Assessing farmers' perceptions and response to weather hazards and climate change

- an interdisciplinary analysis of the adaptive capacity of farmers in Karima North, Kenya -

by

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Abstract

The area of Karima North, in the Central Kenyan Highlands, mainly consists of small-scale farmers. Their agriculture is rainfed and thus depending on rainfall patterns. Due to climate changes, the precipitation in the area is expected to make the rainfall pattern more unpredictable. A fieldwork was conducted in order to investigate how farmers in the area perceive and respond to weather hazards and climate change. In addition, factors influencing the adaptive capacity was identified. Through an interdisciplinary approach, it was found that the farmers are not necessarily vulnerable to changes in weather and climate, but are rather acting upon them; implementing adaptation strategies, such as changing seeds and making terraces. This, together with good natural conditions, give farmers a good potential to adapt. Meanwhile some barriers to carry out this potential was identified. First of all, challenges was found in the communication between the officials providing the information on weather, climate and agricultural practices, and the farmers receiving it. Here the information tend to get lost in translation and the effort of making farmers aware of the effects of long-term climate change fails. Secondly, socio-economic factors, for example income and land size, was found influencing the farmers in terms of exposure to weather hazards and climate change. Thirdly, the given advices from officials on how to adapt is regardless of the socio-economic characteristics of the farmer. We argue the need for increasing long-term perspective, both considering farmers and the government in order to comprehend future challenges in climate.

Preface

This paper is a report with the purpose of satisfyingly end the Interdisciplinary Land Use and Natural Resource Management course offered by the Sustainable Land Use and Natural Resource Management consortium at University of Copenhagen.

Special thanks go to our supervisors. To PhD fellow Daniel Ortiz Gonzalo at University of Copenhagen, Department of Plant and Environmental Sciences, for invaluable support and constructive criticism throughout the process, both in Copenhagen and in the Kenyan heat, in addition to always responding quickly on e-mails at any point during the day or week. It has been *super nice*! To Postdoc Martin Skrydstrup at University of Copenhagen, Department of Food and Resource Economics, we thank you for your skillful organisation in unfamiliar environments as well as hard work and effort to always cater for our personal and professional needs in the field. Further, we appreciate your inspiring and supportive analytical expertise. To Lecturer Ebbe Prag at Department of Environmental, Social and Spatial Change, University of Roskilde, we are thankful for the supervision and introduction to Kenya prior to our field trip. We are saddened to hear about your personal loss and that we did not get to work with you in the field given your valuable experience.

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Further, we wish to thank all the locals who helped us. Our interpreter Anthony Kagwi and field guide Joyce Gachagua for constantly being available, for their long hours of work and for leading the way even through the sunniest of days and tallest of crops. John Githumbi, village elder in Karima North, for sharing your big amounts of knowledge on the area and farmers. To James Mwangi, we are greatly appreciative for your timely work driving us around the area and always being available at the time we requested, a deed that is not easily found to this extent in the area. Assistant Chief Andrew Gachagua for making his office available to us for our entire stay.

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Abbreviations

Methods:

Q: Questionnaire

SA: Soil analysis

IC: Informal conversation

M: Mapping

CM: Cultural mapping

PRA: Participatory Rural Appraisal

SSI: Semi-structured interview

O: Observation

TW: Transect Walk

GPS: Global Positioning System

Measurements:

SOM: Soil organic matter

C: Carbon

C:N: Carbon:Nitrogen

PCA: Principal components analysis

Actors:

KMD: Kenya Meteorological Department

AEO: Agricultural Extensive Officer

WSI: World Soil Information

WMO: World Meteorological Organisation

WHCC: Weather hazards and climate change

All names, except the ones of official persons including our Village Elder, are pseudonyms, used to protect the anonymity of our informants. A list of farmers, including the pseudonyms, is found in table 7 in appendix 1.

1. Introduction

Anthropogenic global climate changes are reported as increased temperatures and increased frequency of climatic hazards. The African continent is expected to have some of the largest increases in temperature, 1.5°C above global average (Bryan et al., 2013). In East Africa precipitation is expected to increase (IPCC, 2014; Schlencker & Lobell, 2010) and the IPCC further predicts higher frequency of extreme weather events. This also includes increases in the frequency of natural phenomena like El Niño Southern Oscillation (ENSO). These global climate changes are predicted to have an influence on the agricultural systems (Herrero et al., 2010; IPCC, 2014). In Kenya, more intense rainfall is expected in October-December and March-May during the rainy seasons, while August and September are predicted to be drier (IPCC, 2014).

In March 2015, Kenya Meteorological Department (KMD) issued an advisory that Kenya would be impacted by ENSO (Vam, 2015). The advisory stated that the October-November-December (OND) 2015 short rains were likely to be higher in most parts of the country and were expected to continue into early 2016. A previous ENSO event in 1997/98 caused extreme intense rainfall, which led to huge floods destroying infrastructure, households and crops (Glantz, 2001).

Our area of study, Karima North, is located in Nyeri district in the Central Highlands of Kenya and is one of the most productive agricultural areas in the country (Herrero et al., 2010). The agriculture is rainfed, hence information on seasonal and long-term precipitation trends are crucial for farmers. While the KMD issues seasonal weather forecasts to farmers, Agricultural Extension Officers (AEOs) advice on farming practices among others related to weather impacts. However, studies show that there is not always a link between weather and climate predictions and the farmers' perception of these (Gichangi et al., 2015; Muita et al., 2016; Rao et al., 2011; Weber, 2015).

When exploring the phenomenon of climate change one has to be aware if using an etic approach[1]. The reason for this is that climate change is interpreted, explained and lived in local contexts, which are based on culture, including traditional practises and local knowledge (Fiske et al., 2014). When discussing climate change the context must be taken into consideration. Using an emic approach[2], we aim to explore how the local people of Karima North perceive and

[1] An etic approach implies the researcher seeing the culture from the outside by applying independent theories or concepts onto a phenomenon (Barnard & Spencer 2012[1998]).

[2] The emic approach implies the researcher seeing the culture from within by explaining phenomena in terms of local ideas and concepts (Barnard & Spencer 2012).

respond to weather variability and climate changes. To understand the relationship between perception and action to such phenomena the term agency is applied. Agency is an individual's potential, possibilities and constraint for taking action when facing a situation. In this case a situation is understood as the currently faced weather hazards and climate changes to which farmers are exposed. Using this approach, the present report aims first to identify the farmers perceptions and responses to weather variabilities and climate change. Secondly, assessing the factors influencing the adaptive capacity of the farmer. These will be investigated through the following problem statement and research questions:

1.1. Problem Statement

How do farmers in Karima North perceive and respond to weather hazards and climate change (WHCC), and what factors are influencing their adaptive capacity?

1. What impact does WHCC have on the farm and what practices do farmers apply due to these impacts?
2. How does access to traditional and meteorological knowledge shape farmers' perceptions of WHCC?
3. How does the socio-economic structure influence the farmers' adaptive capacity?

1.2. Structure of paper

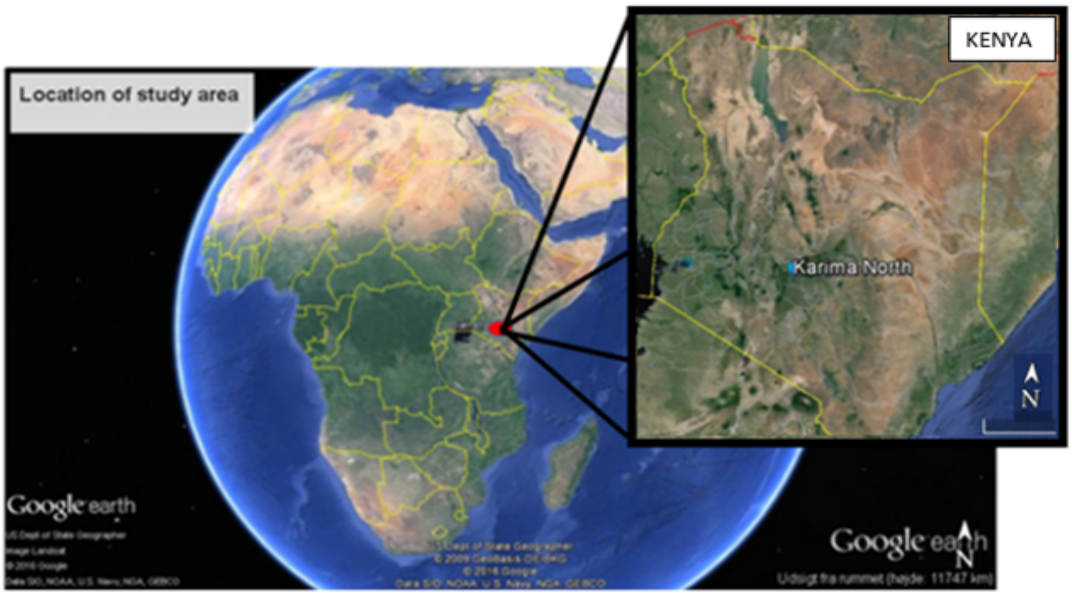
The rest of the paper is structured as follows. The remains of section 1 will present our study area. In section 2 our methodology and methods used in the field is described. We hereafter present our results in section 3 before discussing the findings in section 4. Section 5 will consists of concluding remarks. Overall this report will be a positive story of how farmers of Karima North show a good potential for adapting to short-term climate. Anyway, looking at the long-term this report will add skeptical chapters as well, comprising factors that influence the adaptive capacity of the farmers.

1.3. Karima North - the "ever green"

This report is based on a fieldwork carried out in Karima North, part of Othaya Township in Nyeri County in Kenya, from the 4th to the 14th of March 2016. Karima North can be divided into three areas, Gura, Mutitu and Thuti (see Figure 1 and 2).

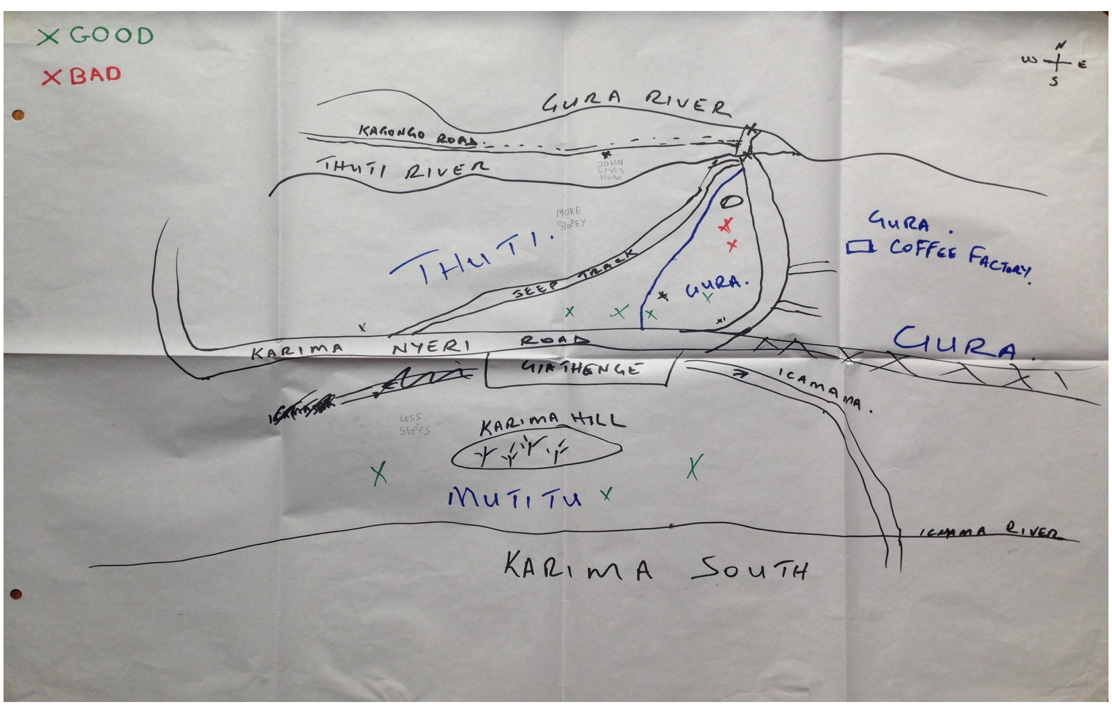
Geographically, Karima North is placed at 00°31'18.83"S and 36°58'36.50"E, 1850 meters above sea level (Ekberg et al., 1985). Othaya is located in a temperate climate zone and receives between 800-1600 mm. of rain per year (Bryan et al., 2013). Rainfall is mainly divided between two rainy seasons, the “long rains” (March-April-May) and the “short rains” (October-November-December). The dominating soil type in Karima North is a Nitisol, a red volcanic soil (Ekberg et al., 1985). Due to presence of volcanic material, the soils around this area are naturally fertile (Holden, 2012; ISRIC, 2001).

Figure 1 - Map of Karima North



Note: Authors’ own illustration. Source: Google Earth Pro, 2016

Figure 2 - Map of the study area



Note: Drawn by John, a Village Elder (M: John)

The main occupation and source of income in Karima North is farming. Agricultural production is mainly allocated in small-scale farms of low input where production of cash and food crops is mixed with livestock holding (Lekasi et al., 2001; Bryan et al., 2013). According to a Village Elder, John, the land size is on average 2 acres. Studies by Bryan et al., (2013) and Lekasi et al., (2001) also suggest similar land sizes in areas located close to Othaya. Due to aforementioned geographical characteristics, Karima North has good farming conditions (Bryan et al., 2013). An opinion shared by the farmers stating that they will go "*ever green*" here (CM: Alice; UI: John).

2. Methodology

2.1. Access to the field and being *out there*

2.1.1. Gate keepers and translation

In the field we worked with several gatekeepers[3], enabling us to navigate in the field. Besides being gatekeepers, John, Joyce and Anthony became middlemen between us and the informants. This meant that all of them took over the role of interpreter, which was very helpful in obtaining data. However, we are aware of the shortcomings of translating English into Kikuyu, and the other way around (referred to as *the problem of translation*[4]). We could therefore not be sure that our questions were understood as aimed for which might have biased our results. To avoid this as much as possible, we went through our questionnaire together with our gatekeepers before starting the survey.

2.1.2. Positioning and ethics

Reflecting upon one's position is a central part of doing fieldwork, as it often decides what kind of information is being obtained (Murray & Overton, 2003). For us, it was important to make clear our position as foreigners and students when facing informants. This we did in the aim of getting as much information as possible, but also to make clear that we could not offer any recommendations or improvements. Our positioning towards farmer in Karima North relates to one of the most common ethical reflections, concerned with the reciprocal relationship between

[3] A gatekeeper is defined as a central person who gives you access to places and people. All people are, in principle, gatekeepers as they are the key to access to information about their own lives (Hastrup 2013[2011]). In our case the gatekeepers were primarily our elder, John, together with our field-guide, Joyce, and interpreter, Anthony. Not to mention our host-families and Kenyan counterparts.

[4] *The problem of translation* concerns how to translate a foreign reality into the researcher's own mode of thought and conceptual world, without distorting the society he aims to describe (Eriksen 2013[1993]).

the researcher and the informant (Bernard, 2011). For us, the expression of gratefulness became the way in which we could thank the farmers for their help and time.

2.2. Applied methods

In order to comprehend all the aspects of the influence that weather and climate variability possess towards farmers in Karima North, an interdisciplinary approach has been applied. In addition to this, part of our analysis lies in the difference between farmers. In the following will be presented first a description of our method to differentiate farmers and thereafter a description of our data collection methods in the field[5].

2.2.1. Farm typology

As part of our study, we used the questionnaire data to compute different farm typologies. Using farm typologies can be an effective tool when there is a variability among farmers as seen in our study area (Alvarez et al., 2014). With the typologies in hand, we were able to explore the natural and socio-economic differences between farmers and analyze whether farmers are differently exposed to weather and climate changes. The computation of farm typologies is based on multivariate analysis in the form of a principal components analysis (PCA). To make the typologies, a set of factors is chosen that is considered important to describe the different types of farms. Details on the computation is found in appendix 1.

During the fieldwork a preliminary farm typology was made after the first two days of questionnaires. These typologies helped determine which farmers to invite for the subsequent PRA and semi-structured interviews. After finishing the field work a new farm typology was made based on new information about important factors[6]. The factors used in the PCA are as seen in table 1.

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[5] Detailed method descriptions can be found in appendix 2.

[6] It should be noted that following the preliminary typology, farmers from the Resourceful and Less Resourceful groups were invited to reflect the diversity of farmers. However, according to the revised typology, one of the farmers from the Resourceful group became a Big farmer. Yet, it does not spoil the results from the PRA as the Big farmer (Jacob) is still one of the best coffee farmers (measured in terms of yields per coffee tree) and only ends up as the Big farmer type as he has a low total household income - a factor that wasn't included in the preliminary typology.

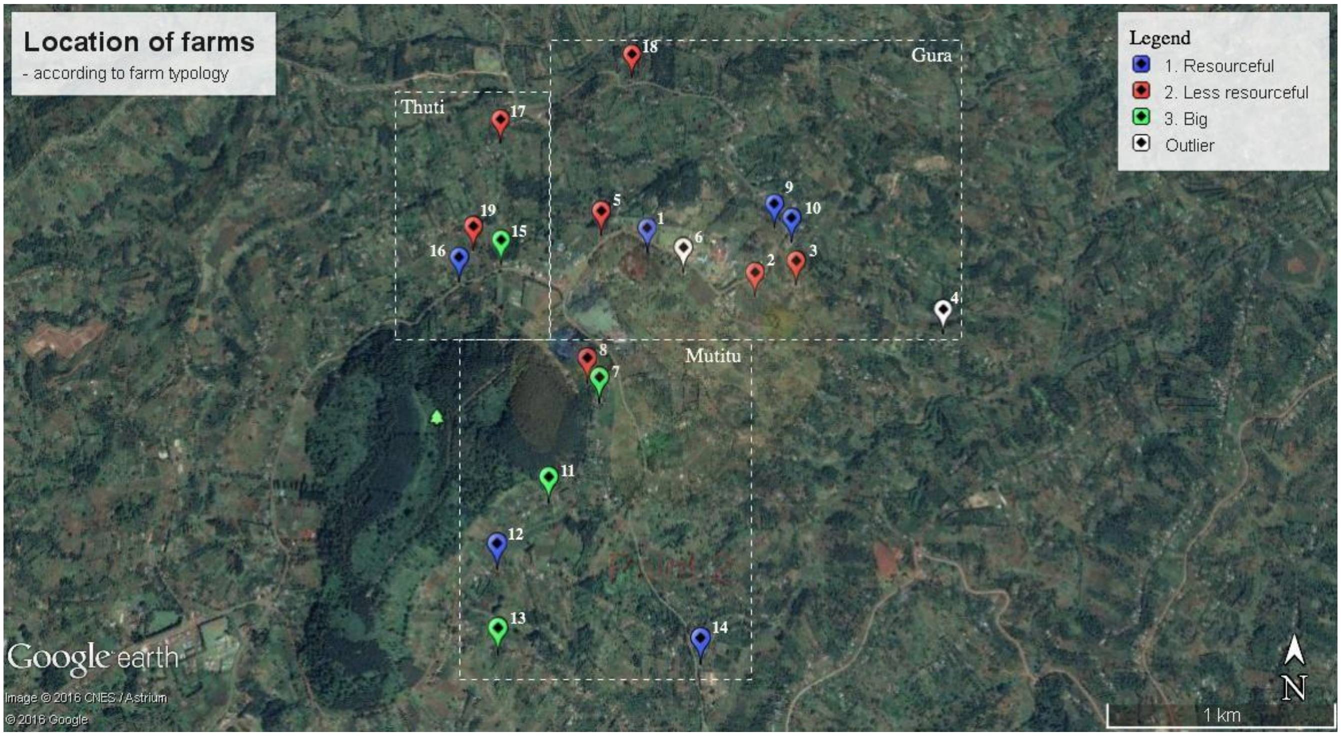
Table 1 - Preliminary and revised typology

Preliminary fieldwork typology	**Revised post-fieldwork typology**
● Total agricultural land, acres; ● Yield per coffee tree in a year, kg; ● Farm inputs in a year, aggregate of manure and fertilizer in kg; ● Cattle	● Total agricultural land, acres; ● Yield per coffee tree in a year, kg; ● Farm inputs in a year, aggregate of manure and fertilizer in kg; ● Total household income in 2015

The choice of factors was based on our initial transect walk, unstructured interview with Village Elder John and informal conversations. As the size of agricultural land plots was mentioned as a limitation (UI: John), it was stipulated that differences would occur between smaller and bigger farmers. As coffee is the cash crop of the area this was included too. In order to differ between efficient and less efficient coffee farmers, yields per tree were chosen. Farm inputs, as an aggregate of manure and fertilizer, were chosen to cover both input and output of a farm. Lastly, it was intended to use relevant factors in a wealth ranking for the preliminary typology which is why cattle were chosen. However, two problems arose: 1) the locals had a hard time expressing relevant factors describing wealth 2) we found little variation among our farmers in terms of cows[7]. Therefore, we decided to use the total household income as we saw big differences in our data on the income of farmers. This resulted better explanatory power of the PCAs. Figure 3 below is a map showing our study area divided into the farm typologies.

[7] Farmers only had between 0 and 4 cows, except for an outlier with 6 cows.

Figure 3 - Map over study area divided into farm typologies



2.2.2 Questionnaire

The questionnaires were carried out in the beginning of the field work to give us an overview and to form the basis for our farm typology. Before going to the field site, we wanted to perform simple random sampling[8], but in practice, we ended up using purposeful sampling (Hardon et al., 2004). Out of several options, we chose maximum variation sampling as we selected respondents in order to represent the variability of the study population. For example, we made sure to go to farmers with large and small land plots, a lot and little coffee, many and few cattle, etc. In order to get geographical variation, based on a mapping done by Village Elder John, we were able to identify three different areas in Karima North that we performed our questionnaires in. An unexpected but great advantage of the questionnaires, was that the method turned out also to function as a semi-structured interview. This was due to the informants not only answering the questions, but in most cases also elaborating thoroughly on them. This was really time consuming, though. Another downside to this method was that we became dependent

[8] The optimal approach would be to use a stratified sample. However, in order to make stratified sampling, one need to know the share of the study population belonging to each of the stratifying criteria (Hardon et al., 2004). Given the nature of the course, we were unable to obtain this information prior to our fieldwork.

on the field guide and interpreter to find farmers. This might have resulted in us meeting farmers they already know which leads to two implications: 1) sampling become less random and 2) there might be a bias in farmers. To counteract this, we explicitly told our locals to show us farmers they did not know and, once in awhile, go down a road unknown to the local.

2.2.3. Soil sampling and temperature iButtons

Soil samples were carried out at the same time as the questionnaires. Therefore, the sampling strategy of farmers is the same as above. We decided to use auguring and 100 cm3 rings in the topsoil to determine pH, C and N and water holding capacity. In addition, it is easy to get many samples with the auger which enabled us to get samples from each farmer[9]. Every sample consisted of a composite of eight soil samples starting in the two furthest corners of the field and making a diagonal cross. Although we tried to capture variations within the field the best, we did not decide properly together on what to do in different kinds of situations like tilted soil.

In order to measure the cooling potential of trees on plots, we observed temperature and humidity differences between plots sun grown coffee and shade grown coffee. iButtons measured temperature and humidity along 6 days in 6 minutes intervals. Three iButtons were placed respectively on shaded and unshaded coffee crops on neighboring plots, therefore exposure and slope are comparable to each other.

2.2.4. Participatory Rural Appraisal

In order to compare different farm typologies, we invited six farmers, representing two people from each of the typologies to a PRA-session. Even though one person did not show up, we had two groups consisting of Resourceful farmers and a merge of Big and Less Resourceful farmers. During the PRA, three exercises were conducted; drawings of historical timeline, seasonal diagram, Venn diagram and problem ranking. These exercises allowed us to collect qualitative data on farmers perceptions, experiences and challenges in relation weather and climate change. The downside of this method was, especially, that some farmers were more dominating than others, leading to a inequality in the information flow and thus a lack of information from the quite farmers.

[9] We were unable to get soil samples from three farmers due to rains falling.

2.2.5. Cultural mapping

The purpose of doing the cultural mapping was to observe farming practices due to changes in weather and climate. It was carried out in the prolonging of the SSI's, also representing the farm typologies. This method turned out to be a great source of information, both in terms of perceptions on and in terms of practices. Not having the time to do participant observation (PO), the cultural mapping functioned as a substitute. The reason for this is we were in a natural setting for the farmers, collecting data *in situ*. In our experience the "walk and talk" made the farmers open up, providing us with lots of information. The drawbacks from this method, compared to PO, was that we were not engaging in an activity. Such engagement would have enabled us to distinguish between what farmers say they do and what they are actually doing while farming.

2.2.6. Semi-structured interviews

The first semi-structured interviews were carried out with the County Director, Nyeri County, of the KMD, Francis Nguatah, and Agricultural Extensive Officer, Nyeri South, Ruffas Kamau, who came to function as key informants in understanding the different informational levels in terms of information on weather, climate and agricultural practices in Karima North. Further, one interview with a farmer from each typology was carried out, first of all to triangulate the data with the questionnaires and to achieve a representative picture of the different farmers. In these interviews the same guide was used to give comparable qualitative data. The semi-structured interviews were especially used to go in depth with farmers' perception of weather hazards and climate change. Anyway, preliminary to the interview, considerations about roles of interviewers, note takers, amount of people and the exact role of the translators should have been defined more clearly among us. This would have avoided a, sometimes, intimidating and confusing situation and a better relationship between the interviewer and informant, leading to more in-depth data.

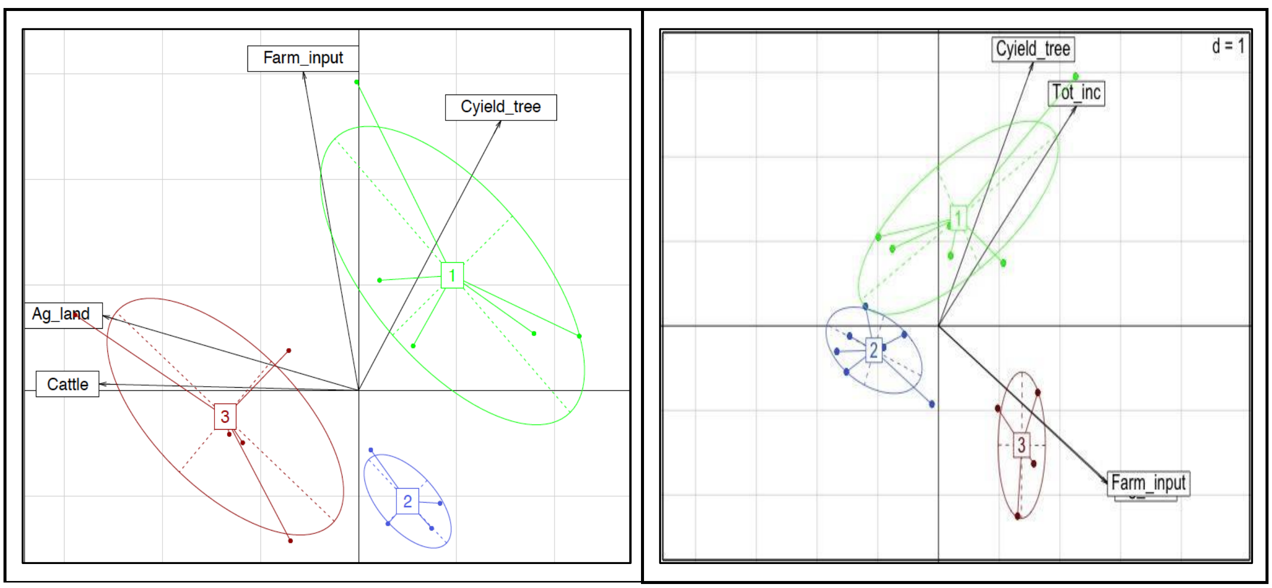
Most importantly, applying both quantitative and qualitative methods have allowed us to achieve a high level of both reliability and validity (Babbie, 2002). An important part of this combination is furthermore that it enabled us to triangulate the data output and create a comprehensive study by comparing the results from each method and identify similarities and discrepancies. This was particularly important given our short time frame in the field where it was impossible to be able to obtain enough observations within each method to rely solely on one result.

3. Results

3.1 Farm typologies

As mentioned in the methodology, one of our first results is the division of farmers into typologies. Figure 4a and 4b below shows our preliminary and revised typologies[10]. The revised typology shows a high correlation between total income and yields per coffee tree as well as between agricultural land size and farm inputs[11]. According to the typology, we define cluster 1 as Resourceful farmers, cluster 2 as Less Resourceful and cluster 3 as Big farmers.

Figure 4a and 4b - Preliminary and revised farm typology



Note: The arrows of each factor expresses the maximum observation. The closer the arrows are to each other, the larger is the correlation. If arrows point in opposite directions, factors have a negative correlation. The eclipses indicate the typologies with the typologies with the dots indicating individual farmers.
Source: Authors' own data and computations using R Studio

Table 2 presents summary statistics of our farm typologies. The results show that Resourceful farmers have higher absolute yields from coffee and that their production is more efficient measured in terms of yield per tree. Big farmers have higher maize yields and apply much more manure and fertilizer. Evidently, the Less Resourceful farmers have the smallest farms, share of cash crops, coffee and maize yields, input use and total household income but do

[10] Scheme over allocation of farmers into typology is found in table 6 in appendix 1.
[11] From this point onwards, the revised typology will simply be referred to as *the* typology.

however use the most labour on the farm. We find that, on average, the Less Resourceful farmers use the least fertilizers and manure and that Big farmers use six times more than the Less Resourceful. Furthermore, the share of chemical fertilizers is 14% and 15%, respectively, for the Resourceful and Less Resourceful farmers. The Big farmers, on the other hand, use only 3.6% of chemical fertilizers. In general, chemical fertilizer and manure is applied by most farmers (95% and 79% respectively).

Table 2 - Summary statistics of farm typologies

	Resourceful (Type 1)	Less Resourceful (Type 2)	Big (Type 3)
Agricultural land, acres	1.32 (0.73)	1.15 (0.71)	2.59 (0.71)
Cash crop, share of ag. land	0.60 (0.74)	0.32 (0.30)	0.47 (1.20)
Coffee trees	293 (269.82)	100 (85.44)	337.5 (125)
Coffee yield, kg	2037.33 (1430.71)	217.14 (230.20)	1205 (752.84)
Coffee yield per tree, kg	9.02 (4.67)	1.67 (1.63)	3.63 (2.04)
Maize yield, kg	349.17 (324.75)	233.57 (162.22)	602.5 (372.32)
Manure, kg/year	1390 (1166.48)	520 (799.98)	8280 (2928.01)
Fertilizer, kg/year	230.83 (159.45)	95.71 (53.42)	310 (188.15)
Aggregate farm input, kg/year	1620.83 (1148.71)	615.71 (807.86)	8590 (3083.75)
Agg. farm input, kg/acre	1721.17 (1712.03)	1209.43 (2557.16)	4201.75 (3612.08)
Cattle	1.83 (2.23)	1 (1.15)	2 (1.41)
Trees	69.83 (76.12)	31.43 (33.49)	182.5 (112.06)
Family labour, man-day/year	271.17 (261.49)	241.43 (238.67)	432.75 (461.11)
Hired labour, man-day/year	137.92 (132.50)	230.5 (258.48)	23 (26.76)
Total labour, man-day/year	409.17 (362.88)	472 (277.50)	455.75 (444.82)
Total income, Ksh	279,150 (238,457.83)	68,771 (78,697.09)	92,500 (65000)

Income share from off-farm	0.495 (0.3846)	0.4814 (0.4651)	0.35 (0.2742)

Note: Standard deviations are in parentheses

3.2. Current impact of weather and climate

Findings on current weather impact and potential climate impacts on the crop production of farmers in dependence of soil and terrain are described in the following.

3.2.1. Natural characteristics of Karima North

Results from soil analysis show that the pH on the farms varies between 5.3 and 6.6. Furthermore, the measured amount of Carbon (C) indicates a soil organic matter (SOM) content between 3.7% and 5.6%, as SOM contains 58% of C (Brady & Weil, 2014). Lastly, the Carbon:Nitrogen (C:N) ratio varies between 8:1 and 10:1. See table 8 in appendix 3 for the results of each farmer.

The soils of Karima North are often very exposed to soil erosion as the hills are relatively sloped (O; SSI; AEO). According to Village Elder John, Thuti is a more sloped area than Gura and Mutitu, and the soils in Thuti contain more gravel and hence is more difficult to manage. However, there was no significant difference between water content in the three areas of Karima North (Gura, Mutitu and Thuti) (P-value: 0.3167[12]), and likewise no significant difference between the three farm typologies according to pH, water content and C:N ratio (P-value: 0.6559, 0.7419 and 0.2821 respectively).

3.2.2. Weather hazards impacts on farm

The short rainy season of 2015 was influenced by ENSO and according to the AEO, the effect was positive in comparison to ENSO 1997/98, since less heavy rain appeared compared to ENSO 1997/98 and to what was predicted. The AEO states that productivity was enhanced due to ENSO 2015 by explaining that: *"Coffee production for this year is 4.7 million, already 1 million above the target for the year"* (SSI: AEO). KMD County Director explains that the drainage system implemented for the ENSO 2015 reduced much of the impact of floods. Likewise, in an informal conversation with Chief Steven it is mentioned that preventive actions were taken by the government such as digging trenches, pruning trees to avoid damages and identifying households vulnerable to floods (IC: Chief Steven). The KMD County Director

[12] One-Way Analysis of Variance (ANOVA)

further argues that the preventive measures are one of the reasons for farmers to experience ENSO 2015 less strong than ENSO 1997/98 (SSI: KMD County Director).

Meanwhile, there are negative effects from ENSO too. Heavy and erratic rainfall caused by ENSO causes mechanical crop destruction and crop damages due to runoff. The latter includes the loss of nutritive topsoil and mechanical damages caused by landslides or runoff material, which is especially exposed due to the domination of steep slopes in Karima North (SSI: AEO; CM: Alice; CM: Sam). In addition, fields in low lying areas downhill may be harmed by floods (IC: Chief Steven).

In our sample, 57.9% of the surveyed farmers consider heavy and unpredicted rain as damaging to their crops, and 52.6% additionally consider erratic rainfall as harmful. During the PRA, farmers pointed out that coffee and maize did well with heavy rain (PRA, Historical timeline). However, participants also indicate that potatoes and beans did worse under higher rainfall, and that diseases on crops and livestock increased (PRA, Seasonal diagram). Farmer Alice states that coffee does not like too much water and is prone to diseases when conditions are too moist (CM: Alice). ENSO 2015 caused the short rainy season to expand into Mid-February delaying the harvest of maize as it requires drying either on the field or after harvest (IC: Chief Steven). Another consequence of the extended rainy season is an increased need of labor for the preparation of plots for the upcoming growing season, starting Mid-March. In the PRA, less resourceful farmers rank lack of labour as a problem related to weather since unreliable rains force usually hired workers tend their own farms first (PRA, Problem ranking: Caroline & Rachel).

3.2.3. Climate change impacts on farm

According to the AEO, long term climate change has been evident with a rise of temperature and less rainfall. When asked in the questionnaires, 61% of the farmers observe a rise in temperature. Nonetheless, only 21% of the farmers experience a decrease in precipitation. The AEO describes a trend towards the disappearance of the short rainy season which, according to him, has already been unreliable since 2006, causing crop failures for maize and irish potatoes.

The AEO expects coffee to be negatively affected by the increasing temperatures since *"(...) there will be no coffee [in the future]"* (SSI: AEO). Maize is found to be more drought-tolerant and farmers in Karima North renew maize seed varieties on a seasonal basis as well as the crop is continually developed towards increasing drought tolerance (SSI: AEO; farmers; Q; UI: Andi). According to the KMD County Director, only few farmers can afford irrigation and the AEO adds that lack of irrigation will lead to negative impact of droughts (SSI: AEO; SSI: KMD County Director).

Figure 5 - Picture of different seed varieties of maize

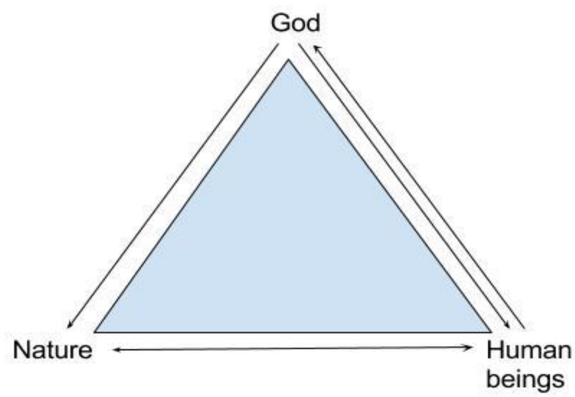
Note: The picture is from the Agro-Dealer, Andi. It shows different hybrid maize seeds that farmers can buy. Bags with purple font is for the long rainy season and bags with red font is for the short rainy season. For this season, H 614 D was developed that succeeded H 629.

3.3. Networks of knowledge: traditional and meteorological approaches

Since weather impacts farmers in different ways, knowledge about weather and climate becomes crucial. As the County Director from the KMD explains: "(...*) there is no aspect of any crop that is immune to the weather. Even ourselves, we are living within the weather, we are breathing the weather, we are eating the weather, so... Weather parameters are very important"* (SSI: Francis). According to director, both human beings and crops are dependent on the weather. Additionally, the importance is supported by the farmers themselves, stating that: *"When you meet a person on the road, mostly you would talk about the weather"* (PRA, Venn diagram: Nadia).

Knowledge of weather and climate today are shaped both by a traditional[13] and meteorological approach. Now, the conditions of the weather is not solely explained as an act of God. Like Joe puts it: *“Nature is controlled by God (...) But humans do contribute to the ‘balance of nature’”* (SSI: Joe). The connection between God, nature and human is illustrated in figure 6.

Figure 6 - Relations between God, nature and human



Note: Authors’ own illustration. Illustration on how God is in control of nature and the human beings. Next it shows how the humans can affect the decisions of God by being good people, but also how the humans, by their behaviour, can influence nature. Lastly it shows how nature can respond to human actions

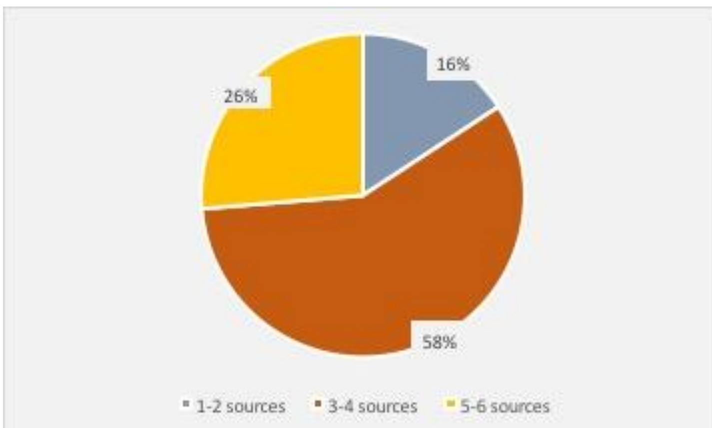
For the meteorological data, observations seem to be the key as well: *“(...) it [the weather] must be observed so we know exactly what is happening. Observation, that is the building block”* (SSI: KMD County Director). In contrast to the traditional approach, this kind of observation is done by using technology. The main difference between the two, the KMD County Director argues, is that the meteorological data can be scientifically documented while the data gained by the traditional approach can not. Nonetheless, the director expresses that both weigh even in the process of mapping the weather.

The mixture of the two observation methods is both used by institutions, like the KMD, and by farmers themselves. The KMD County Director states that after making a draft of a forecast they commonly have a “second opinion” from elders who possess great traditional and indigenous knowledge on weather phenomena in the area. A farmer who uses the traditional approach herself explains that she uses the sky to tell when the rain is coming (IC: Nadia).

[13] By traditional is meant, for example, trusting God, looking at the sky, feeling the direction of the wind or watching plants and animals.

Furthermore, the changing conditions of weather are making it more difficult for people to observe it, and thus the reliability of the traditional approach becomes limited. When a farmer is asked about the role of traditional knowledge in forecasting today, he elaborates: *"To some extent it is okay. But you [have] (...) changes nowadays, (...) [but] they [people who practice the traditional methods] expect to have rainfall in March but nowadays it extends to April"* (SSI: Joe). Like Joe, the KMD County Director argues, that the elders do not know how to interpret these changes. The meteorological approach, comprising the weather forecasts, are according to farmers not very reliable either. As Alice says about her trusts in weather forecasts: *"It's 50/50. Sometimes they say it is going to rain and then it is not raining, and sometimes they tell us that is it* not *going to rain and then it is raining anyway"* (CM: Alice). Due to these uncertainties the farmers use several sources of information to verify the weather. As figure 7 below illustrates, 89.5% of farmers use more than three information sources and only 10.5% use less.

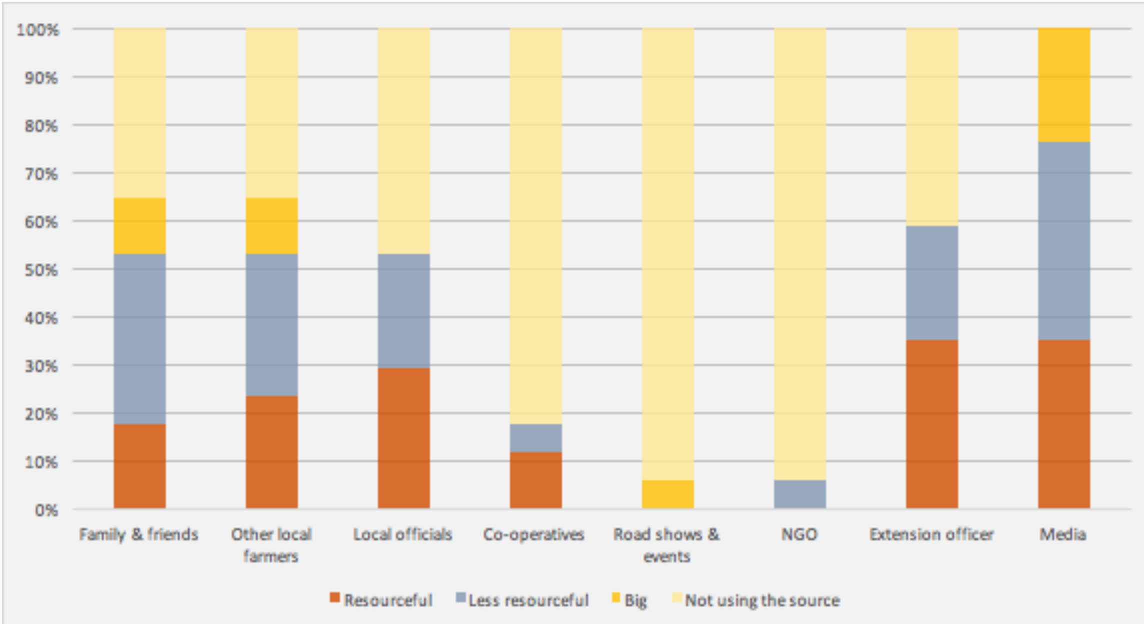
Figure 7 - Amount of information sources used about weather



3.3.1. The transfer of knowledge on weather and climate

The information on weather and climate originates from World Meteorological Organisation (WMO). Then WMO transfers the data to the national KMD, who makes the forecasts, and then transfers it down to the KMD county level (SSI: KMD County Director). From here, the KMD County Director directs the information to the local level through the AEO, media and barassas (SSI: KMD County Director). From our questionnaires it is evident that the main source of information about weather for the farmers is media (78.9%), where, according to SSIs, radio is particularly used. This is followed by friends and family, and other local farmers. Figure 8 show the distribution of received information on weather forecasts.

Figure 8 - The distribution of used information sources between the farm typologies



Note: Churches were not included as a possible answer in the questionnaire. From participant observation and informal talks, it became evident that churches are an important source of information as social networks induce share of information.

The social network is a counterpart to the media as a weather information source. In the questionnaire, 79% answered they use at least one of local farmers, family and friends. Statements from SSIs underpin the importance of social networks. For example, farmers tell us: *"We [the fellow farmers] learn a lot from each other"* (SSI: Zion) and *"(...) if you want to know something, you will go to this guy [your neighbour], because he is the guy you will see what is doing and [then you can] learn from the guy"* (SSI: Joe). Moreover, they also show how farmers rely on each other in terms of integrating new farming practices. In this regard, Zion expressed the importance of experiencing another farmer succeeding with the new measure (CM: Zion). Without the assurance, the new initiatives was too big a risk for the farmers to take.

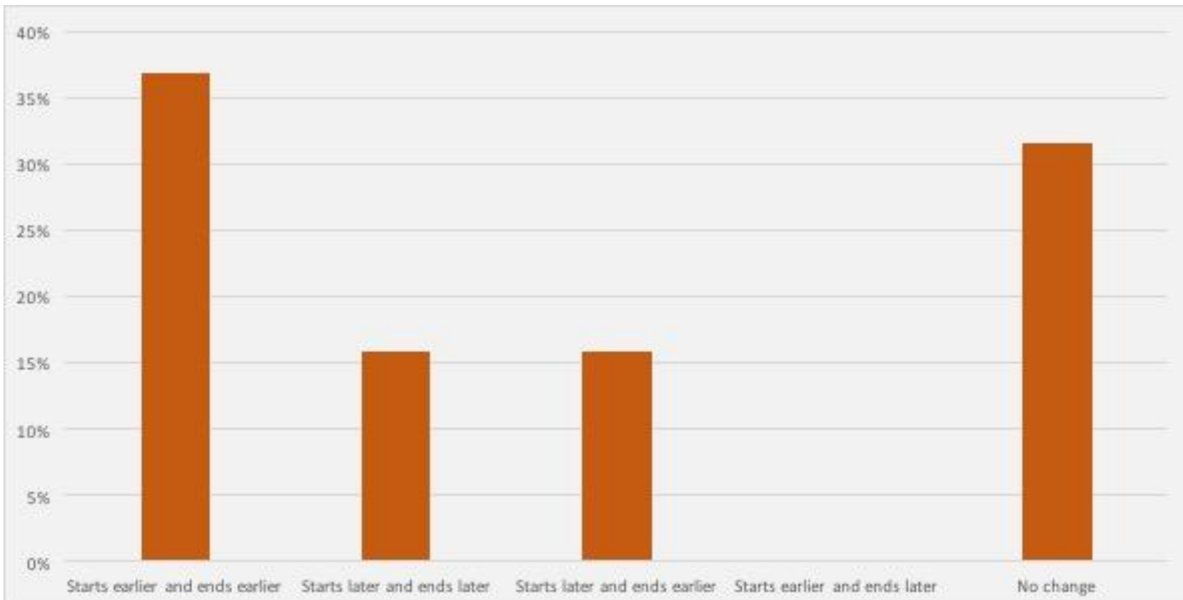
3.3.2. Climate change and seasonal perceptions

Most farmers do not relate climate change as a global climatic phenomenon but as a circumstance that postpones or bring forward the starting date of the seasons. Like Nadia puts it: *"Seasons are a pattern so we know [what we need to know] about the weather but the climate change has changed the weather"* (UI: Nadia).

During the PRA, the participants claimed temperature was irrelevant, because the effect of temperature is impossible to measure on the crops (PRA, Seasonal diagram: Nadia & Jacob).

Contrary, when asking about the changes in rainfall, the pattern is somehow clearer. As figure 9 shows, 68% feel that the pattern of the rainy season has changed somehow. On the contrary, 32% of farmers answered that they did not experience any change. To this end, the KMD County Director states that he needs to simplify the meteorological data on climate change for the farmers to understand it. One example is that he tells them to plant trees so more rain will come (SSI: KMD County Director).

Figure 9 - Rainfall variability over the past ten years



3.3.3. Weather hazards in terms of ENSO

> *"When you are talking to them [the farmers] you do not go into details. They want to know 'is it going to rain or not'? That is the bottom line for them"* (SSI: KMD County Director).

The above is an answer given to a question about farmers' perceptions of ENSO 2015. He argues the farmers' perception of ENSO is influenced by the ENSO 1997/98. This statement is confirmed in our conversations with farmers in Karima North. When asking them what the phenomenon of ENSO consists of, more or less the same answer occurs: It is excessive rain that goes on for longer periods.

When asking farmers about what they experienced as weather hazards, a prolonged sunny period was mentioned rather than ENSO (CM: Alice; CM: Christopher; UI: John). The reason for this is that such periods of drought can cause big problems because, according to the farmers, no crops will grow. That is why, as one farmer told us, when comparing floods and droughts *"Then rain is better!"* (CM: Alice). However, drought is only considered as damaging to the crops for

22% of the farmers asked in the questionnaires.

3.4. Adaptation strategies

3.4.1. Preparation phase - the point of no return

The balance between the rain as an advantage and rain as a shortcoming is held by the quality of the preparation. In cases where unusual weather turns out to have a negative impact, it is common that the informants believe it is caused by poor predictions. In a SSI one farmer explains: *"You may not surely prepare your land on time, because you were told that the rain is going to be with us in March - end March... and then by Mid-March there is rain, and you have not prepared your land"* (SSI: Zion). In the time between the rainy seasons farmers harvest (CM: Alice, IC: Chief Steven) and choose new seed varieties (SSI: AEO). Fields are prepared for seeding by applying manure and fertilizers, tilling and building terraces (CM: Alice). Farmer Alice explains that after preparing the fields they wait for the arrival of the rainy season. With the first rains they start seeding (CM: Alice). Results from the PRA also indicate unpredictable rainfall as the most influential factor to farming practices (PRA, Problem ranking: Nadia).

3.4.2 Existing adaptation measures

While the accuracy of the forecasts plays into the role of the preparation phase, other factors, such as income, land markets, farm input and farm characteristics also influence the farmer's ability to prepare properly. In the following we will describe the existing and new potential adaptation measures. Table 3 provides a summary of the measures with the main benefit and disadvantage.

Table 3 - Summary table of existing and new potential adaptation measures

Existing adaptation measures	**New potential adaptation measures**
Diversifying income sources - Decrease exposure to unanticipated changes in weather and consequent failure of crops - Constrained by lack of land and mobility	"Plastic farming" (Plasticulture) - Conserves water and moist in soil - Expensive to implement
Diversification of crops - Increase farm income - Lack of land	Greenhouses - Crops grow faster and are less exposed to weather variability - Expensive to implement
Expanding farm size - Enables increase in farm income, crop diversification and better soil fertility management - Fragmented and ancestral land	Irrigation - Availability of water during dry season - Expensive to implement
Change of seed varieties/availability of new seed	

varieties - Technology enables seeds to cope with changing weather conditions - More vulnerable to choosing specialized seeds wrongly to the weather	
Terraces - Prevent soil erosion and recycle runoff - constrained by knowledge and resources (income)	
Agroforestry - Decreasing temperatures and increases moisture - Lack of knowledge	

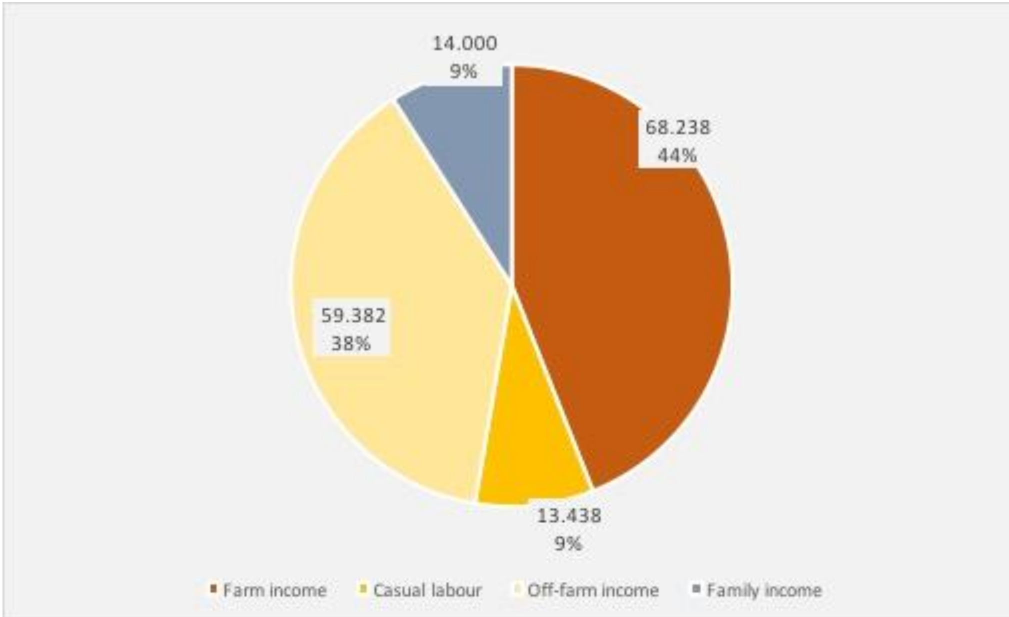
3.4.2.1. Income opportunities

Income not only constitutes the basis of farmers' livelihood; it also influences their ability to adapt. This is best exemplified by the following quotes: *"I have to use money"* and further *"If you want to do changes, you need money"* (SSI: Zion). The quotes are made in response to how the farmer can change his farming practices due to weather.

The average total household income is approximately 150,000 Ksh a year[14]. The difference in income is markable with the Resourceful farmers earning approximately 279,000 Ksh, Less Resourceful farmers 69,000 Ksh and Big farmers 92,500 Ksh a year. During the PRA, both groups expressed a problem of lack of money (PRA, Problem ranking). The Less Resourceful and Big farmers ranked the lack of money in the top four of main problems. The Resourceful farmer, on the other hand, did not mention lack of money as a problem. The Less Resourceful farmers believed that this problem could be overcome through income diversification by finding more income-generating activities (that were not reliant on food crops) and initiating on-farm value-addition to the crops (PRA: Caroline & Rachel).

[14] 100 Ksh is converted to roughly 1 USD.

Figure 10 - Avg. yearly household income sources for farmers, Ksh.



In our sample, two-thirds of farmers have at least two income sources. Figure 10 shows the proportion of income sources. Farm income is mainly based on the direct sale of crops. Only 21% farmers in our sample currently did value-addition to their produce.

Another way to diversify the farm income is to adopt emergent crops.[15] The emergent crops often offer a very high profit for a few seasons until the supply increases from other farmers (SSI: AEO). Another benefit is that, according to farmers, macadamia and avocado do well in both the short and the long rainy season (PRA, Seasonal diagram).

An alternative to low income mentioned in the SSI with Zion is to take a loan (SSI: Zion), however of our sample only four farmers took a formal loan and three farmers an informal loan. According to John, "*Farmers shy away from taking loan because they do not know if the new crop will be able to pay back the loan. If they cannot pay, the bank will take the land and you will be landless. (...) And they [farmers] are [therefore] afraid of taking loans*" Of the farmers that did not take a formal loan in 2015, five stated that they did not want to incur debt, whereas six stated they did not need the money. Furthermore, not a single farmer in our sample had an insurance.

[15] These include macadamia, avocado and tree tomatoes as well as pebion and thorn melon (SSI: AEO).

3.4.2.2. Land markets

The size of farms is important for several reasons. It allows the farmers to diversify crops and perform good soil management practices. For example, the AEO explained that farmers often try new, emergent crops on a small piece of land before expanding. Similarly, he explained how he advises farmers on crop rotation as one of the main agricultural practices (SSI: AEO) that requires land, which farmers are aware of (CM: Alice; PRA, Problem ranking).

While all data clearly indicate that the size of farms is instrumental to adaptation to weather challenges, the data also points unequivocally to the fact that farmers are limited in farm practices due to small plots. This is first and foremost due to the existing structure in the area, where all children inherit their parents' land and therefore have to share it. Data from the questionnaire shows that only 36.8% farmers had any sort of land deal or division within the last year. This is supported by John and the AEO, who both said that the land market is very little in the area (UI: John; SSI: AEO). John elaborates that the land is very fragmented due to the land being ancestral[16]. This results in land plots becoming smaller over time and therefore farmers need to move outside the community to get more land (UI: John). In similar vein, Nadia points out that population growth in the area has led to land scarcity (PRA, Problem ranking). It should be added, that the AEO believes that the land market is unnecessarily strained due to the mindset of farmers. He argues that the problem is partly that farmers mainly want to buy land even though it is possible to just rent or lease land (SSI: AEO).

Farmers are aware of the problems of limited land and how it can be constraining. Zenia said that she could not change her crops but only increase the amount on her plot (SSI: Zenia). Similarly, Nadia expressed concerns that you can not leave the land fallow as you need to produce food to put on the table (PRA, Problem ranking).

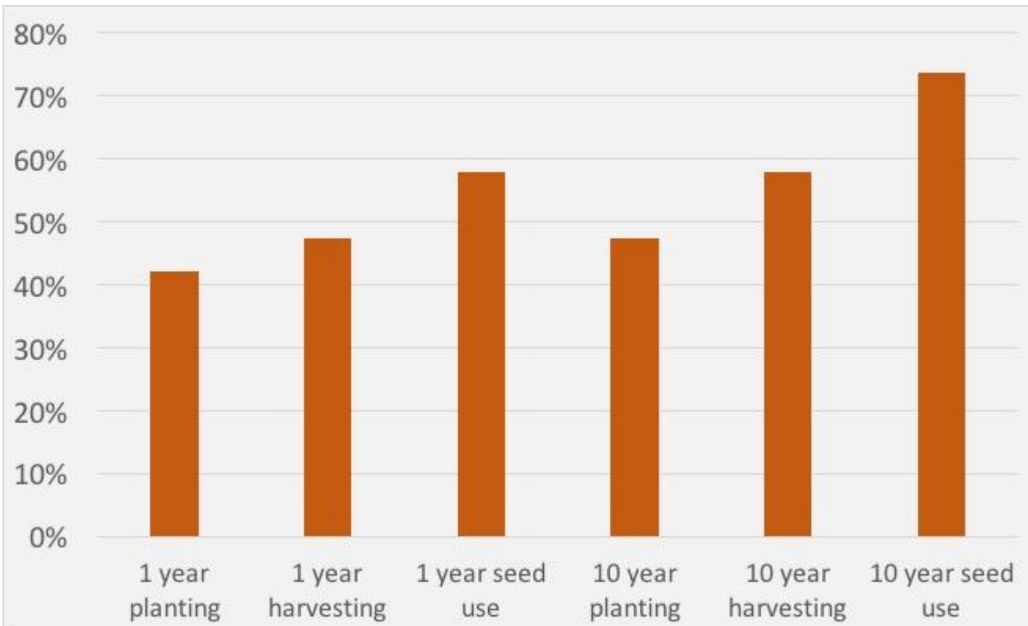
Farmers therefore feel like some of the advice they get from the AEO is impossible to put into practice because of too little land (PRA: Caroline & Rachel). The lack of responsiveness to advice is sustained by the AEO who revealed that despite their advice on crop rotation, only 2% of farmers in the area actually implement it (SSI: AEO).

[16] This implies that when land is inherited, all children of the land have equal right to the land. Land is then divided into equal pieces but still land can not be sold off without everyone agreeing to it (SSI: John).

3.4.2.3. Farm input

In general, input is seen as an obstacle to intensification of production and change of farming practices. Zion states that the main obstacle for his farming at the moment is the cost of inputs (SSI: Zion).

Figure 11 - Change of farm practices due to weather



From the survey it is clear that changing seeds is an integrated part of farm practices. 74% of farmers changed seed varieties within the last 10 years due to changes in weather. This is shown in figure 11 where change of seed varieties is the most common adaptation of farm practices. Fewer farmers have changed their harvesting and planting dates accordingly. Similarly, farmers did not change their fertilizer inputs due to weather variabilities. In terms of the current season, farmers delayed the harvest of maize due to prolonged rains (CM: Alice; IC: Steven; PRA, Seasonal diagram). New maize seeds are constantly developed and more drought-resistant varieties are increasingly available and presented during farm demonstrations (SSI: AEO). The importance of suitable seed varieties is explained by Zion, who states that he experienced loss of yields in the last rainy season as he used varieties adapted to heavy rainfall. The rain was less heavy than predicted though, thus he suffered from reduced yields.

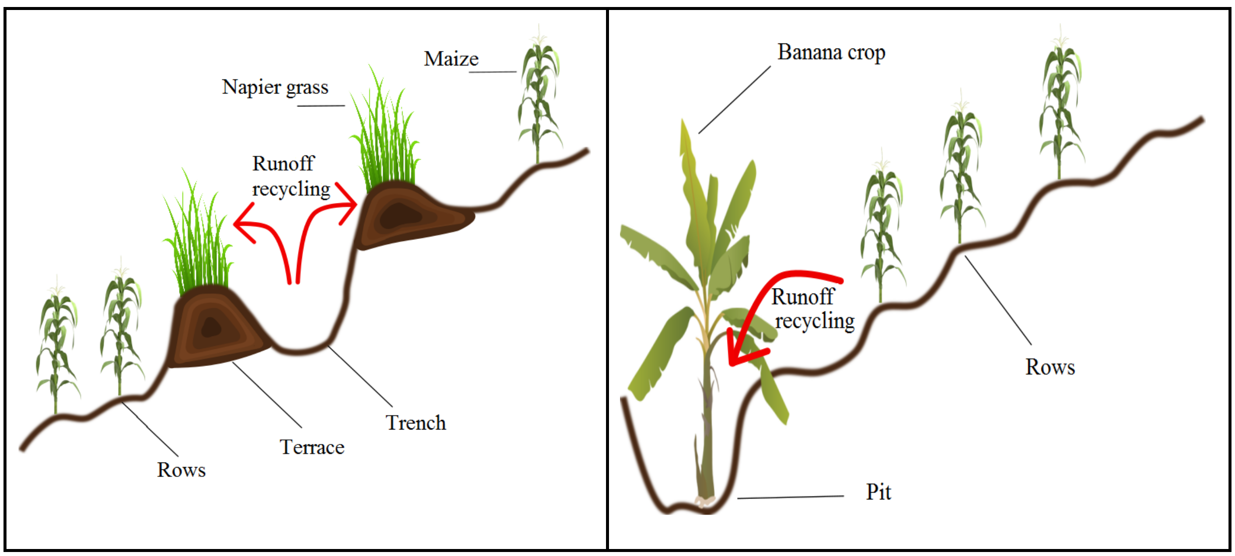
3.4.2.4. Terraces

Terraces are one of the main adaptations to heavy rainfall (CM: Alice; SSI: Zion; SSI: Joe; SSI: AEO; UI: John) and the AEO advises farmers individually on the design of terraces

(CM: Alice). In addition to terraces, the AEO advises farmers to prepare their plots for heavy rain by digging trenches (SSI: AEO).

However, terraces require a lot of input as *"(...) terraces are not for the poor"* (CM: Alice). Terraces are built to avoid erosion of the topsoil, loss of fertilizer inputs and crop damage while some have trenches to recycle runoff of nutrients (SSI: farmers; SSI: AEO). Maize is often grown on rows that are meant to further reduce runoff (CM: Alice). Figure 12a shows an example where topsoil is stacked as terraces on both sides of the trench and napier grass is grown on the terraces. Figure 12b shows another way farmers recycle runoff where pits are dug with bananas by the end of a slope (CM: Alice; O).

Figure 12a and 12b - Examples of constellations to catch runoff, type 1 and 2

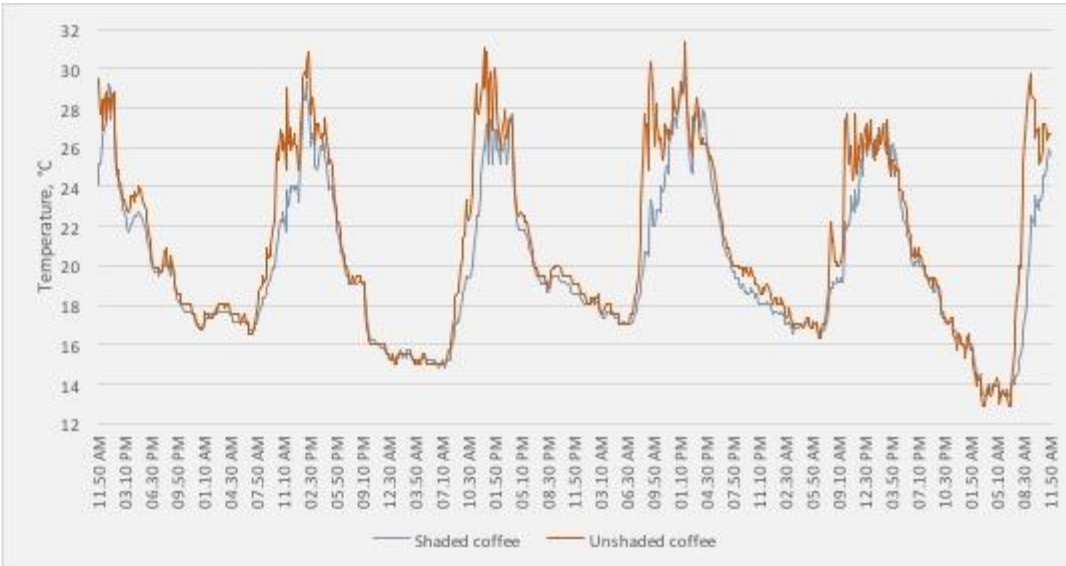


Note: Authors' own illustrations

3.4.2.5. Agroforestry

As adaptation to climate change the AEO further advises farmers on planting trees to create shade that ensure temperature and humidity control (SSI: AEO). The AEO states that farmers have not adopted agroforestry due to small sizes of land and Less Resourceful farmers express the need for information on agroforestry (PRA, Problem ranking: Less Resourceful farmers). Figure 21 in appendix 4 shows temperature measurements with Ibuttons in two coffee fields, one with no trees and one intercropped with macadamia. Temperature differed significantly (P-value: 0.00) between the two plots and became increasingly evident above 20ºC. Figure 21 in appendix 4 shows the fluctuations of relative humidity, which are more narrow in the intercropped field and. These results fit well with the fact that Big farmer Alex, who has the intercropped field, has a yield of 4 kg/coffee tree which is above the average for the Big farmers (3.62 kg/coffee tree) and the Less Resourceful farmers (1.67 kg/coffee tree). In contrast the Resourceful farmers have an average yield of 9.02 kg/coffee tree.

Figure 13 - Differences in temperature fluctuations between shaded and unshaded coffee



3.4.3. New potential adaptation measures

3.4.3.1. "Plastic farming"

New adaptative measures are coming up in Karima North as well. Jacob revealed that he had recently started using plastic on his vegetables (SSI: Jacob). This is supported by the AEO who says that "plastic farming" is good since "*We make a trench, say 10 by 10, put the soil and put some water, and plant the arrowroots. (...) it conserves the water and moist. And you still have food, so you will not rely much on the rain*" (SSI: AEO). Jacob said his yields were much better and his crops more resilient towards weather variability. Although, he was the only farmer we met applying so-called "plastic farming", it is advised by the AEO. Its downside is the high cost of 20,000 Ksh for 10 by 10 meter plastic even though the technical support to lay the plastic is provided for free from the government (SSI: AEO).

3.4.3.2. Greenhouses

Another adaptation measure that is recommended by the AEO is the construction of greenhouses (SSI: AEO). Currently, 10 greenhouses exist in Karima North of which five belong to the same farmer (SSI: AEO). Their main limitation is also the implementation price of minimum 300,000 Ksh.

3.4.3.3. Irrigation systems

Lastly, according to the AEO and the PRA farmers, implementing irrigation builds resilience (SSI: AEO; PRA: Nadia). Sources of water include: pumped river water (SSI, John), the Othaya Water Company and harvested rainwater (SSI: Joe). No respondents used irrigation systems on their farm (Q) due to expensive implementation costs (PRA: Nadia). Harvest and storage of rainwater for use in the dry season seems to be the most viable alternative (SSI: KMD County Director; PRA: Nadia).

4. Discussion

4.1. The adaptation situation - a short term perspective

4.1.1. Farmers as agents of change

Having a society build on agriculture means that many of the current farming practices trace back to the past. This is why, when asked in the first place of farming practices, many farmers answer that they are just doing what they have always been doing. This answer does not necessarily entail that the farmers are not changing anything.

According to our results, being a farmer in Karima North entails that you heavily depend on your farm output - an output, which in turn depends on nature. Due to weather being a dynamic phenomenon, change has always been a central part of being a farmer. The first step for the farmer, in the seasonal preparation phase of the farm, is to map the circumstances of the weather. Farmers change the kind of food crops according to seasonal rainfall patterns like, for example, potatoes and beans are grown primarily when rainfall is less. We argue that dealing with changes is a condition of being a farmer, and farmers can therefore be understood as *agents of change.*

This can be explained by the term *agency,* which refers to one's independent ability to take action on one's own will (Villarreal, 1992). The ability is affected by social and individual perceptions, by one's past experiences, and by the social structure[17] one is socialized into (Villarreal, 1992). In practice, agency is shown in the way people handle constraining and enabling elements encountered in a specific situation (Villarreal, 1992). What defines such elements depends on the individual's personal abilities and perception of the situation. In such

[17] The unity of social institutions and distributions of social status in a society is what makes up what we call the *social structure* (Eriksen, 2013[1993]).

situations, people are capable of strategizing and finding a *space of manoeuvre* (Villarreal, 1992). We argue that the preparation phase is where the farmers perceive how they are able to act, and this phase thus becomes their space of manoeuvre. Since the preparation phase is focused on only the upcoming season, this means that the space consists of only a short-term frame.

Before the rainy season begins, farmers prepare their plots by applying manure and fertilizers, tilling and building terraces on slopes and further decide on the best available seed varieties and food crops. After this process, farmers wait for the rains to arrive in order to start seeding and from that point onwards it is out of their hands. Therefore it is in the preparation phases between the rainy seasons that farmers of Karima North find their space of manoeuvre to act upon changes in weather. Hence, responses to weather hazards and climate change will take place within a time scale only including one season at a time.

4.1.2. Perceptions of weather hazards and how farmers respond

During ENSO 1997/98, erratic and heavy rains created floods, landslides and heavy erosion with damaging impacts for topsoil and crops. Due to the experience of ENSO 1997/98, prior to ENSO 2015 the government improved drainage systems and advised farmers to build terraces on their farms in order to prevent the effects of heavy rain. This time the farmers were already prepared in time, which, instead of damage, resulted in increased yields of maize and coffee in 2016 (SSI: AEO). Thus some farmers perceived ENSO 2015 as beneficial.

ENSO 1997/98 was perceived by the farmers as a weather hazard. In line with Villareal (1992), we argue that farmers' perception of ENSO was therefore shaped by a negative experience. Since some farmers' concept of ENSO is linked to weather hazard, and ENSO 2015 was positive, these farmers do not perceive the weather variabilities of 2015 as an ENSO phenomenon. As the KMD County Director states some farmers believe the KMDs forecast of ENSO 2015 failed, as no hazard ever occurred (SSI: KMD County Director).

4.1.3. Perception of climate change and how farmers respond

The KMD points out that predicting climate change is a challenge. The Kenyan National Climate Change Response Strategy (2010) proved an increasing temperature trend occurred in Central Kenya from 1960-2006 where minimum temperatures increased up to 2 ºC and maximum temperatures up to 0.7 ºC. While temperature changes are relatively easy to predict, precipitation is becoming increasingly unpredictable (IPCC, 2014). Farmers in Karima North could therefore expect to face temperature increases and increasing rainfall variability in the future.

Farmers do not perceive temperature variations as relevant to their crops and therefore do not focus on practices that improve their resilience towards increases in temperature. Nonetheless, they are aware of variable rainfall, since they experience it every season. Variable rainfall constrains their possibility to prepare for the rainy season and thus puts productivity in danger. Farmers already adapt to seasonal patterns by changing maize seed varieties every season. Interestingly, seeds are developed every year towards more drought tolerance. Although the AEO relates this to increases in temperature due to climate change, farmers do not relate it like that. However, if temperatures increase farmers' resilience will probably be increased due to drought-tolerant maize varieties. Further, the diversity in available food crop production allows farmers to evade food shortage by changing between the most suitable crops for the different seasons depending on the rainfall. While farmers currently adapt their food crops to rainfall, they could similarly apply the strategy to increasing temperature.

We find that many of the short-term practices performed by the farmers to prevent weather hazards, like changing seeds, diversifying food crops and building terraces, are also effective as long-term adaptation methods. In that sense, farmers are indirectly adapting to and building resilience towards the long term focus of climate change, even though they do not perceive it as such.

At the same time, we find that soils in Karima North favour crop production due to good physical properties, as indicated by the relatively high amount of soil organic matter[18] and water holding capacity. This creates good natural conditions for the farmers to apply their current adaptation methods. According to Brady & Weil (2014), organic matter increases the stability of the soil and hence reduces the risk of erosion. The findings are also supported by World Soil Information (ISRIC) (2001), who describes that nitisols (the dominating soil in the area) have good structural stability, good infiltration and is naturally fertile (ISRIC, 2001). SOM is enhanced through mulching with crop residues and tree litter. As many farmers already are performing these practices, they are adding structure to the soil. The good physical and chemical properties of the soil enhances possibilities for diversification of crops. The low C:N ratio indicates decomposed SOM which .

While conditions are good for crop diversification, another potential adaptation strategy to climate change is agroforestry. This is still a relatively unused method in Karima North but it

[18] In comparison, soil organic matter in Danish agricultural topsoil is 2-4% (Jensen & Jensen, 2001).

is advised by the AEO as a main method to climate change adaptation, and the potential of it is promising. Our results show a strong cooling effect of intercropped trees on coffee crops which is particularly evident when temperatures are higher than 20ºC. Farmers intercropping trees could be able to sustain coffee production under higher temperatures than farmers growing unshaded coffee. The analyzed coffee farmer grows and intercrop between macadamia and coffee trees. Macadamia emerges as an alternative cash crop to coffee. So, in addition to the temperature and humidity control delivered by macadamia trees, the farmer is diversifying his farm income. In general, since macadamia is an emergent crop, farmers do not grow it on large scale.

To this extent, we argue that farmers have a good potential to adapt to weather hazards and climate change. The natural conditions are good and there are adaptive measures readily available. Likewise, farmers act as agents of change and actively modify their practices every season, according to changes in weather. Yet, good natural conditions are not solely enough to change to bigger and future weather challenges. In the following, we will discuss how social and socio-economic conditions can be an impediment to proper adaptation.

4.2. Barriers for adaptation

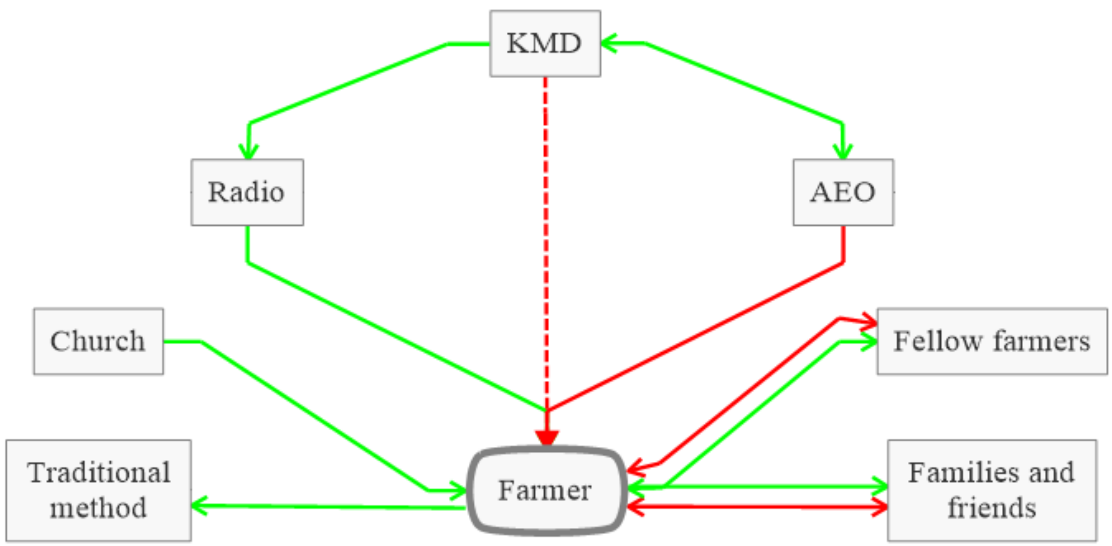
4.2.1. The adaptive capacity

Before discussing how the transfer of knowledge and the socio-economic factors constrain the farmers' adaptive capacity, initially the definition of adaptive capacity will be explained. Gabrielsson et al. (2013) refer to the *adaptive capacity* as "the ability to react to and cope with changes". To distinguish between adaptive situation and adaptive capacity we find the latter including an extended time frame not only focusing on the current situation of the farmers. Thus, when writing adaptive capacity, we refer to the potential and possibility for a farming system to adapt to changes. In the following we will discuss how different social and socio-economic factors affect the adaptive capacity of farmers.

4.2.2. Access to knowledge

In order to adapt to and benefit from weather variability, information is vital. According to Bohn (2000), constraints to benefit from information on weather variability are lack of awareness, incorrect beliefs about the information and inability to implement the information into farming practices. Figure 14 shows our analysis of problematic and unproblematic transfers of knowledge on weather and agricultural practices[19].

Figure 14 - Problematic and unproblematic transfer of knowledge



Note: Green arrows indicate unproblematic communication and red arrows indicate problematic communication. Arrows show the way the flow goes. The dotted line is the end-result of the transfer through the system from the KMD to the farmer.

The role of the KMD is to advise the farmers in advance about weather and climate. The data the KMD uses to produce such forecasts comes from the World Meteorological Organization. Therefore the officials of KMD have to translate information from a global level to a local level. We argue that the officials of KMD can be seen as brokers. A broker is defined as a person, who brings local actors into relationship with global structures (Olivier de Sardan, 2005). In mediating information between different paradigms, the national one, originating in a global discourse on climate change, and the local one, related to farmers' perceptions of weather, we argue that the KMD County Director is acting as broker. The director himself is aware of the difficulties in communicating information on climate change to farmers and therefore adjusts it to farmers' perceptions of weather by, for example, teaching farmers to plant trees by saying it will lead to more rain. Thus the information tends to be reduced to amount of rainfall, not including

[19] In the following we restrict ourselves to only describing the problematic transfers.

the broader phenomenon of climate change. As mentioned, higher amounts of rain is in general perceived as positive by the farmers. This means that making the connection between climate change and more rainfall presents climate change as a benefit for the farmers, because they feel that they are able to act directly (by planting trees) in order to obtain more rain. In that sense it strengthens the farmer's agency. But in the end, the aimed intention to make the farmers act directly to climate change fails because the cause of action (planting trees) from the farmer's point of view is to get more rain and not to minimize the risk of climate change which we find problematic. This way of packaging the information is not necessarily wrong though because, indirectly, farmers are still adapting to climate change.

In line with Bohn (2000), the way the KMD packages the information given to the farmers make them understand the information differently than aimed for, as the County Director still want them to be aware of climate changes. The lack of awareness of climate change constrains them in acting directly to it and likewise benefit from the information. In the end, the farmers still lack information on potential challenges caused by climate change which in the future will possibly limit their capacity to adapt.

On top of this, information on agricultural practices are important which is the responsibility of the agricultural extension officer. Here we identify another problematic transfer of knowledge since the officer focuses exclusively on "practicing farmers". A "practicing farmer" is defined by the AEO as: *"(...) a farmer who will come and learn and go and practice".* By this, farmers who do not have the capacity to leave their farm or economic means to adopt the practices learned will be neglected and farmers already doing well will benefit from informative events. The AEO expects the "practicing farmers" to pass on information to the "non-practicing farmers" which may become yet another problematic link since it implies that the social relations of "non-practicing farmers" is shaping the access to knowledge. Figure 8 indicates that Resourceful farmers draw more on officials such as local officials and AEO. This indicates that Resourceful farmers are probably part of the "practicing farmers". On the other hand, Less Resourceful farmers use more other local farmers, family and friends. In other words, Less Resourceful farmers will depend more on social relations to gain information, just as "non-practicing farmers" are defined by the AEO. The Big farmers seems to rely on the media and not triangulate with many other sources[20].

[20] This might be due to Big farmers representing less of the respondents.

One specific example of the problem of practicing vs. non-practicing farmers is that farmers' main access to knowledge on seeds is through farm demonstrations. As non-practicing farmers are not participating in these and the AEO does not actively promote specific varieties himself, the non-practicing farmers lack a source of information. Knowledge on seeds is directly related to farmers' capacity to change farming practices and limited access to the knowledge can be considered a constraint to their capacity to adapt.

Communication to fellow farmers is influenced by the engagement in social groups. Hence, some farmers will have more access to information transmitted through fellow farmers than others. The community of fellow farmers is further important when implementing new practices. Farmers want to spar with other farmers and experience the successfulness of a measure from others before carrying it out themselves. While, on one hand, this leads to a network of information on new practices, farmers also show a sort of conditionality to adaptation of their situation. Farmers are risk-averse in the sense that they want to be certain of a farm outcome before initiating it. In the present environment, this limits farmers that have fewer social networks as networks are important to confirm successes.

Farmers' access to knowledge will therefore be determined by their access to social groups and events. Further, the kind of knowledge will be influenced both by the decision of the AEO of which farmers to address and the decision of the KMD county director to frame information on weather and climate. We argue that Resourceful and Less Resourceful farmers will navigate differently through the sources of knowledge in order to adapt to changes in weather and climate. Even when access to knowledge is not a problem, other factors, such as economics, might be.

4.2.3. Income diversification and land constraints

Generally, farmers in Karima North are good at diversifying income sources. The majority of farmers have more than one income source which makes them less exposed to unanticipated changes in weather and consequent failure of crops. However, there are big differences in income between the types of farmers. According to the World Bank (2016), GDP per capita was 1,358.3 USD (in current prices) in Kenya in 2014, equivalent to roughly 135,800 Ksh. In comparison, Resourceful farmers in our sample have an average yearly household income of 279,000 Ksh, Big farmers 92,500 Ksh and Less Resourceful farmers 69,000 Ksh. Accordingly, Less Resourceful farmers live on only 1.89 USD a day. Clearly, this results in them being heavily constrained in terms of making investments into the farm in order to adapt. Recall, that one piece of plastic and a greenhouse cost 20,000 Ksh and 300,000 Ksh, respectively. For a Less Resourceful farmer this imply an investment of a third of the yearly household income to purchase and prepare a small piece of land only suitable for vegetables. Even worse, a greenhouse costs five years annual household income which, in comparison, for a Resourceful farmer is “only” a little more than a year’s income. On top of this, the problem of carrying risk is much bigger for Less Resourceful farmers as they do not have a secure source of income that will sustain them through possible hardship. A problem evident to all farmers in the area is that revenue from coffee production is not paid out by the collectives before up till one year later. This further necessitates the need for farmers to have other sources of income to support them until the payment is made.

Interestingly, we have found that lack of land is one of the most impeding factors to the adaptive capacity of farmers. Results from the PRA suggest that the problem of lack of land is biggest for Less Resourceful farmers, who rank it as the highest problem. Resourceful farmers mention lack of land but do not rank it as a problem. Less Resourceful farmers gain lower yields per acre from their cash crop (coffee) and simultaneously own less land. The lack of land is grounded in thin land markets and is further diluted by the social structures with inheritance of land and the subsequent partition of land among families. Therefore it seems that farmers adaptive capacity is constrained as their farms are inefficient and they cannot expand their farm to change this. Being unable to expand farm size in our study area is supported by past research (Place & Migot-Adholla, 1998).

A major problem of small land plots is that the size of land plots naturally limits farm income and in some cases impedes efficient use of inputs. Secondly, the risk of changing farming practices is higher the less land a farmer owns. The implications are twofold; when the farmer occupies a piece of land to try a new crop or practice, he is consequently taking away a relatively big share of his total land. This becomes a problem particularly for farmers seeking new farm income by adopting emergent crops. For farmers lacking additional income sources from outside the farm, trying out an emergent crop is one way of increasing and diversifying income from within the farm. Likewise, while the farmers are generally considered agents of change, the fear of carrying ‘untested’ risk is further enhanced when every small piece of their land contributes a significant part to their income and food intake. Thirdly, farmers are unable to perform crop rotation and lay land fallow which, according to the agricultural extension officer (AEO), is slowly degrading soil fertility.

Moving into the future, the current (social) structures of inheritance along with population growth and thin land markets will very likely further constrain the space of manoeuvre of farmers. This is likely to expose Less Resourceful farmers the hardest. As the Less Resourceful farmers are currently having a low income from outside their farm, their main way of adapting to future weather challenges involves an expansion of the farm. However, the scope for improving their space of manoeuvre through increasing their farm size seems difficult given the current structures. The end result of this is a reduced social mobility and hence a fixed social status from which it appears difficult for the farmer to progress.

5. Conclusion

This study focuses on farmers in Karima North, Nyeri County, Kenya and their ability to adapt to weather hazards and climate change (WHCC). Natural conditions of the area, such as soil fertility and water holding capacity, are good. This entails that the natural setting is less exposed to weather hazards than other parts of the country and that the scope for adopting new agricultural practices is not constrained.

We have argued that farmers' perceptions and past experiences shape how they respond to weather hazards and climate change. Farmers mainly operate within a short time-frame bound by seasons. This makes them good at preparing for short-term changes but constrains them in operating within a longer time-frame, giving space for the preparation for climate change. Anyway, some of the practices already applied by farmers might not only be beneficial in the short term, but also in the long term. This means, that even though farmers are not actively acting upon climate change, they indirectly do. Therefore, adaptation to climate change occur somehow indirectly.

On the other hand, we found negative factors impeding the adaptive capacity of the farmers. We observed problematic communication in the transfer of knowledge from officials, the AEO and KMD County Director, to the farmer. The KMD County Director has to mediate information between the source and the farmer and make sure farmers can adopt it, while the AEO makes a distinction between practicing and non-practicing farmers. Less Resourceful farmers are likely to suffer from this distinction, resulting in differences among farmers in the information obtained. Apart from access to knowledge, small land plots and lack of land limit the farmers' capacity to adapt. Again, Less Resourceful farmers are most affected as they do not have the same possibility to expand their farm or increase their income. In this regard, we argue that Resourceful farmers, that have more resources and better access to information, will have a higher potential to adapt to WHCC than Less Resourceful farmers.

Meanwhile, climate change is not just about predicting the upcoming season, it is equally about taking the responsibility and to act in due time. The farmers in our area of study are, broadly speaking, able to adapt to the current situation. However, nobody seems focused on a future of potentially more extreme weather where, not just rainfall increases, but similarly temperatures. We therefore believe that while Karima North has good conditions in a future of climate change, focus need to be kept on not only the short term but also the long term. This is a perspective that both farmers and government authorities alike need to take into account.

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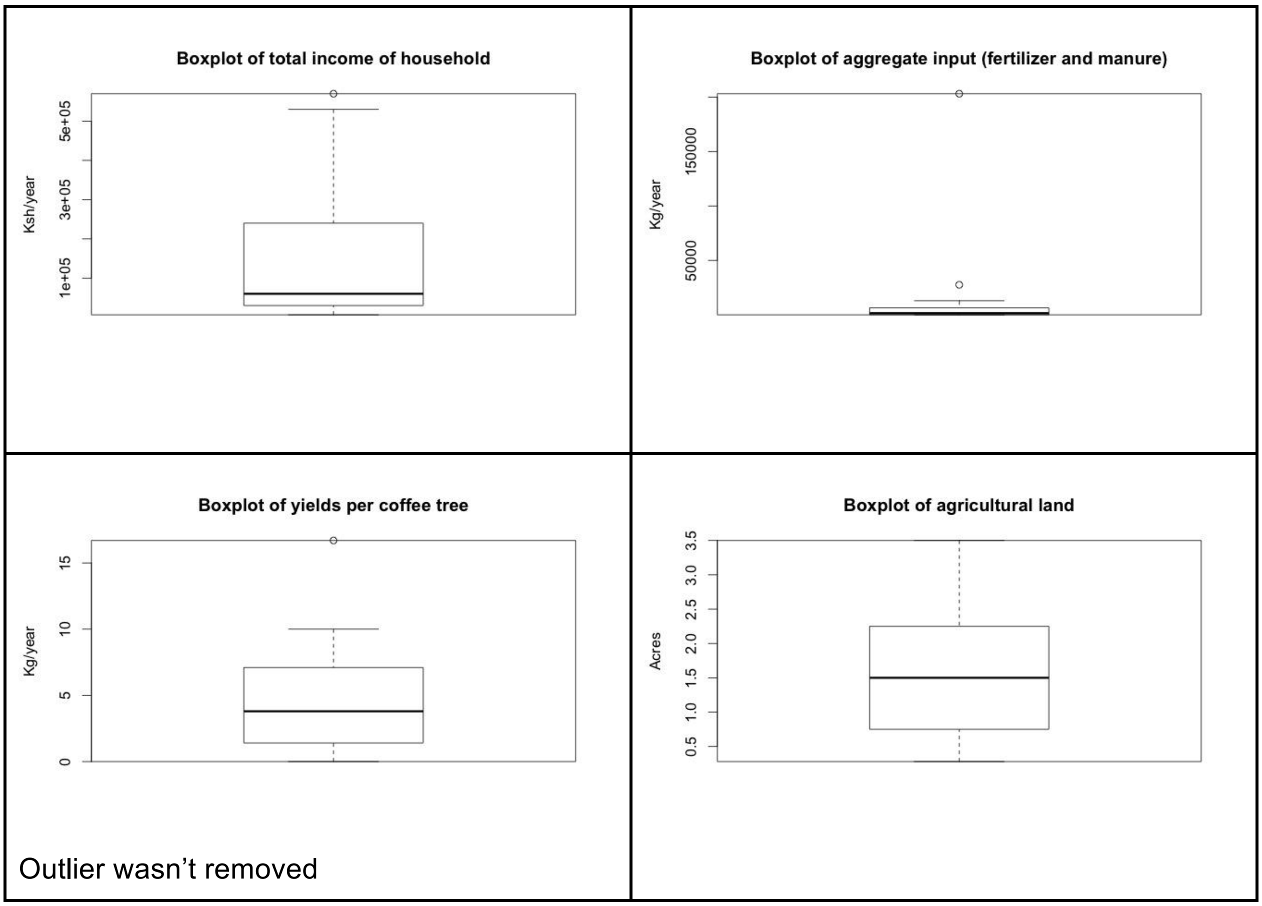
7. Appendix

Appendix 1: Farm typology

Outliers

First boxplots are made to identify outliers. Based on the boxplots, two outliers, one by one, were removed in terms of the aggregate input, leaving 17 farmers left in the sample. The outliers in the within the other variables were kept as the sample couldn't be made too small and since it was considered, based on a preliminary run of the PCA, that they didn't influence the formation of the clusters too much.

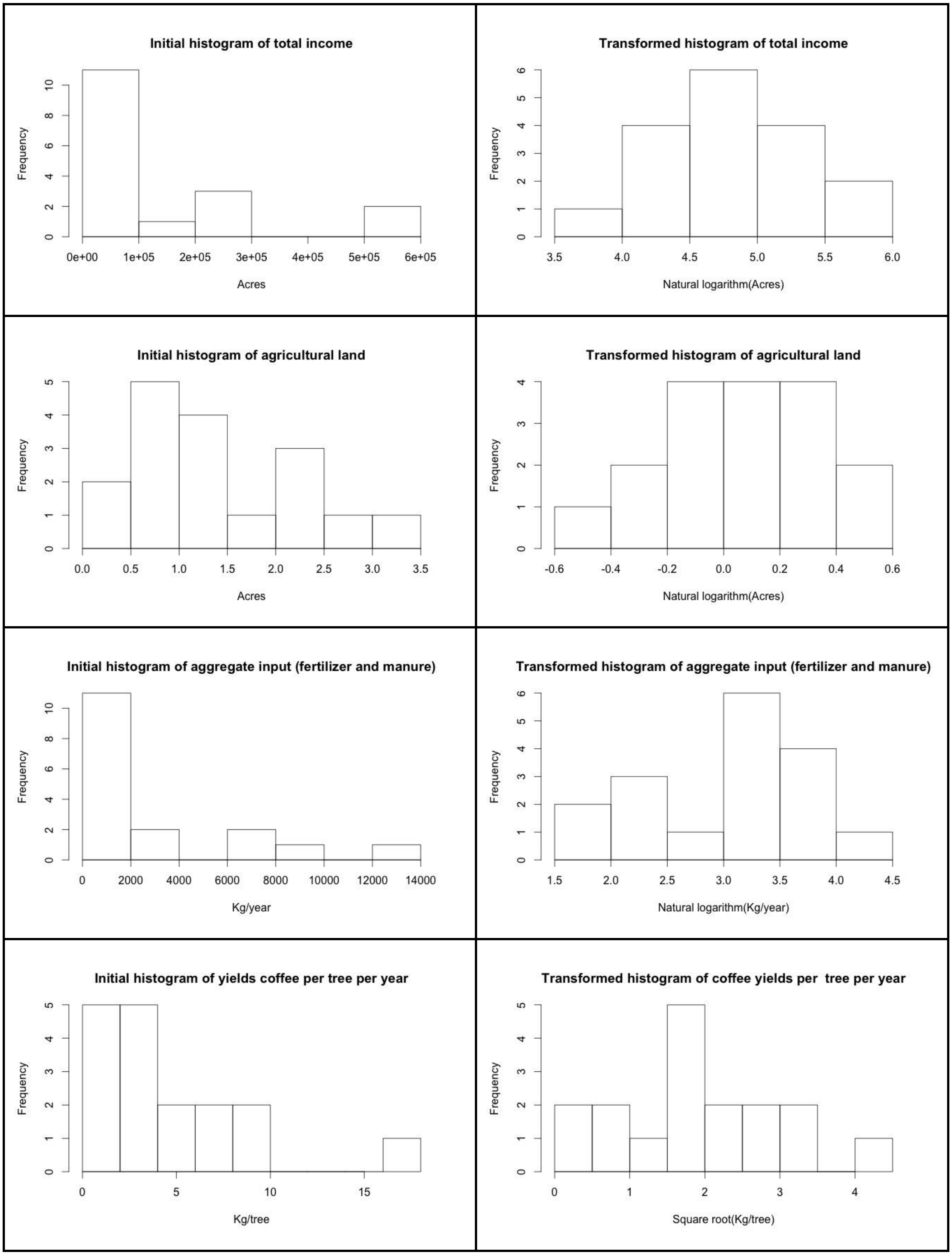
Figure 15 - Boxplots of variables in PCA



Transformations

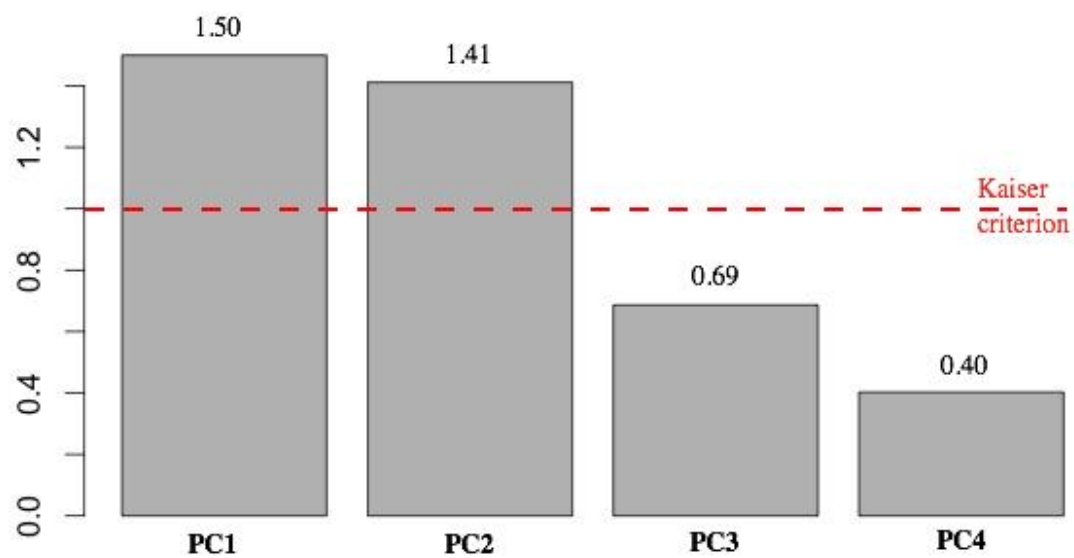
Afterwards transformations of the variables were done as the PCA require normal distribution of the variables included in the model.

Figure 16 - Initial and transformed histograms



The eigenvalues were computed and cut at the Kaiser criterion of 1 as it suggested by the literature (Alvarez et al., 2014).

Figure 17 - Barplot of the eigenvalues per principal component (PC)



The following cumulated percentage of variability was 73% for the two PCs included, i.e. the explanatory power of the PCAs is 73%. As a rule of thumb, the explanatory power needs to be at least 65% (Alvarez, et al., 2014).

Table 4 - Cumulated percentage of variability explained by the PC

	PC1	PC2	PC3	PC4
Cumulative pct. of variability	0.37	0.73	0.90	1.00

This leads to the correlation matrix from which it can be seen that the variables agricultural land and aggregate farm input are correlated to PC1 while coffee yields are correlated to PC2. That is, PC1 explains the variation in the former two variables while PC2 explains the variation of the latter variable.

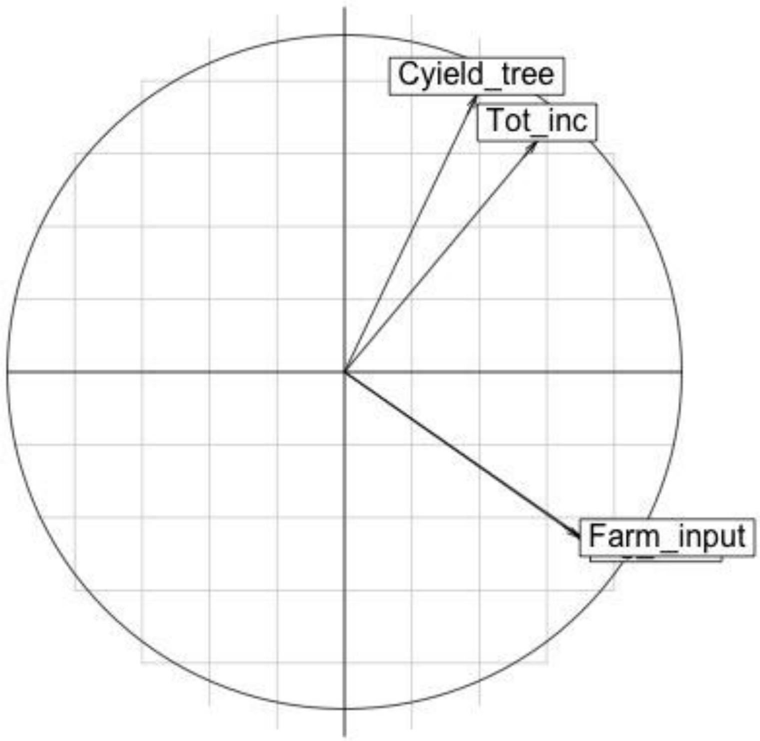
Table 5 - Correlation matrix between the principal components (PC) and the variables from the dataset

	PC1	PC2
Agricultural land	**0.73**	-0.47
Coffee yields per tree	0.39	**0.76**
Aggregate farm input	**0.70**	-0.46

Total income	0.57	0.63

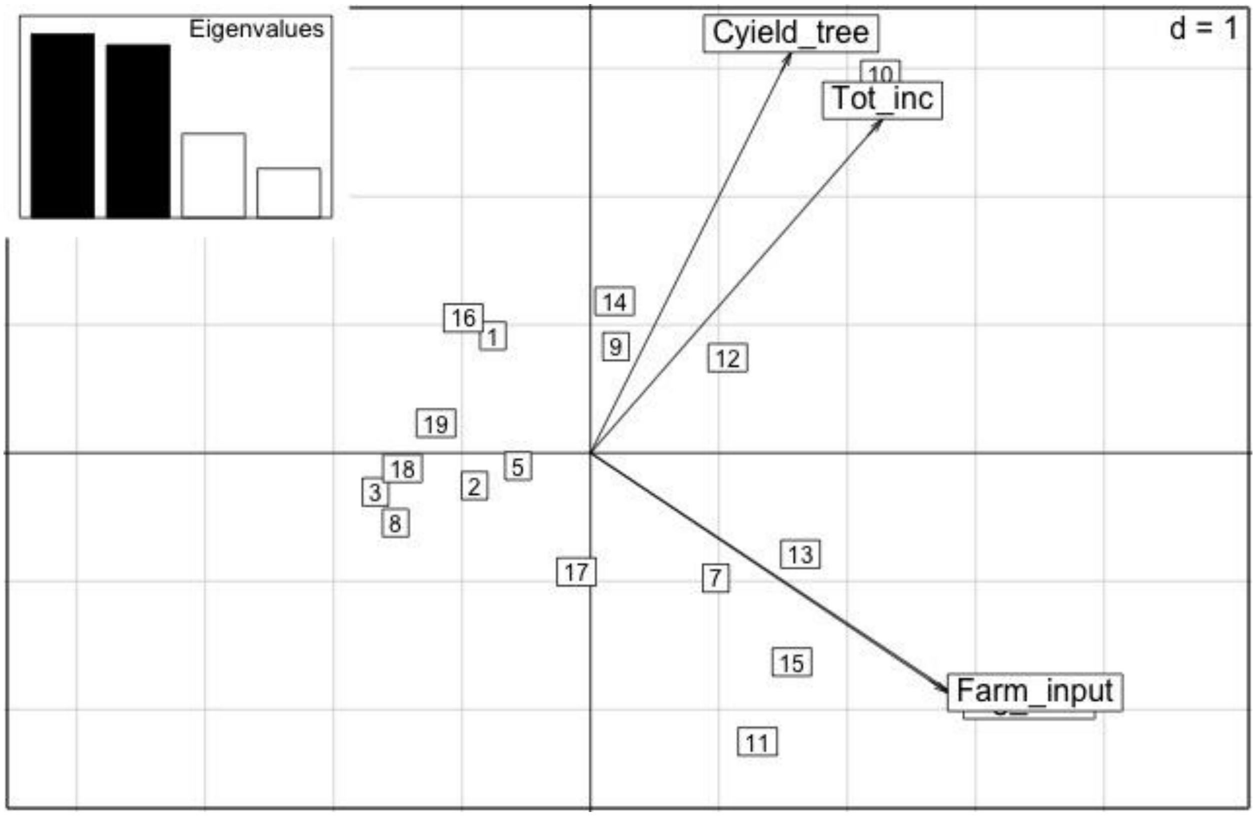
The correlation circle shows the graphically.

Figure 18 - Correlation circle for the principal components PC1-PC2



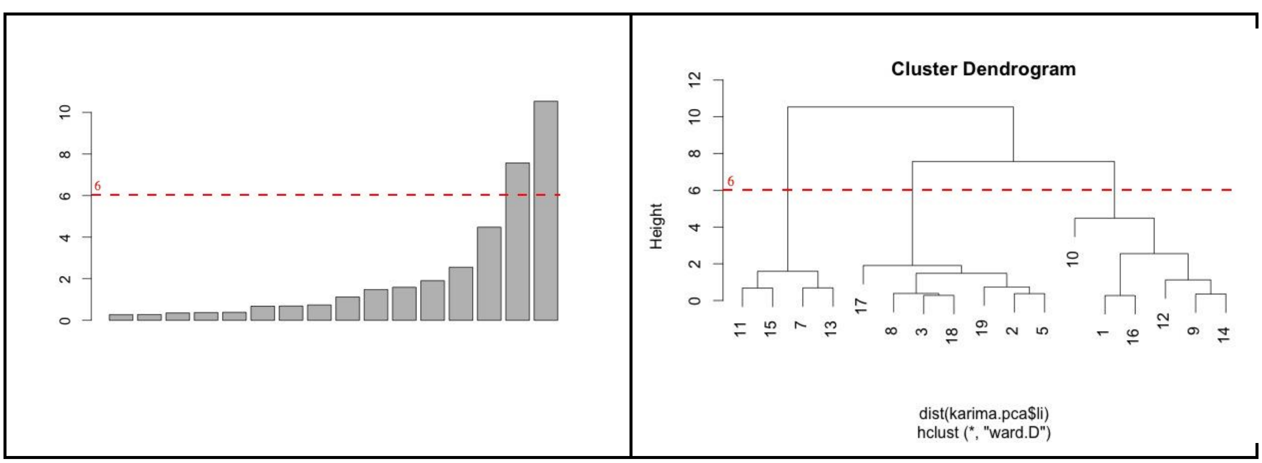
Below can be seen the plot of the farmers together with the correlation of the variables used.

Figure 19 - Farmers and variables illustrated in the principal components plane PC1-PC2



By the end, the decision on how many clusters to have is made. We decided to cut the clusters at the heights of six. This resulted in three clusters.

Figure 20a and 20b - Barplot of the height and Cluster Dendrogram



Finally, below is a scheme showing the allocation of each of the farmers. A graph of the clusters is presented in the main report.

Table 6 - Scheme over allocation of farmers into typology and other informants

Farm ID	Pseudonym	Area	Typology in the field	Revised typology
1	Mary	Gura	Resourceful	Resourceful
2	George	Gura	Less Resourceful	Less Resourceful
3	Rachel	Gura	Big	Less Resourceful
4	Jimmy	Gura		
5	Joshua	Gura	Less Resourceful	Less Resourceful
6	Jack	Gura	Big	
7	Joe	Mutitu	Less Resourceful	Big
8	Zenia	Mutitu	Resourceful	Less Resourceful
9	Nadia	Gura		Resourceful
10	William	Gura		Resourceful
11	Donald	Muitu		Big
12	Zion	Mutitu	Big	Resourceful
13	Jacob	Mutitu	Resourceful	Big
14	Justin	Mutitu	Resourceful	Resourceful
15	Alex	Thuti	Big	Big
16	Christopher	Thuti	Resourceful	Resourceful
17	Jake	Thuti	Big	Less Resourceful
18	Simon	Gura	Less Resourceful	Less Resourceful
19	Lydia	Thuti	Interviewed after typology	Less Resourceful
Substitute for farmer 8 during PRA	Caroline			
Informant, cultural mapping	Alice	Gura		
Informant, cultural mapping	Sam	Thuti		
Agro-dealer	Andi			

Note: Farmers not allocated into a typology is due to them being removed as outliers during the cleaning of the data.

Appendix 2: Method descriptions

Table 7 - Overview of the applied methods

1 x Transect Walk (TW)	5 x Cultural mapping (CM)
2 x Unstructured Interviews (UI) - Village Elder (John) - Agro-dealer (Andi)	1 x Participatory Rural Appraisal (PRA) - Historical timeline - Seasonal diagram - Venn diagram - Problem ranking
1 x Mapping - Village Elder John	15 x Soil samples
19 x Questionnaires (Q)	iButtons

5 x Semi-structured Interviews (SSI) - 3 farmers - 2 officials	GPS
Numerous informal conversations (IC)	

Transect walk

This method is a systematic walk within the field research area together with the local people. Is it used to explore the community by observing, asking, listening and looking. The transect walk is normally carried out during the initial phase of the fieldwork as it functions as an introduction to the research area (Mikkelsen, 2005).

Informal conversation

Informal conversations are characterized by a lack of structure and control. As a method it is mostly used at the beginning of a fieldwork when the researcher is "settling" in and trying to figure out what is at stake (Bernard, 2011).

Participant observation

This is a highly ethnographic approach, where the researcher has to participate in an activity and observe it at the same time. Thus, one must be able to be present but at the same time distance oneself from the activity. Here one has the possibility to be where the "action" takes place. The aim of this method is to understand the activities from the informants' point of view but also observe the potential differences between what an informant tells you he does and what he actually does (Bernard, 2011).

Unstructured interview

This kind of interview is characterized by a clear plan of its aim but also a minimum control over the informant's responses. The idea with this is to get people to open up and express themselves in their own terms, at their own pace (Bernard, 2011).

Mapping

Using this method, a map of the study area is drawn by locals. It can, for example, consist of a social and resource mapping, which will illuminate the local understanding of the organization, infrastructure and natural features of the area (Mikkelsen, 2005).

Cultural mapping

Cultural mapping is a method especially valuable when investigating the interaction between humans and their environment. It entails "doing walkabouts" with informants in the areas that they consider to be important and collecting data *in situ*. To walk with people is another way of participating, as one will place oneself *with* the people and thus get an understanding of their viewpoints (Strang, 2010).

Questionnaire

Questionnaires are based upon closed questions and used to describe the characteristics of a larger group. The questions are made in a way that the answers will be either quantitative or categorical so that the answers are easily used in the statistical analysis (Babbie, 2002).

Semi-structured interview

These are characterized by being based on an interview guide, which is a written list of questions and topics that need to be covered in a particular order. The interviewer guides the direction of the interview but the respondent is free to interpret the questions and express himself fully when answering. Using the same interview guide when carrying out the interviews will give comparable qualitative data on a specific topic (Casley & Kumar, 1988).

Participatory Rural Appraisal (PRA)

PRA is a bunch of methods used for data collecting, analysing of information and both at once. The methods have proven to be useful in defining problems and explore possible solutions. The PRA methods are normally used to empower the target group by including them in the process of implementation strategies. The main PRA methods are as followed: Seasonal Diagram, Venn diagram and Problem Ranking (Mikkelsen, 2005).

1. Seasonal Diagram is a time-related method where the respondent will draw what indicates different seasons and when they occur.
2. Venn diagram is a relational method where the respondents have to draw kinds of social groups existing in the community, how they interrelate to one another and which group has more influence due to farming practices than others.
3. Problem Ranking is likewise a relational method. The respondents will start by discussing which kind of factors that have an influence on their farming practice. Afterwards they have to rank them in order of which factors have more or less influence.

Soil sampling methods

In order to determine pH, water holding capacity (%), C (%) and N (%), composite samples with auger was conducted. For each farm, 8 samples was taken, and afterwards mixed well together in a bucket. Afterwards two handfuls of soil was brought for analysis. The composite sample show an average for every farm. When composite sampling, it is possible to represent the field as a whole, thus varieties within the field is not represented. The soil auger enables quick and numerous of soil sampling, making a broad overview soil fertility in the area.

As it was raining one day, only 12 of the fields, was sampled with a 100 cm3 ring sample in order to measure water holding capacity. The soils were weighed the same day as collected, whereafter they were put on a piece of paper (A4) and left for 4 days to dry. The aim was to take the ring sample in a relatively flat maize field on each farm. However, we did not consider that the results might be more comparable if taken either up- or downhill

Soil analysis in the laboratory in University of Copenhagen

The soils were in the laboratory in the Department of Plant and Environment Sciences, analyzed for pH, C and N. Furthermore, the dry 100cm3 ring samples was weighed. The difference between the wet and dry soil, this can be calculated to water content (%).
The method for measuring pH, was based on water, measured on a pH-meter, the C and N was measured on Isotope-Ratio Mass spectrometry (IR-MS).

The oxidizable Pox was determined by measuring how much Carbon is oxidized in a solution of 0.02 M $KMnO_4$ in 0.1 M $CaCl_2$ at pH 7.2 by determining the bleaching of the purple $KMnO_4$ solution by a handheld spectrometer. This analysis, we did not used in the results, as they did not add value to our results.

GPS

The GPS was fundamental to mapping our activities in the field. Primarily, it was used in two activities 1) mapping our respondents and 2) mapping soil sampling sites. Mapping our respondents is used to get an overview of the geographic placement of the different farm types. Furthermore, this enables us to plot the placement of our farm typologies against the cultural, social and resource mapping from the qualitative methods. Originally, we wanted to do farm size measurements. This was, though, too time consuming and we were too few people in the field together.

iButtons

iButtons are used for temperature measurements. This was used in a coffee field without shade and a intercropped coffee:macadamia field, where the coffee was shaded. This was done in order to measure the effect of agroforestry of temperature and relative humidity.

Appendix 3: Soil sample results

Table 8 - Results from soil samples

Farm ID	Area	pH	Water content (%)	C (%)	N (%)	C/N ratio	Soil Organic Matter (SOM) (%)
1	Gura	5.3	11.2	0.27	2.39	9:1	4.12
2	Gura	5.9	14.4	0.31	2.64	8:1	4.55
3	Gura	5.8	—	0.29	2.43	8:1	4.19
4	Gura	5.8	—	0.28	2.41	9:1	4.16
5	Gura	—	—	—	—	—	—
6	Gura	5.4	14.4	0.25	2.22	9:1	3.83
7	Mutitu	6.4	16	0.3	2.64	9:1	4.55
8	Mutitu	6.2	14.2	0.36	3.25	9:1	5.60
9	Gura	—	—	—	—	—	—
10	Gura	—	—	—	—	—	—
11	Muitu	6.2	12.5	0.24	1.83	8:1	3.16
12	Mutitu	6.1	17.3	0.27	2.33	9:1	4.02
13	Mutitu	6.2	16.8	0.31	2.61	8:1	4.50
14	Mutitu	5.9	11.6	0.19	1.83	10:1	3.16
15	Thuti	5.8	11.8	0.28	2.39	9:1	4.12
16	Thuti	6.5	12.6	0.34	2.97	9:1	5.12
17	Thuti	6	—	0.24	2.15	9:1	3.71
18	Gura	6.6	14.4	0.23	2.21	10:1	3.81
19	Thuti	—	—	—	—	—	—

Note: Blank spaces is due to lack of soil samples from the farmer.

Appendix 4: iButton results

Figure 21 - Relative humidity (%) on shaded and unshaded coffee

Final synopsis

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Assessing the vulnerability of and adaptation to climate change and weather hazards for farm households in Gatugi, Nyeri District, Kenya

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1. Introduction

In March 2015, KMD (Kenya Meteorological Department) issued an advisory that Kenya would be impacted by El Niño in 2015 (Vam, 2015). The advisory stated that the October-November-December (OND) 2015 short rains were likely to be enhanced in most parts of the country and were expected to continue into early 2016. A similar El Niño event in 1997/98 caused extreme intense rainfall, which caused huge floods and resulted in destroyed infrastructure, households and crops (Glantz, 2001).

Anthropogenic global climate changes, in terms of increased temperatures and increased frequency of climatic hazards, such as floods and droughts, are expected to have a considerable impact on agricultural systems worldwide (IPCC, 2014). According to IPCC's (2014) highest emission scenario RCP8.5, which is their worst-case scenario, temperature increases are projected to be between 2.6°C and 4.8°C by 2100. The African continent in general is expected to have some of the largest increases in temperature, on average 1.5°C above global average (Bryan et al., 2012). Additionally, the precipitation is expected to be influenced, but to which extent is likely to vary across Africa (IPCC, 2014). The eastern part of Africa is expected to experience an increase in precipitation which differs from most of the other areas of Sub-Saharan Africa (IPCC, 2014; Schlencker & Lobell, 2010). In East Africa more extreme droughts and floods have already been observed more frequently in the past 30-60 years (IPCC, 2014).

In Kenya, more intense rainfall and less risk of drought is expected in October - December and March - May while August and September are predicted to be drier (IPCC, 2014). In addition, IPCC (2014) predicts, with high level of confidence, that the frequency of days with extreme rainfall and extreme high temperatures in East Africa will increase. This change in climate will have an influence on the agricultural production, such as decreases in e.g. maize yields (Herrero et al., 2010). Thus, climate variability is already evident in Kenya and studies show that the Kenyan people are clearly aware of this. Meanwhile, there is not always a linkage between the forecast information and the farmers' perception of the climate changes (Gichangi et al., 2015; Muita et al., 2016; Rao et al., 2011; Weber, 2015; Bryan et al., 2013).

The prediction of El Niño in 2015 was fundamentally different compared to the El Niño event of 1997/98. Previously, farmers lacked forecasts which led to a lack of proactive behaviour. In contrast, the prediction of El Niño in 2015 led a lot of farmers to harvest maize in an immature stage in order to avoid large damages related to heavy and longer rains. The consequences of this decision has turned out to be immense as maize prices have dropped dramatically and the access to storage is limited for the majority of farmers in Kenya (The Herald, 2015; News Ghana, 2015; The Star, 2015).

In Kenya, rain fed agriculture is the predominant livelihood option, leaving farmers vulnerable to weather related hazards. Therefore, production of seasonal forecast information, a key activity for the Kenya Meteorological Department (KMD), is crucial. Information produced in seasonal forecast activities is used to inform government bodies, livelihood sectors and the general public on the expected conditions in an upcoming rainy season. It is a key piece of information for informing decision-making actors across

Kenya on seasonal timescales, and feeds directly into agricultural practices, food security, water resource management and disaster risk reduction activities.

Nyeri District was one of the districts where above-normal rainfall was forecasted. KMD advised that while the rains might cause disruptions, some sectors may reap maximum benefits from the expected good rains depending on their level of preparedness. Nyeri District, located in the Central Kenyan Highlands, belongs to one of the most productive agricultural areas in Kenya (Herrero et al. 2010). Agricultural production is mainly allocated in small-scale farms of low input and little farm size of 0.5 hectares on average where production of cash and food crops is mixed with livestock holding (Lekasi et al., 2001; Bryan et al., 2013). These mixed systems of small-scale are crucial for food security as they account for the majority of food production consumed by the local population (Herrero et al., 2013). Previous studies of small-scale farms in Kenya found that they are highly vulnerable to climate change, since their agricultural activities rely on precipitation patterns (Gabrielsson et al., 2013; Bryan et al., 2013). Hence, there is a need to address the sustainable livelihoods of small-scale farmers facing climate change. Ellis (2000) defines a livelihood as the living gained by a household. The output of a livelihood is income, achieved by activities and strategies utilizing the assets owned by the household. Access to assets is influenced by social relations, institutions and contextual factors such as climate (Ellis, 2000; DFID, 1999).

For such smallholders, reducing exposure and vulnerability towards climatic changes is crucial in order to maintain a sustainable livelihood. Increasing resilience to potential adverse impacts of climate hazards requires the assessment of risk and adaptive capacity inherent in farming systems (IPCC, 2012). Gabrielsson (2012) finds that farmers' vulnerability is impacted by the exposure to hazards, sensitivity and adaptive capacity. In relation to adaptive capacity and, consequently, adaptation strategies, it is therefore important to include the concept of agency. Agency is the way people handle constraining and enabling elements encountered in a specific social situation (Villarreal, 1992:257). What defines a constraining or an enabling element depends on the individual's personal abilities and perception of the specific situation (Villarreal, 1992). Therefore, it is furthermore important to investigate similarities and differences between farmers' perceptions and scientific data.

2. Problem statement

Facing the current climate changes and hazards to which farmers are exposed, the present report aims to identify the level of vulnerability of farmers in Gatugi, Nyeri District by first investigating the sensitivity of different farms, and, secondly, assessing the factors influencing the adaptive capacity of the farmer. In addition, differences between perceptions and scientific data about climate and weather play a key role into how individuals feel vulnerable and act accordingly. These issues will therefore be investigated through the following problem statement and research questions:

What is the local perception of climate changes and weather hazards (CCWH) and the actual impact on farm households' vulnerability and practices in Gatugi, Nyeri District, Kenya?

1. How are the farm households influenced by CCWH?
    a. What are the soil characteristics of the farms?
    b. How does CCWH affect crops and livestock farming?
    c. Do farmers perceive climatic hazards such as El Niño as a natural variability in the climate or as a part of a long-term climatic change? And how aware are they of the implications of long term climate change to their local area?
    d. Is the meteorological data and agricultural extension records (e.g. KALRO) consistent with the perception of the farmers?
2. What is the adaptive capacity of farmers in relation to the CCWH?
    a. How does the access to knowledge play into the adaptive capacity of the farmer?
        i. Do farmers have access to meteorological data? How does the knowledge of weather forecasts transfer onto the farmers' level?
        ii. What is the role of access to weather forecasts?
        iii. How do other kinds of knowledge influence the adaptive capacity of the farmers? And how does the knowledge transfer between and within groups?
        iv. Has the farmer had access to "best management practices"? If yes, what is the role of this?
    b. How does financial means play into the adaptive capacity of the farmer?
    c. How does the social networks play into the adaptive capacity of the farmer?
    d. How does agricultural practices play into the adaptive capacity of the farmer?
3. Which, if any, adaptation strategies do farmers adopt according to their vulnerability?
    a. Are they adapting to more frequent weather hazards and, if so, which ones and how?
    b. Are they adapting to climate change and, if so, which ones and how?
    c. How, if at all, are farmers limited in their range of adaptation strategies?

3. Methodology

As already touched upon, climate change and climate hazards (CCWH) pose several challenges for small-scale farmers not only related to natural factors but likewise for socio-economic factors. In order to capture all these effects, we apply an interdisciplinary approach, exploiting the different sciences of the group members and using both quantitative and qualitative methods from these sciences.

Among the quantitative methods applied we use questionnaires with closed questions and soil analysis. The soil assessments include measures such as profile, depth of topsoil, soil texture, moisture, temperature and nutrients. In terms of qualitative methods, we use semi-structured interviews (SSI), Focus Group Interview (FGI), Participatory Rural Appraisal (PRA) methods, field and farm walks, informal conversations with farmers, cultural mapping, and possibly expert interviews, if time permits. The mix of methods will give us a broad-based understanding of the impacts of CCWH and the underlying drivers influencing vulnerability.

Most importantly, applying both quantitative and qualitative methods allow us to achieve a high level of both reliability and validity (Babbie, 2002). Quantitative methods, such as questionnaires, offer a high level of reliability in terms of replicability of the results whereas the qualitative methods add more validity to the results and enable us to investigate the proper causal effects more directly (Babbie, 2002). An important part of this practice is furthermore to enable us to triangulate the data output and create a comprehensive study by comparing the results from each method and identify similarities and discrepancies. This is particularly important given our short time frame in the field where we will not be able to obtain enough observations within each method to rely solely on one result.

Lastly, one important differentiation in terms of vulnerability and the underlying factors is the difference between the scientific data and perceptions. Bryan et al. (2013) investigate farmers' perception of the climate change and subsequent adaptation strategies in Kenya. They find that there are discrepancies between actual rainfall data and how farmers perceive the long-run climate change in terms of precipitation. We will therefore use the natural science data to measure sensitivity to exposure and further use the qualitative methods like expert interviews and key informants to explore the adaptive capacity. In contrast, the questionnaires and PRAs will be able to give an insight into how the farmers and community as a whole perceive the challenges mentioned above.

Throughout the study we focus our efforts on the heads of farm households. Here we will use the definition of a household by Casley & Kumar (1988): "A household comprises a person or group of persons generally bound by ties of kinship who live together under a single roof or within a single compound and who share a community of life in that they are answerable to the same head and share a common source of food."

In order to analyse differences among farm households, a fundamental part of our analysis will be to make farm typologies. We expect the farmers in our study population to be very diversified hence why we need to differentiate between types of farm(er)s. Our typology will be based upon a wealth ranking of both pecuniary and nonpecuniary indicators that is considered important by the farmers.

Time plan

Following our time plan (see appendix D), we intend to use the first two days on getting an insight into the village and surrounding community and do our first part of the preliminary survey. We will start by having an informal interview with the village head along with a transect walk. This will give us an indication of the challenges met by the village in relation to the climate. This is followed by a focus group interview (FGI) that will be conducted to find the indicators in a wealth ranking within the community. The wealth ranking is important as it is the basis of our farm typology. Once the indicators are identified we will perform a closed-question questionnaire that we will create the actual wealth ranking using Principal Component Analysis. The questionnaire will form the backbone on which to base upon our subsequent SSI, PRA and soil assessments. The questionnaire will be used to generate an overview of the composition of the farms and assets. Thereafter, we will process the questionnaires in the village and based on the results create expected farm typologies that we can investigate further through the other methods.

Following this, we will do the soil assessments that will give us an idea of the physical attributes and capacity of the farmers' soil from a scientific point of view. An assessment of farm management methods and spatial measurements of plot sizes will be combined with soil assessment in mixed sessions. We will do some on-site assessments such as soil texture, depth of topsoil and soil moisture that we will be able to use actively in the SSIs and PRAs the following days.

This way of structuring our work will create a natural process starting with the bigger picture, to give us insights into the field site we are investigating, before moving onto more specific issues in the later stages. Likewise, there will be a move from the descriptive methods to the more problem-diagnostic methods (Casley & Kumar, 1988).

Limitations to the methods

Overall, the constrained timeframe sets some limitations to our choice of methods. Particularly important for the quantitative methods, it is necessary to have a big sample size in order to do regression analysis. This limits us to do descriptive statistics and do simple tests of significance through analysis of variance.

Likewise, we will only get a snapshot of the current situation. Thus, we are not able to allow for time-varying factors. For example, measuring the assets of a farmer during the second rain season which is considered the toughest period of hardship in a year (Gabrielsson et al., 2013), will give a very different picture than if we were also able to measure amount of assets after the harvest.

Somewhat related to this issue is the problem of recall bias. Questions asking the farmer to recall prior events and actions taken, risk being influenced by the current situation as well as the memory of the individual farmer. For example, if the farmer is currently affected by El Niño he might be more likely to recall climate change and more severe weather variations that he would otherwise not have been. Consequently, questions related to actions taken by the farmer should only go back a limited amount of time, e.g. before the start of the rainy season or one year back, in order to decrease the potential recall bias (Casley & Kumar, 1988). Accordingly, we will be very focused on phrasing questions in a manner that decreases this risk while still enabling us to look at past adaptations made to climate change and weather hazards.

Likewise, another implication might be the problem of translation, which refers to the probability of people understanding the same words, concepts and terms in different ways.

4. Collaboration between counterparts

The study is a collaboration between students from Kenya and Denmark. In order to discuss focus of research, problem statement and relevant methods, two skype meetings have been set up. Due to the fact that the approach is interdisciplinary we as a group represent different disciplines from both natural science and social science.

This synopsis has been composed in collaboration with all of the group members. By using Google Drive, everyone has been able to add comments and see the work of others. Through constructive discussions we have found a shared understanding of the aim of the investigation. During the fieldwork it is intended to arrange small meetings to share different insights obtained in order to secure a shared direction of the data collection and an overview of the process of the fieldwork. In the end, two reports will be written, one by the Kenyan students and one by the Danish students.

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6. Appendix

A. Method descriptions

Transect walk: This method is a systematic walk within the field research area together with the local people. Is it used to explore the community by observing, asking, listening and looking. The transect walk is normally carried out during the initial phase of the fieldwork as it functions as an introduction to the research area (Mikkelsen, 2005:90). We will be using this method as one of the first during our research. The reason for this is that the transect walk can give us an overview of the research area in terms of the structure of the community and thus enable us to navigate. This walk will be conducted together with one person or more who has a comprehensive knowledge of the area, for example, the head of the village.

Informal interviewing: Informal interviewing is characterized by a lack of structure and control. As a method it is mostly used at the beginning of a fieldwork when the researcher is "settling" in and trying to figure out what is at stake (Bernard, 2011:156). We will carry out informal interviewing during the transect walk to explore the local understandings of their farming practices and challenges related to it. In relation to our problem statement informal interviews will help us develop a sense of the current issues faced by the people in the area.

Focus group interviews: A focus group is gathered to discuss a particular topic (Bernard, 2011:172). We will conduct this in one of the first few days with 4-5 people who have a good knowledge on different aspects of the community. We will do both social and resource mapping, which will illuminate the local understanding of the organization, infrastructure and natural features of the community. Afterwards we will do a wealth ranking to see what these people find important according to wealth (Mikkelsen 2005:107-9).

Cultural mapping: Cultural mapping is a method especially valuable when investigating the interaction between humans and their environment. When doing research on climate change this method is therefore useful. It entails "doing walkabouts" with informants in the areas that they consider to be important and collecting data *in situ*. To walk with people is another way of participating, as one will place oneself *with* the people and thus get an understanding of their viewpoints (Strang, 2010). We wish to follow a farmer through his fields asking about his farm and farm practices. We might ask: "Can you show us around your farm?". This will enable the farmer to focus upon what he finds important regarding his farm and thus enable us to see what is relevant to ask about.

Questionnaire: The questionnaire is based upon closed questions. The questions are made in a way that the answers will be either quantitative or categorical so that the answers are easily used in the statistical analysis. The questionnaire is of a length that will take no longer than one hour.

The questionnaire will be conducted face to face at the respondent's farm or home. This is tied together to our sampling strategy mentioned below in which we use maximum variation sampling. Importantly, conducting the questionnaire face to face is more time-consuming than distributing the questionnaire centrally in the village. Nonetheless, centrally distributing the questionnaire will increase the potential bias of the respondents. A bias might arise because, for example, more wealthy people have resources to go to the distribution place (Alvarez et al., 2014) or that farmers mainly growing a crop that is not in season might have more time to leave their farm.

In order to increase the speed of which the questionnaire is conducted we will ask the interpreter to note down the answers himself, in English. The potential downside of this is that we will not be able to keep the same control of whether answers seem reasonable (answers might be unrealistic if the interpreter frames the question wrong or the interviewee misunderstands the question). We will do pilot questionnaires together with the interpreter beforehand to make sure that this will not be a problem. If, for any reason, there seems to be a problem, we will choose to conduct the questionnaire ourselves with the support of the interpreter.

Participant observation: This is a qualitative, and highly ethnographic approach where the researcher has to participate in an activity and observe it at the same time. Thus, one must be able to be present but at the same time distance oneself from the activity. Here one has the possibility to be where the "action" takes place. The aim of this method is to understand the activities from the informants' point of view but also observe the potential differences between what an informant tells you he does and what he actually does (Bernard, 2011:256-8). This method will be conducted to collect data on the daily farming practices, which will show the adaptive strategies used by farmers to tackle hazards or climate change. Hence, this method will also shed light upon different ways of showing agency. We attempt to do participant observation on approximately 4 farms to explore and get data on different kinds of adaptation strategies.

Semi-structured interviews: These are characterized by being based on an interview guide, which is a written list of questions and topics that need to be covered in a particular order. The interviewer guides the direction of the interview but the respondent is free to interpret the questions and express himself fully when answering. Using the same interview guide when carrying out the interviews will give comparable qualitative data on a specific topic (Casley & Kumar, 1988; Bernard, 2011). We will carry out approximately six semi-structured interviews based on the same interview guide to get in depth with local farmers' understandings and perceptions on hazards and climate changes. Each farmer will represent different farm typologies. This will enable us to analyse equalities and differences between them. When comparing these with the meteorological data the interviews might enable us to dis- or uncover challenges related to the farmers' adaptation to weather hazards and climate changes.

Participatory Rural Appraisal (PRA): PRA is a bunch of methods used for data collecting, analysing of information and both at once (Mikkelsen, 2005:65). The methods have proven to be useful in defining problems and explore possible solutions (Mikkelsen, 2005:63). The PRA methods are normally used to empower the target group by including them in the process of implementation strategies. In our case we will use the PRA to explore the local farmers' perceptions of their vulnerability and abilities to adapt within these. Based on the farm typology, we will invite one farmer representing each of the different typologies. The group is diverse to make sure that we will obtain different insights, but we are aware that it is a hindrance to obtain in-depth data, which we will compensate with semi-structured-interviews later on.
The main PRA methods are as followed: Seasonal Diagram, Venn diagram and Problem Ranking (Mikkelsen, 2005:92, 99).

1) Seasonal Diagram is a time-related method where the respondent will draw what indicates different seasons and when they occur (Mikkelsen, 2005:66, 92).
2) Venn diagram is a relational method where the respondents have to draw kinds of social groups existing in the community, how they interrelate to one another and which group has more influence due to farming practices than others (Mikkelsen, 2005:66, 92).
3) Problem Ranking is likewise a relational method (Mikkelsen, 2005:66). The respondents will start by discussing which kind of factors that have an influence on their farming practice. Afterwards they have to rank them in order of which factors have more or less influence.

Soil sampling methods:
The decision of the exact method to collect soil samples will be made in the field, where we have a more realistic idea of the time frame. There are two methods from which we will choose, namely, composite sampling with an auger and soil profile excavation. In the time frame, two days is set aside for soil sampling. Hopefully this will be sufficient.

Method 1 - composite sampling with an auger (*Average measurements)*
In order to determine the average level of nutrients in a field, augering would be suitable, as it is easy to get many samples. In this way, samples from each field could be collected. Augering could be combined with composite sampling. When composite sampling, it is possible to represent the field as a total. This is a suitable method in order to determine the average nutrient level of a field but will not be able to include variations within the field. Furthermore, the augering and composite sampling will not be a sufficient method to determine the soil texture in relation to drainage capacity and risk of erosion, because of compaction of the soil when augering.

Method 2 - Soil profiles

The soil profiles will be excavated to a depth of 30 cm *(Variation in the field taken into account).* The soil samples will only be collected for the plough layer, as the fertility in this layer have the largest influence on crops.

The soil profiles will be used to determine the depth of the topsoil. Furthermore, we will determine the soil texture. The soil texture is used to estimate how well the soils are for agriculture in relation to resistance to erosion, the soil texture will also be estimated. Because of time constraints, the soil texture will be estimated in the field with help from 'Key to soil textural classes' from: FAO (2006): Guidelines for Soil Description. The soil texture will also be used to estimate the level of drainage in the soil.

All soil samples will be dried on paper in one or two days before putting the soil into bags. Soil analysis in the laboratory in Copenhagen. Soil samples will be analyzed in order to determine:

- Phosphor
- Potassium
- Nitrogen
- Soil organic matter

<u>Materials needed</u>

- A shovel
- 50 plastic bags
- 100 cm3 soil rings
- A flattener (a thing to make sure that the soil is only 100 cm3)
- Ibottons

GPS: We will use the GPS with two primary aims; mapping and area measurements. The GPS is fundamental to mapping our activities. This includes mapping our respondents and soil sampling sites, and mapping important points during walks. Mapping our respondents will be used to get an overview of the geographic placement of the different farm types. Furthermore, this enables us to plot the placement of our farm typologies against the cultural, social and resource mapping from the qualitative methods. Additionally, the GPS is very useful in terms of measuring the plot size of the farm households.

Ibuttons: Ibuttons are used for temperature measurements. This is useful to investigate the usefulness of two types of management methods possibly applied to adapt to CCWH. The two methods are mulching and agroforestry. The potential of mulching and agroforestry will be assessed through temperature measurements by the use of ibuttons. This will help to assess the effectiveness towards reducing temperature variations and the related evaporation of soil water.

B. Sampling Strategies

Sampling of focus group interview

The sampling will be done in prolongation of the informal interview with the village head. We will ask the village head for influential people and use the snowball-effect to gather approximately four more people for the focus group interview. We will ask him to find people who also possess a great all-round knowledge of the research area. The choice of the participants for this interview will thus be made by the village head and will reflect who he finds appropriate for doing the job.

Questionnaire sampling

The sampling strategy is very important when working with questionnaires and statistical data. The two fundamental issues are randomization and sample size. Both of these issues are influenced due to the limited time in the field. The major issue is to make a sample that is representative of the total study population. Ideally, we would have a stratified sample consisting of at least 120 respondents. However, this is impossible. In order to make a useful farm typology, we will need at least 20 respondents, though 30 is the goal, as the sample size needs to be at least the fivefold amount of key variables used in the typology and PCA (Alvarez et al., 2014).

In terms of randomizing the respondents, as mentioned, the optimal approach would be to use a stratified sample. However, in order to make stratified sampling, one need to know the share of the study population belonging to each of the stratifying criteria (Harden et al., 2004). We will not be able to obtain this information prior to our field work. Therefore, the second best option will be to perform simple random sampling. This only requires an overview of the sampling frame, i.e. a list of farm households in the village, most likely obtainable from the village head, with which we can do a lottery or another type of randomization method. However, since our sample size will be small this poses problems too. Performing a randomization trial to obtain a small sample size of only 20-30 respondents risks lacking variability, and thus, creating a sample not representative of the study population.

Therefore, in practice, we will need to apply a sampling technique from qualitative studies, namely purposeful sampling. There are several options within the scope of purposeful sampling but for our study maximum variation sampling is the best strategy. With maximum variation sampling we select respondents in order to represent the variability of the study population. For example, we will make sure to question farmers with few and many cattle, large and small shares of maize planted on land plots and vice versa. Thus, the maximum variation sampling supports us the best way possible in the field in order to increase the variation in the sample. By the end of our study, we will use triangulation of all our study methods to ensure that the results derived from the questionnaires are representative of the study population and, accordingly, that our sampling strategy was appropriate.

Soil sampling strategy

The farms we select for the soil sampling depends on the farm typology that we will adopt. Likewise is true for the amount of soil samples and whether we choose to sample with an auger or making soil profiles as our soil sampling methods described below.

In order to examine the level of nutrients on the soil, soil samples will be conducted from several field sites in Gatugi. The field sites selected for soil sampling should represent some varieties of the landscape. These varieties will be determined once we have an idea on the farm typology in the area. Variations could be farm size or farm characteristics such as slopes or layer of the topsoil. Other variations could be crop types.

In case of making soil profiles, it is important first of all to take the variation of the field into account. The excavation of the soil will be to a depth of 30 cm and only in the plough layer, because the fertility in this layer have the largest influence on crops. For each field, three replicates should be made in order to compare. The soil sampling sites should represent the variations within the field. The lack of time in the field though limits the amount of profiles to be made. It would be optimal to have 12 profiles excavated, three profiles on four fields each.

Sampling strategy for management methods

Management method: Mulching. Using preliminary data from the transect walk and our first observations of farms a line of mulch representative for the local practices will be decided. Three ibuttons will measure temperature and humidity along a time frame of seven days while three ibuttons in a row with no mulch treatment will serve as control. Alternatively, a farm plot with specific crops can be selected and rows with and without treatment compared. It should be taken into account that control rows in this case should feature crops to ensure mulching is the only unknown variable.

Management method: Agroforestry. Preliminary data from the transect walk and first observations will allow a site selection representative for local agroforestry practices. Representation will be based on the amount of plots observed growing the crop in question (for example coffee). Once the site is selected, three ibuttons will be placed at 0.5 m height within the agroforestry plot and at 0.5 m height in a control plot.

Sampling of Participatory Rural Appraisal

In order to enable exploration of different perceptions on the topics to be discussed, the participants in the PRA shall be from different groups. As point of departure, the characterization of the groups will be based on the farm typology. Hence, the participants will reflect different wealth “statuses”. Unless, during the fieldwork it will occur that the farm typology isn’t relevant in relation to climatic changes and weather hazards (CCWH). If that is the case, it will be neccesary to adjust the sampling strategy in order to choose other groups based on other differential criteria. For example, it might be that the variations of adaptation occur between young farmers, who have not experienced any weather crises/hazards, and elderly farmers who have.

Sampling of semi-structured interviews

The choice of respondents for the semi-structured interview will be based on the farm typology made from the analysis of the questionnaire as mentioned earlier. Each respondent will represent each kind of typology. Therefore the number of respondents will reflect the differences within the farm typology. We need at least one respondent from each farm typology though in an optimal setting we will have two or more respondents.

C. Data Matrix

Objective	Research question	Sub-question	Sub-sub question	Data required	Method(s)	Equipment
What is the local perception of climate changes and weather hazards (CCWH) and the actual impact on farm households' vulnerability and practices in Gatugi, Nyeri District, Kenya?	1. How are the farm households influences by CCWH?	a. What are the soil characteristics of the farms?		Soil texture Soil moisture	Soil sampling	Moisture stick Shovel "Plastic" hammer Plastic bags Permanent marker Measuring stick Soil rings (100 cm3) GPS
		b. How does CCWH affect crops and livestock farming?		Scientific papers on general effects of hazards. The actual effects in the area	DR Q SSI	Dictaphone Paper Pen
		c. Do farmers perceive El Niño as a natural variability in the climate or as a part of a long-term climatic change? And how aware are they of the implications of long term climate change to their local area?			Q SSI PRA (Seasonal calendar + Historical line)	Dictaphone A2/A3 paper Pen + colour pens Map - blank and satellite photo
		d. Is the meteorological data and agricultural extension records (e.g. KALRO) consistent with the perception of the farmers?		Meteorological data	DR	Computer. Internet access
	2. What is the adaptive capacity of farmers in relation to the CCWH?	a. How does the access to knowledge play into the adaptive capacity of the farmer?	i. Do farmers have access to meteorological data? How does the knowledge of weather forecast transfer onto the farmers' level?		SSI Q	Dictaphone Paper Pen
			ii. What is the role of access to weather forecasts?		SSI Q	Dictaphone Paper

						Pen
			iii. How do other kinds of knowledge influence the adaptive capacity of the farmers? And how does the knowledge transfer between and within groups?		SSI Q	Dictaphone Paper Pen
			iv. Has the farmer had access to "best management practices"? If yes, what is the role of this?		SSI Q	Dictaphone Paper Pen
		b. How does financial means play into the adaptive capacity of the farmer?			DR Q If time permits; Expert interviews (e.g. banks, SACCO, seed & fertilizer company	Computer Paper Pen Dictaphone
		c. How does the social networks play into the adaptive capacity of the farmer?			Q SSI PRA (Venn diagram) PO (Follow a farmer for a day. Who do they interact with?)	Paper Pen Dictaphone
		d. How does agricultural practices play into the adaptive capacity of the farmer?		Soil fertility	Draw system Soil sampling	Paper (A3) Pen Moisture stick Shovel "Plastic" hammer

						Plastic bags Permanent marker Measuring stick Soil rings (100 cm3) GPS
	3. Which, if any, adaptation strategies do farmers adopt according to their vulnerability?	a. Are they adapting to more frequent hazards and, if so, which ones and how?		Natural: Application of fertilizer and (types of) seeds soil fertility	Observation SSI	Dictaphone Paper pen GPS
				Economic: Access to credit Off-farm income possibilities Farm inputs	Q SSI	Dictaphone Paper Pen
				Social/cultural: Social networks	Q and SSI	DIctaphone Paper pen
		b. Are the adapting to climate change and, if so, which ones and how?		Natural: Soil fertility Site characteristics	Soil samples Nutrients Humidity Texture in the field	Moisture stick Shovel “Plastic” hammer Plastic bags Permanent marker Measuring stick Soil rings (100 cm3) GPS
				Economic: Access to credit Off-farm income possibilities Farm inputs	SSI Q	Paper Pen Dictaphone
				Social: Access to knowledge and information through different social networks. Do they have agency?	Q (natural, social, economic factors) SSI	Paper Pen Dictaphone

		c. How, if at all, are farmers limited in their range of adaptation strategies?			PRA (Problem Ranking) SSI	Paper (A2) Pen Dictaphone

Abbreviations: FGI = Focus Group Interview; Q = questionnaire; SSI = Semi-Structured Interview; PO = Participatory Observation; DR = Desktop Research

D. Time schedule

Week	9										10														11			
Day	2		3		4		5		6		7		8		9		10		11		12		13		14		15	
Time of day	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A

Field Work	Persons allocated (tentatively)
Arrival Kenya	ALL
Langata with Kenyan counterpart	ALL
Arrival Othaya	ALL
Preliminary survey	ALL
Informal interview Village Head (identifying FGI participants - snowball effect)	2 pers. (+ interpreter)
Transect walk + GPS + informal interview	2 pers.
FGI (farm typology) Social and resource mappir	3 pers. + interpreter
Preparation of questionnaire and interpreter	2 pers. + interpreter
Test questionnaire with farmer	2 pers. + interpreter
Preparation of questionnaire and interpreter	2 pres. + interpreter
Questionnaire survey (15 respondents)	2 pers. + interpreter
Questionnaire survey (15 respondents)	2 pers. + interpreter
Do short data analysis and revise interview guide	ALL
Church	ALL
Participatory observation	1-7 pers.
Soil quality assesment	ALL
Identifying soil sample sites	2 pers.
Visual assessment of soil erosion + farm walk	1 pers. + GPS
Soil samples 1st day	3 pers. + field guide
Soil samples 2nd day	3 pers. + field guide
Mid-way evaluation of research progress	ALL
PRA	3 pers. + interpreter
Prepare PRA and contact participants	ALL + interpreter
Conduct PRA	ALL + interpreter
Buffer PRA	3 pers. + interpreter
SSI with farmers (3 a day) Cultural mapping	2 pers. + interpreter
Expert interviews?	2. pers. + interpreter
Trip with the Kenya team	ALL
Buffer for unfinished work	ALL
Feedback meeting	ALL
Preparation of feedback meeting	Rest of the group
Summary and catch up on unfinished work	ALL
Farewell	ALL

Abbreviations:

SSI = Semi-Structured Interview; PRA = Participatory Rural Appraisal

Colour code:

(dark grey)	Overview
(light beige)	Preparation of activities
(yellow)	Activities (one interpreter)
(orange)	Activities (two interpreters)
(light green)	Optional
(bright green)	Buffer

Considerations for planning:

Make soil samples the day before the common excursion so soil samples can dry during that day.

Might be difficult to get interviews on Sundays - useful to do soil samples that day

It might be efficient to make soil samplings at times where we need the interpreter for others purposes. The field guide will assist the soil samplings.

E. Questionnaire

MAIN QUESTIONNAIRE

SURVEY OF FARM HOUSEHOLDS IN GATUGI, NYERI DISTRICT, KENYA

MARCH 2016

Interviewer

Supervisor

Date of the interview

Day	Month	Year

Date of the interview

GPS waypoint	Time begun	Time finished

Identifiers

1. Name of respondent_________________________________
2. Gender___
   Code: Male (1), Female (2)
3. Age/Year of birth_________
4. Ethnicity________
   Code: Kikuyu (1), Luo (2), Luhya (3), Kamba (4), Kalenjin (5), Masaai (6), Other (7)
5. Marital status_____
   Code: Single (1), married (2), divorced/widowed (3)
6. Main occupation_________
7. Number in household of adults (above 15) ___ Children___
   a. Female adult ___ Female children ___
8. How many in the household live outside the village of adults___ children___
9. Highest level of education completed: ____
   Code: No education (1), Not finished primary (2), Finished primary (3), Finished lower secondary (4), Finished upper secondary (5)

Household characteristics

10. How many of the following do you own in your household:

Radio	Television	Landline phone	Mobile phone	Computer	Internet

11. Which of the following agricultural tools do you own:

Plough	Seeder	Trailer	Tractor	Water pump	Irrigation system

12. Which of the following means of transportation do you own:

Bicycle	Motorcycle	Car	

Farm characteristics

13. What is the total size of your land area?

14. What is the size of the farm land (acres or hectares)___

15. Main crop produced _________

16. How big a proportion of your total crop use is/On how big of a land do you have?

Crop:	Coffee	Tea	Maize	Beans	Peas	Potatoes	Vegetables	Fodder crops	Cattle	Sheep	Grazing	
Amount /size:												

Measure amount in

17. What amount do you have of the following livestock:

Animal:	Cattle	Sheep	Goats	Poultry	Pigs				
Amount:									

18. How much family labour is used on farm activities___
Measured in man-day/year

19. How much hired labour is used on farm activities___
Measured in man-day/year

Farm practices

20. Have you changed your main crop within the last year ____
Code: Yes (1), No (2)

21. What crop was it previously_________

22. Have you changed your planting date within the last year (due to weather)___
Code: Yes (1), No (2)

23. Have you changed your harvesting date within the last year (due to weather)___

24. Have you changed your use of seed varieties within the last year (due to weather)___
Code: Yes (1), No (2)

   a. If yes, was it a change to better seeds___
   Code: Yes (1), No (2)

   b. If no, was it due to

Lack of money	Lack of knowledge	Lack of supply	Lack of	Others

Note: Mark all relevant with X.

25. Have you changed your use of fertilizers within the last year (due to weather)___
Code: Yes (1), No (2)

   a. If yes, was it an___
   Code: Increase (1), decrease (2)

   b. If no, was it due to

Lack of money	Lack of knowledge	Lack of supply	Lack of	Others

26. Have you changed your use of manure within the last year (due to weather)___
Code: Yes (1), No (2)

   a. If yes, was it an___
   Code: Increase (1), decrease (2)

   b. If no, was it due to

Lack of money	Lack of knowledge	Lack of supply	Lack of	Others

Note: Mark all relevant with X.

27. Have you changed your main crop within the last 10 years ____
Code: Yes (1), No (2)

28. What crop was it previously ________
Code: Yes (1), No (2)

29. Have you changed your planting date within the last 10 years (due to weather)___
Code: Yes (1), No (2)

30. Have you changed your harvesting date within the last 10 years (due to weather)___
Code: Yes (1), No (2)

31. Have you changed your use of seed varieties within the last 10 years (due to weather)___
Code: Yes (1), No (2)

a. If yes, was it a change to better seeds___
Code: Yes (1), No (2)

b. If no, was it due to

Lack of money	Lack of knowledge	Lack of supply	Lack of	Others

Note: Mark all relevant with X.

32. Have you changed your use of fertilizers within the last 10 years (due to weather)___
Code: Yes (1), No (2)

a. If yes, was it an___
Code: Increase (1), decrease (2)

b. If no, was it due to

Lack of money	Lack of knowledge	Lack of supply	Lack of	Others

33. Have you changed your use of manure within the last 10 years (due to weather)___
Code: Yes (1), No (2)

a. If yes, was it an___
Code: Increase (1), decrease (2)

b. If no, was it due to

Lack of money	Lack of knowledge	Lack of supply	Lack of	Others

Note: Mark all relevant with X.

<u>Finances</u>

34. Is the land use for the main crop of the household owned or rented?

35. What is the type of ownership of your land:

Owned by you	Leased	Shared ownership		

Note: Shared ownership with someone not living in the household.

36. Have you done one of the following things with your land within the last year?

Sold land	Bought land	Leased land	Rented out land	Inherited land	Sub-divided your land

37. Do you have the title/rights of your land____
Code: Title of land (1), registration of land (2), none (3)

38. Do you do any value addition for your farm produce____

a. If yes, what

39. Is the farm your main source of income for your household__
Code: Yes (1), No (2)

40. Do you have any off-farm income___
Code: Yes (1), No (2)

41. If yes, how many different sources of income___

42. How many people living in your household contributes to the income of the household____

43. What do you estimate is the total income of your <u>household</u> in 2015_______

a. How much of this is income from your own farm______
b. How much of this is income from kibarua______
c. How much of this is income from off-farm work outside the community______
d. How much of this is income from remittances______

44. How many income generating jobs do you have next to your own farm work____

45. Has your household applied for bank loans or other formal credit within the last year___
Code: Yes (1), No (2)

If No, then skip to question 48.
If Yes, then answer questions 44-47.

46. Did your household experience any problems getting the loan?
Code: Yes (1), No (2)
a. If yes, why___
Code: Lack of collateral (1), Lack of money holdings (2), Others (3)

47. Which bank/formal credit institution do you primarily use
Code: State Owned Commercial Bank (SOCB) (1), State Owner Agricultural Bank (2), Private bank (3), Foreign bank (4), Co-operatives bank (5), DAF (Development assistance fund) (6), Targeted programs (7), Other (8)

48. Do you still think you are in need of a loan___
Code: Yes (1), No (2)

a. If yes, why___
Code: To pay debt (1), to compensate for loss in yields (2), to invest in farm (3), other (4)

b. If no, why___
Code: Have enough own funds (1), don't want/need to invest (2), other (3)

49. Why have you not applied for a formal loan___
Code: Inadequate collateral (1), Don't want to incur debt (2), Process too difficult (3), Didn't need one (4), Interest rate too high (5), Already heavily indebted (6), Other (7).

50. Have you borrowed from informal sources within the last year___
Code: Yes (1), No (2)

If No, then skip to 49.

a) If yes, why___
Code: Couldn't get formal credit (1), Most favourable interest (2), Easier formalities (3), No collateral required (4), Flexible payback (5), Other (6)

51. Which source of loan do you consider most important for your household___
Code: Formal (1), Informal (2)

52. Have you experienced any difficulties in obtaining credit from informal sources within the last year___
Code: Yes (1), No (2)

Weather perceptions

53. Have you experienced changes in temperature over the last 10 years____
Code: Increase (1), Decrease (2), No change(3), Don't know (4)

54. Have you experienced changes in precipitation over the last 10 years____
Code: Increase (1), Decrease (2), No change(3), Don't know (4)

55. Have you experienced changes in rainfall variability over the last 10 years____
Code: Starts early and ends early (1), Starts lately and ends lately (2), Starts lately and ends early (3), Starts early and ends lately (4), No change (5), Don't know (6)

56. Which of the following years have you experienced drought

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015

Note: Mark all relevant with X

57. Which of the following years have you experienced flood

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015

dd

Note: Mark all relevant with X

58. Have you experienced significant challenges to your crops, e.g. crop failure, damaged, reduced yield, within the last 10 years due to

Erratic precipitation	Heavy and unexpected rain	Droughts	Pest and diseases	Crop damage by wildlife

Note: Mark all relevant with X

Social networks and relations

59.

60.

61.

Access to knowledge

62. Have you received information on agricultural practices from the following within the last year:

Other local farmers	Local officials	NGO	Extension agent	Media	

Note: Mark all relevant with X.

63. Have you received information on weather forecasts from the following within the last year:

Other local farmers	Local official	NGO	Extension agent	Media	

Note: Mark all relevant with X.

Final questions

Thank you very much for your time and cooperation.

64. Are we allowed to come and ask you more questions at a later stage ___
Code: Yes (1), No (2)

65. Are we allowed to come and make some soil samples on your farm ___
Code: Yes (1), No (2)

Again, thank you for your time. Please feel free to ask if you have any questions.

F. PRA guide

Participatory Rural Appraisal (PRA)

<u>Starting point:</u>

Procedure:

- **Historical timeline**
  - First we will like to start by exploring what events of significance the respondents have experienced. The facilitator will start out by asking: Let's start out by drawing a time frame, where we together add events you find significant that you either know of or have experienced yourself from back in time until now.
  - The respondents are drawing by turn on a piece of paper.
- **Question in plenum:** How do these events play a role today?

<u>Exercise one: Seasonal diagram and historical line</u>

Agenda:
Explore perceptions of time and annual variations related to sub-question: Do farmers perceive El Niño as a hazard or part of a long-term climate change?

Procedure:

- **Seasonal Diagram (Mikkelsen, 2005:92).**
  - In plenum the facilitators will ask the respondents to draw a seasonal diagram by first of all asking:
    - How will you describe different seasons?
    - When will they occur? Can you draw it?
  - The facilitators will ask the respondents to add symbols and signs indicating the characteristic of the seasons.
  - Afterwards the facilitator will ask the respondents to point on the drawing to state where on the "seasonal diagram" we are at the moment.

<u>Exercise two: Venn diagram</u>

Agenda: Explore social networks in relation to sub-questions: How do the social networks play into the adaptive capacity of the farmer?

Procedure:

- **Question in plenum:**

    - In relation to your farming operations, what different kinds of groups of people are important?
    - What characterizes them?

- **Venn diagram:** The facilitators ask the respondents to draw the different groups mentioned in circles of different sizes that reflects how much influence they each have. Afterwards the respondents have to place the circles in relation to each other in order of how the different groups influence each other.
    - The facilitators ask into why one group does or doesn't overlap one or another.

<u>Exercise three: Problem Ranking (Mikkelsen, 2005:99)</u>

Agenda:
Explore subquestion: How, if at all, are farmers limited in their range of adaptation strategies?

Procedure:
Based on exercise number one the facilitators will use the phrase climate change and/or weather hazards.

1) Identify limiting factors in relation to the respondent farming operating.

- **Question in plenum:**
    - Which factors have an influence on your farming operation?
    - Facilitators write mentioned concepts down.

- **Ranking:**
    - When we have different limiting factors in hand we will ask the respondents to put them in nominal order in relation to what constraints have the most influence and vice versa.
    - During the exercise the facilitators will observe the discussions between the respondents and ask why they have ranked one limiting factor higher than others.
    - The facilitators will have focus on the mentioned constraints relating to climatic changes and weather hazards (CCWH).

2) Elaborate possible strategies to minimize mentioned constraints due to climate change and weather hazards (CCWH).

- **Question in plenum:**
    - How can the "high ranked limiting factor" be minimized in the future?
    - If the respondents have not mentioned anything about climate changes and specific weather hazards then the facilitators will ask: What about climate changes? What about weather hazards?

G. Interview guide

Note: Remember to give an introduction to our study and the reason for this interviews (They can be anonymous - no question is right or wrong - remember to ask for permission to take notes and to record the interview).
Note: Make the respondent to use examples and descriptions. Remember probing techniques.

<table>
<tr><th>Themes</th><th colspan="2">Research questions</th><th>Questions to ask</th></tr>
<tr><td rowspan="4">Vulnerability

- Indicators of influence</td><td colspan="2" rowspan="4">How are the farm households influenced by CCWH? (The households livestock, soil, crops - others?)

(If they mention CCWH - ask into that)</td><td>What is the current situations of your different crops?</td></tr>
<tr><td>How is the situation compared to (last year)?</td></tr>
<tr><td>What do you think has influence on your crops?</td></tr>
<tr><td>How does soil play into all of “this”?</td></tr>
<tr><td rowspan="5">Perception
- short- or long-term</td><td colspan="2" rowspan="5">Do farmers perceive climatic hazards such as El Niño as a natural variability in the climate or as a part of a long-term climatic change? And how aware are they of the implications of long term climate change to their local area?</td><td>Have you during your time as a farmer experience changes in the weather conditions?</td></tr>
<tr><td>(What is climate change - how, if, do you experience climate change?)</td></tr>
<tr><td>What is El Nino?</td></tr>
<tr><td>Have you experienced El Nino - what happened?</td></tr>
<tr><td>Why do you think El Nino is here in Othaya?</td></tr>
<tr><td rowspan="2">Adaptive capacity

- access
- network
- financial means
- technology</td><td rowspan="2">How does the access to knowledge play into the adaptive capacity of the farmer?</td><td>What is the role of access to weather forecasts?</td><td>Where have you learned about your farming operations? (If they do not mention the weather forecasts, ask).</td></tr>
<tr><td>Do farmers have access to meteorological data? How does the knowledge of weather forecasts transfer onto the farmers level?</td><td>From whom or how do you learn about farming operations now if you do?</td></tr>
</table>

		How do other kinds of knowledge influence the adaptive capacity of the farmers? And how does he knowledge transfer between and within groups?	What should be the reason to change your farming practice?
Adaptation strategies	Ask about specific adaptations strategies that we have explored from other farmers through the Q and PO. Possible adaptation strategies to discover: Diversification (worked outside their farm) Labour division (e.g. sent someone to the city to work)		Has it been necessary to change your farming practice during your time as a farmer?
			If yes (or no) ⇒ why has it been necessary (or not)?
			Answer ⇒ what have you changed?
			What enabled you to do that?
Probing question			Some might say that you as a farmer is vulnerable to climate change due to El Niño - what do you think about that?
			We have made some soil sampling (depth of topsoil, soil texture) in different farms which implies ____ and ____ - what do you think about that?
Indicators related to farm typology	Ask about personal information if needed?		