commented that agroforestry is not common on farms.

The use of green manure, which is the incorporation of crop residue into the soil, was identified in five of the RFM farms; examples of residue crops include maize, kale, beans, bananas and weeds.

1.2 Soil management practice preferences

When asked to rank their soil fertility management preferences, the Ranking PRA participants chose either manure or fertilizer as the first or second preferred practice (Table 1). The majority of the participants also chose fertilizer as their least preferred practice. Table 2 summarizes the reasons for the participants' preferences.

Table 1: Farmers' preferences of soil fertility management practices. Source: Ranking PRA (n=5).

First Preference	Second Preference	Last Preference
Manure (3)	**Fertilizer (4)**	**Fertilizer (4)**
Fertilizer (1)	**Manure (1)**	**Mulching (1)**
Compost (1)		

Table 2: Reasons given by farmers for soil fertility management practice preferences. Source: Ranking PRA (n=5).

Soil fertility management practice	Reasons for	Reasons against
Manure	Gives better yield than fertilizer 'Strong' crops Inherited practice	Livestock costs money
Fertilizer	Used for specific problems Used when manure is insufficient	Makes soil acidic Requires experts and soil testing
Compost	Inexpensive	
Mulching		Material is hard to find because it is used for fodder

When asked to rank their soil conservation practice preferences, most of the ranking PRA participants chose terracing as their first preference, and grass strips and mulching as either their first or second preferences (Table 3). Table 4 summarizes the reasons for the participants' preferences.

Table 3: Farmers' preferences of soil conservation practices. Source: Ranking PRA (n=5).

First Preference	Second Preference	Last Preference
Terracing (3)	Grass strips (2)	Terracing (2)
Grass strips (1)	Mulching (2)	Grass strips (2)
Mulching (1)	Cover crops (1)	Mulching (1)

Table 4: Reasons given by Ranking PRA participants for their soil conservation practice preferences. Source: Ranking PRA (n=5).

Soil conservation practice	Reasons for	Reasons against
Terracing	Prevents soil erosion by water Absorbs water quickly	Labour intensive and expensive
Grass strips	Prevents soil erosion Provides fodder for livestock Provides material for mulching	Not able to stop heavy rain
Mulching	Prevents splash effect from rain Degradable and helps crop growth Less expensive than terracing	Not a long-lasting solution
Cover crops	Prevents soil erosion Functions as food crops	

The men's focus group discussed the ease of implementing different soil conservation practices, and cited terracing, grass strips, cover crops and agroforestry as relatively easier to implement. Terracing was also thought to be easier because it had to be done "only once". However, terracing was also seen as difficult to implement because it is "tedious and expensive", having to be redone every season.

1.3 Cropping practices that affect soil fertility and conservation

Although not cited by farmers as soil management practices, certain cropping systems that farmers use in Thuti village are known to have soil fertility and/or conservation effects.

Intercropping, which is the growing of two or more crops simultaneously, is known to increase soil fertility when nitrogen-fixing crops, such as beans, are one of the crops intercropped. However, crop competition may also increase nutrient depletion (IIRR and ACT, 2005). From the survey, intercropping was found to be used by 86% of the households, and with maize/bean intercropping as one of the most common combinations (26%). This concurs with the men's FGD statement that maize/bean intercropping is the most common form of intercropping in the area. Mixed

intercropping, in which crops are planted with little or no order, was the main type of intercropping observed.

Crop rotation, including allowing land to lie fallow, can improve soil fertility and soil structure (IIRR and ACT, 2005). Among the farmers participating in the RFMs, one uses seasonal crop rotation regularly and has recently allowed certain plots to lie fallow (RFM 6). Two do occasional crop rotation with certain crops: RFM 5 rotates between Napier grass and maize/bean every other year, while RFM 3 replaces the Napier grass on one plot with maize after 5-7 years, stating that the grass roots left in the ground increase soil fertility.

2. Factors affecting soil management practices

2.1 Extension services

Access and awareness

The Government of Kenya provides free extension services through the AEO who has an office 4 km away from Thuti village, where he is present one day per week. The AEO gives advice on conservation structures such as terracing, grass strips and ditches, and on manure and fertilizers inputs. Over half of the farmers surveyed do not access extension through the AEO and/or agricultural shows (Figure 4). Two of these said that their old age prevented them from visiting the AEO, while a few seemed to be unaware of the possibility.

The AEO covers all of Karima location, which comprises 5,453 households; this makes it difficult for him to reach out to all farmers. The farmers can contact him by appointment or by organizing group trainings. Transport costs are not facilitated by the Ministry, which further limits extension access. The CoE expressed that people's access to the AEO is inadequate and that there is insufficient personnel. The AEO commented on the "starved" state of extension, stating that no new staff had been employed since 1989.

Reduced access to extension can limit farmers' knowledge and incentive for SMP implementation. For example, he used to assist the farmers in constructing the terraces and trenches, but the conservation structures are not maintained, as the frequency of AEO visits has declined (interview with AC).

Figure 1: Percentage of households surveyed who obtain farming advice from various sources (n=21).

Recommendations and knowledge gaps

The AEO discussed the management and application of fertilizers and manure as an area in which many farmers do not follow recommendations. For example, he advises them to cover stored manure from rain and sun to reduce evaporation and nutrient leaching, and separate liquids and solids; from the RFMs, only one of the six farmers separates manure, while one covers manure on a regular basis and two others cover occasionally during heavy rain. This knowledge gap may be due to the limited reach of extension services.

Some of the farmers interviewed demonstrate awareness of the need for plot-specific recommendations for fertilizer application; in the ranking PRA, one farmer mentioned that soil-testing is needed when choosing the right type and amount of fertilizer to apply. One challenge raised in the men's FGD was the lack of expert recommendations for fertilizers.

The AEO and DAO do not recommend intercropping because it makes management difficult and gives a lower yield than monoculture, unless when done with beans. The men's knowledge of the shortcoming of intercropping is more in line with the words of the DAO; they mention that management is made difficult, crops compete for nutrients and sunlight, and maximum yields are not realized. The nitrogen fixing property of beans is also mentioned by the men as an advantage of intercropping. None of the women mention this aspect, possibly because they do not have the knowledge. This may show a knowledge gap for women, possibly due to their relatively limited access to extension.

For numerous reasons stated above, many farmers do not follow recommendations adequately. This has implications for soils as they do not receive the optimal amount and combination of nutrients. The men's FGD participants commented that many opt not to use the AEO service because his recommendations can be difficult to practice due to the lack of space, and the high costs involved.

Gender

According to the AEO, gender-based division of responsibilities and decision-making on the farms affect soil management. He explains that most women work on the farm, while men often take off farm jobs. However, men are still the main recipients of agricultural training, "because the decision-making power is with the men". "Women may not get the required training" which results in them doing an insufficient job managing the soil fertility, and even if they do get training, they may not be in a position to make decisions. The AC and the CoE share this view.

The division of decision-making responsibilities described by the AEO, AC and CoE does not, however, completely correspond with the questionnaire results. Women are the sole decision-makers in 33% of the households, and men in 13%. The high percentage of women making decisions on their own is due to the number of widows in the sample (4 out of 15 informants). In 20% of the households decision-making is shared between the man and the woman, and a few respond that they include hired labourers in the decision-making as well. Therefore, it seems that women do have some decision-making power, although they may not be able to acquire the training needed to implement SMPs effectively.

2.3 Financing

While much of the farmers consumption is supported by subsistence farming, farmers supplement their livelihoods with income from a variety of sources. Income sources from RFM farmers include coffee, food crop such as maize and bananas, milk, day jobs and family members who work off-farm. The extra income is often use by farmers to cover expenses, which include farm inputs and farm labour (RFM 2, RFM 4), helping the farmers implement soil management practices.

Labour

91% of the households surveyed are farmed by at least one family member, while the rest are farmed only by hired labour. In 44.4% of the former category, more than one family member contributes as labour. 47.6% of the households surveyed hire labour at least some of the time.

Labour is hired for a variety of tasks. One farmer interviewed hires 10 labourers at different times for soil preparation, spraying, digging and planting, while he and his wife harvest the crops (RFM 6). Labour required for soil conservation was a common theme during the Ranking PRA. Both female participants cited the labour-intensive nature of terracing compared to mulching, and two of the three male participants chose terracing as their least preferred soil conservation option because it “needs a lot of labour” to establish and maintain. Because of the fragility of their soil they also argued that during heavy rain, the soil and the terraces will eventually disappear if they are not maintained. The DAO described bench terracing as a labour-intensive measure that can be difficult for farmers to implement, and recommended grass strips as an alternative for those without sufficient labour.

Some farmers find the cost of hiring labour too high; for example, one farmer hires labour only when there is money available (RFM 4), while another has to do everything himself because he “cannot afford to hire” (RFM 3). From the questionnaires, wealthier households seem to hire labour more (Figure 5). Limited ability to hire labour can therefore reduce ability to implement labour-intensive SMPs.

Figure 2: Percentage of households surveyed who employ labour at least part-time (n=7 for each wealth group).

Fertilizers

Many farmers cite buying fertilizers is cited as a major challenge (RFM), which the AC and CoE suggest is a reason for not following recommended application practices. The AEO cites that there are further challenges in accessing government subsidized fertilizer (e.g. DAP), as farmers need to organize groups to obtain the fertilizer from centralized government stores. Delays in availability of subsidized fertilizer can affect farmers' ability to apply fertilizers at the right time (RFM 6). These uncertainties makes it difficult for the farmers to rely on subsidized fertilizers, and while many struggle to afford subsidized fertilizers.

Gender

The CoE and AC state that men manage the funds within the household in Thuti village. This can limit the female farmers' ability to invest in SMPs, as they are dependent on funding from the men. In RFM 4, the farmer stresses that only if she get the funds from the husband, she is able to employ labour. The husband is also providing funds for inputs such as fertilizers and seeds.

2.4 Livestock

Manure

76.2% of the 21 households surveyed own at least one cow and 33.3% at least one goat. The AC and CoE cite livestock manure as the most common soil fertility management practice, saying that farmers obtain manure "from their 1 or 2 cows", and that very few buy manure or inorganic fertilizers. All of the RFM participants use cow and/or goat manure on their farms, and one of them states using chicken manure. The farmers stress in the ranking PRA that they are dependent on livestock to produce manure, that they can use as fertilizer. At times the farmer may not have sufficient manure to cover the entire farm; one ranking PRA participant said that if he had the funds, he would buy extra livestock to secure more manure, while another stated that she uses fertilizer when she does not have enough manure.

Figure 3: Manure on fieldsite, RFM 3

The average numbers of cows, goats and chickens seem to increase with wealth (Table 5). This may have implications for the quantity and quality of manure they can produce on the farm.

Table 5: Average number of livestock per household surveyed. Source: Questionnaire data (total n=21; n=7 for each wealth group).

Wealth group	**Cows**	**Goats**	**Chickens**
Above average	2.7	0	37
Average	1.6	2	11.3
Below average	0.6	1.4	2.6

Crop residue

Owning livestock can influence whether a farmer incorporates crop residue from the farm and household into the soil as green manure, or feeds the residue to their livestock as fodder.

We found that all of the RFM participants use at least some of their crop residues for their livestock (Table 6).

Table 6: Use of crop residue for fodder and green manure or mulching. Source: Resource flow mapping (n=6).

RFM	Fodder	Green manure/mulching
RFM 1	Maize, banana, beans, Irish potato	Kale, uprooted weeds
RFM 2	Maize, kitchen waste	Maize
RFM 3	Maize, banana, beans, kitchen waste	Kale, Irish potato
RFM 4	Maize, kale, banana, beans, Irish potato	Uprooted weeds
RFM 5	All	-
RFM 6	Maize, kale, cabbage	Banana, beans, thorn melon, pumpkin

In general the farmers seem to prefer using the residues for the livestock over green manure or mulching. This may be to reduce the cost of feed, and because many of the farmers are dependent on the manure, and to some extent the milk, produced from the livestock.

2.5 Land fragmentation

Small farm sizes are a characteristic of the study area. According to the CoE, landholding varies between 0.25 and 4 acres per household, with the average farm size being 1.5 to 2 acres. Land ownership is established through inheritance between primarily male family members, and fragmentation of land is clearly observable, with members of the same family farming narrow adjacent strips of land.

Barriers to soil management practices

One female farmer interviewed said that a major challenge she faces is that her land is “too small”. The AEO cited small farm sizes as the main barrier preventing farmers from using soil management practices such as crop rotation. This was supported by the farmers interviewed: limited land was said by participants of the men’s FGD to be a challenge in controlling certain crop diseases that could be reduced through crop rotation. Farmer RFM 6, who had the largest farm area of the RFM farms, was the only RFM participant to use regular season crop rotation and fallow.

Optimising land use

The AC and CoE view that land fragmentation influences SMPs; for example, land shortage is the main reason for widespread intercropping. The men's FGD participants and the women interviewed stated that intercropping allows them to maximise the use of their limited land. Two of the women cite intercropping food crops for the household as an important advantage of intercropping.

Youth and land fragmentation

The AEO and village guide cite land fragmentation as a reason for youth moving away from the area. This is because of the high inputs costs compared to low outputs from small farms, and because many youth prefer to own their own land, while much of the land still belongs to the older generation. There are also various disincentives for youth to stay in agriculture, including the attraction of urban "white collar jobs" (CoE), the lack of initial capital, and the lack of inspiration from older farmers (AEO). According to the CoE, youth moving away has critical implications for the area. For example, youth are especially needed when implementing labour-intensive practices, and systems of terracing and benches are disappearing because older farmers do not have the power to maintain them (AC and CoE).

3. Soil parameter results

3.1 Site properties and soil formation factors

Physical and chemical soil conditions are some of the most important factors influencing farm management and soil fertility. Soil structure and texture are indicators for how easily the soil can be affected through tillage. However the soil structure is strongly connected to texture, current cultivation, management practices and organic matter in the soil (Scheffer et al., 2002). But the soil organic matter is also influenced by for example applying manure or fertilizer, crop residues and other methods.

All our investigation and classification are according to the FAO Guidelines (2001) for soil description.

3.2 Profiles/Soil characteristics

We discovered that the size of the maize plots from the investigated farms during the RFM is around an average size of 0.062 acres. Most of the maize is intercropped with different food crops, the most common being potatoes, pumpkins and kale. We classified the land use for all plots as rainfed arable cultivation.

Figure 4: RFM 2 profile picture.

To identify soil important characteristics we analysed one profile of 0-30 cm in depth for each plot . All profiles profiles showed a diffuse or not visible horizon boundary between the Ap and B

horizon, which could be due to tilling in the A horizon. All dry soils from the profiles are reddish-brown in colour, except for RFM 4 which is brown and RFM 6 which is dark reddish-brown. From field texture determination, all the profiles show a silty clay loam, silty loam or clay loam structure among 0-30 cm horizons, with a massive (coherent) soil structure. Pore size and abundance is described as fine and very common in all of the profiles, with few signs of biological activity. The consistency of the soil was sticky and slightly plastic to plastic, which confirms a silty loam, clay loam or silty clay loam soil structure. A technical soil classification demands deeper horizons, data on clay observations etc. that we do not have. We infer from our field testing and previous studies that the analysed soils were nitisols. Nitisols are according to the FAO (2001) reddish-brown soils, with stable structure that permits deep rooting, well drained soils with more than 30% clay and developed from volcanic rocks which makes them relatively fertile and productive soils in the in terms of agricultural usage in the humid tropics.

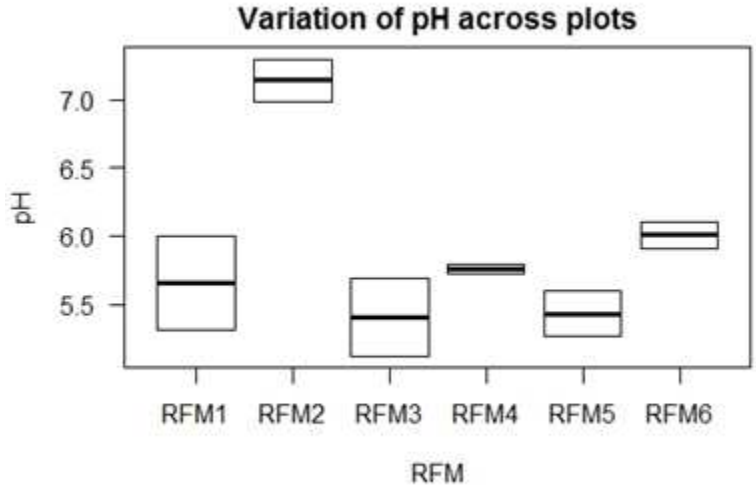
3.3 Soil chemical characteristics:

As important soil fertility indicators we decided to analyse following soil chemical and physical properties like pH, Total N and C, MnoxC and bulk density. All the statistical tests were conducted on the 5% significance level. The analysis of variance was conducted with the ANOVA and the non-parametric Kruskal Wallis test, the significant differences of the means were tested with the post hoc Tukey HSD test.

3.4 pH

The pH range of the soil is varied from 5.1 as the lowest to 7.3 as the highest and the average pH is 5.9. Comparing all plots with each other there is evidence for differences in the pH value between the plot from RFM 2 and the plots of RFM 3, RFM 5 (Figure 8). The other plots show no significant differences. All plots except for RFM 2 which is in neutral pH range, have a slightly acidic pH level and correspond with former studies in similar areas (Tittonell et al., 2009). For the mentioned pH range the silicate buffer in the soil is active, which is connected to a active soil life in terms of release of nutrients, clay mineral regeneration and it supports the activity of the microorganisms (Dunger and Fiedler, 1997). According to literature the optimal range for growing maize is between 6-6.5 (Glendinning, 2000). The measured pH range is slightly below this optimum which could be due to insufficient use of nitrogen fertilizer, like CAN, DAP and urea which are

used in the area of Thuti village or it could be also caused by leaching of bases for example (Schuhmann, 2009).



.

Figure 5: Boxplot Variation of pH across plots

The significant higher pH of the plot from RFM 2 might be due to use of ash, since there are no other indicators for liming or slash and burn which could explain the high pH. The farmer from RFM 2 is not mentioning any practices that could serve as explanation.

3.4 The Permanganate Oxidizable Carbon (MnoxC)

The MnoxC values for all plots are located in a range from 283.4 to 661.5 mg/kg with an average of 464.6 mg/kg (Figure 9).

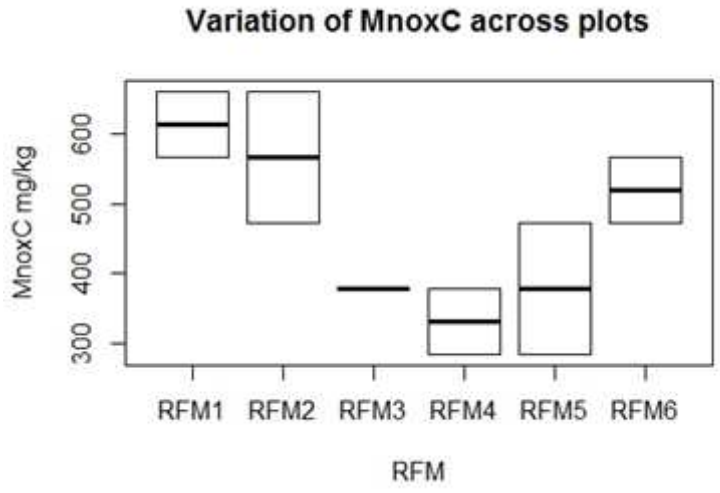


Figure 6: Boxplot variation of MnoxC across plots

There is no evidence for a difference in MnoxC values between the different RFM plots. The MnoxC is directly related to the soil organic carbon.

Compared to studies from Weil et al.2(003) the measured MnoxC values are in a lower to medium range within all of the plots. The medium values are indicators for sufficient microbial biomass, soil organic matter, a higher cation exchange capacity and water holding capacity (Culman et al., 2012).

3.5 Bulk density

The bulk density is in a range from 0.79 g/cm³ to 1.03 g/cm³ and has an average of 0.94 g/cm³.

We discovered a significant difference between the plots from RFM 5 compared with RFM 2 and RFM 1 as well as between RFM 4 and RFM 1 (Figure 10).

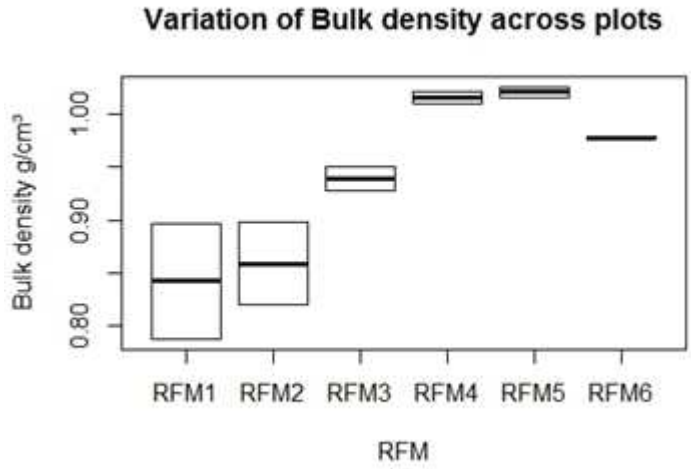


Figure 7: Boxplot Variation of Bulk density across plots

According to Askin and Özdemir (2003) the bulk density is a dynamic property that varies with soil structural conditions such as clay/silt/sand content and organic matter in the soil. According to Arshad et al. (1996) a value <1.40 in a silty soil texture is ideal for plant growth. All the measured values are below 1.40 and are according to the literature in an optimal range for plant growth. From our data we are not able to explain this difference. Occurred changes between the plots could be related to different organic matter contents of the plots or limited crop rotation.

3.6 C/N

The C/N values for all the plots varies in a range from 8.89 to 10.12 with an average from 9.24.

There is no evidence that the C/N values differ significantly between the different RFM plots (Figure 11).

All plots are having a close C/N ratio which is an indicator for a relatively high content of microorganisms in the soil and a good activity of microorganisms. A close C/N ratio also indicates a good decomposition rate by microorganisms as well as good nutrient release in the soil and mineralisation rate (Blume, 2001).

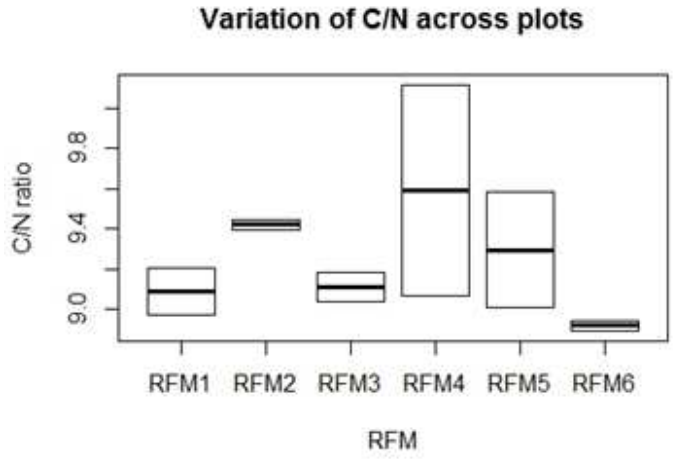


Figure 11: Boxplot, variation of C/N across plots

3.7 Active Carbon

The active carbon % for the six RFM plots varies in a range from 1.71% as lowest to 3.90% as highest with an average from 2.41%. There is no evidence that the active carbon values differ significantly across the different RFM plots (Figure 12).

The active carbon is correlated with the MnoxC and the total C but is a more sensitive indicator for changes in management, soil quality and microbial biomass due to a separation from the passive C pool (Weil et al., 2003).

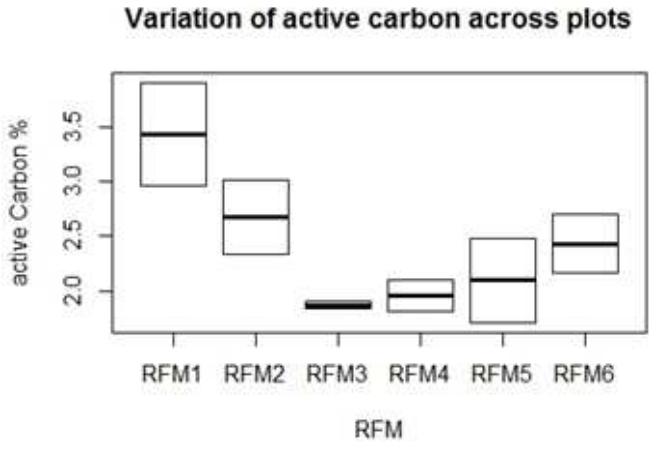


Figure 8: Boxplot, Variation of active Carbon across plots

In comparison to the measurements of Islam and Weil (2000) our results seem relatively low for all the plots. A low active carbon can be caused due to insufficient crop rotation or organic inputs (Islam and Weil, 2000; Kennedy and Papendick, 1995).

3.8 Summary

Even though there is a small difference in between the some plots the overall soil fertility is according to our analysis appropriate for cultivated areas. Some of the parameters like the C/N ratio, pH and the bulk density show values that are indicators for an active soil life, good decomposition by microorganisms and a texture that supports the plant growth well. The MnoxC and active Carbon are both in a lower to medium range which can be an indicator for a lower soil organic carbon content. According to our very limited measurements and analyses it is difficult to make a statement about the general soil fertility of the different maize plots and this should be considered in our results.

4. Perceptions of soil erosion

From the literature, we expected to find obvious signs of soil erosion on the field site due to the steep slopes. The AEO commented that the soils in the area are infertile due to intense soil erosion, and that terracing is one topic of extension focus during the rainy season to prevent soil erosion. The CoE corroborates this, saying that erosion "happens all the time" but is more severe during rains. From our own observations, we conclude that there are few signs of soil erosion on farming land, which may be because we were present during the dry season.

However, we also noted that RFM farmers interviewed perceive little erosion themselves as a result of the conservation practices that they implement. The RFM 1 interviewees say that they do not experience soil erosion because they use terraces; similarly, farmers from RFMs 2, 4 and 6 stated that they use measures such as grass strips, terracing and cover crops specifically to prevent soil erosion. Two of the farmers interviewed say that erosion occurs on paths and uncropped areas (RFM 2, RFM 6). 50% of the investigated maize slopes are situated on the middle slope whereas the others are on the foot slope of the hill, with an average slope gradient of 11%. This might be a factors why we didn't observe erosion signs.

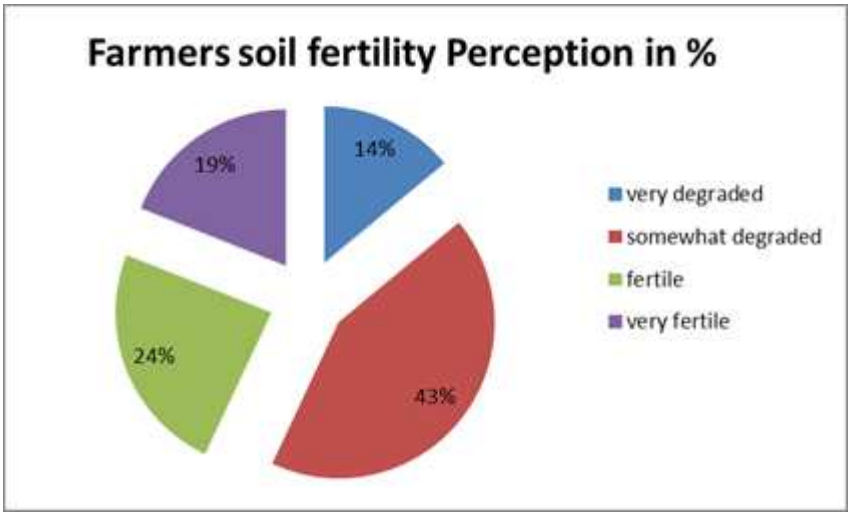


Figure 9: Farmers perceptions of soil fertility, derived from the introductionary questionnaire.

5. The Farmers perception of soil quality

Analysing the data from questionnaires we discovered that most of the farmers (43%) perceive their soils as somewhat degraded. Only 14% stated to have very degraded fields. 24% of the farmers said they have fertile soils on their land and 19% perceive to have very fertile soils. The perception of the soil fertility is based on the whole farm and not on the specific maize plots.

There is a perceived change in soil fertility along the slopes. Farmers with average or steep land stated in the questionnaire survey that the steep plots on the upper or mid slope often are less fertile than the plots at the bottom. Another factor mentioned by questionnaire and RFM respondents was that the maize plots are often more fertile compared to coffee and other plots on the farm because the farmers prefer these plots when considering adding manure and fertilizer.

According to the CoE and AEO the soils used to be black and more fertile but this changed over time into a more reddish soil colour and more infertile soils due to overuse. Adding manure however gives a darker colour which is associated with a more fertile soil compared to the red, uncultivated soils in the area (CoE).

For the soil colour, we found out that almost all farmers during the questionnaire survey identify their soils to be red or reddish/brown.

In most of the cases the farmers stated to have loamy soils, some rare cases stated to have sandy or rocky soils.

Discussion

Discussion of applied methods

Facilitation and planning of methods

The execution of the RFM was demanding for both the facilitator and the respondent, because of the many detailed questions (see interview guide appendix C).The different facilitators chose slightly different procedures when going through the questions, and some facilitators were less persistent in following up to clarify answers, and tried to cut down on the interview to minimize disturbance of the informant. Therefore questions were not asked consistently in the six sessions, resulting in data that was not perfectly comparable at times. The amount of time and effort we could demand from our informants was a delicate judgement and the expectations should have been better aligned within the group. When carrying out the sessions, our group was split up into two teams to work more efficiently, but we did not prioritize knowledge sharing enough between the teams due to time restrictions.

Questions on quantities of inputs and outputs were very hard for most of the respondents to answer, supposedly because they do not measure them accurately. We were therefore not able to quantify many resource flows for comparison between the farms.

As the questionnaire was originally planned to obtain general knowledge and selecting participants for further methods, many of the questions were designed to be open-ended. Such questions are good for learning about perceptions, but limiting for discovering what farmers actually do, because they may not be able to recall and report data accurately. We encountered an issue with some respondents providing contradicting responses in the questionnaire compared to other methods; for instance, some mention fewer crops grown on their farm than they do in the RFM, or respond that they do not have soil conservation measures when they have visible terraces. We have therefore interpreted statistics from the questionnaire with caution, and noted observations on incomplete data provided by farmers; how, we took care not to do this with responses regarding farmers' perceptions.

Translation

Prior to each method we discussed the procedure and made effort to explain to the interpreters our expectations and what was important to our results, to ensure accurate translation of all relevant data. Despite this, translation was a continuous challenge. Often the interpreter would have long

conversations with informants but translate their response using few words, perhaps to save time or because of misunderstandings of our data requirements. We expect that details and nuances were lost along the way due to oversimplification.

Another aspect was the influence of evolving friendships between interpreters and group members on professionalism, in some cases resulting in loose attitudes towards the work. This may have affected the ability of some group members to be critical towards quality of interpretation. This could have been addressed by strengthening communication within the group, including the interpreters.

Selection of respondents

The selection of participants for various methods may have elements of bias. The wealth ranking, our starting point for selecting questionnaire respondents, was done by one person alone, relying solely on his memory and subjective opinions. He may have forgotten to draw some households, or his perception of their wealth may be biased.

Some informants were used in more than one session because they seemed available, interested and willing to share. This may have resulted in more resourceful farmers being over-represented among our respondents, and lost the perspectives of the less resourceful.

This effect may have especially affected FGD data, as a large portion of participants did not show up as they were busy or may have felt they did not have the knowledge to contribute.

Soil sampling

Major constraints included limited resources (sampling bags) that had to be shared with the Kenyan students, which did not allow us to take more replicates, or sample on different farms concurrently. Time also limited the number of samples possible to collect. To address this, we adopted the composite sampling approached suggested by an advisor, although we were not aware that this would limit our ability to analyse variation within in the field and explore possible correlations between soil parameters. We were not critical enough of the method because we did not have clear plan on how to analyse the data before entering the field.

We should also have been more careful about plot selection to increase the chance of including variables that may create interesting points of comparison, like differences in SMPs.

Factors influencing decision-making regarding SMPs

Our approach in exploring factors that influence SMP decision-making was fairly open, so as to not restrict the informants' responses and allow us to consider factors that we may not have considered previously. We focused our analysis on factors based on the issues that were prominently raised from different sources and methods.

Our results show that land fragmentation and youth leaving agriculture are limiting factors in implementing SMPs. Land fragmentation is known to be occurring in Nyeri South (Owuor et al., 2009), which concurs with our findings of small farm sizes. In addition to causing soil depletion directly through encouraging intensification of land use, it may also cause a decline in SMP implementation through the loss of youth. Land fragmentation is cited as a reason for migration to urban areas (Ekbom et al., 2001; Owuor et al., 2009), which supports the frequently raised issue among our informants of youth moving away from agriculture due to land shortages, among other reasons. Bekele and Drake (2003) suggest that younger farmers "have longer planning horizons and, hence, may be more likely to invest in conservation", while Marenya and Barrett (2007) indicate that planning horizons decrease with a farmer's age, reducing incentives to "invest in the future productivity of their farms". Marenya and Barrett (2007) also state that younger farmers can adopt soil fertility management practices more easily because of their lower "learning and adjustment costs". The loss of youth from Thuti may therefore result in less investment and innovation in soil management and conservation.

A farmer's labour resources to implement SMPs can also be affected by the farmer's age. From our questionnaires, the average age of farmers in the village was found to be 57, which is relatively high, and we observed that old age can be a challenge in carrying out physically demanding farming practices, especially on a steep terrain. This can mean that older farmers are less likely to implement SMPS, which tend to involve physical effort (Marenya and Barrett, 2007). The loss of youth from the area and limited resources in hiring labour cause further labour restrictions. Labour has been found to be a key constraint in implementing soil conservation practices (Marenya and Barrett, 2007; Okoba and De Graaff, 2005), which corresponds with many of our respondents citing the high cost of hiring labour as a challenge to establishing and maintaining terraces.

From the above, it may be concluded that land fragmentation, aging farmers and restricted labour-

hiring ability interact to limit incentive and potential for SMP implementation. This has significant implications for potential soil degradation in the future.

We also investigated the influence of gender on the factors that we explored, such as access to extension and financing for SMPs. A study on gender and soil conservation practices in Kenya found that male headed households are more likely to implement soil conservation practices compared to female headed households, due to differences in access to information and credit (Willy and Holm-Müller, 2013). Women farmers in Kenya are also said to have limited power in farm decision-making (Alila and Atieno, 2006). These concur with statements from our key informant interviews that men are more likely to make decisions in the household, and that women have less access to training.

However, our questionnaires and RFMs show that women are actually largely included in decision-making. The conflicting findings may be due to the sensitivity of the question as female farmers may have exaggerated and responded that they do more decision-making than they actually do. Likewise, men may be reluctant to admit if the women do more decision-making than them. Our planned FGD with only women was supposed to deal with this as a method that is better suited for treating sensitive issues, but unfortunately the FGD with women did not take place.

In our questionnaire results, 52% of the respondents are female; in the whole of Thuti sublocation, the percentage of women is estimated to be 54%. If women's access to knowledge is lower than men's, and yet they are still the ones to carry out soil management practices, this may have considerable implications for future soil fertility if targeting women for agricultural training is not improved.

We identify multiple levels of challenges involving extension, which affect both knowledge and ability of farmers to implement SMPs. First of all, some of our informants were not aware of the availability of extension services on request. The limited resources that the one AEO has to support an immense number of households is likely a major reason for this. Owuor et al. (2009) comment on the Nyeri South district agricultural office's lack of staff, and the Ministry of Agriculture's practice of cutting budgets of the office with little communication, which leaves the office "no choice" but to reduce its planned activities. This includes the reduction of individual farm visits,

which farmers in Nyeri South viewed as valuable (Owuor et al., 2009). This corresponds with some of our informants attributing their lack of AEO contact to the absence of AEO visits in recent years.

Furthermore, our findings suggest that those who are aware of extension services may have restricted access to the AEO due to factors such as old age and gender; those who do have access may also face financial and land restrictions in implementing recommended SMPs, despite their awareness of the appropriate recommendations. Therefore, merely increasing government investment in extension services may not be sufficient in ensuring that extension services reach all farmers who need them; the various factors that may prevent farmers from benefiting from extension need to be considered in implementing extension support policies.

Effects of SMP decisions on soil fertility

In the Ministry of Agriculture farming handbook, Jaetzold et al. (2006) describes the soils in the Central Province as nutrient-depleted "due to permanent cultivation and almost no return to the shambas", and the resulting halved maize yields compared to 1977 "in spite of higher inputs now". However, our measurements of soil on maize plots suggest that the soils are, in fact, not severely degraded, and even possibly somewhat fertile, likely due to the widespread use of manure and to some extent green manure, which return nutrients to the shambas. Our soil fertility evaluation seems to correspond to the majority of the surveyed farmers' perceptions of their soils as "somewhat degraded" or "fertile"; only 14% of the farmers surveyed perceived their soils as very degraded. These perceptions were not specific to the maize plot, however, and therefore may not be the best comparison.

If our soil testing results from the sampled plots are representative of the maize plot soils in the village, they may be an indicator of the effectiveness of their past and current SMPs. That the testing did not indicate very degraded soils was somewhat surprising, given past studies describing the problem of declining soil fertility and nutrient depletion in Kenya and the Central highlands (Bett et al., 2007; Jaetzold et al., 2006; Omamo et al., 2002), and given the limiting factors discussed earlier.

The relative fertility of the sampled soils may be an illustration of the prioritized investment in soil fertility management. When questionnaire participants were asked what they do to their soils to

improve yields and conserve soil, they focused mainly on manure and fertilizer application. Okoba and De Graaff (2005) found that a large proportion of poor farmers in the Central highlands used only manure to improve soil fertility; this corresponds to our findings that manure is a widely used soil fertility management measure, partly because it is a relatively cheaper input.

In the survey, only around 20% of the participants mentioned soil conservation practices such as terraces, grass strips and mulching. However, terraces were observed on a majority of the farms, and we sometimes found grass strips and mulching on farms that did not mention their implementation in the survey. When asked specifically about soil conservation, it is apparent that the farmers are knowledgeable about soil conservation, with participants of the Ranking PRA expressing their views of the advantages and disadvantages of different practices, and with the majority of the RFM participants stating that they use soil erosion prevention methods. There seems to be a discrepancy between the survey results, which suggest a relatively low use of conservation practices when compared to nutrient inputs, and the PRA and observations, which suggest farmers' actual knowledge and widespread use of conservation practices. This may reflect the lower priority and attention given to soil conservation, when farmers with limited resources are considering SMPs. One example cited by the AC and CoE is that terraces are not being maintained due to limited funding and labour; this was also something we observed.

The lower priority placed on soil conservation when compared to soil fertility management is likely to have implications. Although the current conservation practices seem effective in controlling soil erosion, if current conservation structures are not well-maintained and there is little investment in additional conservation, the farmland, much of which is already prone to soil erosion because of its steepness, is prone to increasingly severe erosion in the future.

Recommendations

It is difficult to give practical recommendations on improving farmers' practices because we are aware of the restrictions they face, especially their limited ability to invest. Policy recommendations should be made keeping these limiting factors in mind. They should also keep in mind that with restricted resources, farmers have to split their investment between soil and other priorities also important for their livelihoods. One possible recommendation that requires little additional investment can be choosing crops and practices that have multiple purposes, such as planting trees

on cropland for soil conservation and firewood, using grass strips for soil conservation and fodder as well as planting beans that function as a food crop and increase soil fertility through nitrogen fixation.

A suggestion that could improve knowledge sharing within the community would be to encourage peer-training, where few farmers are trained by the AEO to train others. The training should deliberately target household decision-makers, regardless of gender. The formation of support groups or organizations that focus on farming could also be a way to improve knowledge sharing among farmers and increase access to AEO. Community farming where inputs and outputs are shared between collaborating farmers would be a way to bypass the challenges of fragmented land. Directed at the Ministry of Agriculture, we identify a need to improve the logistics related to accessing subsidized fertilizer.

Conclusion

Our study identified numerous factors that influence each farmer's decision-making process regarding soil management practices. These factors also point to challenges farmers face when implementing soil management practices.

One key challenge identified is that some farmers in Thuti village lack awareness and access to agricultural extension provided by the Government of Kenya. The limited access to extension may prevent farmers from following recommendations fully. We found insufficient data to conclude whether women are less likely to get access to the agricultural extension officer, and identify this as an important area for future investigation.

An additional challenge is the restrictions farmers have to implement recommended soil management practices, even when they have access to knowledge. These restrictions can be of a financial nature and prevent farmers from getting sufficient manure and fertilizers for their soils. Restrictions can also be limited ability to hire labour, which is a challenge for farmers when implementing physically demanding soil management practices.

Land fragmentation is a challenge found to pose confinements on farmers' options for choosing farming practices. It is found to be the cause of widespread intercropping in Thuti village, which may have negative effect on soil fertility and yields if done with crops that compete for soil nutrients. Likewise, the ability to perform soil fertility enhancing practices like crop rotation and fallowing diminishes when land is scarce. Land fragmentation is also found to negatively affect the attitudes of the younger generation in the village towards farming. Their loss of interest in the agricultural sector and preference for work in urban areas further decreases the availability of labour in the village for soil management investments.

Soil analysis reveals fertility levels on selected maize plots that are higher than those in sources describing the state of soil degradation in the area. This may indicate that despite the various challenges that farmers face in implementing soil management practices, their current practices, especially manure, have been somewhat successful in contributing to a soil quality suitable for agricultural production.

References

Alila, P.O., Atieno, R., 2006. Agricultural policy in Kenya: Issues and processes, in: A Paper for the Future Agricultures Consortium Workshop, Institute of Development Studies. pp. 20–22.

Andersson, E., Gabrielsson, S., 2012. "Because of poverty, we had to come together": collective action for improved food security in rural Kenya and Uganda. Int. J. Agric. Sustain. 10, 245–262. doi:10.1080/14735903.2012.666029

Arshad, M.A., Lowery, B., Grossmann, B., 1996. Physical tests for monitoring soil quality. Soil Sci. Soc. Am. Spec. Publ. 49, 123–142.

Askin, T., Özdemir, N., 2003. Soil Bulk density as related to soil particle size distribution and organic matter content.

Bekele, W., Drake, L., 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. Ecol. Econ. 46, 437–451. doi:10.1016/S0921-8009(03)00166-6

Bett, E., Freyer, B., Leonhartsberger, P., 2007. The Potential Role of Organic Soil Fertility Management in the Kenya Highlands.

Black, C.A., 1965. Methods of Soil. American Society of Agronomy, Analysis Part 1 9.

Blair, G.J., Lefroy, R.D., Lisle, L., 1995. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. Crop Pasture Sci. 46, 1459–1466.

Blake, G.R., Hartge, K.H., n.d. Bulk density, in: Methods of Soil Analysis Part 1.2. Madison, WL.

Blanco, H, Lal R., 2010. Soil and water conservation. Principles of Soil Conservation and Management.

Blume, H.P., n.d. Handbuch des Bodenschutzes: Bodenökologie und belastung; vorbeugende und abwehrende Schutzmaßnahme. Wiley-VCH-Verl. 4.

Central Bureau of Statistics, 2007. Geographic Dimensions of Well-Being in Kenya [WWW Document]. Scribd. URL http://www.scribd.com/doc/2224390/geographic-Dimensions-of-WellBeing-in-Kenya (accessed 2.20.14).

Culman, S.W., Snapp, S.S., Freeman, M.A., Schipanski, M.E., Beniston, J., Lal, R., Drinkwater, L.E., Franzluebbers, A.J., Glover, J.D., Grandy, A.S., Lee, J., Six, J., Maul, J.E., Mirksy, S.B., Spargo, J.T., Wander, M.M., 2012. Permanganate Oxidizable Carbon Reflects a Processed Soil Fraction that is Sensitive to Management. Soil Sci. Soc. Am. J. 76, 494. doi:10.2136/sssaj2011.0286

Dunger, W., Fiedler, H.J., 1997. Methoden der Bodenbiologie, 2nd ed. Gustav Fischer, Jena.

Ekbom, A., Alem, Y., Sterner, T., 2013. Integrating soil science into agricultural production frontiers. Environ. Dev. Econ. 18, 291–308. doi:10.1017/S1355770X13000089

Ekbom, A., Knutsson, P., Ovuka, M., 2001. Is sustainable development based on agriculture attainable in Kenya? A multidisciplinary case study of Murang'a district. Land Degrad. Dev. 12, 435–447. doi:10.1002/ldr.460

FAO, 2001. Lecture notes on the major soil of the world. World soil resources reports.

Fischer, E., Qaim, M., 2012. Gender, agricultural commercialization, and collective action in Kenya. Food Secur. 4, 441–453.

Gachene, C.K.K., Kimaru, G., 2004. Soil fertility and land productivity. A guide for extension workers in the eastern Africa region. RELMA Technical Handbook Series 30. Nairobi, Kenya ….

Gezon, L., 1996. Additional Conference Abstracts. Popul. Environ. 18.

Glendinning, J.S., 2000. Australian soil fertility manual. Fertiliser Industry Australia and CSIRO.

Guto, S.N., de Ridder, N., Giller, K.E., Pypers, P., Vanlauwe, B., 2012. Minimum tillage and vegetative barrier effects on crop yields in relation to soil water content in the Central Kenya highlands. Field Crops Res. 132, 129–138. doi:10.1016/j.fcr.2011.10.014

Hilhorst, T., Muchena, 2000. Nutrients on the move. Soil fertility dynamics in African farming system. International Institute for Environment and development.

IIRR and ACT, 2005. Conservation Agriculture: A Manual for Farmers and Extension Workers in Africa. International Institute of Rural Reconstruction, Nairobi; African Conservation Tillage Network, Harare.
Islam, K.R., Weil, R.R., 2000. Soil quality indicator properties in mid-Atlantic soils as influenced by conservation management. J. Soil and Water Conserv. 55, 69–78.
Jaetzold, R., Schmidt, H., Hornetz, B., Shisanya, C., 2006. Farm Management Handbook of Kenya, Subpart B2, Central Province 516.
Kabubo-Mariara, J., 2007. Land conservation and tenure security in Kenya: Boserup's hypothesis revisited. Ecol. Econ. 64, 25–35. doi:10.1016/j.ecolecon.2007.06.007
Kabubo-Mariara, J., Linderhof, V., Kruseman, G., Atieno, R., Mwabu, G., 2006. Household welfare, investment in soil and water conservation and tenure security: Evidence from Kenya. Poverty Reduct. Environ. Manag. PREM Work. Pap. 06–06.
Kennedy, A.C., Papendick, R.I., 1995. Microbial characteristics of soil quality. J. Soil and Water Conserv. 50, 243–248.
Kiome, R., Stocking, M., 1995. Rationality of farmer perception of soil erosion-the effectiveness of soil conservation in semi-arid Kenya. Global Environmental Change 281–295.
Kjedahl, J., 1883. Neue Methoden zur Bestimmung des Stickstoffs in organischen Körpern. Zeitschrift für Analytische Chemie 366–382.
Mackenzie, F., 1986. Local initiatives and national policy: gender and agricultural change in Murang'a District, Kenya. Can. J. Afr. Stud. 377–401.
Mackenzie, F., 1989. Land and Territory: The Interface between Two Systems of Land Tenure, Murang'a District, Kenya. Afr. J. Int. Afr. Inst. 59, 91. doi:10.2307/1160765
Mairura, F.S., Mugendi, D.N., Mwanje, J.I., Ramisch, J.J., Mbugua, P.K., Chianu, J.N., 2008. Scientific evaluation of smallholder land use knowledge in Central Kenya. Land Degrad. Dev. 19, 77–90. doi:10.1002/ldr.815
Marenya, P.P., Barrett, C.B., 2007. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. Food Policy 32, 515–536. doi:10.1016/j.foodpol.2006.10.002
Murage, E.W., Karanja, N.K., Smithson, P.C., Woomer, P.L., 2000. Diagnostic indicators of soil quality in productive and non-productive smallholders' fields of Kenya's Central Highlands. Agric. Ecosyst. Environ. 79, 1–8.
Ngome, A.F., Becker, M., Mtei, K.M., Mussgnug, F., 2011. Fertility management for maize cultivation in some soils of Western Kenya. Soil Tillage Res. 117, 69–75. doi:10.1016/j.still.2011.08.010
Odendo, M., Obare, G., Salasya, B., 2010. Farmers' perceptions and knowledge of soil fertility degradation in two contrasting sites in western Kenya. Land Degrad. Dev. 21, 557–564. doi:10.1002/ldr.996
Ojano, F.F., Ogendo, R.B., 1988. A study in physical and human geography 228.
Okoba, B.O., De Graaff, J., 2005. Farmers' knowledge and perceptions of soil erosion and conservation measures in the Central Highlands, Kenya. Land Degrad. Dev. 16, 475–487. doi:10.1002/ldr.678
Okoba, B.O., Sterk, G., 2006. Farmers' identification of erosion indicators and related erosion damage in the Central Highlands of Kenya. CATENA 65, 292–301. doi:10.1016/j.catena.2005.12.004
Omamo, S.W., Williams, J.C., Obare, G.A., Ndiwa, N.N., 2002. Soil fertility management on small farms in Africa: evidence from Nakuru District, Kenya. Food Policy 27, 159–170.
Oostendorp, R.H., Zaal, F., 2012. Land Acquisition and the Adoption of Soil and Water Conservation Techniques: A Duration Analysis for Kenya and The Philippines. World Dev. 40, 1240–1254. doi:10.1016/j.worlddev.2011.11.001
Owuor, B., Wambui, B., Argwings-Kodhek, G., Poulton, C., 2009. The Role and Performance of Ministry of Agriculture in Nyeri South District.
Pretty, J.N., Thompson, J., Kiara, J.K., 1995. Agricultural Regeneration in Kenya: The Catchment Approach to Soil and Water Conservation. Ambio 24, 7–15.

Scheffer, F., Schachtschabel, P., Blume, H.P., n.d. Lehrbuch der Bodenkunde, 15th ed. Spektrumm Akad. Verlg., Heidelberg.
Schuhmann, B., 2009. The causes of soil acidity. New South Wales Acid Soil Action Program, Acid Soil Management.
Stephens, E.C., Nicholson, C.F., Brown, D.R., Parsons, D., Barrett, C.B., Lehmann, J., Mbugua, D., Ngoze, S., Pell, A.N., Riha, S.J., 2012. Modeling the impact of natural resource-based poverty traps on food security in Kenya: The Crops, Livestock and Soils in Smallholder Economic Systems (CLASSES) model. Food Secur. 4, 423–439. doi:10.1007/s12571-012-0176-1
Tittonell, P., Muriuki, A., Klapwijk, C.J., Shepherd, K.D., Coe, R., Vanlauwe, B., 2013. Soil Heterogeneity and Soil Fertility Gradients in Smallholder Farms of the East African Highlands. Soil Sci. Soc. Am. J. 77, 525. doi:10.2136/sssaj2012.0250
Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L., Coe, R., Vanlauwe, B., 2009. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa - A typology of smallholder farms. Agricultural Systems, 103 83–97.
Weil, R.R., Islam, K.R., Stine, M.A., Gruver, J.B., Samson-Liebig, S.E., 2003. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use. Am. J. Altern. Agric. 18, 3–17.
Wenner, C.G., 1989. Soil and water conservation in the farming area of Lesotho: a review and some proposal., in: Topics in Applied Resource Management in the Tropics. DISTL, Germany, pp. 57–86.
Westerberg, L.-O., Christiansson, C., 1999. Highlands in East Africa: Unstable Slopes, Unstable Environments? Ambio 28, 419–429.
Willy, D.K., Holm-Müller, K., 2013. Social influence and collective action effects on farm level soil conservation effort in rural Kenya. Ecol. Econ. 90, 94–103. doi:10.1016/j.ecolecon.2013.03.008
Zöbisch, M.A., 1983. Auswirkungen der Bewuchsdichte auf den Bodenabtrag und Maßnahmen zur Eindämung der Erosion auf Kleinbürgerlichen Weideflächen in Machakos Distrikt, Kenia. Dtsch. Bodenkundlichen Ges.

Appendices

Appendix A: Key informant semi-structured interview with government extension officer or head of village administration – Revised.

Introduction

- Habari and thank you very much for agreeing to meet with us
- Outline the scope of our study
- We have some questions about your village in general, but with special attention to soil fertility management practices and extension services

Introduction of informant

- What is your function in the village/community?
- Can you tell us more about extension services? E.g. number of officers, frequency of visits and trainings, training topics (In Thuti)

Village characteristics

- How big is the area of the village? How many people live in the village?
- Are there smaller communities or units within the village?
- Are there different ethnic groups within the village or are all villagers Kikuyu?
    - If there are different ethnic groups, how is this evident in the structure of the village?
    - Do most of the villagers speak Swahili? Which other languages exist?

Cropping systems and soil fertility (+ terminology)

- What kind of soils are present
    - What are the names of the different types of soils and how can we identify them?
- What kinds of crops are being produced in the village?
    - Local terminology
    - Cropping systems
- How well do farmers in Thuti village manage their farms/soil?
- Which soil fertility management practices are being used in the village? Which ones are the most common?
    - What are the local expressions of:
        - Agroforestry, terraces, intercropping, monocropping, mulching, inorganic fertilizers, organic fertilizers, compost, tillage (add more to the list)

Regulation and extension services

- What legislation exists regarding soil management and fertilizers?
    - How is this implemented and controlled?
    - How is information about this legislation distributed farmers in Thuti village?
- What are the recommended practices regarding soil fertility management?
    - Are the farmers following the recommended practices and legislation?
    - Is there any bad associations linked to government recommended soil fertility management e.g. from colonial time?
- Does land tenure affect the soil fertility management practices?
    - in relation to gender?

- Are there NGOs working on soil fertility management in the area?

Regulation, organisation, financial issues

- Are there any government recommended soil fertility management practices or extension programmes?
    - What are the local terms for these?
- How have farmers responded towards extension officers and government recommended soil fertility management practices? Is there any hostility? Why?
- What are the different kinds of land tenure we can find? E.g. Legal ownership/land title, rent, inheritance
    - Is the land managed communally?
    - How do you obtain land titles and do they hold any value?
- Do the farmers take up loans?
    - Do they use formal banks or informal arrangements?
    - What does the farmer present as collateral if taking a loan?
- Do the village farmers organize themselves - and how?
    - Is there a farmers' union within the village?
- Who is typically the head of household and is this person also responsible for farming - food crops/cash crops?

Village life:

- Are there different ethnic groups within the village or are all villagers Kikuyu?
    - If there are different ethnic groups, how is this evident in the structure of the village?
    - Do most of the villagers speak Swahili? Which other languages exist?
- When we are conducting interviews with local farmers and villagers is it impolite to ask about income, age and household relations?
- Do you use Swahili time or international time? (6 hours later?) 2 → 8 o'clock.
- When is the most appropriate time to interview the village farmers?
    - Is it okay to interview the farmers during Sundays and holidays?
- When will the farmers be at their houses? - When do they leave for work, when do they return and when would be the appropriate time for us to do interviews and questionnaires?
- Is there anything else that would be useful for us to know? E.g. customs, gender (walking around at night)

Time: Approximately 30-60 min.

Equipment: Interview guide, notebook, pen, recorder, camera

Considerations:

The Ministry of Agriculture officer based in Othaya may not be familiar with the village and the soil fertility management practices there. The interviewees' views and awareness of certain issues may be influenced by their position.

Appendix B: Introductory Questionnaires – Revised.

GPS-point: x:_____ y:_____ z:_____	**Interviewer:**
Note taker:	**Translator:**
Picture:	**Date and time: / / : :**

Introduction

We are students from University of Copenhagen and University of Nairobi and we are taking a course together on Sustainable Land Use and Natural Resource Management. We are interested in soils and soil management practices in Thuti village. That's why we would like to speak with the person who is responsible for the farming in your household. This will maybe take 20-30minutes and the results of the survey will be shared with in the community.

- **Introducing the different present Persons and their Functions**

Personal characteristics

1. Full name:_____

2. Age:_____

3. Male _____ or Female_____

4. Highest education level obtained:
a) Primary school_____ b) Secondary school_____
c) University_____ d) Other_____
g) None_____

(Marital status: (we are not asking the question, we will get the information from our guide))

a) Single_____ b) Married_____ c)Widowed_____ d) Divorced_____

5. Who makes decisions regarding farming practices?

_____

Household characteristics

6. Who else works on your farm?

_____

Farm Characteristics

7. How big is your farm, compared to the rest of the village (in acre)?
a) Small _____ b) Medium_____ c) Large_____

8. How steep are your fields, compared to the rest of the village?
a) Not/a little steep _____ b) Average steep _____ c) Very steep_____

9. Does your family owns the land?_____

- a) If you do not own your land, who does? _____
- b) If you own land, do you rent out any of your land? _____

10. How many years have you been working on your farm (approx.)? _____

11. Does your family own livestock? How many?
a) Cows_____ b) Goats_____ c) Chickens_____ d) Sheep_____ e)Other_____

Crops, soil fertility and management

13. How fertile are your soils?
a) Very degraded_____ b) Somewhat degraded_____ c) Fertile_____ d) Very fertile_____

14. What crops do you grow, and what kinds of soil do you grown them on (relatively/try to explain in an order from top to bottom of farm?

Crop/crop combination	Soils (Red/black/Texture)	Fertility (categories)	Steepness
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

14. What do you do to your soils in order to improve the yields/conserve the soils? (Note to interviewer: categorize)
1)
2)
3)

15. If you could do anything, what practice would you choose as the best practice for improving your soils/soil fertility?
_____

16. Where do you get your farming advice?
_____

17. Observations (e.g household assets):

_____

- Ask permission to take photos!
- Ask for the phonenumber!

Time: 20-30 minutes

Equipment: Questionnaire guide with coding procedure, paper for recording responses, pen, GPS, camera

Considerations:
As an introductory questionnaire, the questions and options will need to be simple to understand and translate. Standardized translations will need to be agreed on prior to administration. We will need to have a general understanding of the variety of cropping systems and SFMPs we may encounter, and we will need to obtain the corresponding terminology for crops and practices before the questionnaire. We are aware that there may be different people responsible for different cropping systems on the farm (e.g. food crops and cash crops). We will decide after the transect walk if we will choose to interview certain people, or all people responsible for crop management in the household. Depending on whether an interviewee speaks Swahili or Kikuyu, we may be limited in how many questionnaires we can administer concurrently.

Appendix C: PRA Session 3 (Resource flow mapping on farm scale) – Revised.

- Remember to note the classification of the farm, location and GPS waypoint.
- Observe characteristics inside the household and surrounding to find indicators of wealth that are not asked about (furniture, electronic devices, the state of the house etc)
- Ask permission to record interview

Before drawing:

Household head's characteristics/ farm details:

- What are the farm's affiliations? (village organisations, clan, networks)

Labour and responsibilities on the farm:

- Do you hire labour? (compare to questionnaire)
    - How many workers and for how many months? (specify for each person)
    - What are their responsibilities?
- How do you divide the farming responsibilities within the household?
- Do the other people working on the farm take part in decision making?

Income/wealth:

- What sources of income do you have?
    - Du you recieve money from remittences (from familymembes)?
    - Sell crops on the market?
    - Pension?
- Who pays for farm management investments? Fertilizer, tools, seeds etc?
- How do you transport inputs and outputs to and from your farm?
- What kind of agricultural equipment do you have access to/own?

Mapping on the big paper:

House(s) / hut(s), stalls/kraals, boundaries of the farm, fields/plots, grazing areas, paths, benchmarks, trees, bushes, fences etc.

Indicate on the map:

- Crop types grown now, in the preceding season (prepare symbols for crop types in advance).
    - Which are annual/ perennial crops?
- Which plots/fields are rented out or in?
- What and where are the more and less fertile soils on your land?
- What and where are the different soil types on your land (e.g. red/black soils – texture and colour)?
- How and where does you soils differ in terms of texture and colour?
- Where do you experience soil erosion?
- Where have you put in measures to control soil erosion?

Landuse history

- For our selected plot ask about land use history further back in time (duration to be determined)

Last season's crop production

- How much did you harvest from each plot/field? (local units)
- How much did you sell?

Draw the harvest as an arrow (where does the harvest go?).

Residues:

- Last season's crop residues – where do they go – and in which amounts? (fodder/litter/grazing/on farm/off farm)
- What happens to the household organic waste?

Note "internal flow" if last seasons residues are left on the same field.

Fertilisation (for each plot):

- What kind of fertiliser do you use – and how much?
- How much manure have you used in this season and where do you get it from?
- How much compost/green manure have you used this season where do you get it from?
- How much chemical fertilizer have you used in this season and where do you get it from (use EM)?
- If the participant uses manure:
    - Where and how do you store it (separating solids and liquids, protected from rain and sunlight)?
- Do you use ashes – or anything else?

For perennial crops ask the same, but over the last past 6 or 12 months

Management practices:

- Why are some soils more fertile than others? (If this is indicated on the map)
- Does the soil quality affect your choice of crops? How?
- Does the soil quality affect your soil management practices?
- Are any plots left fallow?
- What are the biggest problems/challenges you face as a farmer? (to see if soil status is a prioritized problem)
- Which management practice would you have liked to use if you could?
- What influences your ability to implement the practices that you prefer?
- Do you follow any extension programmes?
- Do you get advice from anyone regarding your soil fertility management (compare with questionnaire)?
    - What have you adopted
    - What has been effective?

Livestock:

- Do they graze on your land?
    - If not, what do you feed them?
- Do you sell manure?

Seasonal Calendar:

- What do you grow when and where?
  - Soil management practices for each crop
  - For each crop you grow, when do you plant, add manure, fertilizer, top dressing and when do you harvest ect.

Time: Approximately 2 hours

Equipment:
Interview guide, big paper to draw map, markers of different colours, pens, notebooks, camera, recorder, GPS, treats/snacks

Considerations:
We will decide on how far back in land use history we reach based on results of the introductory questionnaires, on what symbols to use for different crops, and if to colour-code.
We need to connect the information in this guide with the data we get from the questionnaire, so that we don't ask about the same thing twice.
We should consider if we need to include a seasonal calendar to this session.

Appendix D: Focus groups discussions – revised.

Introduction:

- Karibu and Habari
- Present ourselves
- The objective of our study
- Why you were chosen as participants
- Each person introduce themselves with name and a few characteristics about their farm

Questions:

Intercropping:

- What do you think is the best way to intercrop?
    - Which cops do you think are the best to intercrop?
    - What are the advantages of intercropping?
    - What are the disadvantages of intercropping?
    - How do you use beans (explain our reason for this question: beans function as a legume – adds nitrogen to the soil)

Conservation:

- What are the easiest soil conservation structures to establish and maintain?
    - And what are the hardest/more difficult
        - And why?
            - Ex. Grass strips, terraces, trenches, agroforestry, mulching ect.

Youth:

- Why do you think the younger population is moving away from the area?
- What attracts some to stay?
- What are the challenges they face?

Challenges:

- As a woman/man what challenges do you face as a farmer?
- If you could access extra funding what would you prioritise (use is for)?

AEO:

- Do you know of the AEO located in Karima ward?
    - Do you use or contact him?
        - If yes – do you have an on going contact?
        - If no – why not?

Time: *Approximately 1 hour.*

Equipment*:* Interview guide, notebooks, pens, recorder, camera, tea, treats/snacks

Considerations:
We should be careful not to ask leading questions that will phrase gender as a significant challenge in soil fertility management. We should also be aware of the biases of group dynamics and personal relations between the participants. Translating during the discussion is a big challenge, because this will break up the flow of the discussion. Since this is our last method, questions may need adjustment according to our findings throughout our field work.

Possible categorization of factors:
Social factors: social networks (sources of recommended practices), access to information and resources (e.g. inputs, labour)
Socioeconomic factors: wealth (indicators of wealth, sources of income, financial assets, livestock, livelihood diversification), household composition (age, education, skills, knowledge, health) and labour availability/accessibility; ethnicity, religion, political party affiliation,
Biophysical challenges: Soil fertility - current and past.

Appendix E: Table of applied methods and data obtained

Applied methods	Number of samples/Participants	Data obtained
PRA Session 1: Transectwalk	1	Overview of the area, farming systems and practices, soil types, village structures
Key Informant Interview 1	2	Village and family structure, farming practices and difficulties,
PRA Wealth Mapping	1	wealth categories within the village
Questionnaire survey	21	Perceptions, farming practices, household composition,livestock, characteristics for selecting participants for RFM and other methods
PRA Session 2: Ranking exercise	6	Perception of best, second best and worst practices and reasons
PRA Session 3: Resource Flow Mapping	6	farming practices, preferred practices, resources flows within the farm, responsibilities within the farm
PRA Session 3: Seasonal Calendar	6	Maize plot variation within a year, information about soil preparation, planting, weeding, fertilizer application and harvest
Soil Sampling: chemical analysis	24	pH, permanganate oxidizabble Carbon, Total C and N
Soil Sampling: Bulk density	36	Bulk density
Key Informant Interview 2: Agricultral extension officer	1	farming practices, village compostion, farming recommendation
Key Informant Interview 3: District agricultural officer	1	farming practices and recommendations
PRA Session 4: Focus Group Discussion	7	youth behaviour, additional knowledge about farming practices
GPS		Outline of the village, mark points for the questionnaires and RFM households, measuring farm and plot size

Appendix F: Soil Sampling and RFM Results (seasonal calendar)

RFM	Top/Bottom	pH	Temperature (°C)	MnoxC (mg/kg)	Dry soil colour (Munsel)
1	T	5,31	23,3	567	5YR 4/3
1	B	6	22,2	661,5	5YR 4/4
2	T	6,98	22,4	661,5	5YR 4/4
2	B	7,3	22,7	472,5	5YR 4/4
3	T	5,69	22,1	378	5YR 4/4
3	B	5,12	22,1	378	5YR 4/4
4	T	5,72	22,3	283,5	7.5YR 4/4
4	B	5,79	22	378	7.5YR 4/4
5	T	5,26	22,2	283,5	5YR 4/4
5	B	5,6	22,1	472,5	5YR 4/4
6	T	6,1	22,8	567	5YR 3/4
6	B	5,91	21,8	472,5	5YR 3/4

RFM	Top/Bottom	Bulk density (g/cm^3)	N%	C%	C/N
1	T	0,897	0,213	1,911	8,976
1	B	0,788	0,184	1,695	9,205
2	T	0,820	0,234	2,197	9,397
2	B	0,898	0,214	2,019	9,444
3	T	0,927	0,224	2,053	9,184
3	B	0,950	0,220	1,986	9,038
4	T	1,010	0,172	1,561	9,067
4	B	1,020	0,178	1,795	10,115
5	T	1,025	0,184	1,656	9,011
5	B	1,015	0,199	1,905	9,582
6	T	0,978	0,236	2,099	8,894
6	B	0,977	0,244	2,182	8,943

RFM/ Q	1/ Q7 (Gitahi)	2/ Q19 (Susan)	3/ Q12 (Wilfred)	4/ Q1 (Magareth)	5/ Q3 (Lukas)	6/ Q18 (Josiah)
farm size:	0.2512	0.3344 acre	0.959	1.3237 acre	0.6130 acre	2.85 acre
plot size:	0.0431	0.071	0.0425	0.1346	0.0487	0.0349
Weather:	sunny (rainy night before)	sunny	sunny	PC	PC	PC
Current Vegetation:	Maize intercropped with potatoes and cassave	Maize, intercropped with Amaranthus, Kales(1) Pumpkin (2)	Maize, Kale	Maize (2-3 pumpkins)	Maize	Maize intercropped with beans(just harvested), small potatoes
Elevation (m):	1857	1784	1846	1706	1701	1784
Slope (%):	11,6	11	11	3	8,5	21
Physiographie:	Terrace	Terrace/ Upland	Terrace with slight slope	Upland	Upland	Terrace with slope
Landscape Position:	Mid-slope, VS	Mid-Slope, VS	upper Slope	Footslope/ LS-straight	Footslope/flat	Mid-Slope
Land-use classification:		SH, medium gradient hill	SH	LP	LP	SH
Land use classification:	AA4	AA4	AA4	AA4	AA4	AA4
Horizon Colour:						
Ap	10R 3/3	2.5 YR 3/3	10R 4/3	5YR 4/3	2.5YR 4/3	10R 3/3
B	2.5YR 3/4	2.5 YR 3/4	10R 3/4	5YR 3/4	5YR 4/4	10R 3/4
Texture:						
Ap	silty clay loam	clay loam	loam	clay loam	silty clay loam	clay loam
B	clay loam	silty loam	silty clay	silty clay	silty clay loam	silty clay
Structure type:						
Ap	massive coherent	massive coherent	massive coherent	massive coherent	massive coherent	massive coherent
B	massive coherent	massive coherent	massive coherent	massive coherent	massive coherent	massive coherent
Pores:						
Ap	very fine/common	very fine/ common		very fine/common	very fine/common	
B	very fine/common	fine/ few		very fine/common	fine/common	
Biological activity:						
Ap	few	few	few	few	few	few
B	few	none	common	few	few	none
Stickiness:	ST	ST	SST	SST	ST	SST
Plasticity:	SPL	PL	very plastic	PL	SPL	PL

Seasonal calendar

We compiled the seasonal calendars from the RFM sessions, focusing on the maize plots. It shows the general pattern of field management over the year. The timing of different activities varies slightly between farmers, and depends partly on accessibility to inputs such as fertilizer (Table 5).

Table 5. General seasonal calendar of crop and soil management practices for maize plots. Source: Resource Flow Mapping (n=6).

Period	Management activities
January – March	**Maize and intercropped vegetables harvested** **Field preparation by tilling** **Manure applied fields before rainy reason**
March – April	**Maize planted before rainy season** **Fertilizer applied during planting** **Manure applied during planting (if not applied before)**
May – June	**Weeding and fertilizer top dressing**
September – October	**Maize and intercropped vegetables harvested** **Manure applied before rainy season**
October – November	**Field preparation by tilling** **Maize planted before rainy season**

Tilling is done with a hoe, and planting is done by hand. Manure application technique differs between farmers; some mix manure into the fields, while others add manure into planting holes. Most of the farmers add manure directly before a rainy season. In addition to manure, some of the farmers apply inorganic fertilizer, such as CAN, DAP, NPK and urea. These are applied by hand, and can be applied during the planting season and as top dressing later in the growing

season. Weeding is done by hand and with a hoe. During labour-intensive periods, such as field preparation or pre-rainy season planting, some farmers hire additional labour.

Appendix G: Synopsis

What factors influence farmers' decisions-making regarding soil fertility management in Thuti village, Nyeri South District, Kenya and how do their decisions affect soil fertility?

Synopsis

21. 02. 2014

Authors:
Tanja Lübbers
Pin Pravalprukskul
Anne Damgaard Møller
Pernille Spangsberg Nielsen

Table of Contents

Introduction

As a high agricultural potential area with fertile soil types and favourable rainfall conditions, the Central Highlands are important for Kenya's food production (Ekbom et al., 2013). Major land use changes with the introduction of coffee and tea as cash crops, combined with population pressure and subsequent land fragmentation, have greatly intensified agriculture in the area, which includes Nyeri district. The agricultural pressure has resulted in severe land degradation problems, threatening agricultural production of cash crops and food security in the area, especially since 82% of the population of Nyeri South District are dependent on agriculture as their main source of income (Owuor et al., 2009; Westerberg and Christiansson, 1999; Ministry of Agriculture, 2006).

Soil fertility is the ability of the soil to support the growth of plants on a sustained basis. It requires a balanced amount of nutrients and other important factors necessary for proper plant growth, such as soil moisture, pH, texture, organic matter and biological activity (Gachene and Kimaru, 2004). One of the major sources for declining soil fertility in the sloping highlands is soil erosion (Blanco & Lal, 2010; Zöbisch, 1983; Mati & Zöbisch, 1993). The loss of nutrients, topsoil, soil organic matter and rooting depth due to soil erosion are highly dependent on agricultural management. Although many studies in Kenya have shown that farmers are aware of soil fertility decline due to agricultural intensification and environmental factors, not much adoption of soil fertility management practices (SFMPs) has been shown (Kiome and Stocking, 1995; Odendo et al., 2010; Okoba and De Graaff, 2005; Wenner, 1989).

To identify SFMPs that are both effective and feasible, it is crucial to evaluate the success of different practices in improving soil fertility, as well as understand the factors that affect a farmer's choice of practice. In doing so, key challenges to effective soil fertility management can be brought to light, and concrete steps can be taken to target soil degradation.

There are many studies evaluating the effects of SFMPs on soil fertility in Kenya (Guto et al., 2012; Kabubo-Mariara et al., 2006; Ngome et al., 2011). Numerous studies have also been conducted on the determinants of a farmer's adoption of SFMPs, especially in areas with increasingly degraded soils such as the Central Highlands. Such determinants include economic factors, such as assets, income, farm size, access to labour, and access to credit (Marenya and Barrett, 2007; Omamo et al., 2002); institutional factors, such as land tenure security (Kabubo-Mariara, 2007; Mackenzie, 1989; Oostendorp and Zaal, 2012) and extension (Pretty et al., 1995), social factors, such as the influence of networks and collective action (Andersson and Gabrielsson, 2012; Fischer and Qaim, 2012; Willy and Holm-Müller, 2013); and individual characteristics, such as gender, education and age (Bekele and Drake, 2003; Fischer and Qaim, 2012; Gezon, 1996; Mackenzie, 1989, 1986; Marenya and Barrett, 2007; Omamo et al., 2002). Gender has been a particular area of research focus, as farming in the Central Highlands is mostly done by women (Ekbom et al., 2013). Studies have also examined the effects of farmers' perceptions of soil fertility on their behaviour in adopting SFMPs (Mairura et al., 2008; Murage et al., 2000; Odendo et al., 2010; Okoba and De Graaff, 2005; Okoba and Sterk, 2006; Tittonell et al., 2013).

A large number of the studies mentioned above utilize data from large-scale surveys to model regressions relating determinants of interest with the adoption or extent of use of certain management practices (Bekele and Drake, 2003; Omamo et al., 2002; Oostendorp and Zaal, 2012). However, few studies incorporate qualitative methods to delve into how multiple determinants influence different aspects of the decision-making process. We hypothesize that certain determinants may affect the perceptions of what constitutes an effective SFMP, while other determinants may prevent or enable successful implementation of a practice.

There also seems to be a lack of studies that integrate farmers' soil fertility management decision-making processes with the actual effects of their decisions on soil fertility; studies that do integrate the two have tended to utilize models (Ekbom et al., 2013; Stephens et al., 2012). In addition, there is a distinct lack of research on farmers' soil fertility management decisions in Nyeri district compared to neighbouring districts in the Central Highlands, particularly Murang'a district, despite the relative poverty of Nyeri compared to the rest of the Central Province (Central Bureau of Statistics, 2007).

This study aims to explore how factors influencing perceptions and implementation of effective SFMPs affect decisions made by farmers, and evaluate the implications for soil fertility. We focus on farm-level decision-making processes, integrating in-depth qualitative analysis of factors examined in previous studies with quantitative measurements of the effects of the resulting practices.

We aim to answer the following research question:

What factors influence farmers' decision-making regarding soil fertility management practices in Thuti Village, Nyeri South District, Kenya, and how do their decisions affect soil fertility?

Methodology

Outline

In this chapter we will describe the different methods used to obtain our empirical data. We will use methods such as key informant interviews, participatory rural appraisals (PRAs), focus group discussions, questionnaires, and soil sampling. In addition, any relevant observations during the field study will be recorded for further analysis. Special considerations to be taken into account and guides for each method are described in Appendices D-K. Once we meet our counterparts from the University of Nairobi (UON), we will exchange ideas and goals and develop a common understanding of the study. As communication with them has been limited, division of responsibilities will be decided during our fieldwork. Upon arrival to the village we will seek the village leader to ask permission to conduct our research.

Before each activity, we will have a meeting with the whole group to coordinate practicalities and make sure everyone has the same understanding of our activities. Likewise, we will do an evaluation meeting after each method to log our activities, share important findings and make possible changes for further activities.

Key informant interviews

a) Interview with village guide and translator

Purpose:

- To understand the composition of the village, and whether internal boundaries exist
- To be introduced to the different types of cropping systems, SFMPs and general perceptions towards these, and the status of soil degradation
- To learn about village dynamics and issues we should be concerned about
- To get to know our guide and translator and introduce them to the purpose of our research
- To learn local terminology for practices and soils

Informants*:* The village guide and/or translator

Research team members present: All

Procedure:
The interview is semi-structured (see Appendix D) and will be held in the beginning of our stay in Thuti village.
One facilitator and a translator for the facilitator will be appointed. The interview will be recorded if permission is given. This interview could take place at one of our host families' houses.

b) Interview with Ministry of Agriculture officer (from Othaya) or head of village

administration

Purpose:

- To learn about soil fertility regulations, government-recommended management practices and the extension system
- To learn the interviewee's perceptions of farmers' reception toward recommended practices, and the effectiveness of current practices
- To understand the composition of the village, and whether internal boundaries exist
- To learn about village dynamics and issues we should be concerned about
- To learn local terminology for practices and soils

Informants*:* Ministry of Agriculture officer (Othaya) and/or the head of village administration

Procedure:
The interview is semi-structured (see Appendix E) and will be held in the beginning of our stay in Thuti village.
One facilitator and a translator for the facilitator will be appointed. The interview will be recorded if permission is given. An appropriate location will be determined.

PRA Session 1: Transect walk

Purpose:

- To gain an overview of the topography, different cropping systems and farming sites
- To observe examples of different SFMPs, soil fertility conditions, and challenges faced in soil management
- To identify the spatial boundaries for further selection of informants and study sites
- To learn local terminology for practices and soils
- To establish rapport and meet people

Expected outputs

- GPS measurement of our route (waypoints and tracks)
- Categories of cropping systems for farm stratification

Informants: 1-3 farmers with extensive knowledge about the variety of cropping systems, SFMPs and soil fertility in the area

Sampling: Our village guide will suggest informants based on the criteria above

Group members present: All

Procedure
First we will state the objective of the transect walk clearly to the informants. During the walk we

will do an informal interview (see Appendix F). The informants will chose a route, which we will map with GPS tracking. Interesting examples of conservation practices will be marked as waypoints. At the end we will ask the informants to take us around the borders of the community if they feel they can identify one. This will be tracked with GPS.

Introductory questionnaires

Purpose:

- To obtain an overview of cropping systems and SFMPs, as well as household and farm characteristics
- To further define our study area, and identify participants for PRA sessions 2 and 3
- To meet a variety of farmers and establish rapport

Expected outputs:

- GPS waypoints of households interviewed
- Sampling pool of farms within an identified community boundary, with different cropping systems and SFMPs
- Photographs of farms for reference

Informants: The person responsible for crop management in the household, for 20-30 households

Sampling:

The boundary of sampling may be defined by the transect walk boundaries. Alternatively, a list of households in the village will be obtained from the village administration, and community subdivisions can be obtained from the knowledge of the households in which students will be living, or the guide and translator. The boundary drawn should contain farms with a variety of cropping systems and SFMPs. One sampling strategy could be to sample every other household along a road within the boundary, but the final strategy is not yet decided.

Group members present: All

Procedure:

Pre-testing will be conducted with a UON student in English, and with the guide or translator in both Swahili and Kikuyu, using the local terminology obtained from key-informant interviews. All questionnaire administrators will agree on standardized translations, and introductory and coding procedures. Pilot-testing will be carried out with the households with whom we are staying.

Each student from University of Copenhagen (UCPH) will pair up with a UON student, guide or translator. Each pair will approach a household and administer the questionnaire in the local language using the introductory questionnaire guide (Appendix G), and record the responses on a separate sheet in English, noting the corresponding local terminology for crops and practices. Any relevant observations regarding the household and farm will also be recorded. If permission is granted, photographs of the farms will be taken, and the photo identification (camera, date

and time) will be noted on the questionnaire response sheet. One student who is not administering the questionnaire will record the GPS waypoint of each farm, and the coordinates will be noted.

PRA Session 2: Identification and ranking of management practices and factors that influence implementation

Purpose:

- To understand the farmers' perceptions of different SFMPs and the challenges to implement them.
- To observe possible power related dynamics (e.g. gender) in a collaborative situation

Expected outputs

- A list of SFMPs ranked according to how effective they are perceived to be by the farmers
- A ranked list of the factors that influence the implementation of effective management practices

Informants: Approximately 3 women and 3 men who are responsible for farming in their households

Sampling:

We aim to identify the participants from the pool of farms from the transect walk and the introductory questionnaire. Depending on patterns observed within the pool, we will decide whether to sample for maximum variation in wealth, cropping systems and management practices, or for participants who are similar in these aspects.

Group members present:

1 facilitator, at least 1 note taker, 2 translators (at least one for each), possibly 1 observer (social interactions, body language, etc.)

Procedure:

First the objectives of the session are clearly explained to the group and everyone in the room presents themselves. As an introduction to the exercise, they are encouraged to discuss indicators of soil fertility and how these relate to SFMPs.

The respondents will hereafter be asked to discuss and make a list of the SFMPs they know and choose symbols to represent each of them. These different SFMPs are first ranked individually by the participants according to how effective they think they are. Each participant will be asked to present their rankings and reasons for their choices. They will then discuss the rankings in a group and collaborate to make one list. Discussions will be translated as we go along.

Further, they are asked to discuss what they think are the criteria that influences implementation of these management practices. These criteria should be given symbols and ranked 1-X

according to how important they are in allowing implementation of the ranked SFMPs. The exact procedure of how to use symbols is yet to be decided. Throughout the whole session the facilitator should ask elaborating questions to understand *why* they rank as they do.

PRA Session 3: Resource flow mapping on farm scale

Purpose:

- To get a fundamental understanding of farmers' SFMPs and the reasons behind them
- To understand the farmers' perceptions of different SFMPs and the challenges to implementing them
- To identify plots for soil sampling

Expected output:

- A map of each farm with the flows in and out of the different plots.

Informants:
6 farmers who are heads of farming in their respective households.

Sampling strategy:
The farms will be identified from the introductory questionnaire stratified by the SFMPs applied: 3 farms using the most effective (according to the PRA sessions 2) and 3 farms lacking the use of these (or applying ineffective methods). Further, we have the following criteria:
All farms should have plots that are located on slopes and have similar biophysical conditions (e.g. same soil type). All farms should have the same type of cropping systems on the plots chosen for analysis (which will be decided). There should be at least one female-headed and one male-headed farming system.

Group members present:
1 facilitator (and note taker), 1 translator and 1 note taker

Procedure:
Sit down with the head of the household and have him/her map the farm area including all plots and features. The activities should be described and the inputs/outputs of each plot should be attempted to be quantified: seeds, chemical fertilizers, manure, crop residues, mulching, labour inputs, harvest yields (see Appendix I).
When the map is done, take a walk around the farm to verify the things on the map and add more details if necessary.

Soil Sampling

Purpose:

- Analyse the actual soil fertility of the different plots
- Evaluate the effectiveness of current practices on soil fertility

Procedure :

- Ask permission to take soil samples.
- 2 soil profiles per plot, one profile on the top of the slope and one at the bottom with characterization of the soil typical horizons, layers and depth
- Soil samples are taken in equal proportions (rings) from the topsoil within a depth of 20cm (depending on topsoil depth), from each plot 3x3 soil samples from the top-mid-bottom of the slope are taken.
- Analysis will be carried out according to FAO guide (Appendix K)

Group members present: 3-4 people

Focus group discussions

Purpose*:*

To observe or specify if there are differences between genders in terms of:

- Current SFMPs
- Perceptions regarding effective SFMPs, and factors affecting this
- Factors influencing farmers' implementation of effective SFMPs

Expected output:

An identification of the different challenges and incentives that affect men and women in their SFMPs. We expect that social relations and access to resources, especially for the women, are challenges.

Informants:

One focus group with 5-6 men and one with 5-6 women. The participants should all be responsible for the farming in their household.

Sampling Strategy:

Informants will be sampled from the introductory questionnaire pool. If this is not sufficient our guide will point us to relevant subjects (snow balling).

Group members present: 1 facilitator, at least 1 note taker, 2 translators (at least one for each), possibly 1 observer (social interactions, body language, etc.)

Procedure:

The groups are divided by gender. Thereafter the facilitator presents the general purpose of our research and the themes that we would like them to discuss (see Appendix J).

References

Alila, P.O., Atieno, R., 2006. Agricultural policy in Kenya: Issues and processes, in: A Paper for the Future Agricultures Consortium Workshop, Institute of Development Studies. pp. 20–22.

Andersson, E., Gabrielsson, S., 2012. "Because of poverty, we had to come together": collective action for improved food security in rural Kenya and Uganda. Int. J. Agric. Sustain. 10, 245–262. doi:10.1080/14735903.2012.666029

Arshad, M.A., Lowery, B., Grossmann, B., 1996. Physical tests for monitoring soil quality. Soil Sci. Soc. Am. Spec. Publ. 49, 123–142.

Askin, T., Özdemir, N., 2003. Soil Bulk density as related to soil particle size distribution and organic matter content.

Bekele, W., Drake, L., 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. Ecol. Econ. 46, 437–451. doi:10.1016/S0921-8009(03)00166-6

Bett, E., Freyer, B., Leonhartsberger, P., 2007. The Potential Role of Organic Soil Fertility Management in the Kenya Highlands.

Black, C.A., 1965. Methods of Soil. American Society of Agronomy, Analysis Part 1 9.

Blair, G.J., Lefroy, R.D., Lisle, L., 1995. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. Crop Pasture Sci. 46, 1459–1466.

Blake, G.R., Hartge, K.H., n.d. Bulk density, in: Methods of Soil Analysis Part 1.2. Madison, WL.

Blanco, H, Lal R., 2010. Soil and water conservation. Principles of Soil Conservation and Management.

Blume, H.P., n.d. Handbuch des Bodenschutzes: Bodenökologie und belastung; vorbeugende und abwehrende Schutzmaßnahme. Wiley-VCH-Verl. 4.

Central Bureau of Statistics, 2007. Geographic Dimensions of Well-Being in Kenya [WWW Document]. Scribd. URL http://www.scribd.com/doc/2224390/geographic-Dimensions-of-WellBeing-in-Kenya (accessed 2.20.14).

Culman, S.W., Snapp, S.S., Freeman, M.A., Schipanski, M.E., Beniston, J., Lal, R., Drinkwater, L.E., Franzluebbers, A.J., Glover, J.D., Grandy, A.S., Lee, J., Six, J., Maul, J.E., Mirksy, S.B., Spargo, J.T., Wander, M.M., 2012. Permanganate Oxidizable Carbon Reflects a Processed Soil Fraction that is Sensitive to Management. Soil Sci. Soc. Am. J. 76, 494. doi:10.2136/sssaj2011.0286

Dunger, W., Fiedler, H.J., 1997. Methoden der Bodenbiologie, 2nd ed. Gustav Fischer, Jena.

Ekbom, A., Alem, Y., Sterner, T., 2013. Integrating soil science into agricultural production frontiers. Environ. Dev. Econ. 18, 291–308. doi:10.1017/S1355770X13000089

Ekbom, A., Knutsson, P., Ovuka, M., 2001. Is sustainable development based on agriculture attainable in Kenya? A multidisciplinary case study of Murang'a district. Land Degrad. Dev. 12, 435–447. doi:10.1002/ldr.460

FAO, 2001. Lecture notes on the major soil of the world. World soil resources reports.

Fischer, E., Qaim, M., 2012. Gender, agricultural commercialization, and collective action in Kenya. Food Secur. 4, 441–453.

Gachene, C.K.K., Kimaru, G., 2004. Soil fertility and land productivity. A guide for extension workers in the eastern Africa region. RELMA Technical Handbook Series 30. Nairobi, Kenya ….

Gezon, L., 1996. Additional Conference Abstracts. Popul. Environ. 18.

Glendinning, J.S., 2000. Australian soil fertility manual. Fertiliser Industry Australia and CSIRO.

Guto, S.N., de Ridder, N., Giller, K.E., Pypers, P., Vanlauwe, B., 2012. Minimum tillage and vegetative barrier effects on crop yields in relation to soil water content in the Central Kenya highlands. Field Crops Res. 132, 129–138. doi:10.1016/j.fcr.2011.10.014
Hilhorst, T., Muchena, 2000. Nutrients on the move. Soil fertility dynamics in African farming system. International Institute for Environment and development.
IIRR and ACT, 2005. Conservation Agriculture: A Manual for Farmers and Extension Workers in Africa. International Institute of Rural Reconstruction, Nairobi; African Conservation Tillage Network, Harare.
Islam, K.R., Weil, R.R., 2000. Soil quality indicator properties in mid-Atlantic soils as influenced by conservation management. J. Soil and Water Conserv. 55, 69–78.
Jaetzold, R., Schmidt, H., Hornetz, B., Shisanya, C., 2006. Farm Management Handbook of Kenya, Subpart B2, Central Province 516.
Kabubo-Mariara, J., 2007. Land conservation and tenure security in Kenya: Boserup's hypothesis revisited. Ecol. Econ. 64, 25–35. doi:10.1016/j.ecolecon.2007.06.007
Kabubo-Mariara, J., Linderhof, V., Kruseman, G., Atieno, R., Mwabu, G., 2006. Household welfare, investment in soil and water conservation and tenure security: Evidence from Kenya. Poverty Reduct. Environ. Manag. PREM Work. Pap. 06–06.
Kennedy, A.C., Papendick, R.I., 1995. Microbial characteristics of soil quality. J. Soil and Water Conserv. 50, 243–248.
Kiome, R., Stocking, M., 1995. Rationality of farmer perception of soil erosion-the effectiveness of soil conservation in semi-arid Kenya. Global Environmental Change 281–295.
Kjedahl, J., 1883. Neue Methoden zur Bestimmung des Stickstoffs in organischen Körpern. Zeitschrift für Analytische Chemie 366–382.
Mackenzie, F., 1986. Local initiatives and national policy: gender and agricultural change in Murang'a District, Kenya. Can. J. Afr. Stud. 377–401.
Mackenzie, F., 1989. Land and Territory: The Interface between Two Systems of Land Tenure, Murang'a District, Kenya. Afr. J. Int. Afr. Inst. 59, 91. doi:10.2307/1160765
Mairura, F.S., Mugendi, D.N., Mwanje, J.I., Ramisch, J.J., Mbugua, P.K., Chianu, J.N., 2008. Scientific evaluation of smallholder land use knowledge in Central Kenya. Land Degrad. Dev. 19, 77–90. doi:10.1002/ldr.815
Marenya, P.P., Barrett, C.B., 2007. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. Food Policy 32, 515–536. doi:10.1016/j.foodpol.2006.10.002
Murage, E.W., Karanja, N.K., Smithson, P.C., Woomer, P.L., 2000. Diagnostic indicators of soil quality in productive and non-productive smallholders' fields of Kenya's Central Highlands. Agric. Ecosyst. Environ. 79, 1–8.
Ngome, A.F., Becker, M., Mtei, K.M., Mussgnug, F., 2011. Fertility management for maize cultivation in some soils of Western Kenya. Soil Tillage Res. 117, 69–75. doi:10.1016/j.still.2011.08.010
Odendo, M., Obare, G., Salasya, B., 2010. Farmers' perceptions and knowledge of soil fertility degradation in two contrasting sites in western Kenya. Land Degrad. Dev. 21, 557–564. doi:10.1002/ldr.996
Ojano, F.F., Ogendo, R.B., 1988. A study in physical and human geography 228.
Okoba, B.O., De Graaff, J., 2005. Farmers' knowledge and perceptions of soil erosion and conservation measures in the Central Highlands, Kenya. Land Degrad. Dev. 16, 475–487. doi:10.1002/ldr.678
Okoba, B.O., Sterk, G., 2006. Farmers' identification of erosion indicators and related erosion damage in the Central Highlands of Kenya. CATENA 65, 292–301. doi:10.1016/j.catena.2005.12.004
Omamo, S.W., Williams, J.C., Obare, G.A., Ndiwa, N.N., 2002. Soil fertility management on small farms in Africa: evidence from Nakuru District, Kenya. Food Policy 27, 159–170.

Oostendorp, R.H., Zaal, F., 2012. Land Acquisition and the Adoption of Soil and Water Conservation Techniques: A Duration Analysis for Kenya and The Philippines. World Dev. 40, 1240–1254. doi:10.1016/j.worlddev.2011.11.001
Owuor, B., Wambui, B., Argwings-Kodhek, G., Poulton, C., 2009. The Role and Performance of Ministry of Agriculture in Nyeri South District.
Pretty, J.N., Thompson, J., Kiara, J.K., 1995. Agricultural Regeneration in Kenya: The Catchment Approach to Soil and Water Conservation. Ambio 24, 7–15.
Scheffer, F., Schachtschabel, P., Blume, H.P., n.d. Lehrbuch der Bodenkunde, 15th ed. Spektrumm Akad. Verlg., Heidelberg.
Schuhmann, B., 2009. The causes of soil acidity. New South Wales Acid Soil Action Program, Acid Soil Management.
Stephens, E.C., Nicholson, C.F., Brown, D.R., Parsons, D., Barrett, C.B., Lehmann, J., Mbugua, D., Ngoze, S., Pell, A.N., Riha, S.J., 2012. Modeling the impact of natural resource-based poverty traps on food security in Kenya: The Crops, Livestock and Soils in Smallholder Economic Systems (CLASSES) model. Food Secur. 4, 423–439. doi:10.1007/s12571-012-0176-1
Tittonell, P., Muriuki, A., Klapwijk, C.J., Shepherd, K.D., Coe, R., Vanlauwe, B., 2013. Soil Heterogeneity and Soil Fertility Gradients in Smallholder Farms of the East African Highlands. Soil Sci. Soc. Am. J. 77, 525. doi:10.2136/sssaj2012.0250
Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L., Coe, R., Vanlauwe, B., 2009. The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa - A typology of smallholder farms. Agricultural Systems, 103 83–97.
Weil, R.R., Islam, K.R., Stine, M.A., Gruver, J.B., Samson-Liebig, S.E., 2003. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use. Am. J. Altern. Agric. 18, 3–17.
Wenner, C.G., 1989. Soil and water conservation in the farming area of Lesotho: a review and some proposal., in: Topics in Applied Resource Management in the Tropics. DISTL, Germany, pp. 57–86.
Westerberg, L.-O., Christiansson, C., 1999. Highlands in East Africa: Unstable Slopes, Unstable Environments? Ambio 28, 419–429.
Willy, D.K., Holm-Müller, K., 2013. Social influence and collective action effects on farm level soil conservation effort in rural Kenya. Ecol. Econ. 90, 94–103. doi:10.1016/j.ecolecon.2013.03.008
Zöbisch, M.A., 1983. Auswirkungen der Bewuchsdichte auf den Bodenabtrag und Maßnahmen zur Eindämung der Erosion auf Kleinbürgerlichen Weideflächen in Machakos Distrikt, Kenia. Dtsch. Bodenkundlichen Ges.

Appendices

Appendix A: Research Matrix

Research Question	Sub-questions	Sub-sub-questions	Data required	Methods	Equipment
1. What factors influence farmers' decision-making regarding SFMPs in Thuti Village, Nyeri South District, Kenya	**1.1 What are farmers' perceptions of different SFMPs?**	1.1.1 What SFMPs do farmers perceive as effective?	Overview of current SFMPs by different farmers. Local soil and crop terminology Overview of which methods are used in which locations and for which crops.	PRA Session 1 (Transect walk), PRA Session 2 (preference ranking), focus group discussions, key informant interviews, introductory questionnaire	Large pieces of paper - if not possible use nearby materials. Notebooks, pen, markers recorder, camera, GPS, interview-guide
		1.1.2 What are the factors that determine preference, and how?	Requirements for implementation of perceived appropriate practices, e.g. labour, capital, cattle, transport, knowledge/information Other influencing factors, e.g. extension recommendations, influence of past colonial history, past experience	PRA Session 2 (preference ranking), focus group discussions, key informant interviews	Large pieces of paper - if not possible use nearby materials. Notebook, pen, markers, interview-guide, recorder, GPS, camera
	1.2 What influences actual implementation of SFMPs?	1.2.1 What are the current SFMPs?	Current SFMPs, practices over the year/cropping seasons	PRA Session 3 (Resource Flow Mapping), focus group discussions, introductory questionnaire	Large pieces of paper - if not possible use nearby materials, recorder, interview guides, notebook, pen, GPS, camera
Research Question	**Sub-questions**	**Sub-sub-questions**	**Data required**	**Methods**	**Equipment**

		1.2.2 What are the challenges and incentives that farmers face when trying to implement their preferred practices?	Factors that influence farmer's implementation of preferred practices, e.g. gender, socio-economic challenges, biophysical challenges, social challenges	Focus group discussions, key informant interviews, observations	Notebook, pen, large pieces of paper - if not possible use nearby materials, recorder, interview-guide, GPS, camera
2. How do their decisions affect the soil fertility?	2.1 What are the actual effects of their current practices on soil fertility?		Measure indicators of soil fertility: soil erosion, physical factors (depth of topsoil, density, color), chemical factors (pH, SOM, total N, conductivity, Pox-C)] Where and what kinds of erosion can be observed? What is the local soil terminology?	Soil profile sampling, observations during Resource Flow mapping, transect walk, introductory questionnaire	Camera, Munsell colour chart, measuring tape, shovel, plastic bags for soil samples, shovel, sample ring kit, knife/machete
	2.2. What are the perceived effects of their current practices on soil fertility?		Perceptions of current soil fertility Perceptions of effects of practices on perceived soil fertility	PRA Session 3 (Resource Flow mapping)	GPS, notebook, pen, recorder
	2.3 How may past land use changes have affected the current soil fertility?		Different types of landuse in the past e.g. agroforestry, intercropping, legumes, shifting cultivation, mono cropping Past observations of soil fertility e.g. increase/decrease in soil erosion	PRA Session 3 (Resource Flow mapping), PRA Session 1 (Transect walk)	GPS, notebook, pen, large paper for mapping, camera, recorder

Appendix B: Timeline

Month	Feb	March										
Date	**28**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**
Getting settled													
Key informant interviews													
Transect walk (PRA session 1)													
Finalizing and pre-testing questionnaires													
Pilot-testing questionnaires													
Questionnaires													
Ranking exercise (PRA session 2)													
Preliminary analysis of questionnaires													
Resource flow mapping (PRA session 3)													
Soil sampling													
Focus group discussions													
Buffer													
Goodbye to families													

Special dates:
2nd March: Church
8th March: Half day
11th March: Feedback

Appendix C: Introduction to the field site

The environment of the field site

The village of Thuti where the fieldwork is carried out is located in the Nyeri South District of the Central Highlands of Kenya. Nyeri District is situated at an elevation of 1.100-2.400 m above sea level (Hilhorst & Muchena, 2000). The rainfall is bimodal with a long rain period from mid-March to the end of May and a short period from October to mid-December which supports the medium to long growing seasons of the cultivated crops in the area. The mean annual rainfall in the areas ranges between 1.200 and 2.000 mm (Hillhors & Muchena, 2000). January, February and September are dry months at the end of the growing seasons (Ovuka, 2000). Central areas of Kenya including the Nyeri District have a daily mean temperature of about 15°C (Ojany & Ogendo, 1988).

Approximately 1.023 households reside in the 6.8 km^2 area of Thuti, giving a high population density with over 600 people per km^2 (Ministry of Agriculture, 2006). Agriculture in the Nyeri district is the main source of livelihood for over 82% of its residents (Owuor et al., 2009). Thuti is located in the upper midland zones and the dominant agriculture elements in the district are coffee, tea and dairy products. Coffee is often intercropped with horticultural crops. The staple crops are maize and beans as well as a wide range of vegetables and fruits (Owuor et al., 2009; Ministry of Agriculture, 2006).

The most important soils in the Central Highlands are Andosols and Nitisols. These occur on volcanic steep slopes which are developed from volcanic rocks; these are weathered soils but more productive than most other red tropical soils. Andosols are black, porous, acidic soils with a good internal drainage. Their high permeability to water makes these soils relatively resistant to water erosion. They are fertile soils, easy to till, have good rootability and water storage properties; because of this they have a high potential for agricultural production. Nitisols are reddish-brown, well drained soils with more than 30 percent clay. They are among the most productive soils of the humid tropics, and because of the stable structure and the porous solum that permits deep rooting, these soils are quite resistant to erosion (FAO, 2001). Because of intensive agriculture in the Central Highlands, especially in areas with poor soil conservation methods, the soils are degrading, reducing fertility and increasing vulnerability to soil erosion (Westerberg & Christiansson, 1999).

History of soil fertility regulation

The problem of soil degradation has been acknowledged since colonial times, when soil and water conservation (SWC) programmes were introduced to increase soil fertility. SWC methods based on conventional agricultural science were brought in from abroad and forced upon the farmers regardless of their existing indigenous SWC practices (Pretty et al., 1995; Hilhorst & Muchena, 2000). The introduced practices included terracing, contour farming, tree planting on hill sides and destocking of herds in certain areas to decrease grassing (Hilhorst & Muchena, 2000; Ovuka, 1999). When the British lost control over the country in the early 1960's, the farmers soon abandoned the SWC practices, partly due to their negative associations from the enforcement of these methods. The problem of water and soil conservation became a politically

sensitive issue and was left without much attention for a decade resulting in widespread and severe land degradation (Ovuka, 1999). Subsequent SWC programs tried to address SWC issues taking participatory methods into account to include the farmers' own knowledge and experience. Nevertheless they were often short-lived and seldom have maintenance been adequate to sustain the positive immediate effects of the extension programmes (Pretty et al., 1995). The overall picture is thus still declining soil fertility and low level of adoption of SWC practices by farmers. Today the most common soil fertility management technologies practiced by farmers in Kenya are: the use of fertilizer and manure, erosion control measures, compost, mulching, crop rotation, intercropping and agroforestry (Bett et al., 2008; Gachene & Kimaru, 2003; Kimaru-Muchai et al., 2013)

Appendix D: Key informant semi-structured interview with guide and translator

Introduction

- Habari and nice to meet you, we are grateful for your assistance
- Outline scope of our study
- We have a lot of various questions about your society that we would like to ask you

Village characteristics

- How big is the area of the village? How many people live in the village?
- Are there smaller communities or units within the village?

Cropping systems and soil fertility (+terminology)

- What kinds of soils are present?
    - What are the names of the different types of soils and how can we identify them?
- What kinds of crops are being produced in the village?
    - Local terminology
    - Cropping systems
- Which soil fertility management practices are being used in the village? Which ones are the most common?
    - What are the local expressions of:
        - Agroforestry, terraces, intercropping, monocropping, mulching, inorganic fertilizers, organic fertilizers, compost, tillage (add to the list)

Regulation, organisation, financial issues

- Are there any government recommended soil fertility management practices or extension programmes?
    - What are the local terms for these?
- How have farmers responded towards extension officers and government recommended soil fertility management practices? Is there any hostility? Why?
- What are the different kinds of land tenure we can find? E.g. Legal ownership/land title, rent, inheritance
    - Is the land managed communally?
    - How do you obtain land titles and do they hold any value?
- Do the farmers take up loans?
    - Do they use formal banks or informal arrangements?
    - What does the farmer present as collateral if taking a loan?
- Do the village farmers organize themselves - and how?
    - Is there a farmers' union within the village?
- Who is typically the head of household and is this person also responsible for farming - food crops/cash crops?

Village life:

- Are there different ethnic groups within the village or are all villagers Kikuyu?
    - If there are different ethnic groups, how is this evident in the structure of the village?
    - Do most of the villagers speak Swahili? Which other languages exist?
- When we are conducting interviews with local farmers and villagers is it impolite to ask about income, age and household relations?
- Do you use Swahili time or international time? (6 hours later?) 2 → 8 o'clock.
- When is the most appropriate time to interview the village farmers?
    - Is it okay to interview the farmers during Sundays and holidays?
- When will the farmers be at their houses? - When do they leave for work, when do they return and when would be the appropriate time for us to do interviews and questionnaires?
- Is there anything else that would be useful for us to know? E.g. customs, gender (walking around at night)

Time: 1 hour.

Equipment: Interview guide, notebook, pen, recorder, camera.

Considerations:
There is a possibility that our guide does not have knowledge of all subjects we wish to cover. In that case, an interview with the head of village administration will supplement this interview.

Appendix E: Key informant semi-structured interview with government extension officer or head of village administration

Introduction

- Habari and thank you very much for agreeing to meet with us
- Outline the scope of our study
- We have some questions about your village in general, but with special attention to soil fertility management practices and extension services

Introduction of informant

- What is your function in the village/community?
- Can you tell us more about extension services? E.g. number of officers, frequency of visits and trainings, training topics (In Thuti)

Village characteristics

- How big is the area of the village? How many people live in the village?
- Are there smaller communities or units within the village?
- Are there different ethnic groups within the village or are all villagers Kikuyu?
    - If there are different ethnic groups, how is this evident in the structure of the village?
    - Do most of the villagers speak Swahili? Which other languages exist?

Cropping systems and soil fertility (+ terminology)

- What kind of soils are present
    - What are the names of the different types of soils and how can we identify them?
- What kinds of crops are being produced in the village?
    - Local terminology
    - Cropping systems
- How well do farmers in Thuti village manage their farms/soil?
- Which soil fertility management practices are being used in the village? Which ones are the most common?
    - What are the local expressions of:
        - Agroforestry, terraces, intercropping, monocropping, mulching, inorganic fertilizers, organic fertilizers, compost, tillage (add more to the list)

Regulation and extension services

- What legislation exists regarding soil management and fertilizers?
    - How is this implemented and controlled?
    - How is information about this legislation distributed farmers in Thuti village?
- What are the recommended practices regarding soil fertility management?
    - Are the farmers following the recommended practices and legislation?
    - Is there any bad associations linked to government recommended soil fertility management e.g. from colonial time?

- Does land tenure affect the soil fertility management practices?
    - in relation to gender?
- Are there NGOs working on soil fertility management in the area?

Time: Approximately 30-60 min.

Equipment: Interview guide, notebook, pen, recorder, camera

Considerations:
The Ministry of Agriculture officer based in Othaya may not be familiar with the village and the soil fertility management practices there. The interviewees' views and awareness of certain issues may be influenced by their position.

Appendix F: PRA Session 1 (Transect walk)

Introduction
Please show us: different cropping systems, farming sites on slopes, different soil fertility management practices, different soil fertility conditions, challenges faced in soil and crop management

Questions

- What are the crops and cropping systems we are passing by?
- What are the challenges the farmers' face regarding soil fertility?
- What are the reasons for soil degradation?
- Why do the management practices vary?
- Are there any extension programmes in the area?
    - Do people adopt recommendations from these?
- Ask about local terminology for the things we are seeing
- What is the community structure?
    - Are there smaller units within Thuti? Are there sub-borders to the village?
    - Please take us around the boarder of your community

Time: Approximately 1.5 hour

Equipment:
Interview guide, notebooks, pen, recorder, GPS, camera

Considerations:
We are aware that the selection of the area that we will be presented to relies on what our informants find relevant to our objective. It is therefore crucial to state the purpose clearly when the informants are invited. Furthermore, we do not know whether the informants will be able to identify their local community as a sub-division of the village. The range of practices we observe during the walk may be limited. If the guide cannot identify informants, we will ask the village leader or our host families to suggest some informants.

Appendix G: Introductory Questionnaires

GPS-point: x:_____ y:_____ z:_____	**Interviewer:**
Note taker:	**Translator:**
Picture:	**Date and time: / / : :**

Introduction

Personal characteristics

1. Full name:_____

2. Age:_____

3. Male _____ or Female_____

4. Highest education level obtained:
a) Primary school_____ b) Secondary school_____ c) Pre-university_____
d) University_____ e) Military School _____ f) Other_____
g) None_____

5. Marital status:
a) Single_____ b) Married_____ c)Widowed_____ d) Divorced_____

Household characteristics

6. How many people are there in your household (including living outside the village)? Please state their relationship to you, ages, genders, occupations, and whether they work on your family farm:

Relationship	Age	Gender	Occupation	Work on farm?
1) Yourself	_____	_____	_____	Yes __ No __
2) _____	_____	_____	_____	Yes __ No __
3) _____	_____	_____	_____	Yes __ No __

Farm Characteristics

8. How big is your farm, compared to the rest of the village?
a) Small _____ b) Medium_____ c) Large_____

9. How steep are your fields, compared to the rest of the village?
a) Not/a little steep _____ b) Average steep _____ c) Very steep_____

10. Do you own or rent the land you work on?_____

- a) If you do not own your land, who does? _____
- b) If you rent, from whom do you rent? _____
- c) If you own land, do you rent out any of your land? _____

11. a) When was your farm established? _____
b) How many years have you been working on your farm? _____

12. Does your family own livestock? How many?
a) Cows_____ b) Goats_____ c) Chickens_____ d) Sheep_____ e)Other_____

Crops, soil fertility and management

13. What is the general quality of your soils?
a) Very degraded_____ b) Somewhat degraded_____ c) Fertile_____ d) Very fertile_____

14. What crops do you grow, and what kinds of soil do you grown them on (relatively)?

Crop/crop combinations	Soils (Red/black)	Fertility (categories)
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

15. What practices do you use to improve your soils? (Note to interviewer: categorize)
1)
2)
3)

16. If you could do anything, what practice would you choose as the best practice for improving your soils/soil fertility?
_____

17. Where do you get your farming advice?
_____

18. Observations (e.g household assets):
_____
_____
_____

Time: 20-30 minutes

Equipment: Questionnaire guide with coding procedure, paper for recording responses, pen, GPS, camera

Considerations:
As an introductory questionnaire, the questions and options will need to be simple to understand and translate. Standardized translations will need to be agreed on prior to administration. We will need to have a general understanding of the variety of cropping systems and SFMPs we may encounter, and we will need to obtain the corresponding terminology for crops and practices before the questionnaire. We are aware that there may be different people responsible for different cropping systems on the farm (e.g. food crops and cash crops). We will decide after the transect walk if we will choose to interview certain people, or all people responsible for crop management in the household. Depending on whether an interviewee speaks Swahili or Kikuyu, we may be limited in how many questionnaires we can administer concurrently.

Appendix H: PRA Session 2 (Identification and ranking of management practices and factors that influence implementation)

Introduction

- Habari and karibu
- Purpose of research
- How participants were selected (e.g. good knowledge of practices)

Introductory questions:

- How do you tell if your soils are fertile or not?
- Are certain practices used for certain soils and crops?

Issues to note:

- Farmers' perceptions of different SFMPs
- Challenges to implement them.
- Power related dynamics observed (e.g. gender)

Time: Approximately 2 hours (include break)

Equipment:

Guide for session structure, papers for noting down different practices (what kind is to be decided), notebooks, markers, pens, camera, recorder, treats/snacks

Considerations:

The translation can be an issue, both with regards to the practical situation where the discussion needs to be translated as we go along in order to facilitate and understand the outputs, but also regarding the expressions used for different farming methods. For this method to generate useful data we need to prepare: a clear and logical structure, good training of our interpreters, a understanding of all practices that they may mention and the local terminology.
Another challenge is to explain the concept of ranking according to the right criteria in an intuitive and non-academic way.
We need to consider that the choice of having mixed genders here may influence the discussion and the outcome. Doing the ranking individually and collectively allows us to take into account both individual reasons and group dynamics.

Appendix I: PRA Session 3 (Resource flow mapping on farm scale)

- Remember to note the classification of the farm, location and GPS waypoint.
- Observe characteristics inside the household and surrounding to find indicators of wealth that are not asked about (furniture, electronic devices, the state of the house etc)
- Ask permission to record interview

Before drawing:

Household head's characteristics/ farm details:

- Farm heads' gender?
- His/her name?
- His/her age?
- His/her educational level?
- When was the farm established?
- What are the farm's affiliations? (village organisations, clan, networks)
- Is the land owned? By who?
    - Or is it rented? Of who?

Labour and responsibilities on the farm:

- How many of the household members work on the farm?
    - Their gender, age, educational level?
- Do you hire labour?
    - How many workers and for how many months? (specify for each person)
    - What are their responsibilities?
- How do you divide the farming responsibilities within the household?
- Do the other people working on the farm take part in decision making?

Income/wealth:

- What sources of income do you have?
- Who pays for farm management investments? Fertilizer, tools, seeds etc?
- What means of transport do you have access to?
- What kind of agricultural equipment do you have access to/own?

Mapping on the big paper:

House(s) / hut(s), stalls/kraals, boundaries of the farm, fields/plots, grazing areas, paths, benchmarks, trees, bushes, fences etc.

Indicate on the map:

- Crop types grown now, in the preceding season (prepare symbols for crop types in advance).
    - Which are annual/ perennial crops?
- Which plots/fields are rented out or in?
- What and where are the more and less fertile soils on your land?
- What and where are the different soil types on your land (e.g. red/black soils)

- Where do you experience soil erosion?
- Where have you put in measures to control soil erosion?

Landuse history

- For our selected plot ask about land use history further back in time (duration to be determined)

Last season's crop production

- Which fields give the better output and why? (distinguish between seasonal and perennial crops)
- How much did you harvest from each plot/field? (local units)

Draw the harvest as an arrow (where does the harvest go?).

Residues:

- Last season's crop residues – where do they go? (fodder/litter/grazing/on farm/off farm)

Note "internal flow" if last seasons residues are left on the same field.

Fertilisation:

- What kind of fertiliser do you use?
- How much manure have you used in this season?
- How much compost/green manure have you used this season?
- How much chemical fertilizer have you used in this season?

For perennial crops ask the same, but over the last past 6 or 12 months

Management practices:

- Why are some soils more fertile than others? (If this is indicated on the map)
- Does the soil quality affect your choice of crops? How?
- Do you choose your soil management practices based on the soil quality?
- Are any plots left fallow?
- What are the biggest problems/challenges you face as a farmer? (to see if soil status is a prioritized problem)
- Which management practice would you have liked to use if you could?
- What influences your ability to implement the practices that you prefer?
- Do you follow any extension programmes?
- Do you get advice from anyone regarding your soil fertility management?

Livestock:

- What livestock do you own? How many?
- Do they graze on your land?
    - If not, what do you feed them?

Seasonal Calendar:

- Do you grow other crops during other seasons/times of the year?
    - What do you grow when and where?

- Soil management practices for each crop

Time: Approximately 2 hours

Equipment:
Interview guide, big paper to draw map, markers of different colours, pens, notebooks, camera, recorder, GPS, treats/snacks

Considerations:
We will decide on how far back in land use history we reach based on results of the introductory questionnaires, on what symbols to use for different crops, and if to colour-code.
We need to connect the information in this guide with the data we get from the questionnaire, so that we don't ask about the same thing twice.
We should consider if we need to include a seasonal calendar to this session.

Appendix J: Focus groups discussions

Introduction:

- Karibu and Habari
- Present ourselves
- The objective of our study
- Why you were chosen as participants
- Each person introduce themselves with name and a few characteristics about their farm

Questions:

- What are your current soil fertility management practices?
- What are the most effective practices - Why are they effective?
- Would you like to manage your soil/plot differently? - How?
- Why are you not using the practices that you find the most effective?
- What are the challenges you face as a farmer? (to see if social status is a prioritized problem)

Time: *Approximately 1 hour.*

Equipment*:* Interview guide, notebooks, pens, recorder, camera, tea, treats/snacks

Considerations:

We should be careful not to ask leading questions that will phrase gender as a significant challenge in soil fertility management. We should also be aware of the biases of group dynamics and personal relations between the participants. Translating during the discussion is a big challenge, because this will break up the flow of the discussion. Since this is our last method, questions may need adjustment according to our findings throughout our field work.

Possible categorization of factors:

Social factors: social networks (sources of recommended practices), access to information and resources (e.g. inputs, labour)

Socioeconomic factors: wealth (indicators of wealth, sources of income, financial assets, livestock, livelihood diversification), household composition (age, education, skills, knowledge, health) and labour availability/accessibility; ethnicity, religion, political party affiliation,

Biophysical challenges: Soil fertility - current and past.

Appendix K: Soil Sampling

Sampling according to FAO Guidelines (Appendix K):

- Description of the soil location, elevation, slope form and land-use classification
- 2 soil profiles per plot, one profile on the top of the slope and one at the bottom with characterization of the soil typical horizons, layers and depth
- Soil samples are taken in equal proportions (rings) from the topsoil within a depth of 20cm (depending on topsoil depth), from each plot 3x3 soil samples from the top-mid-bottom of the slope are taken.
- The soil description contains following parameters and is going to take place at the field site: surface characteristics (cracks, erosion, coarse rock fragments), field estimation of texture classes, soil colour/organic matter content (dry or moist soil), soil structure, consistence (stickiness and plasticity), moisture status of the soil (at the time the profile is described), bulk density and biological activity.
- Following chemical parameters are going to be measured and analyzed in Denmark: Total Organic Carbon, Permanganate Oxidizable Carbon, Total Nitrogen, pH and Electronic Conductivity.

Time: 1-2 hours

Equipment: sampling rings, measuring tape, plastic bags, shovel, knife, GPS, soil description sheet, Munsell colour chart

Considerations: Ask farmer for permission. Difficulties after rainfall with the soil sampling.

Person describing the soil		Profile Number:
Date:		Farmer:
Locality/ Coordinates:		Picture:
Comments:	plot: farming size:	
Site Properties / Soil formation factors: Weather (Tabl. 2):		
Curren Vegetation (Tabl. 9):		
Elevation (m):		
Slope gradient (%):		
Cracks:	Stones in/on surface (%):	
Commments:		
Physiographie:	Terrace: with slope	
	Upland:	

Closed Depression:

Flood Plain:

parental Material:

Landscape Position (Fig.2/Tabl.6):

Topslope: Mid-Slope:

Backslope: Footslope:

Landsurface shape:

Classification of erosion (Tabl.16):

Land-use classification (Tabl. 8):

Soil Profile characteristics:

Horizon	Depth (cm)	Colour	Rock fragments	biological act.	Texture
Tabl. 85		Munsell	Tabl. 26	Tabl. 81/82	(Fig.4/Tabl.25)

Comments:						
Horizon	Structure type	bulk denstiy	Pores	Coarse Fragments:		
Tabl. 85	Fig. 6	Tabl. 58	Fig. 8	Tabl. 15		
Consistence: Stickiness (Tabl.55): Plasticity (Tabl.56):						
Comments:						