Down to Earth

Perceptions, Management Practices, and Communication Issues related to Soil Acidification in the Highlands of Kenya

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Abstract

This report studies soil acidification of smallholder maize and coffee farmers in the Central highlands of Kenya, using triangulation of natural science and social sciences methods. By analysing 61 soil samples from the site, the report investigates whether soil acidification represents a problem in coffee and maize plots of Thuti village. The study then investigates whether this correlates with how farmers perceive and manage acidification issues at the site. Finally, the study investigates available sources of communication for farmers, and how these function in relation to awareness of soil acidification issues and related management practices. The findings show farmers associate fertilizer use with soil fertility and often implement ammonium-based treatments on their plots. Acidification was not found to be a severe problem in the area but might be in the future if the overuse of fertilizers remains. The report also finds only a small number of famers concerned with acidification are utilizing provided government resources such as soil testing and lime usage. This is shown to be the cause of miscommunications between farmers and authorities resulting in a lack of information and access to resources.

Acknowledgements

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A special thanks to John and Mary, who did not only translate most of our conversations with small scale farmers, but also guided us geographically and culturally.

Outline

Introduction

FAO (2015) has estimated that 30% of topsoils and 75% of subsoils in all ice-free land areas around the world are affected by acidity, meaning that pH is less than 5.5 (FAO 2015). Soil acidification refers to the process in which soils become more acidic over time, and negatively affect the ability for crops to uptake nutrients, resulting in yellow leaves and decreased yields. Consequences often include the emergence of toxicities, low water holding capacities in combination with a susceptibility to erosion, crusting, and compaction (Schroth & Sinclair, 2003). Soil acidification is a serious constraint to food production worldwide, but especially in developing countries where the use of lime is more constrained by poverty, and where acidification of agricultural plots as a result is increasing (Sumner and Noble, 2003; FAO 2015).

Some of the most commonly used inorganic fertilisers like urea and ammonium sulphate have been shown to increase acidity in soils over time (Schroth & Sinclair, 2003). The inappropriate use of fertilisers has been accredited by scholars as one of the main drivers in Kenya for a graduate acidification of soils (Schroth & Sinclair, 2003). Due to acidification issues throughout the central highlands of Kenya, the cultivation of horticultural crops for subsistence can be quite challenging. For example, in the Nyeri South sub county, a sample of 30 farms showed that the soil pH has a wide range of 4.1 to 6.67 (NAAIAP & KARI 2014). More than half of these farms have a soil pH below 5.5 meaning they are less suitable for the cultivation of subsistence crops like maize, which typically tends to lie in the medium tolerance range of 5.5-6.0 pH values (Kanyanjua et al., 2002).

The government in Kenya has implemented various policy instruments to address issues related to soil acidification; e.g. subsidised lime and fertilisers and subsidised testing kits. However, there is little evidence suggesting the adoption of these governmental services. A study from 2016 in nine Kenyan counties including Nyeri found that less than 4% of small-scale farmers assessed were aware of soil acidity problems. As well, less than 3% of the farmers studied had applied lime once on their farms and less than 8% had carried out soil analyses on their farms, while subsidised fertilisers were not being utilised due to inaccessibility (Muindi et al., 2016; Muthoni et al., 2016). This indicates that there is either a discrepancy between perceptions of soil acidity between farmers and governments or issues concerning dissemination of information from governmental agencies.

This report wants to address the following knowledge gaps: 1) We want to investigate whether the narrative of increasing acidity in Nyeri county is actually an issue that can be observed. 2) Since there is a wide range of soil pH throughout the Nyeri South sub county, its unclear which agricultural practices have a significant effect on soil acidity in Thuti. 3) Additionally, there have already been several studies (e.g. Muindi et al., 2016; Muthoni et al., 2016) regarding soil acidification and farmers' perceptions of it throughout Kenya, but no previous research included the influence of governmental services on farmers' management strategies. 4) Finally, Glendenning et al., (2010) has pointed out that the quality and dissemination channels within agricultural systems, together with information needs for farmers are blind spots in research.

In order to avoid uncritical reproduction of narratives based on a-priori assumptions and little evidence we follow Benjaminsen et al., (2010) argument that debates on environment and development issues should take a starting point in natural sciences. On the other hand, we also want to avoid the risk of reductionism by taking a pure positivist natural scientists' approach and excludes social context and dynamics (e.g Scoones 2015). We thus approach the following research question and sub questions through triangulation.

Research questions

RQ: Is soil acidification a problem for smallholder farmers in Thuti village?

We formulate the following sub-questions:

> **SQ1:** How acidic are the soils at the study site?
> **SQ2:** How do agricultural management practices influence pH levels at the study site?
> **SQ3:** Do farmers perceive acidification as a problem?
> **SQ4:** How are farmers utilising available agricultural resources at the study site?

Before the field trip and the collection of data, the following hypotheses laid the boundaries for the scope of study:

Hypotheses

> **H1:** The soils in Thuti village are acidic and have been increasing in acidity leading to decreased quality and quantity of yields in low tolerance crops.
> **H2:** There are positive correlations between the management strategies such as liming, the use of manure e.g. deployed by small scale farmers and acidity of their soils; and negative correlation between the application of ammonium-based fertilisers and acidity.
> **H3:** There is a general lack of awareness among small scale farmers on both acidification issues and the governmental programs introduced to address these issues.
> **H4:** The policy instruments implemented by the national and county government in Thuti village have yet been unsuccessful.

These hypotheses are mainly influenced by previous literature on the local situation. One main objective for the study was to test these hypotheses through our research subquestions.

Background

Soil Acidification

Acidic soils are technically those with pH values below 7.0, but lower values are those that are potentially harmful (see *Figure 1*). Acidification develops very slowly (FAO 2016). Toxicities of aluminium (Al), iron (Fe), and manganese (Mn), along with deficiencies in phosphorus (P), molybdenum (Mo), calcium (Ca), magnesium (Mg), and potassium (K) are also common in acidic soils (Muindi et al., 2016). Acid-forming N fertilizers decrease CEC values in the long term leading to nutrients deficiency and the degradation of soils (Barak et al., 1997). Tandzi et al. (2015) has found maize yield reduction under acid soils to be up to 69%. In 2002, 13% (7.5 million hectares) of the agricultural land in Kenya was considered acidic (Kanyanjua et al., 2002) and there is a general drop in pH and decline in soil organic matter in Kenyan soils (Muthoni, 2016). Acidic soils commonly develop in a humid climate and are thus typically found in tropical savanna and rainforest zones where severe leaching and weathering can be experienced. Other drivers are the use of acidic fertilisers and the removal of basic cations through harvest (Schroth & Sinclair, 2003).

Degree of acidity	pH range
Extremely acidic	<4.5
Strongly acidic	4.5-5.0
Moderately acidic	5.0-6.0
Slightly acidic	6.0-6.5
Near neutral	6.5-7.0

KARI–Kabete working manual

Figure 1: Grading of levels of soil acidity (Kanyanjua et al., 2002)

Acidification issues can be reduced if they're managed so that pH balance is re-established. This can be done in several ways, e.g. by implementing water and soil conservation practices to improve soil organic matter content, by transitioning to appropriate fertilisers, or by applying lime on the soils (FAO 2015). However, since acidification is a relatively unknown issue to many small-scale farmers, changes in management practices initially require awareness on the issue and education on management practices. On top of this, scholars point out that most African countries have not adequately devoted attention to providing rural citizens with access to information (Okello, et al., 2010; Langat et al. 2016).

Kenya

Smallholder farmers play a key role in many developing countries, providing food security, ecosystem services, source of employment and poverty reduction (Deininger & Squire, 1998). In Kenya, the agricultural sector plays a fundamental role in Kenya's economy, contributing approximately to 25% of the GDP while employing over 70% of rural people and over 40% of the total population (Langat et al. 2016). It has been estimated that approximately 5 million farmers in Kenya are small holders producing for subsistence and for sale (Munyua & Stilwell, 2009). These represent approximately 80% of all farmers and account for about 75% of the total agricultural production in the country (Langat et al., 2016).

Previously, the national government financed agricultural consulting and supervision for smallholder farmers through home visits, but two main institutional changes since displaced this responsibility from the national government onto the county level. First, the constitutional reforms in the mid 80's with the liberalisation of the agricultural sector and secondly, a new constitution that was introduced in 2010 which officially decentralized and transferred powers and functions from the national government into 47 new county governments (Cheeseman et al., 2016). The expectations of more economic self-reliance of counties in practice means that home visits are no longer possible (KKI 4&5 2020).

As a result of a rapid increase in population, agricultural plots are decreasing in size, resulting in farmers competing for access to natural resources with consequences in land conflicts. In addition, agricultural productivity is constrained by different factors in remote rural areas: market accessibility, unsustainable land management practices, and institutional isolation. These constraints have hindered the adoption of soil conservation technologies and have prevented farmers from applying inputs in ideal quantities (Kabubo-Mariara, 2015). While the Kenyan agricultural sector encourages food policies emphasizing self-sufficiency, a decline in crop production has led to over 10 million Kenyans being considered as chronically food insecure (Muindi et al., 2016). Among this variety of factors resulting in a reduced production, the focus of this report will be soil acidification.

Study Site: Thuti Village

The Thuti village is between the major city of Othaya and the main district headquarter Nyeri, shown as the study site in the map below. The study site is placed within Nyeri county which has a high population density of 228,3 habitants pr. km2, with the majority occupied on small subsistence plots with labour intensive polycultures.

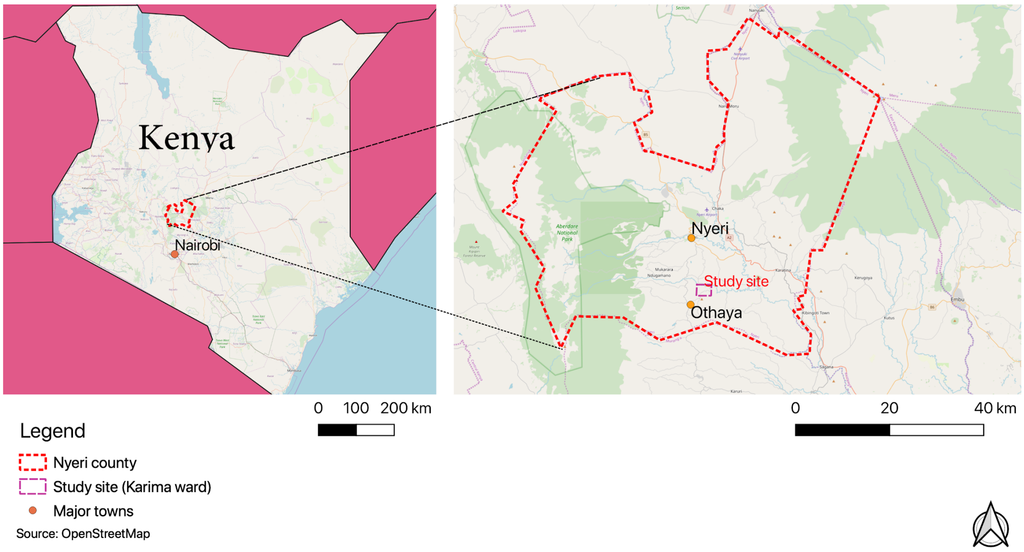


Figure 2: Study site location (Source: Based on OpenStreetMap)

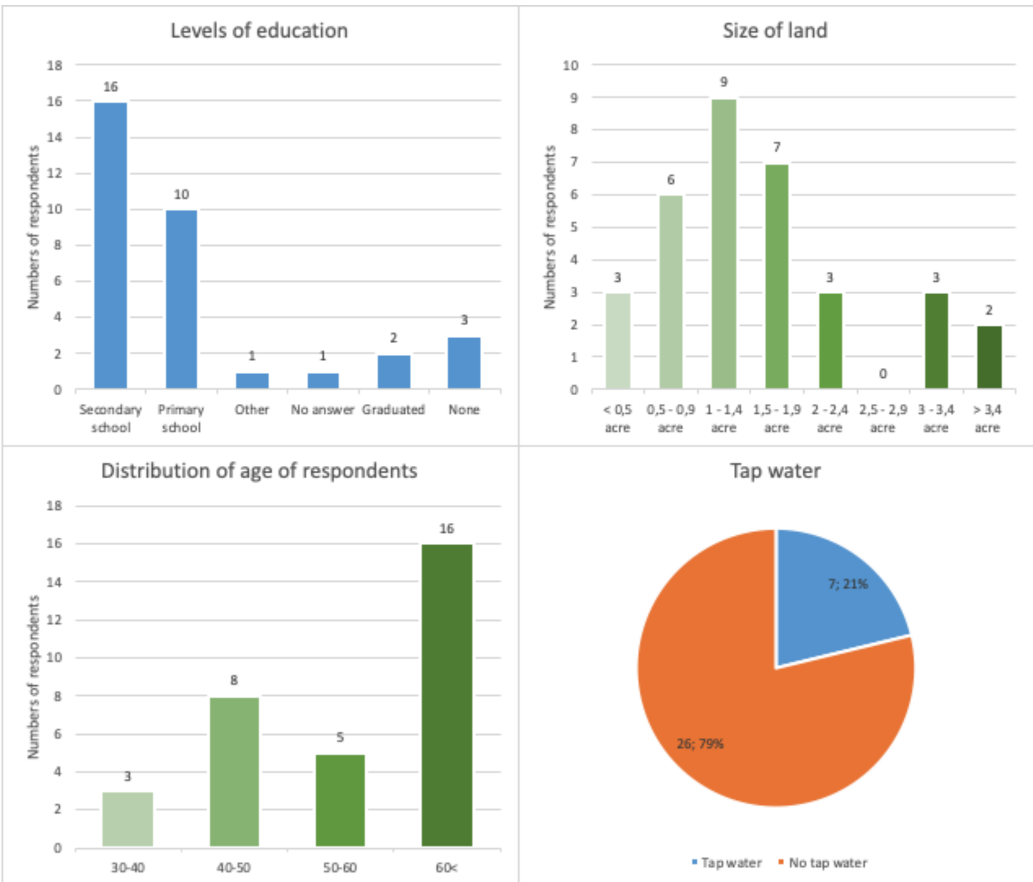


Figure 3: Upper left; levels of education; upper right; size of land; lower left; distribution of age respondents; lower right; access to tap water (Source: Q 1-33 2020)

The figure above shows some basic statistics on the population assessed in this report based on the results from our questionnaires. About 49% of respondents had completed secondary school, 30% completed primary school and 9% have no education. Land size in our study ranged from 0.25 acres to 4.9 acres, with an average size of 1.44 acres (Q 1-33 2020). However, based on our observations, it seemed that some farmer perceptions of their land size might not be completely accurate. Additionally, literature suggests that average land size in the area is 2.1 acres (Jaetzold, 2012).

Concerning the respondents age, 50% were more than 60 years old, which is peculiar since life expectancy in Kenya is estimated to be 64.6 years (in 2018) and only 3 % of the population is estimated to be over 65 (Index Mundi 2019). This could indicate that our respondents might be less eager to adapt to new strategies, since long term benefits for short term risks would be less desirable. Only 21% of respondents have access to tap water, indicating that our study site has a lower level of developed infrastructure. Everyone except for one respondent has electricity in their home and 3 out of 33 own a private vehicle (Q 1-33 2020).

Climatic Settings and Agro-ecology

The best agricultural conditions in Kenya are generally found in the highlands, which is why these areas were preferred settlements by the first British colonizers (Government of Kenya, 2020). The Nyeri county lies in the central highlands and is characterized by cooler temperatures, volcanic valleys rich in phosphorus, which is considered to be more fertile for agriculture compared to most parts of Kenya (NAAIAP & KARI, 2014).

The study site lies within a Coffee-tea Zone which is characterised by average temperatures of 17.5-17.8 °C, altitudes of 1710-1780m and annual average rainfall of 1100-1600 (Jaetzold, 2012). The most important perennial crops in the area are the cash crops, coffee and tea. Other perennial crops include macadamia, banana, advocado, mango. Typical subsistence crops produced are kale, cabbage, beans, sweet potatoes, and Irish potatoes, with maize being the most dominant annual crop throughout the year (Pinard, 2014; Jaetzold, 2012). The main variety of maize cultivated in Thuti is the H6 series, and is relied on as a source of food, even though some gain limited revenues from this production (Kibet et al., 2011; Jaetzold, 2012). As a general rule, the optimal pH for growing maize is 5.5 to 7.0 (NAAIAP & KARI, 2014). The coffee produced in the area is *Coffea arabica*, which is typically grown in lower altitudes and in pH range from 5.4 to 6.0. (Kuit et al., 2004).

Levels of Governance in Thuti Village

In the Nyeri county there are three levels of governance present. In different locations throughout the county such as the Thuti village, you find a local administration typically consisting of a Chief, an Assistant Chief and two Village Elders, who all represent the national government and seek to facilitate discussions and conflict solving among the community (KII5 2020). On the county level, you find the Agricultural Extension Officers who serve the farmers and assists them in managing their soils through different services. In the Nyeri county there are today approximately 60 agricultural extension officers (KII1 2020). The national administration is primarily represented through financing mechanisms (KII4 2020).

Methodology

As we would carry on an interdisciplinary research, during our field work we applied different methods both from natural and social sciences gathering quantitative and qualitative data. To assert the situation and gain first-hand insights into the issues, perceptions on these issues and their management, a field trip was conducted in Thuti village in Nyeri county from 27th of February to 9th of March 2020. The report bases its findings on 33 questionnaires, 61 soil samples, 25 semi structured interviews and participatory observations obtained through this field trip. See annex 8 for references to these interviews.

Quantitative Data Collection

Transect Walk

GPS mapping was used to track the location of participants in the study chosen for sampling. The 33 selected plots for soil analysis and questionnaires interviews were measured for elevation using GPS. The motive was to enable spatial analyses, but these were not conducted since there were few indicators of correlations with our data and geographical locations. The GPS points only illustrate our attempt to collect data from the most uniform distribution of data points.

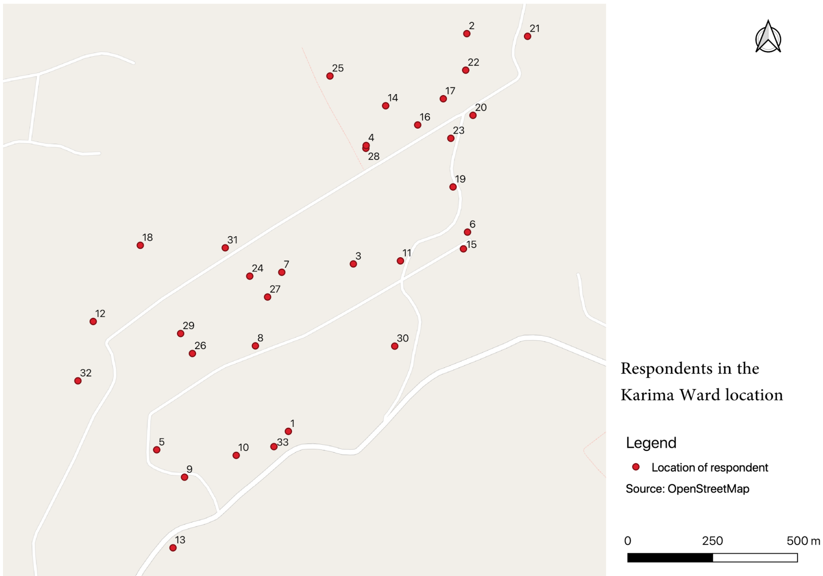


Figure 4: Distribution of respondents in the Thuti village. (Basemap: OpenStreetMap; own GPS points)

Questionnaire Survey

A questionnaire containing mainly close ended questions was first conducted with farmers selected during the transect walk throughout Thuti. Initially we defined a set of criteria for our population of interest: The respondents had to be smallholder farmers, they should grow either coffee, maize or both and they should be located within a walking distance of 1,5 km from our headquarters for logistical purposes. Here, Lipton's (2005) definition of small-scale farmers being those with a low assets base and less than 2 hectares of cropland is used, as it is also the case for other Kenyan studies (e.g. Langat et al., 2016). From this population of interest, we selected our respondents systematically by visiting only every second plot for our questionnaires, in order to enable a coverage of a wider geographical area with an intended uniform distribution (see figure 4).

The 33 quantitative samples provide a representative sample of the community that included farmers of ages, genders, plot sizes and soil management practices (see figure 3). We asked questions regarding their age, main occupation, number of members in the household, level of education, size and yield of the plots, type of fertilizers and agricultural practices used, as well as perceptions on soil fertility and acidification issues. This close ended approach encouraged the respondent not to divert from the questions and allowed us to select farmers for a secondary in-depth interview. We also used this data to analyse the correlations between different categorical indicators.

pH Testing

Soil pH data was collected on all the farm sites participating in the study in order to differentiate acidity levels between maize and coffee plots and look for correlations to management practices. For each plot, 3 to 5 core samples were randomly taken by walking in a 'W' shaped pattern and pooled to one sample per plot. On farms that had more than one coffee or maize plot, we tried to acquire at least one sample from each one, resulting in one large coffee sample and one large maize sample per farmer. It was attempted to take all soil samples from a depth of approximately 25cm.

Image 1: Soil samples being tested for pH values (Source: Own picture)

Samples were dried in open air after collection to acquire a more accurate pH value. Additionally, they were shaken in order to homogenize the soil in preparation for testing. Testing for pH was initiated by filling a clean 50 ml cylindrical tube with 25ml of distilled water. Next, the dry soil samples were added into the tube until the solution reached the 35ml mark. The tube was then shaken for 10 minutes and left to settle for 15 minutes. Following the settling period, the solution was quickly shaken again and poured into a miniature cup. A portable pH meter was placed in the cup and a pH value was recorded after several minutes.

Total Inorganic Nitrogen

Using soil samples acquired when conducting our questionnaires, we intended to collect total inorganic nitrogen values by testing separately nitrate ($NO3^{-}$) and ammonium ($NH4^{+}$) concentration from each farmer selected for in-depth interviews. Regarding the nitrate content the procedure was started by adding 30ml of distilled water to a 50ml tube and adding soil until the solution reached the 40ml mark. The tube was then shaken for 5 minutes to homogenize the solution. Afterwards, the solution was to rest until the sediment settled and the top layer of it was clear enough for the nitrate testing strips. Finally, we compared the strip with the colour scale in the box. While for the ammonium content, we proceeded with the same method, but we added 30ml of KCl instead of water. After the sediment settled, we tested 5ml of solution added with 10 drips of sodium hydroxide solution by using the ammonium testing strips.

Due to the high clay content and subsequent turbidity of the solutions created, we had difficulties in reading the test results on the strips. We attempted to filter these solutions while in Thuti but couldn't manage to find a proper filtration method. Therefore, only 10 of the originally intended 14 farmer's samples were assessed. However, in order to have consistent results, we ultimately repeated this process back in Copenhagen with all 14 farmer's samples using a proper filter but resorted to using dried samples.

Statistical Methods

In the result section we correlate these data from our soil samples with data from our questionnaire, in particular data on utilised management practices. This is done by comparing the calculated average pH values with management practices for maize and coffee and visualising this with pie and column charts. The Student's t-test is then used when appropriate to see if there are statistically significant differences between samples. The Student's t-test allows us to compare two sample groups to see if they differ significantly. In all tests, we conduct independent and two tailed tests assuming unequal variance. In other words, we are conducting a heteroscedastic t-test with a two-sample unequal variance. We also assume a standard normal distribution and therefore use a critical value of 0.05%. When calculating the p-value, we only reject the null-hypothesis (being that the samples don't differ) if the p-value is lower than the critical value of 0.05%.

R-squared calculations are added to some of our regression charts to see if there are relevant correlations on the variables, looking for numbers over 0.25 before there can be identified even a weak correlation.

We chose not to utilise the Chi-squared test since when appropriate, we had to rely on data from semi structured interviews, which could hardly be quantified due to the low sample size.

Qualitative Data Collection

Semi-structured Interviews with Farmers

Using information acquired from the questionnaires, we selected 15 respondents for a second round of interviews based on their common crops (coffee and maize) and management practices as well as their possible contribution to relevant outcomes for our research. These semi-structured interviews were focused on acquiring more qualitative data. The data collected contained more open-ended questions, allowing for in depth elaboration on certain topics and the provision of more unique perspectives.

Image 2: Conducting interviews using a translator (Source: Own picture)

We also conducted 10 semi-structured interviews with key informants. These were Agrovet shops, 4 of which were located in Othaya and one of them near Thuti, being the main suppliers in the area for fertilizers, pesticides, lime and other agricultural products. We also conducted semi-structured interviews with the Wambugu Farm (a training centre supported by the government located nearby), the Coffee Factory (a cooperative for coffee producers) and governmental bodies such as the agriculture extension officer and different agents in the local administration in Thuti. In the semi-structured interviews elaborations, explanations and detours were welcome. The key informants were selected based on relevance to our research and knowledge on soil acidification management strategies for coffee and maize in Othaya area.

Participant Observations

When possible, our semi structured interviews with key informants were supplemented with a guided visit to the facilities. While completing questionnaires and soil samplings, participatory observations were also systematically noted to provide the opportunity for discussing the quality of the data collected. This method was more exploratory and descriptive. Information collected through this method included searching for observations that might contradict the statements of the respondents.

In order to understand the process of acquiring and using soil testing kits, we invited three farmers to test their soils at the extension office to observe this process. These observations were intended to compliment the semi-structured interviews with the extension officer.

Image 3: Participatory observations on acquiring results from the soil testing kit (Source: Own picture)

Limitations on Methodology

During this research, we faced some limitations within the methodologies that hindered our final results. In order to have the most precise results, the pH testing method needed to be revised many times. Initially, we wanted to measure pH values during farmer questionnaires. However, we soon realized this would not be feasible due to the lengthy time needed for measuring the samples. We also found the pH values were not reliable because the soils were not dry enough to be tested and compared with values in the literature. Hence, the selection of respondents for the in-depth interviews was affected since we originally wanted to choose them based on the pH results by dividing them in different ranges.

Consequently, after the field trip, we could not test the nutrient content (P, K, Ca, Mg), water holding capacity and soil organic matter since access to the University of Copenhagen's lab was prohibited due to the outbreak of Covid-19. Therefore, we have only relied on pH and total inorganic nitrogen results for soil data. This influenced our ability to properly draw conclusions regarding the effects of fertilizers on soil fertility. In addition, we realized farmers did not have a clear idea of the size of their plot which may have resulted in faulty data analysis.

In regard to our interview method, the Hawthorne effect could have affected our results. A few questions could be considered leading and respondents may have wanted to correlate their answers to our expectations in order to appear better. This could be the case for those yes/no questions where we ask if they know about a certain service provided by the county, such as lime. Even though the Hawthorne effect is often a risk for social studies, we assume it has not influenced our results significantly since with some yes/no concerning fairly unknown services all respondents seem to be honest about being unfamiliar with the service.

Ethical Questions

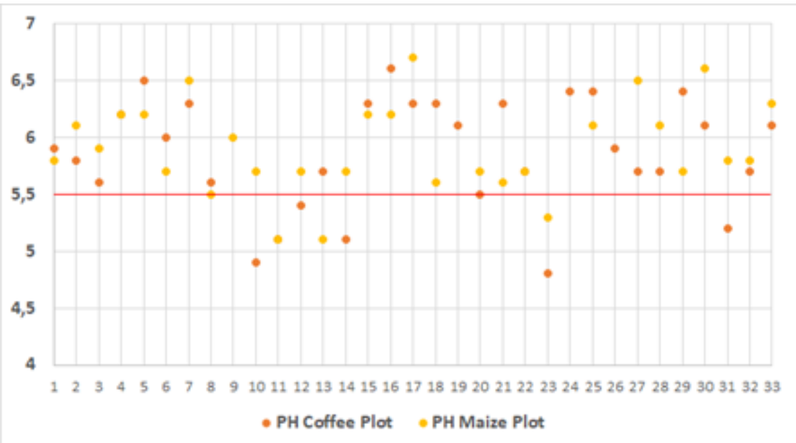
The participatory characteristics of a field study combined with the intercultural aspects of studying in another country means that there are some considerations that must be taken into account. First of all, our study is based on private information from our respondents such as information on their level of education, age and different assets. Secondly, we ask questions from which answers for some might be considered as criticism of governmental efforts or even individuals. To accommodate these circumstances, we have ensured respondents are well informed on the data we are collecting and what risks they are taking by participating. We also gave each respondent the opportunity to be anonymous.

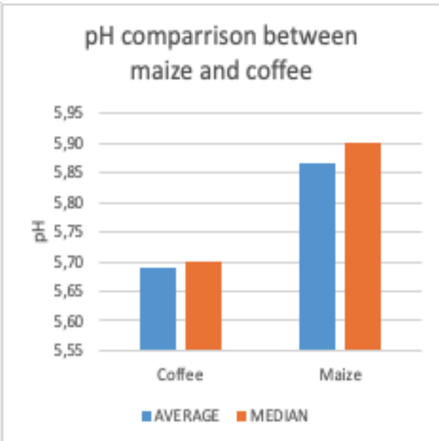
Moreover, we hope that our findings are valuable for farmers and governments in Nyeri County. We have sent back the results from our soil samples to each respondent, and the final report will be sent to each key informant (except shop owners). Together with these results, we underline for the respondents that we are not experts in the field, but students and that our findings must be received with corresponding critique.

Results

Levels of Acidity in Soils at the Study Site

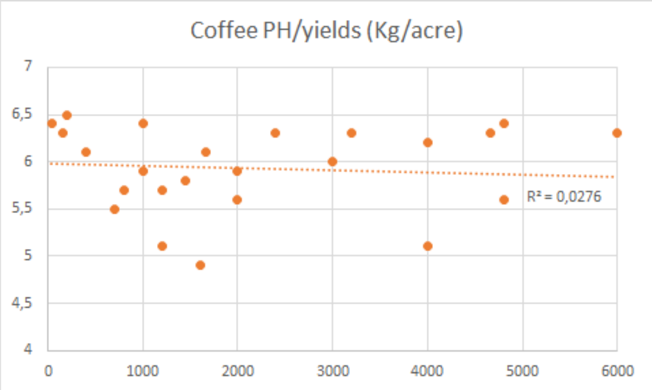
Analysis of our soil samples acquired throughout the Thuti village show a wide range of pH. In coffee plots the soil pH ranged from 4.8 to 6.5. Average pH levels are 5.82 and standard deviation in the distribution is 0.48. In the maize plots the pH ranged from 5.1 to 6.7. Average pH values are 5.91 and standard deviation is 1,17 meaning that these values are more spread out compared to the coffee (see *Figure 5*). Although the average values in both types of plots tested are not very acidic, there were still a significant number of acidic plots discovered by sampling the soils. For example, 18% of the 61 plots tested were moderately to strongly acidic with a pH of 5.5 or lower and soil acidity in this range can be troublesome for both maize and coffee productions (see *Figure 5*).

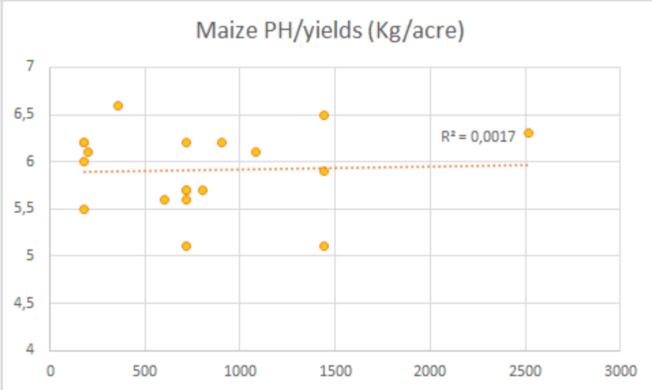




(Left) Figure 5: pH levels on coffee and maize plots on the 33 sampled farmers
(Right) Figure 6: pH averages on Maize and Coffee plots (Source: Q 1-33 2020).

Running two tailed t-test on the pH values for the 61 samples gives us a p-value of 0.57. With the p-value being higher than our critical value of 0.05 we cannot reject the null-hypothesis and conclude that there is no statistically significant difference between the maize and coffee samples. This means that we will not use the t-test to compare maize and coffee in the following sections, and instead we will focus on assessing the correlation between pH and different management practices only.





(Left) Figure 7: Coffee pH vs yields in Kg /acre (Source: Q 1-33 2020)
**9 farmers have had to be removed because of the lack of data on yields as they could not give us a value.*
(Right) Figure 8: Maize pH vs yields in Kg/acre (Source: Q 1-33 2020)
**13 farmers have had to be removed because of the lack of data on yields as they could not give us a value.*

We did calculations and correlated the pH on maize and coffee plots with the yields, but a significant number of farmers have had to be removed from both calculations because of the lack of data on yields and/or because they were not growing both of the crops. *Figure 8* shows a trend on maize indicating that the higher the pH slightly higher the yields are, although the R-squared tells us that there is no significant correlation. The opposite trend can be found for coffee (*Figure 7*), but again the R-squared tells us that there is no significant correlation, which is interesting as other parameters might be influencing the yields more than the pH at the study site. We are aware the lack of data might have had an impact on our analysis.

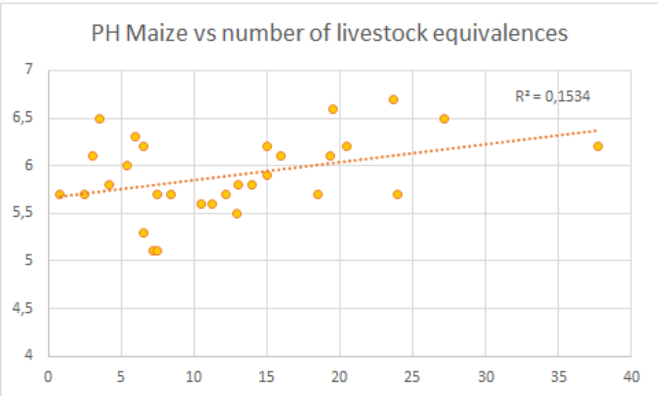
Agricultural Management Practices in Thuti

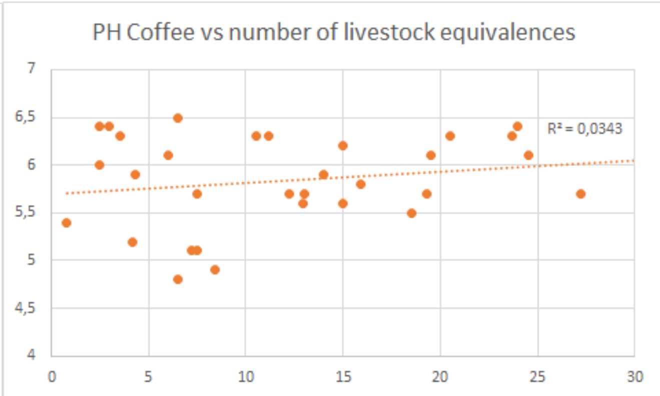
While conducting our research, farmers were asked about which management practices they utilised respectively on their coffee and maize plots. Specific management strategies we inquired about included: liming, irrigation, crop rotation, inorganic fertilisers, organic fertilisers, intercropping, machinery and fallow. Knowing that there are several other management practices available, we also had one open ended question allowing for mentioning other management practices. This led us to discovering several main trends within their soil management practices, plus it allowed us to assess whether there is a correlation between those management practices and the pH in their soils. For machinery, fallow and intercropping, there was insufficient variation (less than 10% variate from the others) in the questionnaire samples, so we chose not to compare those strategies with pH values.

All respondents used both organic and inorganic fertilizers. Between the two, the use of various inorganic fertilizers had been a significant trend. Commonly utilized ones included DAP (used by 45%), CAN (58%), and NPK (64%, usually 17-17-17 and 23-23-0). On the other hand, the use of manure was also very popular. It was the most common application seen in our sample pool, being used by almost every farmer. This can of course be attributed to the fact that farmers sourced it from their own livestock such as cows, goats, chickens, and other animals (Q 1-33 2020). 8 farmers out of 15 interviewed also mentioned the use of leftover plant biomass as a mulch, but even this isn't a viable option for everyone because many farmers subsequently wouldn't have enough feed for their livestock (SSI 1-15 2020).

Manure

All farmers selected for our questionnaire used manure from their livestock, typically consisting of cows, chickens and/or goats. The amount of manure applied depends on animal type. To compare applied manure with pH, we calculated a livestock equivalence for each animal. Cows and pigs were multiplied by 1, goats and sheeps by 0.5 and chickens and rabbits by 0.1. *Figures 10* and *11* below illustrate a trend indicating that higher values in 'livestock equivalences' correspond with slightly higher pH in soils, but we can't say there is a significant correlation since the R-squared values are too low and under 0.25.





(Left) Figure 9: pH for coffee plots compared with number of livestock equivalences (Source: Q 1-33 2020)
(Right) Figure 10: pH for maize plots compared with number of livestock equivalences (Source: Q 1-33 2020)

DAP

There was a fairly even distribution of those who chose to apply DAP (45%) and those who chose not to (52%) (Q 1-33 2020). The 45% who did apply DAP had an average pH that was 0.03 lower on coffee and 0.2 lower on maize compared to those who didn't. Data from our semi structured interview show that only 2 of the 15 farmers mention specific DAP applications on either maize or coffee. Unfortunately, a lack of collecting data on amounts of DAP application respective to each crop hinders our ability to compare its effect on maize and coffee plots separately.

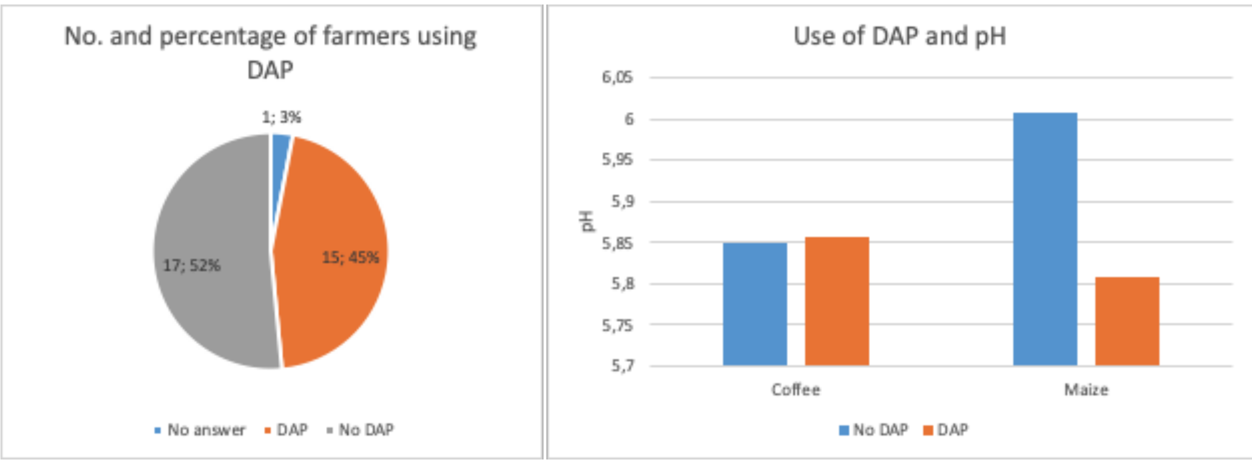


Figure 11: To the left*: Farmers using DAP* (Source: Q 1-33 2020;)
To the right*: Use of DAP and pH* (Source: Q 1-33 2020)

When conducting a t-test comparing all DAP-users with all non-users, we find a p-value of 0.42 meaning that there is no significant difference in pH between the two samples. In other words, the observed difference between the sample means is not convincing enough to say that the average pH values between DAP-users and non-users differ significantly.

Lime

In spite of subsidized prices allowing farmers to buy lime for 100 KSh instead of 700 KSh, and governmental lime programs, the utilization of lime was not common amongst farmers in Thuti. This was a surprising result because we found that 88% of our respondents were aware of liming. However, only 11 out of the 33 (33%) interviewed had actually ever applied lime before (see *Figure 12).* One farmer we interviewed had actually been using ashes, instead of lime, as a means for decreasing the acidity of their soil. For this particular respondent the pH of their coffee plot proved to be 5.9 (Q 16 2020).

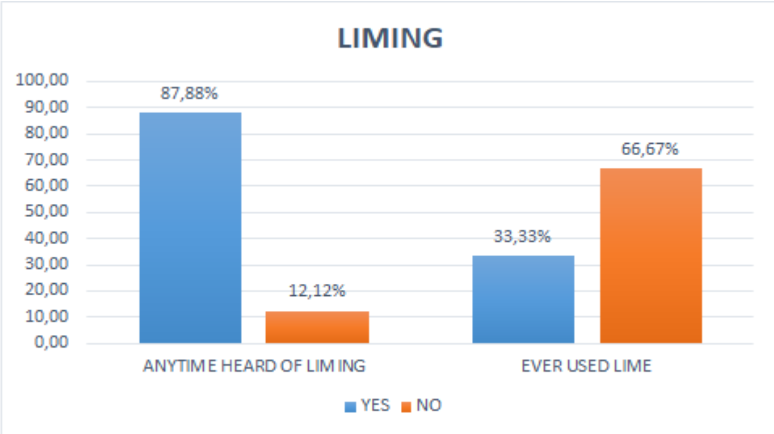


Figure 12: Liming awareness vs lime use (Source: Q 1-33 2020)

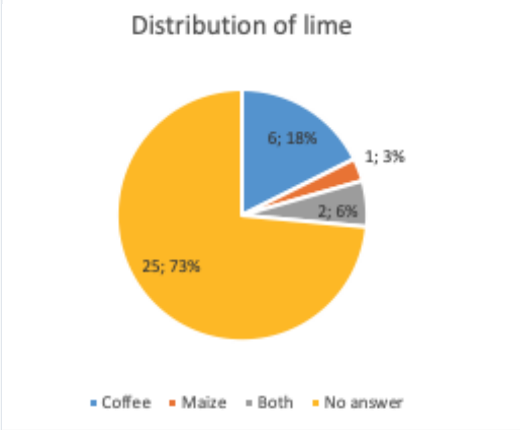


Figure 13: Distribution of lime (Q 1-33 2020)

The difference in average pH values between farmers utilising lime and those not utilising lime, as displayed in *Figure 14*, is greater on coffee plots (0.19 difference in average pH) than on maize plots (0.6 difference in average pH) (Q 1-33 2020). However, 4 of the 8 farmers that have used lime have applied it just once (SSI 1-15). A total of 24% answered that they applied lime on coffee, while only 9% had applied the lime on maize (Q 1-33 2020). This further helps to explain the correlation between pH and applied lime as lime applied on 9% maize soils is not expected to raise the average pH of all 33% soils. Therefore, the effect of lime might be even higher than indicated in the data results. In general, it seems to be a trend that more lime is applied on coffee.

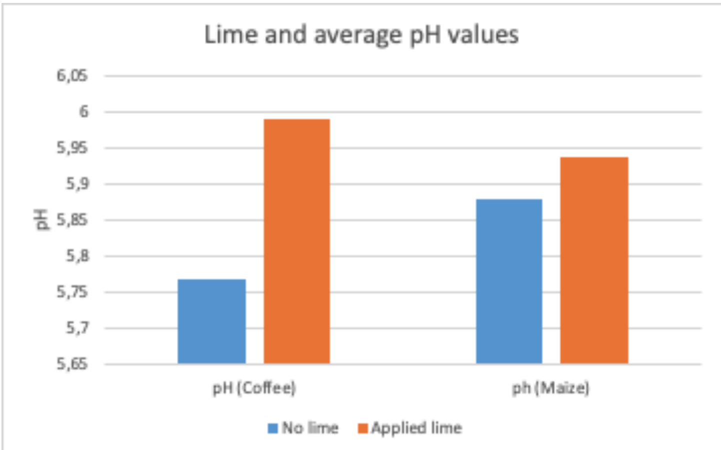


Figure 14: Lime and average pH values (Source: Q 1-33 2020)

The t-test gives us a value of 0.20, meaning that there is after all no statistically significant difference between lime users and non-lime users. Again, the observed difference between the sample means is not convincing enough to say that the average pH values between lime-users and non-users differ significantly.

Irrigation

Using the same approach as above, we can look for correlations between farms with irrigation systems and pH. Irrigation systems were seen throughout Thuti, but only 18% of the interviewed farmers had them and even less indicated that they would want them. Due to a lack of economic resources it's not very common. Plus, few farmers indicated that legislation in the county prevents farmers from utilising this management strategy because tap water cannot be used for irrigation (Q 14 2020). Farmers that did have irrigation systems were often located near the local river, and they admitted to hardly be using the irrigation systems stating that rainfall is often substantial for their crops, but these respondents (Q 1-33 2020). However, we still observed that most plots along the river had active systems.

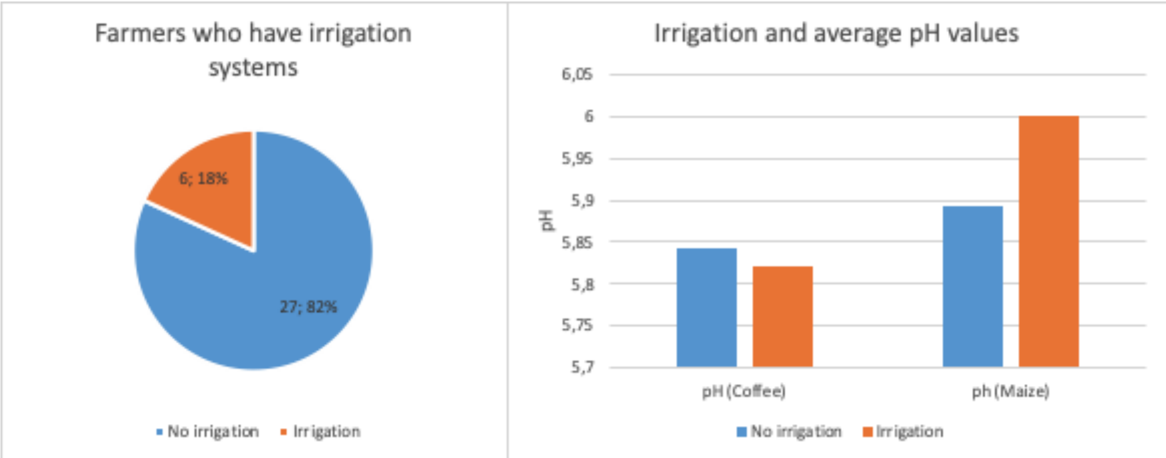


Figure 15: To the left: *Farmers and irrigation;* To the right: *Irrigation and pH values* (Source: Q 1-33 2020).

For coffee there seemed to be little variation between pH in irrigated soils and non-irrigated soils. For maize the variation is a bit higher. Looking at maize and coffee together, comparing only irrigated soils with non-irrigated soils, t-test gives the p-value of 0.73 meaning that there is no statistically significant difference between the two groups.

Other Practices

Another common practice amongst farmers in Thuti is tilling the soil. About 73% of the respondents stated they till on both maize and coffee, while 12 % only till their maize plots. Farmers till 1 to 3 times a year, and more commonly on maize due to the difficulties that can be faced when tilling coffee plots (Q 1-33 2020).

Our questionnaire indicates that 58% of respondents use CAN as an inorganic fertiliser while 39% do not. Looking at maize, there seems to be absolutely no difference in average pH values for those plots that use CAN and those that don't. Looking at coffee however, there's a minimal difference (0.09) in average pH.

Land size limits farmers in Thuti from effectively utilizing several management practices. Crop rotation, for example, is not common and practiced by 30% of farmers. In these cases, maize is usually rotated with potatoes and beans (Q 1-33 2020). Since you cannot crop rotate coffee, this management practice can only be compared with pH for maize, where there seemed to be a small correlation, with a variation of 0.16 in average pH value between plots using rotation and plots not using rotation. The t-test shows no significant correlation.

Intercropping is another management that is more commonly practiced on maize by 26 of the 33 farmers. Potatoes, beans, bananas, and other horticultural crops could be seen growing throughout maize plots. We did also observe horticultural crops growing throughout a few coffee plots, however none of the farmers mentioned this practice themselves, potentially due to the demands of the coffee factories advising against intercropping with coffee. Nevertheless, intercropping appears to be essential for farmers because of the small size of their land (Q 1-33 2020).

Only practiced by 9%, fallowing is uncommon in our sample pool, as the farmers in the area rely on their land for a constant food supply. According to respondents, the size of the plots is the main factor that prevents the use of machinery, but some respondents were not even aware agricultural machinery existed (Q 1-33 2020). For smallholder farming, you can also imagine that there wouldn't be an economy in using machinery or that it was impractical on slope farms.

Farmer Perceptions

Results from our questionnaire showed that 76% of farmers feel their soil is fertile and 24% consider it infertile (Q 1-33 2020). To elaborate on this, we questioned farmers about what soil fertility meant to them in the second round of interviews. When differentiating between fertile and infertile soils, the biggest indication for most farmers was their yield amount (see *Figure 16*). Some also found soil colour to be an indicator, referring to a darker colour, in relation to organic matter content (SSI 13 2020), as a good sign of fertility, whereas a more red, lightweight soil is a sign of low fertility (SSI 1,14 2020). There was even one farmer who saw certain weeds, known to contain deep taproots, as an indicator of infertile soils (SSI 1 2020).

Essentially, the general perception of soil fertility to most farmers in Thuti is commonly related to yields and expressed as sufficient productivity of their crop (Q 1-33 2020). Often farmers declare that if their yields are good then their soils are fertile (SSI 3, 4, 6, 8, 11, 12, 14 2020). Out of the 15 farmers we interviewed twice, 9 felt that their yields have been increasing over time, but just 8 felt that their production is sufficient enough for them. In contrast, 3 see their productions decreasing and 2 were unable to tell (SSI 1-15 2020). Most respondents believe that in general, the management practices they carry out is having the intended results (SSI 1-15 2020).

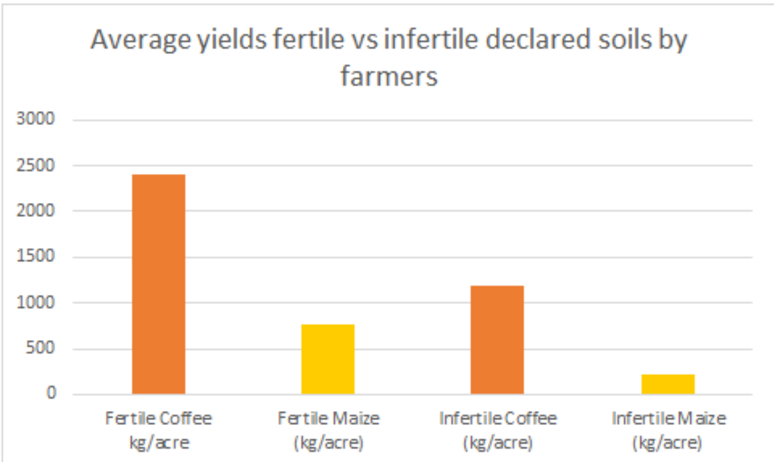


*Figure 16: Average yields on fertile vs infertile declared soils by farmers** (Source: Q 1-33 2020)
**one outlier has been removed from the infertile coffee plots.*

When questioned about the changes in their soil fertility, many farmers in the second sample pool noted improvements and attributed them to the increased application of fertilizers and manures (SSI 1-15 2020). Some directly related fertile soils with the use of fertilizers, declaring that when they do not use fertilizers the yields are lower (SSI 1 & 14 2020). In contrast, a few farmers also shared thoughts on the potential risks of using inorganic fertilizers, suggesting that the consistent application of certain fertilizers damages the long-term health of the soil (SSI 4, 7 2020). One farmer perceived soil fertility as the completeness of the soil (SSI 5 2020) and another compared it to the human body, saying feeding your soils chemicals is like feeding yourself junk food (SSI 4 & 5 2020).

Nonetheless, there still appears to be a generalized belief that using fertilizers is the main solution to increase the yields of the harvest. It was also pointed out during a few interviews that fertilizers were previously promoted by the government when agricultural extension officers recommended them to everyone years ago (SSI 11 2020), so the generalized belief could perhaps be additionally influenced by these recommendations.

The total inorganic nitrogen content of 14 farmers' plots was calculated by testing soil samples for nitrate and ammonium respectively. The highest values of 53,25 mg N/kg can be found in two coffee plots and one maize, while the lowest value of 4,5 mg N/kg is seen in maize (see figure 17). On average, the inorganic nitrogen level is 25.81 mg N/kg in coffee plots and 22.92 mg N/kg in maize. From our interviews we know that respondents 2 and 15 think their plots are infertile, but we did not find any relevant nitrogen correlations in regard to these perceptions (see figure 17). Although the average inorganic nitrogen content is slightly higher in coffee, this could potentially be related to the amount and time of application. Unfortunately, due to a lack of this specific data we could not correlate these two factors.

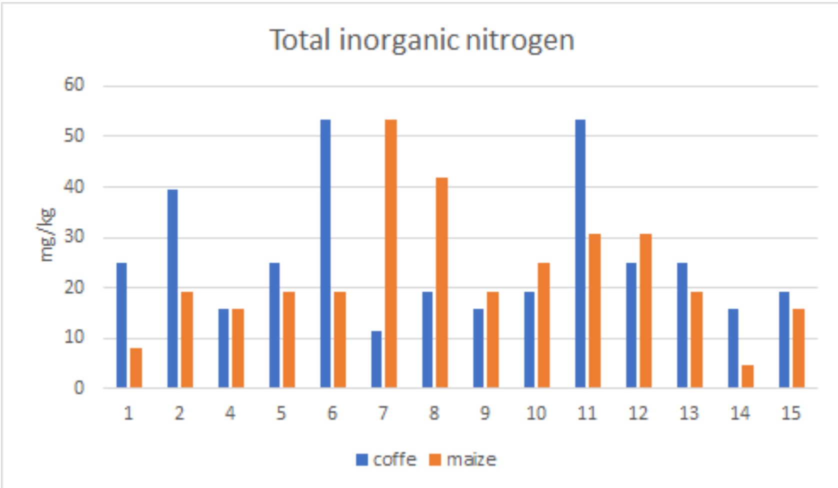


Figure 17: Total inorganic nitrogen (mg N/kg soil) in coffee and maize plots. (Source: SSI 1-15 2020).
**Farmer no. 3 have had to be removed because of the lack of data.*

When asked about soil acidification, many farmers did not know what it was (Q 1-33 2020). Only 60% of the farmers admitted to being aware of it, while the rest were unaware or didn't understand the question. Some were also told by friends or relatives that acidification is caused by exhaustion of the soil (SSI 10 2020). Those that were familiar with soil acidification were aware of its consequences regarding the growth of the crops and problems like stunting of plants (SSI 10 2020). A few farmers did know that it affects productivity (SSI 1-15 2020), and others heard that it is a consequence of fertilizers (SSI 4 & 11 2020). They also referred to specific crop problems like beans not producing pods, coffee producing beans that fell off before ripening (SSI 8 2020) or scorching on maize (SSI 14 2020).

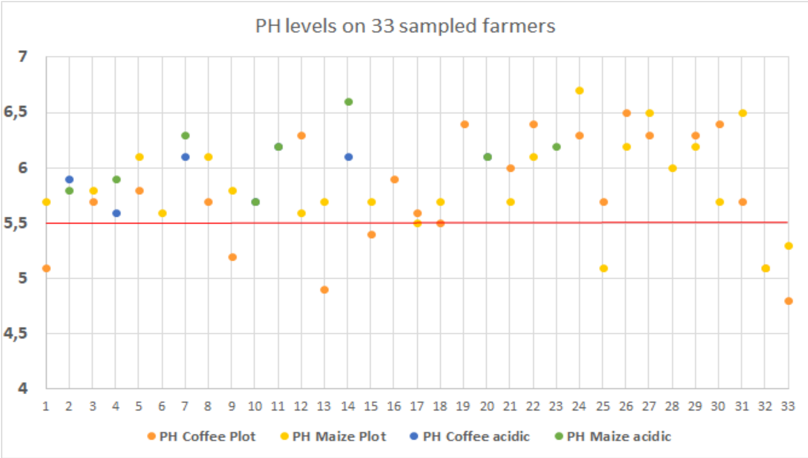


Figure 18: pH levels on coffee and maize plots on the 33 sampled farmers - in blue (Coffee) and green (Maize) are marked the plots whose farmers believe are affected by acidification (Source: Q 1-33 2020)

From our sample 29% of respondents thought the soils on their plot were affected by acidification, but we couldn't correlate those with our results on pH testing (see *Figure 18)*. Most farmers have actually felt the need of testing the soil pH (85%), but this result could also be explained by our influence during the questionnaires by the Hawthorne effect.

Sources of Information

Agricultural Extension Office

Agricultural extension offices in Kenya have been financed by newly established county governments ever since Kenya's liberalisation in the 80s and constitutional changes in 2010. In the past years, extension services were significantly cut down in Othaya from more than 50 extension officers to 5 (KII 1 2020). Farmers often referred to the lack of advice on agricultural practices and missed some kind of support from the local and governmental authorities for their land management (Q 1-33 2020; SII 1-15 2020).

Findings from our questionnaire show that 30% of respondents referred to the agricultural extension officers as one of their sources of information. However, it is likely that this last happened before Kenya's devolution as 50% are more than 60 years old (Q 1-33 2020). Today, no farmers receive home visits from agricultural officers, but instead they have to rely on sources such as private entities, vendors, or the coffee factory. Moreover, 47% of respondents indicated in the questionnaire that they had no external sources of agricultural information. Among our respondents, many advocated for reinstating home visits. They also agree that the dissemination of information regarding acidity should be the responsibility of the government (Q 1-33 2020; SII 1-15 2020).

In addition to home visits, the Nyeri county government offers subsidized soil testing and fertilizers. The most basic testing option is a 300 KSh soil test involving a scanner and phone application designed by the Dutch Company, Agrocares. Results are given with high-low ranges and assess soil based on type of crop grown (see *Image 4*).

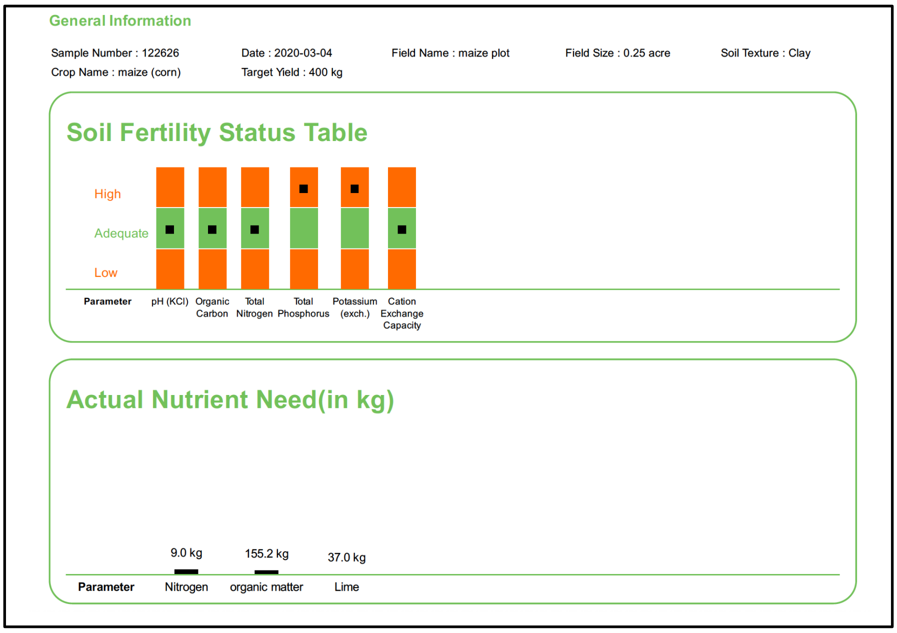


Image 4: Results report from Soil Testing Kit in Othaya on maize plot from farmer 5 (Source: SoilCares from Agrocares)

For actual values, farmers can pay 2,000 KSh to bring their samples to have it sent to laboratories in Nyeri county or Nairobi. In both cases, farmers are expected to interpret their own results and recommendations (KII 1 2020). Overall, we only found 1 farmer that participated in our semi-structured interviews to have independently tested their soils. Five out of our 15 respondents had heard about the possibility of testing soils in Kenya, but two of those didn't know it was possible in Nyeri. Despite evidence of few farmers utilizing testing services, 100% of farmers surveyed during the in-depth interviews agreed it's important (Q 1-33 2020; SSI 1-15 2020). The dichotomy between utilization and awareness leads us to question the real reasons farmers don't seek the provided services. Nearly half of the respondents indicated that lack of information was the reason for the testing kit not being used (48%) (SSI 1-15 2020).

Fertilizer subsidies, offered through a collaboration between the Kenyan government and local county governments, are intended to assist small scale farmers. Depending on the fertilizer type, commercial prices are lowered from approximately 3500 KSh to 2500 KSh pr 50 kg (Muthoni, 2016). Currently, farmers are required to go to the chief's office for registration. Although the chief claims the system is highly popular, we found no current evidence of farmers utilizing the system (KII5 2020). A total of 500 million KSh has been invested to procure and distribute lime to 82,000 farmers throughout the county (Nyeri County Government, 2018). However, we did find subsidized lime to be largely disseminated through local coffee factories by the Nyeri County government (Q 1-33 2020).

The Coffee Factory

Coffee is a major source of income in Othaya. For 70% of farmers surveyed during the questionnaires it was their only cash crop (Q 1-33 2020). Othaya Coffee Cooperative is an organization of 19 wet mills, also referred to as factories, made up of 15,000 members. Each factory is responsible for coffee drying, processing, and providing agricultural support for its members. In order to reach production goals and function in a supportive role for growers the factory employs promoters, trainers, officers and an agronomist (KII 3 2020). When asked about their main source of agriculture information, 11% of respondents in our questionnaire referred to the factory. This was challenged by semi-structured interview data that showed 40% of respondents used coffee factory resources (SSI 1-15).

Three years ago, the cooperative started supplying government subsidized lime for the price of 100 KES per 50 kg bag to address acidification in coffee plots. As shown by *Figure 19*, the majority of respondents (52%) mentioned the

Coffee Factory as their source of information on lime (Q 1-33 2020). Farmers can register with the factory for a specific number of bags needed dependent on the number of trees owned. Generally, the cooperative maintains the policy of 1 bag for every 100 coffee bushes. According to the Gatugi Coffee Factory manager, 40% of the farmers bought lime in 2019 which is fairly consistent with our own findings of 33% farmer usage (Q 1-33 2020). In 2020, yields were reported to be 332,080 kg which was a significant increase from last year's 279,567 kg. The manager also expressed confidence that this increase can be attributed to the promotion of both the lime and agriculture support.

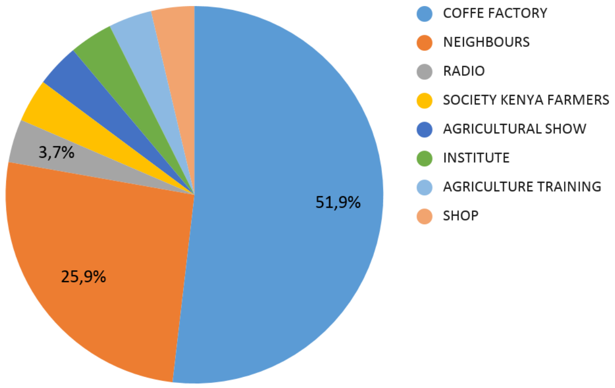


Figure 19: Where farmers have heard about lime (Source: Q 1-33 2020)

The Wambugu Farm

Wambugu farm is partially government funded centre with two main functions: Firstly, as a farm with its own production and revenue, and secondly as an agricultural training centre for local small-scale farmers. According to the manager at Wambugu farm, the centre has several services to offer. Every Thursday, the centre is open for individual consultancy and during the week various trainings are offered. Once a year, there is a free annual event where private companies can demonstrate techniques and products for farmers on demonstration plots. In addition, farmers are often referred to Wambugu services by local extension officers.

Wambugu farm claims to prioritize the management of acidification in the area and offers soil testing to help educate farmers. When results are returned to Wambugu the staff goes over the analysis with the respective farmers. According to our questionnaire data, 11% of surveyed participants had sought services from Wambugu farm and agricultural shows. These results are challenged by the findings from the semi structured interview, where the response rate was higher. Four mentioned the Wambugu farm (27%). Common recommendations given to farmers regarding soil acidity include moderate lime use, organic manures, soil/water conservation, and minimization of the use of DAP by changing fertilizers. Looking at respondent management practices and awareness on acidification respectively, there seems to be no statistically significant correlation between those who list Wambugu farm as their source of knowledge and use of lime: A t-test comparing those who heard about Wambugu and those who didn't related to their use of lime gave a p-value of 0.21 meaning that assuming there is a standard normal distribution, the two groups don't differ significantly.

Shops

To gain further insight on what farmers in the Othaya were applying to their soils, we conducted semi structured interviews with five agricultural shops in the region. Results from our farmer interviews showed that a majority of respondents (80%) obtained their fertilizers from these local shops (SSI 1-15 2020). Each shop sold a variety of fertilizers including CAN, DAP, NPK (17-17-17 and 23-23-0), and UREA for prices ranging from 35KSh/kg to 70KSh/kg. Throughout all the shops DAP was the most expensive and one of the more sought out items (KII 6-10 2020).

Only one of the interviewed shops, located in Othaya, actually sold lime. Although the shop recommended lime usage, the owner claimed it is highly unpopular due to subsidies offered at the coffee factory. Other shops surveyed either used to previously sell lime or never have, claiming that farmers in the area either don't know about lime or are not interested (KII 6-10 2020). This is consistent with our questionnaire data which showed that only 1 respondent, of the 11 who use lime, purchased it from a shop.

All shops unanimously reported that farmers indeed ask for advice when purchasing items, saying that there is a big knowledge gap amongst them. Overall, it appears that advice can greatly differ depending on the shop that a farmer chooses to go to. For example, 1 shop recommended the use of DAP, while another recommends organic manure and NPK applications.

Additional Sources

We found several additional formal and informal platforms of community information sharing. The weekly church service, for example, is considered a well-established tradition within the community. In addition to its religious purposes, local announcements are also made. From our semi structured interviews, 4 farmers mentioned it as their preferred source for information regarding governmental programs such as the soil testing kit. About 27% of the sample pool also mentioned other sources including neighbours, television, and radio. The local chief also spoke of barazas (local meetings for community members) as a place for agriculture discussions and education outreach (SII 1-15 2020). However, we found no evidence in our data of community members attending.

Historical patterns also seem to play a role in the choice of farmer management strategies, 3 out of 15 respondents referred to their knowledge of DAP came from their parents and previous landowners.

Discussion

The hypothesis laying the foundation for this study questions whether there is an increasing presence of acidic soils in Thuti, and if this has been negatively impacting productivity in crops such as maize or coffee. This was amongst other things built upon in our literature review, where studies show high levels of acidity in the Nyeri south sub county: NAAIAP & KARI (2014), for example, illustrate that 15 out of 30 assessed study samples have a pH below 5.5, finding samples with pH as low as 4.1. It may seem presumptuous to compare their values with ours since we don't know their analytic methods, but generally sources of literature on tropical soil also present pH values measured in water.

Our findings have indicated that currently soils in the study site are moderately acidic, with pH values on coffee plots ranging from 4.8 to 6.5, and pH values in maize ranging from 5.1 to 6.7. Based on the parameters presented by Kanyanjua et al., (2002), there are a few sites that could be considered 'severely acidic', but most are 'moderately acidic', leaning towards 'slightly acidic'. The optimal pH for growing maize is 5.5 to 7.0 (NAAIAP & KARI, 2014) and for growing coffee arabica it's 5.4 to 6.0 (Kuit et al., 2004), but this of course also depends on the crop variety, which was unknown or not specified by our farmers.

Acidification in soils is known to prevent nutrient uptake and hinder crop production. A majority of our respondents have in fact heard of it, which challenges previous data indicating that only 4% of small-scale farmers are aware of soil acidity problems (Muindi et al., 2016), but a very small portion of our sample actually knew what acidity entailed. Key informants informed us that farmers in the study site have had insufficient productions, only producing half the optimal yields expected from their plot sizes (KII 1&2 2020). This was confirmed for some of the farmers in our sample pool, but whether the insufficient production can be directly attributed to acidity is questionable considering that our data shows no significant correlation between pH and yields.

Even though just a few farmers had a more in depth understanding about the consequences of acidification, a significant amount still assumed that it somehow negatively influenced crop production and soil fertility. Many respondents that we spoke to actually directly related fertile soils with the application of fertilizers, so naturally their focus in responding to soil fertility issues lied in their inputs. Manure application, for example, is essential in Thuti as it was utilized by all farmers we interviewed except one. This we assume to be partially influenced by agricultural extension officers that had previously visited Thuti preaching for more application of manure and fertilizers. A study on humic nitisols in the Kenyan highlands did actually find that cattle manure effectively improved soil fertility by increasing pH (Mugwe, Mugendi, Mucheru-Muna, Odee & Mairura, 2009). Perhaps emphasis on manure application is helping stabilize any acidification that's perceived to be in Thuti soils, but due to missing data on specific amounts applied accurate correlations could not be found.

The use of inorganic fertilizers, specifically DAP, CAN, and various NPKs, are also very popular in Thuti. This we also assume to be an influence of the agricultural extension officers' past efforts, in addition to the local Agrovet shops. The shops we interviewed reported that farmers often come in seeking advice, which was confirmed by several of our respondents. A popular requested and suggested fertilizer amongst all of them appears to be DAP. A study on acidity management in Kenya, presumes that despite its acidifying effect on soils, there is still a preference for DAP (Muindi, Semu, Mrema, Mtakwa & Gachene, 2016). Its popularity could also be attributed to its traditional use, as many farmers apply it simply because their families historically have. In contrast, there were several farmers aware of the potential long-term negative effects of applying chemical fertilizers like DAP, illustrating the knowledge gap in our sample pool. However, there is no significant enough correlation in our data to claim whether DAP application is indeed acidifying, but pH values in maize are higher amongst those farmers that don't apply it.

Still, key informants express that acidification is a serious matter that's not adequately being taken into account by all farmers (KKI 1-5). Lime application is another method being promoted by local services in response to acidification concerns, although it's not yet very popular in Thuti. The coffee factories in particular have played a significant role in encouraging it by offering subsidized lime to farmers for the price of 100 KSh. A majority of our respondents had previously heard of liming, but our findings suggests that just one third of the farmers have utilized lime at least once before, which is actually substantially greater than previous findings that found just 3% of farmers in Nyeri county using lime (Muindi, Semu, Mrema, Mtakwa & Gachene, 2016). Looking at our data, pH values are slightly higher on plots where lime was applied, but there is no significant correlation visible between liming and the pH.

Despite a 50,000 kg annual increase of coffee yields reported by a coffee factory manager, which he confidently attributes to the promotion of lime and agricultural support, there still seem to be conflicting opinions about liming amongst farmers in our sample pool. Some respondents simply weren't aware of its purpose or benefits, perhaps due to the fact that not all were educated about the specifics of acidification. There was also a respondent who didn't trust liming as a solution and was under the impression that it would add chemicals to the soil that would decrease its fertility (SSI 4 2020). Out of respondents who applied lime, there were those who felt it was necessary once having learned about its purpose, while a couple would argue that they couldn't really tell if it had an effect. This contrast in opinions appears to be another reflection of the knowledge gap within our respondents.

Reflecting on the knowledge gaps within our sample pool, a narrative involving many farmers being misinformed or uneducated on soil acidification and fertility management is visible. Interestingly, this is somewhat challenged by the fact that a majority of our respondents felt a need for testing their soil. In 2013, in an attempt to alleviate soil acidification issues, Nyeri county partnered with the national government to plan to offer mobile soil testing and extension services to farmers for a lower fee compared to marked prices (Nyeri County Government, 2013). Additionally, the government in the Nyeri county claims that 4 million KSh have been invested into purchasing soil testing kits that provide farmers with information about their soil (Nyeri County Government, 2018). Even with this resource available, we found that soil testing was not very popular amongst our respondents. Although interest was expressed by many, only one farmer had properly tested their soils before. This could be due to a widespread misunderstanding regarding the availability and price of the testing kits. We found that a lack of communication between authorities and farmers hindered the accessibility of information about agricultural programs like these.

We argue that in Thuti village, access to information is limited. Farmers who want access to agricultural information have to go through more powerful actors. In the case of Thuti, there is an increased risk that interests of these actors influence the information provided considering the low capital of farmers. For example, Wambugu farm advises farmers to reduce their use of fertilisers but it seems unlikely that vendors will advise the same, as this will reduce their revenues.

Our findings also show that between sources of information, there were contradictions, misunderstandings and miscommunications. The extension office explained that there was no cooperation between national and county administrations. On the local level, no administration had heard of the soil testing kit provided as a service from the county government. This lack of communication is an obstacle for farmers to receive accurate information and apply proper soil management strategies. Many farmers are also excluded from accessing information, since many don't have necessary structural means of access (mobility, knowledge, social identity etc.) to consult the extension officer.

In addition, we found no evidence of advertisement for the provided government services. This is exemplified by the majority of respondents who reported a lack of information was the primary reason they didn't utilize the soil testing kit. Muindi et al. (2016) similarly found a lack of awareness on acidification and management in the Kenyan highlands was due to both a lack of formalized discussions and promotion of agricultural trainings.

Langat et al. (2016) further confirms our results by arguing that in general, farmers seldom feel the impact of agricultural innovations because they don't have access to vital information or because it is poorly disseminated by most African governments. Although there are barazas (meetings with the chief), the chief confirmed that they are rarely used for an agricultural capacity. Informal spaces of communication between neighbours have also been shown to lead to misinformation. Many reported hearing about soil testing and lime from other community members but did not have accurate information on the price or process.

Conclusion

Based on our results, we did not find soil acidity to be a central problem for smallholder farmers in Thuti. We also could not find any correlations between yield amounts and pH for both coffee and maize. However, our findings do not suggest acidity doesn't exist in the area. Additionally, we believe acidification has the potential to become the most prominent soil fertility issue due to overuse of chemical fertilizers. Considering the popularity of DAP, future studies could explore if the long-term DAP usage in the community has contributed to increasing acidification.

We found a majority of farmers heard of acidification but could not provide an explanation of the problem and therefore did not employ management strategies for acid soils. The majority of farmers also considered fertile soil to be attributed to fertilizer use due to immediate visible changes in yield. Contrary to this perception, we recommend farmers dealing with acidity to consider reduction of DAP usage, liming, and manure application to raise pH levels. Additionally, we advocate for periodic soil testing for farmers to understand the specific needs of their soil. Although we found provided resources available to address acidification issues, we found only a small amount of farmers utilizing them. We believe this is due to both a general lack of information on the resources and miscommunications between stakeholders. Local officials had never heard of testing programs offered by the extension office and there seemed to be a lack of advertisement of agricultural programs. We recommend the government to establish effective communication links, coordinate main sources of information, and promote awareness through campaigns. These recommendations could be accomplished through meeting facilitation, advertisement in churches, and demonstration plots to reach more farmers.

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Appendixes

Annex 1: Synopsis

Soil Fertility and Management Practices addressing Soil Acidification in Thuti, Kenya - Synopsis

Unit: 5480-B3-3F20; Thematic Course: Interdisciplinary Land Use and Natural Resource Management

Date: 21/02/2020

Location of field study: Othaya, Kenya

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Outline of synopsis

Introduction

The agricultural sector plays a fundamental role in Kenya's economy, contributing approximately to 26% of the GDP and employing more than 70% of Kenya's rural people. Kenya's population has increased from 11 million in 1970 to 51.3 million in 2018 (World Bank, 2019). As a result of this rapid increase, land parcels in areas of high agricultural potential are decreasing in size, resulting in farmers competing for access to natural resources with consequences in land conflicts. In addition to population pressure, agricultural productivity is constrained by different factors in remote rural areas: market accessibility, unsustainable land management practices, climate variability, and institutional isolation due to weak governmental policies and investments. These constraints have hindered the adoption of soil conservation technologies and have prevented farmers from applying inputs in ideal quantities (Kabubo-Mariara, 2015).

While the Kenyan agricultural sector encourages food policies emphasizing self-sufficiency, a decline in crop production has led to over 10 million Kenyans being considered as chronically food insecure (Muindi et al., 2016). This decrease in production can be attributed to a variety of factors including soil fertility, farm management, and postharvest practices. Specifically, one issue seen affecting Kenyan soils is acidification.

Soil acidification refers to the process in which soils become more acidic over time, and negatively affect the ability for crops to uptake nutrients, resulting in yellow leaves and decreased yields over time. Acidic soils are technically those with pH values below 7.0, but lower values are those that are potentially harmful (see Figure 1). In 2002, 13% (7.5 million hectares) of the agricultural land in Kenya was considered acidic (Kanyanjua et al., 2002) and there is a general drop in pH and decline in soil organic matter in Kenyan soils (Muthoni, 2016).

Degree of acidity	pH range
Extremely acidic	<4.5
Strongly acidic	4.5-5.0
Moderately acidic	5.0-6.0
Slightly acidic	6.0-6.5
Near neutral	6.5-7.0

KARI–Kabete working manual

Figure 1: Grading of levels of soil acidity: (Kanyanjua et al., 2002)

Acidic soils commonly develop in a humid climate and are thus typically found in tropical savanna and rainforest zones where severe leaching and weathering can be experienced (Schroth & Sinclair, 2003). In agricultural systems, soil acidification can actually be catalysed by the leaching of basic cations or by their removal with harvested crops. Additionally, some fertilizers like urea, ammonium sulphate, and potassium chloride can also have an acidifying effect (Schroth & Sinclair, 2003). Toxicities of hydrogen (H), aluminium (Al), iron (Fe), and manganese (Mn), along with deficiencies in phosphorus (P), molybdenum (Mo), calcium (Ca), magnesium (Mg), and potassium (K) are also common in acidic soils (Muindi et al., 2016). Other soil characteristics often include low water holding capacities in combination with a susceptibility to erosion, crusting, and compaction (Schroth & Sinclair, 2003).

Acidification can be managed through different strategies, such as the application of lime, management of leaching and the use of appropriate fertilisers, however, if acidification is not managed in relation to crop tolerances, no matter the amount of nutrients in the soil, crops are likely to provide less than the optimal yields.

Background

The scope of the study is isolated to the specific context of the Thuti in the highlands of central Kenya. Thuti is located within Nyeri county which has a high population density of 228 habitants pr. km2 and is considered an important agricultural area (KNBS, 2019). This area has cooler temperatures, volcanic soils rich in phosphorus, and is considered to be more fertile for agriculture compared to most parts of Kenya (NAAIAP & KARI, 2014). More specifically, the predominant soil type is a productive soil type called humic nitisol (FAO, 1997; Ovuka, 2000).

Figure 2: Satellite picture marking Thuti and Othaya. Souce: Google maps [edited].

Being characterized as tropical highlands, there are minimal seasonal fluctuations in temperatures throughout the year while there are greater daily fluctuations in temperature compared to other climatic zones (Encyclopaedia Britannica, 2020). Rainfall is bimodal and the county has a yearly average rainfall of 1,401 mm.(Climate-Data.org, 2019). Average temperature is 16.8 degrees celsius in the county and the Köppen-Geiger classification is Cfb, meaning that the climate is a more stable temperate oceanic climate (Climate-Data.org, 2019). However, there might be great variations between years and specific geographical location, even though the categories above apply to the whole county.

Typical cash crops cultivated in the region are coffee and tea, while the typical subsistence crops produced are fodder crops, maize, beans, sweet potatoes, Irish potatoes, beans, sugar cane, and yams (Pinard, 2014; FAO, 2016). Most farmers in Kenya have at least a small subsistence plot in labour dependent polycultures (MacKenzie, 1989), which contrast agricultural practices in developed countries that are characterised by monocultures and machination (Weis, 2013).

Due to acidification issues throughout the central highlands, the cultivation of horticultural crops for subsistence can be quite challenging. For example, in the Nyeri South sub county, a sample of 30 farms showed that the soil pH has a wide range of 4.1 to 6.67 (see Figure 3) (NAAIAP & KARI 2014). More than half of these farms have a soil pH below 5.5 meaning they're not suitable for the cultivation of subsistence crops like maize, which typically tends to lie in the medium tolerance range of 5.5-6.0 pH values (Kanyanjua et al., 2002).

Soil Parameter	Min	Max	Target (critical) level	Samples with below adequate levels	% of 60 samples (30 farms)
pH	4.08	6.67	≥ 5.5	31 (< 5.5)	52
Total Organic Carbon (%)	0.98	3.82	≥ 2.7	4	7
Total Nitrogen (%)	0.10	0.38	≥ 0.2	32	53
Available P (ppm)	5	222	≥ 30.0	48	80
Potassium (me %)	0.10	2.07	≥ 0.24	5	8
Calcium (me %)	0.6	17.1	≥ 2.0	17	28
Magnesium (me %)	0.03	8.41	≥ 1.0	7	12
Manganese (me %)	0.03	1.36	≥ 0.11	4	7
Copper ppm	2.95	322	≥ 1.0	0	0
Iron ppm	12.5	143	≥ 10.0	0	0
Zinc ppm	3.10	127	≥ 5.0	3	5

Figure 3: Soil fertility status of Nyeri South sub county: (NAAIAP & KARI, 2014)

In 2013, in an attempt to alleviate soil acidification issues, Nyeri county partnered with the national government to plan to offer mobile soil testing and extension services to farmers for a lower fee compared to marked prices (Nyeri County Government, 2013). Additionally, the government in the Nyeri county claims that 4 million KSh have been invested into purchase soil testing kits that provide farmers with information about their soil (Nyeri County Government, 2018). A total of 500 million KSh has also been invested to procure and distribute lime to 82,000 farmers throughout the county (Nyeri County Government, 2018).

The Kenyan government has also been subsidizing fertilizers for small scale farmers, lowering the commercial price from 3500 KSh to 2500 KSh pr 50 kg (Muthoni, 2016). However, there is little evidence suggesting the adoption of these governmental services in the following years. A study from 2016 in nine Kenyan counties including Nyeri found that less than 3% of the farmers studied had applied lime once on their farms and less than 8% had carried out soil analyses on their farms. Moreover, less than 4% were aware of soil acidity problems (Muindi et al., 2016). Studies also suggest that subsidized fertilisers are not being utilised, as the fertilizers can only be bought from National Cereals and Produce Board (NCPB), which are inaccessible for many farmers due to long distances (Muthoni, 2016).

Research questions

Since there is a wide range of soil pH throughout the Nyeri South sub county, it's unclear which agricultural practices have a significant effect on soil acidity in Thuti. Additionally, there have already been several studies regarding soil acidification and farmers' perceptions of it throughout Kenya, but no previous research included the influence of governmental services on farmers' management strategies. Therefore, for our study we formulate the following main research question:

How is soil acidification perceived by farmers in Thuti and how do their management practices affect soil acidity?

By focusing on perceptions of farmers we formulate the following sub-questions:

1. What kind of agricultural methods are practiced?
2. Do farmers perceive acidification as a problem?
3. How have services provided by the national and local government addressing soil acidification been adopted by farmers in Thuti?
4. How do different applications and management practices affect pH, fertility, and organic matter content?

To limit the scope of our study we will focus only on two crops that will serve as a foundation for comparing the different management practices between farmers. A cash crop and a subsistence crop will be chosen based on the information we acquire from our first questionnaire, as elaborated in our methods section.

To narrow down the scope of the study, ideally we want to focus on only one service provided by either the Nyeri county or the national government. At this state of the project, and in order to maintain flexibility, we'll retain from choosing only one program yet, until we have a better understanding of the realities in Othaya.

Methodologies

The following section is an introduction to the methods that will be applied throughout the field course, followed by arguments for their selection and considerations on their limitations. Both social science methods and natural science methods will be utilized and both quantitative and qualitative data will be collected. As such the general scientific approach can be described as triangulation.

Ideally, we will gather our data from a broad range of participants, so that it includes a range of diversity in Othaya relating gender, wealth, management practices etc.

Some considerations have influenced how each of the described methods are conducted more practically. These considerations cover our roles and ethics as researchers and how our background in an anglocentric, male dominated scientific paradigm influences our findings and effects on the community in which we operate.

Ethic issues and conflicts might e.g. arise if governmental agencies are criticised publicly, or their authority is questioned. Our motives and considerations on who benefits from the research have been discussed prior to the field work, but a section specifically addressing these questions will be included in the final report.

Quantitative data collection

pH testing

Soil pH data will be collected on all the farm sites participating in the study in order to differentiate acidity levels between subsistence and coffee plots. Separate pH tests will be conducted for each plot and an acidification assessment by collecting four samples from each plot measured. A composite sampling strategy will be used by taking two samples from opposite ends of the field, in which soil samples are extracted from the surface at a 25 cm depth. After shaking and adding them to a 50 ml centrifuge tube, the pH meter will be dipped into 20 mm of the suspension fluid to obtain the pH value. A composite average of the soil samples will be calculated for each plot tested.

Nitrate concentration and nutrient analysis testing

A composite sampling strategy will be used to acquire soil nitrate concentrations and a nutrient analysis to assess if there is a correlation with soil acidity. Nitrate can be tested on site. Samples will also be taken back to the lab for nutrient and organic matter analysis. The nutrients being tested for will include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), and Magnesium (Mg). Fifteen farms will be selected in the study based on the type of crops grown and management strategy used by the farmer. Ideally there will be an equal number of coffee and subsistence plots tested. A total of 4 samples will be taken from each plot. Using a soil core, samples will be collected from a 15 - 60 cm depth from opposite ends of the plot. Nutrient samples will be dried, weighed, and sealed for transport back to the lab. Nitrate samples will then be divided into subsamples to reduce the chance of erratic readings. To determine the total nitrate concentration for each plot an average of score will be calculated.

The high variability of nutrient content and pH in soil may result in less precise results. Therefore, these cannot be considered suitable for a general recommendation of all soils in Othaya and is considered a limitation of our methods.

GPS mapping

GPS mapping will be used to track the location of participants in the study chosen for sampling. Locations marked during the transect walks will be differentiated based on the type of sampling method performed. The fifteen selected plots for nutrient analysis and semi-structured interviews will be measured for area and elevation using GPS.

Questionnaires

A questionnaire containing mostly closed ended questions will first be distributed to farmers throughout Thuti. This close ended approach formulates a structured interview that will not encourage the respondent to divert from the questions. Although quantitative information is not well suited for understanding causal relations compared with qualitative data collection, benefits from this approach are that the data is more homogenous. This allows us to analyse the correlations between different categorical indicators and to select farmers for a secondary more qualitative interview. Shortly after arrival to the field site we will try to map relevant farmers for these questionnaires. The provided opportunity to consult a local senior will be utilised for this.

Qualitative data collection

semi-structured interviews

Using information acquired from the questionnaires, we will systematically select respondents for a second round of interviews based on their common crops and management practices. These semi-structured interviews will be focused on acquiring more qualitative data. The data will be collected via more open-ended questions, allowing for in depth elaboration on certain topics and the provision of more unique answers. There is also potential for respondents to provide information that we overlooked while designing our questionnaire. As one of our objectives is to understand perceptions of acidification, it is not as important if the answers provided are factually correct. However, as a case analysis, it provides the opportunity for gathering an understanding of the wide variety of perspectives. One challenge to this approach is that both the data collection and data assessment becomes less uniform.

Selection of governmental actors

The final approach for the selection of respondents will be pragmatic and purposeful as fewer options are expected. Those opportunities for interviewing governmental bodies that arrive will be utilised immediately. We intend to locate the agriculture extension officer as a starting point. For interviewing governmental bodies, the semi-structured interviews will be the primary approach, as the need for uniformity is lesser, while elaborations, explanations and detours are more welcome.

Focus group

As an extension to our qualitative data collection, focus groups should ideally be conducted. This allows for testing of our findings, as participants will have the opportunity to question the data we have collected prior to the interview. It also allows us to observe interactions and discussions between stakeholders with different perspectives or values, where members from different groups can challenge or confirm each others' arguments. As such, contradicting findings are not our sole responsibility to compare, as some contradictions might be clarified under the focus group.

Participant observations

While completing questionnaires and soil samplings, participatory observations are systematically noted to provide the opportunity for discussing the quality of the data collected. Information collected through this method includes searching for observations that might contradict the statements of the respondents.

To get a better understanding of the process of acquiring and using soil testing kits, and understanding of the results from the test, we wish to observe this process. We plan to obtain a soil test to record the process and results. However, the approach might be challenged by lack of interest in participating from farmers, lack of access to the service or too long time frames on acquiring the soil testing kit.

Overall Objective: To research how farmers perceive acidification in order to assess how their management practices affect soil acidity in Thuti		
Sub Question	**Data Required/Output**	**Methods**
What kind of agricultural methods are practiced?	Distribution/location of farms Technology and management strategies used, highlighting those intended to treat acidification What crops are cultivated	GPS mapping Questionnaires and semi-structured interviews Questionnaires
Do farmers perceive acidification as a problem?	Farmers' awareness and perceptions of soil acidification	Questionnaires and semi-structured interviews
How have services provided by the national and local government addressing soil acidification been adopted by farmers in Thuti?	Farmers' perceptions of governmental services Utilization of the governmental services (soil testing kit, lime, subsidiaries) Perceptions of issues from governmental bodies	Questionnaires and semi-structured interviews Semi-structured interviews. Participant observation
How do applications and management practices affect PH, fertility, and organic matter content? (in coffee and subsistence crops)	Type of fertilizers/limes applied Annual yield totals pH (Soil acidity) OM/SOC Macro/micro nutrients (N,P,K,Ca, Mg) Water holding capacity	Soil testing on site Questionnaires Lab tests

Annex 2: Questionnaire 1: for practitioners/farmers

GPS-point: s___________ e ____________ **Elevation:_________________** **Area:_________________**	**Interviewer:**
References for recordings:	**Group Number:**
Note taker:	**Translator:**
Reference number:	**Date and time: / / :**
pH value maize: _________________	**pH value coffee: _________________**

Introduction

1. Introduce all students present and ask for the respondents' name as well.
2. We are students from the University of Copenhagen in Denmark merged with the University of Nairobi, performing a field trip as a part of our learning experience. As such we are here to learn. Our research is aimed at assessing how farmer perception and management of soil affects soil acidification. The data we gather is not part of any private or governmental activity. However, the result may become public, as we wish to be able to send back our reports to everyone who has contributed. Therefore, we would also like to give the opportunity for you to stay anonymous, if you don't wish that your answers can be linked to you.
3. We are grateful to be able to experience your country and culture, and wish to thank you for your time and contribution.
4. Make sure they grow either maize, coffee or both.

Background information	
5. What is your name?	
6. Do you prefer to stay anonymous in our report?	yes______ no________

7. How old are you?	<20: ___________ 20-30: ___________ 30-40: ___________ 40-50: ___________ 50-60: ___________ 60< ___________
8. What is your main occupation?	a) Employed ___________ b) Unemployed ___________ c) Farmer ___________ d) Other ___________
9. How many individuals are in your household?	Number:
10. Do you have access to electricity in the house you live in?	yes______ no________
11. Do you have access to tap water?	yes______ no________
12. Do you own any means of transport? If so, please specify	yes______ no________ Specify which: ______________________
13. Who owns the land/livestock you work on?	
14. Who owns the house you live in?	
15. How many units of livestock?	Cow: ______ unit ________ Goat: ______ unit ________ Chicken: ______ unit ________ Other: ______ unit _______
16. What is the size of the land (specify unit)?	Size: ______ unit ________
17. How long have you owned the land?	
18. Did you complete an educational program? Please specify which.	a) Graduate___ b) Secondary school___ c) Primary school___ d) Not completed primary___

	e) Never gone to school___ f) Other________________
19. Did you participate in any agricultural training programs? Please specify which.	

Information on the plot	
20. Are you the main worker on the plot?	yes______ no________
21. Do you have any other workers on the land? How many?	yes______ no________ Within family number: ______ Outside family number:______
22. If so please specify if seasonal or permanent workers.	Seasonal ______ permanent________
23. What crops do you farm?	
24. What crops do you sell?	
25. Do you produce the two following crops (please specify the average yields)	Yields Quantity unit a) Maize: ________ _______ b) Coffee: ________ ________
26. How big are the coffee and maize plots?	unit a) Maize: ________ b) Coffee: ________

Soil management IMPORTANT: All questions only apply to the two specified crops	

27. Do you use fertilizers? (Both organic and inorganic) If so, on maize or coffee?	yes______ no________
28. What kind of fertilizers do you use?	
29. Do you use irrigation systems on your crops? If so, on maize or coffee? If not, why not?	yes______ no________
30. Do you till? If so, how often? If so, on maize or coffee? If not, why not?	
31. Have you ever heard of liming before? Where?	
32. Do you consider liming as an effective way of dealing with soil acidity?	
33. Do you apply lime on the soils? If so, how much(unit) and how often? If so, on maize or coffee? If not, why not?	

34. Do you practice intercropping? If so, on maize or coffee? If not, why not?	
35. Do you practice crop rotation? If so, how often do you rotate crops? If so, on maize or coffee? If no, why not?	
36. Do you practice fallow in your land? If so, how often? If not, why not?	
37. Do you use any kind of machinery? If so, please specify what type. If so, on maize or coffee? If not, why not?	
38. Do you do anything else to improve soil fertility?	
39. Have the management strategies had the intended effects?	yes______ no________
40. Which soil fertility management practices and technologies that you are aware of that you wish to try on your farm in the future?	
41. Do you get advice from anyone regarding your soil fertility management? If so, who and how frequently?	

Soil acidification	

42. Would you consider your soil to be fertile?	
43. On a scale on 1-10 how fertile do you consider your soil?	
44. Are you aware of issues related to acid soils?	
45. Are the soils on the plot affected by acidification? If so, is it a problem? If so, on a scale on 1-10 how acid do you think it is?	yes______ no________ yes______ no________
46. If so, how is the problem managed?	
47. Have you ever felt the need to test the soil pH of your farm?	

Wrapping up	
48. Do you have any questions you would like to ask us?	
49. Would you like to participate in a more comprehensive test of your soils through the soil testing kits provided by the county?	yes______ no________

Observations:	
50. What's the gender of the respondent	male______ female________ other________
51. Any signs of the respondent feeling uncomfortable during the interview?	yes______ no________
52. Does s/he seem reliable?	yes______ no________
53. Any observations that contrasts the answers given? Please specify.	
54. Characteristics of assets and immediate surroundings. Neatness, facilities, etc.	
55. Which assets do they have?	Tv): __________ Cellphone): __________ Radio): __________ other): __________

Annex 3: Semi structured interview guide 1: for practitioners/farmers

GPS-point: s:____________e:___________ **Elevation:_________________** **Area:_________________**	**Interviewer:**
References for recordings:	**Group Number:**
Note taker:	**Translator:**
	Date and time: / / :

1. Introduce all students present
2. We are students from the University of Copenhagen in Denmark merged with the University of Nairobi, performing a field trip as a part of our learning experience. As such we are here to learn. Our research is aimed at assessing how farmer perception and management of soil affects soil acidification. The data we gather is not part of any private or governmental activity. However, the result may become public, as we wish to be able to send back our reports to everyone who has contributed. Therefore, we would also like to give the opportunity for you to stay anonymous, if you don't wish that your answers can be linked to you.

Introduction	
1. What is your name?	
2. Can we record this interview?	
3. Do you wish to stay anonymous?	

Soil fertility	

4. What does soil fertility mean to you?	
5. How do you differentiate between fertile soils and infertile soils?	
6. During the last 5-10 years, has the fertility of soils on your farm changed and how?	
7. What are indicators of this change?	
8. What has caused this change in soil fertility?	
9. Does your soil fertility influence your crop choice?	
10. What influences your ability to implement the management practices that you prefer?	
11. Do you feel that your annual productions are sufficient?	

Soil acidification	
12. What do you understand by soil acidification?	

13. What are the consequences of acidification?	

Management practices	
14. What challenges have you faced in implementing soil fertility management practices?	
15. Have you seen changes before and after you implemented management practices?	
16. When do you apply fertilizers on your coffee?	
17. How much fertilizers do you apply on your coffee?	
18. When do you plant and harvest your coffee?	
19. When do you apply fertilizers on your maize?	
20. How much fertilizers do you apply on your maize?	
21. When do you plant and harvest your maize?	

22. Where do you get your fertilizers and pesticides?	
23. Do you think the price of fertilizers is fair?	
24. Do you leave plant residues on your field?	
25. Where do you get lime?	
26. If you apply lime how much do you apply? If you don't, why not?	
27. How much does lime cost?	
28. If you use DAP where do you get it and how much do you apply?	
29. Where did you hear about DAP?	
30. Do you apply pesticides on your crops? How much?	
31. (If they have received advice from an outside source) what did you take away from it?	

Policy instruments	
32. Are you aware of the soil testing kit offered by Nyeri County Government?	

33. What is your perception on soil testing?	
34. Do you understand the need for soil testing?	
35. Do you understand the process of soil testing?	
36. Have you ever tried using the soil testing kit on your plots/land? If no Why? If yes, when did you last conduct soil testing?	
37. If yes, was it easy or difficult to use?	
38. Was it giving reliable and clear results?	
39. Would you use it again?	
40. Did the test affect how you manage your soils	
41. Few are utilising the soil testing kits. Can you	a) Lack of information b) It is not effective c) Not reliable

imagine why this is the case?	d) Difficult to use e) Difficult to access f) Expensive g) Other:
42. Are you aware of any other governmental programs for soil fertility and or acidification?	
43. If so, do you consider it/them to be helpful programs?	
44. Why do you think those were implemented?	
45. Have you ever participated? If not, would you try to participate?	
46. How could the soil testing kits be improved?	
47. To you, how can the government best help farmers manage acidic soils?	

Wrapping up	
48. Any questions for us?	

49. Would you like us to send the results from our soil tests? If so, provide contact details.	

Annex 4: Key informant interview 1: Semi-structured interview guide for agricultural officer

Department	**Interviewer:**
References for recordings:	**Group Number:**
Note taker:	**Translator:**
	Date and time: / / :

1. Introduce all students present and ask for the respondents' name as well.
2. We are students from the University of Copenhagen in Denmark merged with the University of Nairobi, performing a field trip as a part of our learning experience. As such we are here to learn. Our research is aimed at assessing how farmer perception and management of soil affects soil acidification. The data we gather is not part of any private or governmental activity. However, the result may become public, as we wish to be able to send back our reports to everyone who has contributed. Therefore, we would also like to give the opportunity for you to stay anonymous, if you don't wish that your answers can be linked to you.
3. We are grateful to be able to experience your country and culture, and wish to thank you for your time and contribution.

What is your name?	
Can we record this interview?	
Do you prefer to stay anonymous in our report?	
Which governmental agency do you represent?	
How long and in what capacity have you worked with farmers in this area?	

Acidification and responsibilities	
1. Is acidification of soils an issue in Nyeri county?	
2. Do most farmers perceive it as an issue?	
3. If so, how is it managed by farmers?	
4. How is it managed by the national government?	
5. How is it managed by the Nyeri county?	
6. Whose responsibility is it?	
7. What are the causes of acidification?	
Governmental programs	
8. Have you heard of the soil testing kits provided by the Nyeri county?	
9. What were the intentions behind the soil testing kits provided by the government?	

10. What is the process for obtaining a soil testing kit for the farmers?	
11. How are farmers informed about the service?	
12. Are there any challenges in promoting the testing kit to farmers?	
13. Why would the farmer use the service?	
14. Few farmers we've talked to are aware of issues related to acidification. Can the program reach these farmers? If no, how can these farmers be addressed?	
15. Do most farmers find it easy to utilize the service?	
16. What are the main challenges for farmers who want to use the service?	
17. How long has the service been provided?	

18. Who finances the testings? (Is it free to use for the farmers?	
19. How can the farmers use the feedback from the testings?	
20. Has there been any feedback from farmers?	
21. Few of the people we have talked to have utilised the soil testing kits. Can you imagine why this is the case?	
22. Some we have talked to say the kit costs 3000 to use. Why would they say that?	
Management in general	
23. What are the most common soil fertility management practices used by farmers in this area?	
24. What other solutions are offered for soil management for farmers	
25. To what extent are these practices adopted by farmers?	
26. What specific challenges have you encountered in promoting these new soil fertility management practices?	

27. Do you offer any advice support to farmers having issues with soil fertility? If so, is it paid or unpaid?	
28. Do you keep track of specific issues with acidic soils in the county area? If so, could we have access to that information?	
29. Does the county government subsidy fertilizers and lime for farmers? Why/why not?	
30. What constraints do farmers say they face in utilizing various soil fertility management practices and technologies?	
31. Do farmers interact with each other, to discuss issues related to adoption, and their own innovations? Are there formalised arenas?	
32. What suggestions would you make to improve the adoption of soil fertility management by farmers in this area?	

Annex 5: Key informant interview 2: Semi-structured interview guide for Wambugu farm

Department	**Interviewer:**
References for recordings:	**Group Number:**
Note taker:	**Translator:**
	Date and time: / / :

4. Introduce all students present and ask for the respondents' name as well.
5. We are students from the University of Copenhagen in Denmark merged with the University of Nairobi, performing a field trip as a part of our learning experience. As such we are here to learn. Our research is aimed at assessing how farmer perception and management of soil affects soil acidification. The data we gather is not part of any private or governmental activity. However, the result may become public, as we wish to be able to send back our reports to everyone who has contributed. Therefore, we would also like to give the opportunity for you to stay anonymous, if you don't wish that your answers can be linked to you.
6. We are grateful to be able to experience your country and culture, and wish to thank you for your time and contribution.

What is your name?	
Can we record this interview?	
Do you prefer to stay anonymous in our report?	

Questions:

1. Can you explain what is the purpose of the Wambugu agricultural training centre?
2. Is the training available for anyone? (Are there any requirements?)
3. What kind of management practices do you educate on?
4. Who finances the training?
5. Do you conduct any research that informs the recommendations you offer to farmers?
6. What do you consider to be fertile soil?

7. Do you cooperate with the government? How?
8. How does your program reflect governmental recommendations?

Acidification

9. Is acidic soils a problem in Nyeri County?
10. Does the training at Wambugu address soil acidification?
11. How can farmers test their soils for acidification?
12. How can farmers manage acidification?
13. Can you help farmers manage acidification?
14. Is the government doing enough to help farmers identify and manage soil acidification?
15. In your opinion - how should the government help farmers identify and manage acidification?

Annex 6: Key informant interview 3: Semi-structured interview for the Coffee factory

Department	**Interviewer:**
References for recordings:	**Group Number:**
Note taker:	**Translator:**
	Date and time: / / :

7. Introduce all students present and ask for the respondents' name as well.
8. We are students from the University of Copenhagen in Denmark merged with the University of Nairobi, performing a field trip as a part of our learning experience. As such we are here to learn. Our research is aimed at assessing how farmer perception and management of soil affects soil acidification. The data we gather is not part of any private or governmental activity. However, the result may become public, as we wish to be able to send back our reports to everyone who has contributed. Therefore, we would also like to give the opportunity for you to stay anonymous, if you don't wish that your answers can be linked to you.
9. We are grateful to be able to experience your country and culture, and wish to thank you for your time and contribution.

What is your name?	

Can we record this interview?	
Do you prefer to stay anonymous in our report?	

Questions:

1. General questions in the introduction: who are they? When did the factory start its operation?
2. What criteria do you use to register new farmers and visit them for recommendations and advice?
3. Please would you take us through the process of registering a new farmer up to when they get paid
4. Do you conduct any research to create the recommendations you offer to farmers?
5. Do you export processed coffee and to which countries?
6. Do you provide lime to the farmers? If so, what is the price?
7. What is your connection with the government? Which government department supplies the lime to you?
8. Is a part of your mission to help farmers with management strategies

Annex 7: Key informant interview 4: Semi-structured interview guide for shop owners

Shop type	**Interviewer:**
References for recordings:	**Group Number:**
Note taker:	**Translator:**
	Date and time: / / :

1. Introduce all students present and ask for the respondents' name as well.
2. We are students from the University of Copenhagen in Denmark merged with the University of Nairobi, performing a field trip as a part of our learning experience. As such we are here to learn. Our research is aimed at assessing how farmer perception and management of soil affects soil acidification. The data we gather is not part of any private or governmental activity. However, the result may become public, as we wish to be able to send back our reports to everyone who has contributed. Therefore, we would also like to give the opportunity for you to stay anonymous, if you don't wish that your answers can be linked to you.
3. We are grateful to be able to experience your country and culture, and wish to thank you for your time and contribution.

1. Do you prefer to stay anonymous?	
2. What fertilisers do you sell?	
3. What fertilisers are most popular?	
4. Do you provide any illegal / non-recommended fertilizers?	
5. What advices do you normally give to farmers who don't know what fertilizers to use?	
6. Do you sell lime?	
7. If so, how much do you sell per year?	
8. What limes are most popular?	
9. Are there any limitations in the supply of fertilizers?	

10. Are there any limitations in the supply of lime?	
11. Do you recommend farmers to use lime? Why/why not?	
12. Can farmers easily acquire machinery for their farms?	
13. What pesticides do you sell?	
14. How much pesticides do you sell annually?	
15. What advices related to pesticides do you give farmers	
16. Can a farmer buy as much of everything as he/she needs?	

Observations	
What fertilizers are available? Prices?	

What kind of lime is available? Prices?	
What kind of pesticides are available? Prices?	
What kind of machinery is available? Prices?	
Any written recommendations?	
Do farmers come to the owner for advices?	

Annex 8: Interview references

Questionnaires (Q n 2020)

Name of respondent	Reference no.
Agatha Wakarine	1
Charles Nderitu	2
Felisiana Wairimu	3
John Kahure	4
John Mwangi Wambui	5
John Nderitu	6
Mary Kangema Nderitu	7
Theresa	8
Mama Zakari	9
Rosemary Wambui	10
Peter Mureithi	11
Serah Wangui	12
Sofia Nyambura	13
Susane Ndiritu	14
Albert	15
Ann Wanjiku	16
Charles Weru	17
Constantine	18
Esther Mureithi	19
Helen	20
James Njanjo	21
Janet Njeri	22
Jemimah	23
Joseph Ndirangu	24
Leah Wanjohi	25
Lois Nyambura	26
Judy	27
Margaret Muthoni	28
Mary Mumbi	29
Nancy Gathoni	30
Rebecca Mumbi	31
Susan Kathure	32
Teresa Wanjungu	33

Semi structured interviews (SSI n 2020)

Name of respondent	Reference no.
Agatha Wa Karima	1
Charles Nderitu	2
Felisiana Wairimu	3
John Kahure	4
Anonymous 5	5
John Nderitu	6
Mary Kangema Nderitu	7
Teresa	8
Helen Mwendia	9
Rosemary Wambui	10
Anonymous 11	11
Serah	12
Sofia Nyambura	13
Susan Nderitu	14
Constantine	15

Key informant interviews (KII n 2020)

Name of respondent	Stakeholder	Reference no.
Charles Kabia	Agricultural extension officer	1
John Wambugu	Wambugu Farm	2
Anonymous 3	Coffee factory	3
Peter Wambugu	The chief assistant	4
John Githumbi Rasta	The village elder	5
Anonymous 6	Shop owner	6
Anonymous 7	Shop owner	7
Anonymous 8	Shop owner	8
Anonymous 9	Shop owner	9
Anonymous 10	Shop owner	10