Forside

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Climate Change and Smallholder Adaptation in Thuti, Kenya.

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Clara Grivel Mads Bak Sørensen Maria Pamies Vallvé Carl Stadie

ABSTRACT

Climate Change has significant impacts on the agricultural systems and livelihoods in Sub Saharan Africa, and thus, Kenya. This report focuses on Thuti, a village located in the Central Highlands of Kenya and seeks to describe the effects of climate change on the region and the farmer's adaptation to them. Thus, an interdisciplinary approach combining interviews, surveys, soil and Seasonality-Analysis as well as a land-cover-change detection has been utilized. The main focus lay on the farmers' adaptation through the changes in crops and agricultural practices as well as on the main barriers and opportunities they are facing. Results indicate increased drought in combination with delayed, but longer and more irregular growing seasons, which lead to a decrease in agricultural land, and in turn, a decrease in agricultural production. Adaptation occurred mainly through change in agricultural practices, most of them water related. Significant changes were seen in the adaptation of lime, water capture ponds, mulching and tilling. No adaptation through implementation of new crops was observed, however, an increase on the implementation of modified seeds has been detected. Lack of knowledge, finances and government support were identified as the main barriers. Provision of education through extension programs and financial aid, plus improved collaboration and communication between farmers and institutions was determined as the primary opportunities to help farmers to better adapt to the changes and challenges they are faced with.

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1 INTRODUCTION

Climate Change has significant impacts on the earth's ecosystems as well as on the social structures within them (IPCC, 2022). As such, climate change has also affected agricultural systems, making them less productive (Wiebe et al., 2019). One region particularly affected by this trend is Sub Saharan Africa, which Kenya is a part of (Serdeczny et al., 2017).

Agricultural products make up a considerable part of the Kenyan economy, with tea and coffee contributing the most to the country's GDP (Karuri, 2021). Climate change, however, has had a considerable impact on the country's agricultural sector. Changing rain patterns and growing seasons are posing a threat to Kenyan agricultural production, as the unfavourable conditions lead to lower crop yield (Kogo et al., 2021). Rain events tend to be heavier and less predictable (Nathan et al., 2020), and the growing season is getting longer, resulting in a higher production of unprofitable biomass (Kogo et al., 2021).

In this context, the Central Highlands and in particular the sub county of Othaya as the agricultural heartland of Kenya (Government of Kenya, 2016) have long been subject to research focusing on the effects climate change has on the agricultural sector. These studies are reaching from the perception and adaptation of farmers to climate change towards the impact climate change has on the ecosystem. Many studies states that climate change is perceived by farmers mainly through declining precipitation, which is congruent with meteorological observations (Arunrat et al., 2017; Ayanlade et al., 2017; Mkonda et al., 2018) and, in combination with increasing temperatures, leads to an increased risk of drought and a loss in soil quality (Tesfahunegn et al., 2016; Ochieng et al., 2016; Kogo et al., 2020). Ayal and Leal Filho (2017) and Mubiru et al. (2018) could further show that this leads to a later start of growing seasons as well as a generally shorter growing season. The degree of change however, is highly unpredictable. On average, the growing season tends to be longer and start later (Kogo et al., 2021) with an estimated increase of length by 20-30 days by 2040, due to changing rain patterns (Cook and Vizy, 2012). These changes lead to changes in land cover, showing a decline of forest cover coupled to an increase in cropland (Mwangi et al., 2020). However, these croplands tend to be less productive, providing lower yields (Whitmarsh and Capstick, 2018) as well as total crop failure leading to fields remaining idle (Rojas-Downing et al., 2017).

The study of Mairura et al. (2021) finds that the perception of and adaptation to these changes is mostly dependent on socioeconomic factors. Farmers adapted by changing practices like increasing the use of fertilizer and manure and terraces (Whitmarsh and Capstick, 2018). Further adaptation includes the use of climate smart agriculture like soil water conservation,

agroforestry and crop diversification (Musafiri et al., 2022). This includes also the introduction of new crops, or varieties of existing crops, which are more drought resistant (Kogo et al., 2021). The area furthermore saw the introduction of irrigation systems (Musafiri et al., 2022). For further expansion, dam based or small-scale systems could be useful (Xie et al., 2014). Management and regulation as well as the provision of irrigation designs is conducted by the regional governments (FAO, 2019). Irrigation projects are further supported through the National Irrigation Authority (NIA, 2023). In addition to the adoption of irrigation, came a heavy reliance on outside aid (Quandt, 2021). All these changes were implemented with the aim of mitigating the largest challenge for agricultural production, which is the increased water scarcity (Shin et al., 2015). Apart from these farm-level strategies, several national adaptation schemes exist. Their main goal is the promotion of rainwater harvesting and drought tolerant crops, as well as including the communication of agricultural knowledge into extension programs (Government of Kenya, 2016).

There are, however, significant barriers preventing farmers from successfully adapting to the challenges of a changing climate, which are mostly related to the access of education and financial aid (Mairura et al., 2021). Many ways of adaptation are further hampered by biophysical constraints (Shackleton et al., 2015). Apart from these, adaptation can also be challenged by administrative structures, like inefficient extension systems, often in combination with bad communication, but also the sheer lack of opportunities for adaptation (Odwori, 2022; Asokan et al., 2020). Opportunities to tackle these challenges are mostly based around mitigating practices, such as mixed- and intercropping, planting early-maturing crop varieties and early planting (Stefanovic et al., 2019). Furthermore, re/afforestation is also well suited to mitigate some effects of climate change, as a carbon capture mechanism in the long, and by spending shade and hampering evaporation in the short term (Omambia et al., 2009). However, the main challenges, lack of knowledge and financial aid, can be tackled through the provision of agricultural extension as well as loans with low interest rates (Mairura et al., 2021). Lastly, a democratization of the administration is identified as beneficial, as it prevents corruption and ensures the success of adaptation programs (Odwori, 2022).

Most studies presented above analyse the effects of climate change, the adaptation strategies as well as barriers and opportunities separately and are missing an interdisciplinary approach. To add to this research gap, many studies, which have investigated land use (Mwangi et al., 2020) and change in seasonality (Cook and Vizy, 2012) in the region lack the necessary spatial detail and detail in land cover classes to make a meaningful contribution to the effects climate change had on smallholder agricultural practices. Therefore, this report seeks to provide a combined

approach, analysing the effects of climate change on the region, the farmer's adaptation strategies and the reasons for their implementation and identifying opportunities to resolve them. Furthermore, the study uses the Sustainable-Livelihood-Framework to analyse the collected data (Ellis, 2000; Paksi and Pyhala, 2018). This way, it is believed to give a more in-depth impression of how climate change has influenced smallholder farmers for the case of Thuti compared to the studies mentioned above.
The following research question, as well as sub questions and methods are proposed:

How have farmers in Thuti adapted their agricultural practices to climate change, and which barriers and opportunities can be identified for their adaptivity?

- *What effects of climate change can be identified in the study area?*
- *How have farmers adapted to climate change?*
- *Which barriers and opportunities are farmers faced with, in relation to their adaptation to climate change?*

The study covers the period from 2016-2023 as methods applied are delimited to a time frame not longer than 10 years as the data relies on the involved actor's memory, as well as the imager's spatial resolution available for the land-Cover-Classification.
In the following chapters, the study area, its background, as well as the Sustainable-Livelihood-Framework will be introduced, followed by the methods used. The produced results will be presented and discussed in the context of the available literature, before reaching a final conclusion where some recommendations will be proposed.

2 BACKGROUND AND FRAMEWORK

2.1 Study Site

The research took place around the Karima Ward of the small village of Thuti, in the Othaya sub-county of the Nyeri county in Kenya (fig. 1). The Nyeri county holds an aging population, estimated to be of around 760 000 people in 2019 (Kenya National Bureau of Statistics, 2023). The area is located in the tropical highlands, at around 1800 m.a.s.l. The average annual rainfall is usually relatively high, with around 1500 mm per year, and is bimodal. The soils in this region are seen as very productive, and are mainly Humic Nitisols (climate-data.org, 2023; FAO, 1997; Driessen, 2001). Two main agro-ecological zones are present in the Othaya region: the tea-dairy zone and the coffee zone (Mackenzie, 1989); this research will mainly take place in the former.

The population's key livelihood strategies revolve around agriculture. The main cash crops for export are coffee and tea, and common subsistence crops that can also serve as cash crops are cabbage, maize, bananas, beans, potatoes (sweet and Irish) and vegetables (Pinard et al., 2014; FAO, 2019). Households also rely on owning dairy cows to provide milk for the household, as a source of additional income as well as a source of organic fertilizers for the farmers (Tengnäs, 1994).

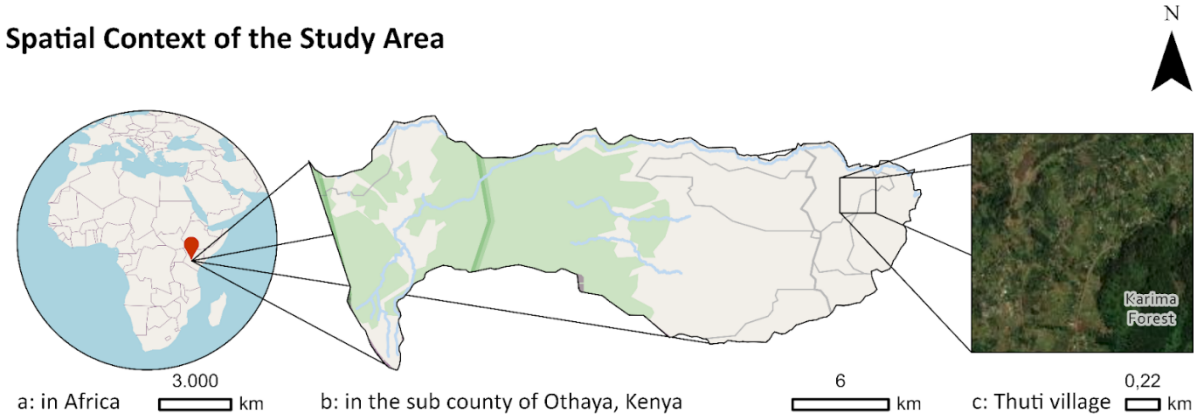

Figure 1: Study area (OpenStreetMap contributors, 2017)

2.2 Historical and Current Trends in Agriculture

The agricultural landscape found in Nyeri county today was shaped by colonial history. In the 1890s, a series of catastrophes hit the communities provoking considerable depopulation.

During that time, British colonizers discovered the Nyeri region to be very profitable due to the high soil fertility, and easy to conquer, because of the low population. The local population was forced to relocate into “native reserves”, where they got heavily involved in producing cash crops for distant markets (Bates, 2005; Tignor, 2015). The post-colonial era was marked with major agricultural upheavals and the sector was liberalized, meaning that people had the freedom to decide what they wanted to grow. However, some instructions from the extension officers remained, and the president Kenyatta called on people to buy land. The 1990’s marked the worst interval in the agricultural transformation of the district as most farmers were suffering from political interferences that were leading to the farmer’s collapse (Owuor et al., 2010). The period starting in the 2000s is marked with a relief to most farmers, mostly due to the creation of some farmer’s support structures such as the Agricultural Finance Corporation and Kenya Farmers association, and the emergence of credit institutions (Owour et al., 2010).

2. 3 Legislative Context

Climate Change and its effects on agriculture have long been in the focus of Kenyan lawmakers. The Climate Change Act from 2016 places duties on the national and county governments to mainstream climate change responses into decision-making (National Council for Law Reporting, 2016). Furthermore, acts were passed to create funds to finance climate change programmes and climate smart agricultural practices (National Council for Law Reporting, 2019a). To regulate land use planning in the agricultural context, the Physical and Land Use Planning Act was passed in 2019. It establishes principles and guidelines whereby entities involved in land use should promote sustainable land use practices in the face of climate change (National Council for Law Reporting, 2019b)

2.4 Sustainable-Livelihoods-Framework

The Sustainable-Livelihood-Framework used in this report is designed by (Paksi and Pyhala, 2018) and inspired by the thoughts of (Ellis, 2000). It illustrates how elements in relation to livelihoods are interconnected and influence each other in different ways (fig. 2). As the Capital Assets are very central in this project, the particular capitals characteristics are defined below:

- The Natural Capital covers environmental resources such as water, plants and soil quality.

- The Physical Capital looks into the infrastructural assets such as irrigation or water-capture-ponds.
- The Financial Capital is referring to the monetary properties of a household, for instance credits and loans.
- The Human Capital refers to the labour that is available to households including its health, education and skills.
- The Social Capital attempts to capture community and social relations made up of networks both of voluntary and ascriptive relationships (Ellis, 2000).

The framework focuses on several factors and therefore can be used for multiple purposes and with different scopes, depending on the objectives of a given study.

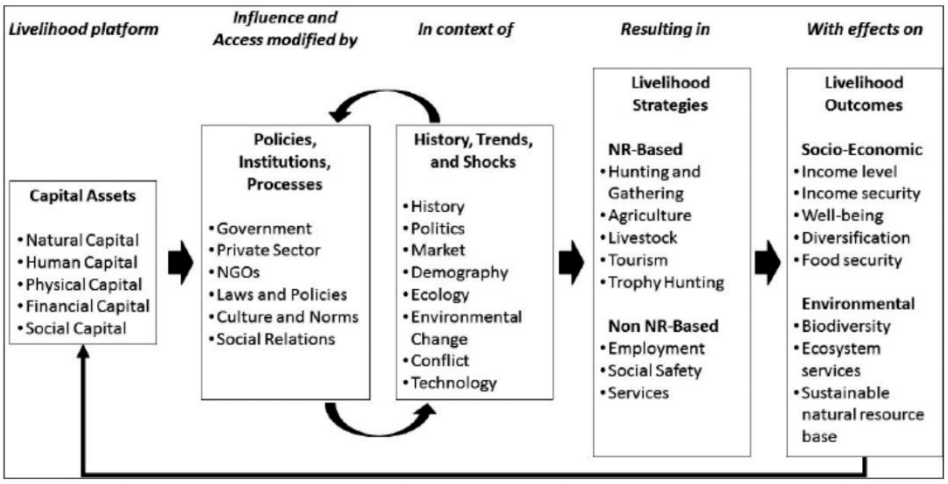

Figure 2: Sustainable Livelihood Framework (Paksi and Pyhala, 2018).

The main focus of this report is on how farmers are affected by, and adapt to, the effects of climate change, and in particular, drought. As a result of this focus, the study approach, the methodological choices, and the collected data, some particular elements in the framework are central which is illustrated in figure 3.

First, it is sought to get a deeper understanding of the current situation in the study area. To do this, section 4.1 (survey characteristics) and 4.2 (climate change), are used to investigate the *Demography* and the *Environmental Changes* in the study area.

In Section 4.3, the practices and changes of *Agricultural Strategies* over time are analysed. Moreover, the section seeks to get a deeper understanding on what barriers and opportunities the farmers are facing. In this examination, the study's data suggests that many of the barriers and opportunities are dependent not only on the "capital assets" that farmers possess or lack,

but also to the "policies, institutions, and processes", namely: *government, laws and policies,* and *social relations*. Moreover, the section circles around traditional *Technology* such as irrigation and water capture ponds, as well as new trends relating to these. The barriers and opportunities are structured around and directly linked to the changes in agricultural practices identified in the field.

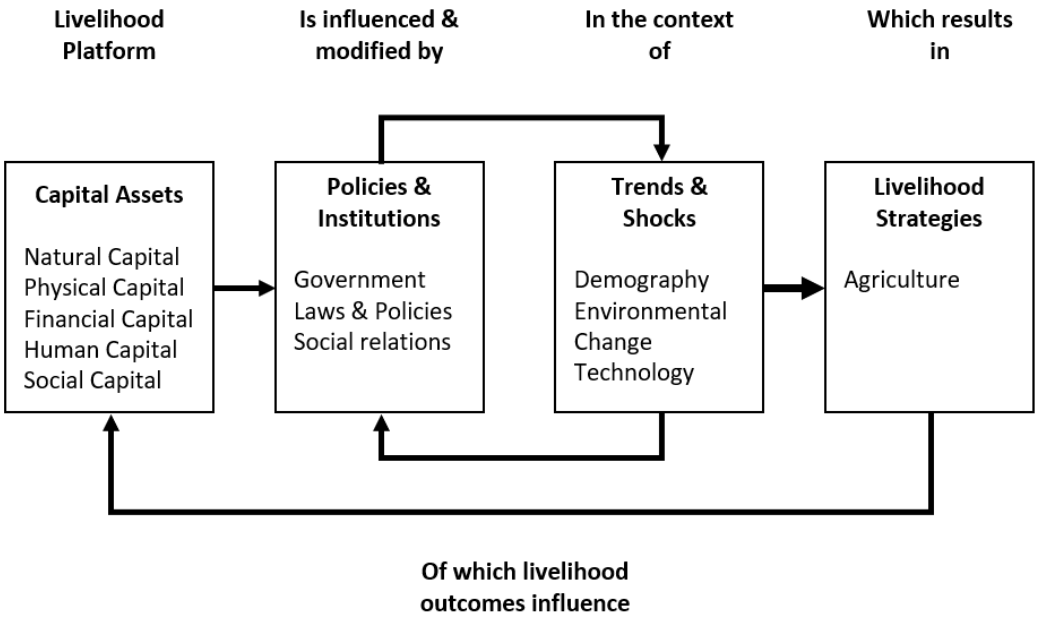

Figure 3: The Framework applied to our study (own creation).

3. METHODS

3.1 Surveys

To obtain a representative overview of the practices and experiences of the population of interest, farmer household surveys were carried out, with each household head (fig. 4). The survey consisted mostly of closed-ended questions, which would facilitate the analysis, and avoided questions that could cloud the analysis, such as double-barrelled, vague, or leading questions (Rea and Parker, 2014). The survey blended factual and perceptual questions, focusing on what farmers did, owned and thought (Appendix M1). A simple systematic sampling method was followed (Bickman and Rog, 2009) where every 3rd house was selected, along the pre-selected roads. The survey was tested with randomly selected farmers and all group members present. For the real survey, subgroups were formed, to reach as many respondents as possible; although this could influence the results, as every person conducting a survey will do it differently. In the event that the selected household was unable to participate, the "2nd" household was selected, or the "4th" in the event that the "2nd" couldn't participate. This was rarely the case, but proved successful. This sampling strategy was adopted as it selects more equally within the population. The survey was conducted on SurveyXact, and statistical analyses were carried out in Microsoft Excel.

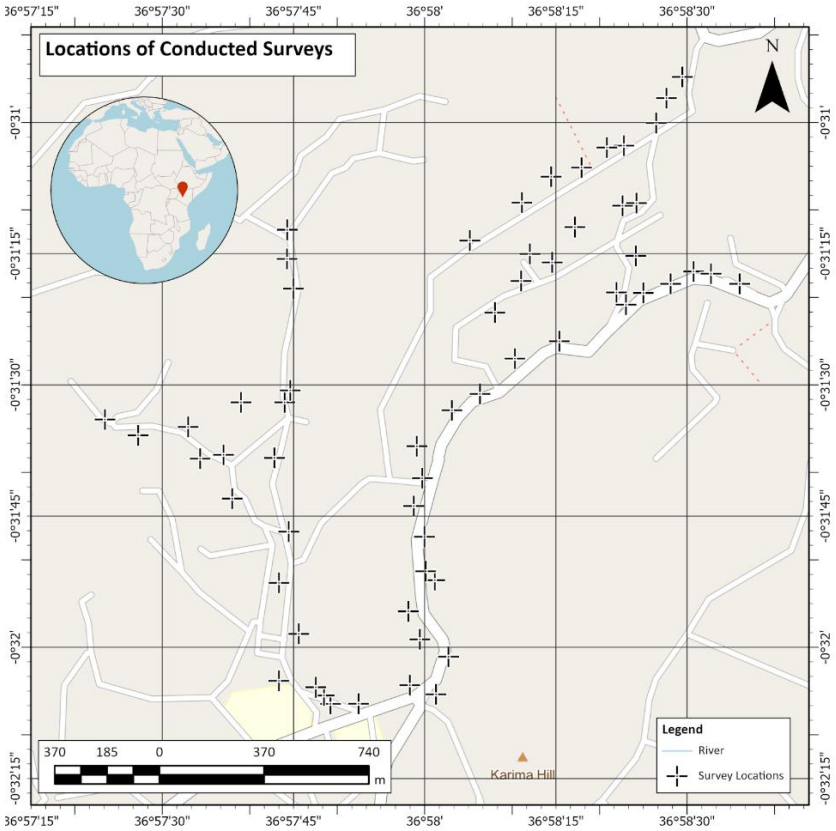

Figure 4: Locations of the surveys, in the Thuti village (OpenStreetMap contributors, 2017)

3.2 Interviews

To complement the surveys, seven semi-structured interviews were undertaken. Among the interviewees, three were considered as key informants; namely an Agricultural Officer (AO), the Karima Ward Member of Communal Assembly (MCA), and a soil expert. They were asked questions concerning the community's agricultural practices and context. The remaining four interviews were conducted with farmers, targeting the trends identified in the survey. This approach was advantageous in providing a better understanding of the patterns and underlying drivers (Bickman and Rog, 2009). However, it should be kept in mind that the limited number of farmer interviews conducted limits the generalization of the results.

Important or unexpected aspects which were not previously considered were touched upon, due to the exploratory nature of these interviews. A purposeful sampling method was employed to ensure an accurate representation of the context, taking into consideration the data from the survey on the socio-economic status and agricultural practices of the farmers (Scheyvens, 2013; Table 1). The interview guides (appendix M2) were customized to each interviewee, and included context-specific questions and elements from the previously conducted key informant interviews, to capture their stance on the statements. The guides also included questions to facilitate comparisons between interviews (Bickman and Rog, 2009). The interviews were transcribed (Appendix M3) and a coded analysis was carried out to answer our questions.

Table 1: Interviewee characteristics

Interviewee	Notes	Date
Farmer 100002 (report ID: Farmer 1)	Surveyed. Without irrigation. Without water capture pond. Lower socio-economic status (land size, education level, agricultural practices).	March 6th
Farmer 100008 (report ID: Farmer 2)	Surveyed. With irrigation. With water capture pond. Middle socio-economic status (land size, education level, agricultural practices).	March 11th
Farmer 2000017 (report ID: Farmer 3)	Surveyed. With irrigation. With water capture pond. High socio-economic status (land size, education level, agricultural practices).	March 10th
Farmer 400001 (report ID: Farmer 4)	Not surveyed. With irrigation. Without water capture ponds. Only grew coffee. High socio-economic status.	March 10th
Agricultural Officer (report ID: AO)	First interview conducted.	March 10th
Karima Ward MCA (report ID: MCA)	Interview conducted simultaneously as other groups.	March 10th
Soil Expert (report ID: SE)	No interview recording available.	March 6th

3.3 Soil sampling

A quantitative analysis of soil samples was conducted, which involved obtaining 12 samples from seven farms without irrigation and five farms with irrigation. The decision to focus on irrigation was two-fold: it had the potential to lead to significant differences in the soil, compared to other agricultural practices, and it was understood from the surveys and interviews that the central theme of this study was access to water and irrigation. (Kaduyu and Musinguzi, 2021) analysed irrigated and non-irrigated cropping systems soil properties, finding significant differences for the pH, electrical conductivity, soil organic matter, and total nitrogen. Therefore, it was decided to analyse these same variables in order to see if the soils from our area were showing similar results.

Simple random sampling was utilized on each farm as it proved to be time-efficient. However, this approach may have resulted in a less thorough methodology behind the sampling, which could influence the results. Samples were taken at depths of 0 to 20 cm after removing litter and surface residues (Okalebo et al., 2002). Soil cores were used to obtain composite samples for determining the soil pH, electrical conductivity, soil organic matter, and total nitrogen of each farm. During the sampling process, a description of the farm and the used practices was noted to account for any variability in observations. The chosen parameters were analysed in the laboratory. A comparative statistical analysis was carried out in Microsoft Excel.

3.4 Seasonality-Analysis

To assess changes in growing seasons, images acquired by the spaceborne MODIS sensor between 2002 and 2022 were collected and the satellites EVI (Enhanced Vegetation Index) band was selected (Didan et al., 2015). The EVI is a spectral Index that serves as a proxy for biomass productivity. Compared to other indices such as the more frequently used NDVI, it does not saturate after a certain productivity level and thus gives a trustworthy impression of biomass productivity on the ground (Jensen, 2013).

Every pixel represents its own time series. For each pixel, the start of season date (SOS) and the season length (LOS) were extracted. To do so, a Savitsky-Golay smoothing algorithm was used, which has proven suitable in similar environments (Horion et al., 2014). It smooths the time series by fitting the individual pixel values to an additive polynomial. From this curve, SOS and LOS can be extracted (fig. 5). SOS is defined as each point on the curve where the value has increased by 10% from a local minimum. LOS can be computed as the timespan

between SOS and the corresponding end of season, which is defined similar to SOS (Jönsson and Eklundh, 2010),

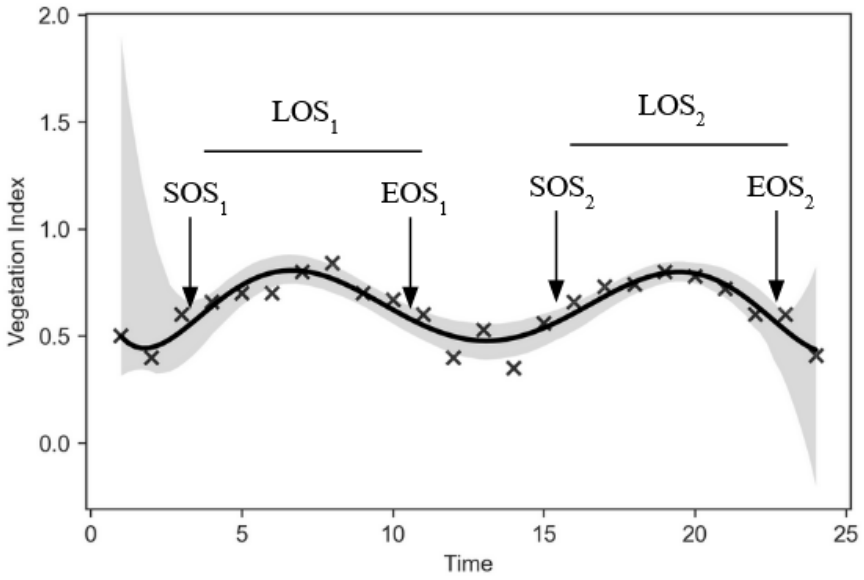

Figure 5: Exemplary extraction of seasonal metrics (own creation)

From the resulting parameters a Theil-Sen-Median Trend was computed to quantify the changes in SOS and LOS. This operator was chosen, as it is more resistant against outliers, which are likely to be erroneous measurements (Eastman, 2020). To test the significance of the trend, the Mann-Kendall significance was calculated, which evaluates a trend based on its consistency (Eastman, 2020).

3.5 Land Cover Classification and Change Detection

Additionally, a land cover change detection was performed. All images available for the years 2016 and 2022 acquired by the spaceborne Sentinel 2 MSI sensor were collected. The sensor was chosen due to its high spatial resolution, which was needed to capture small-scale agriculture, typical for the region (SUHET, 2013). As the classifier requires a single image as an input, the collected images were reduced to a single image using Spectral Temporal Metrics (STMs). Instead of using the raw data of a single image, STMs extract the percentiles 10, 25, 50, 75 and 90 throughout the image collection thus capturing the temporal variation within it. This leads to an improved performance of the classifier (Pflugmacher et al., 2019). The resulting images for 2016 and 2022 were classified using a random forest classifier with 100 decision trees (Louppe, 2014). It assigns each pixel a distinct class based on its similarity with previously

collected training data. The classes used were: woody vegetation, water, urban structures and open soil, tea, low vegetation and other crops, maize and coffee. Both training and validation data were collected from high resolution images from the respective years. Lastly, the classified images were compared to quantify changes. The analyses were performed in TIME-SAT (Jönsson and Eklundh, 2010) and Google Earth Engine (Gorelick et al., 2017). The code is available in the appendix M4.

4 RESULTS

4.1 Socio-economic characteristics of the sample

The household surveys gathered 60 respondents from the population of interest. From these, socio-economic characteristics were compiled, regarding the age, gender, land tenure system, years of farming experience, main source of income, and type of farming practices of the sample (fig. 6).

Figure 6: Key socio-economic characteristics of the respondents (Survey)

4.2 Effects of Climate Change

4.2.1 Drought

The story of climate change in Thuti is a story of drought, where 100% of the respondents experienced increased drought in the past five years. This was further substantiated during the conducted interviews, with the AO stating:

"The climate has seriously changed for the last 5 years, actually the last time they had a good harvest was in 2019. From 2020, the seasons have changed a lot." (AO).

This was continued on the farmer's side, with them saying that the received rainfalls were not enough for most crops to grow (farmer 1). The drought has not only affected farmers relying on rainfed agriculture, but also farmers using irrigation, as their boreholes are drying up, which has negative effects on crop production (farmer 4). This trend of increased drought can also be seen in precipitation data for the study area. In the last twenty years, there has been a continuous decrease in precipitation, with heavy seasonal rain nearly absent since 2020 (fig. 7).

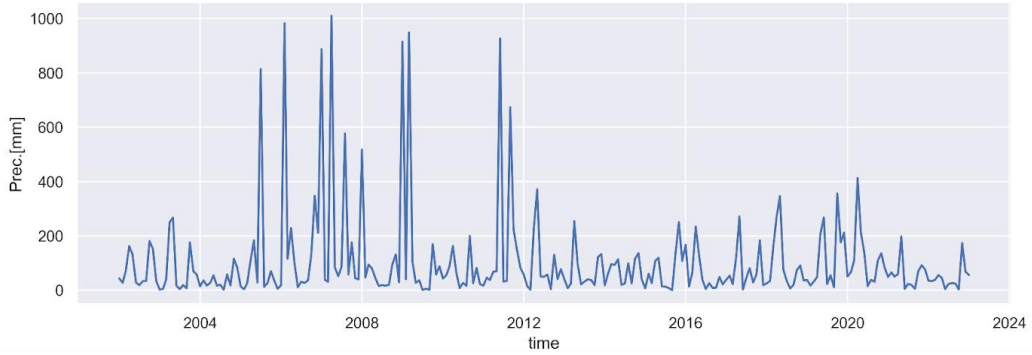

Figure 7: Monthly Precipitation development in Nyeri County (KMD, 2023)

4.2.2 Change in Growing Seasons

Furthermore, with the drought comes a change in seasonality, meaning rain seasons and as a direct result thereof, growing seasons (Horion et al., 2014). The change was experienced by 97% of the respondents. However, the degree to which changes in seasonality were perceived varied through the sample (fig. 8). Seasonality and weather patterns were described in an interview as becoming more irregular, making the forecast of planting seasons almost impossible and thus leading to a loss of seedlings to drought (MCA). This irregularity, in combination with changed harvesting times, reduces the ability of farmers to plan for the future and ultimately, leads to food insecurity (MCA).

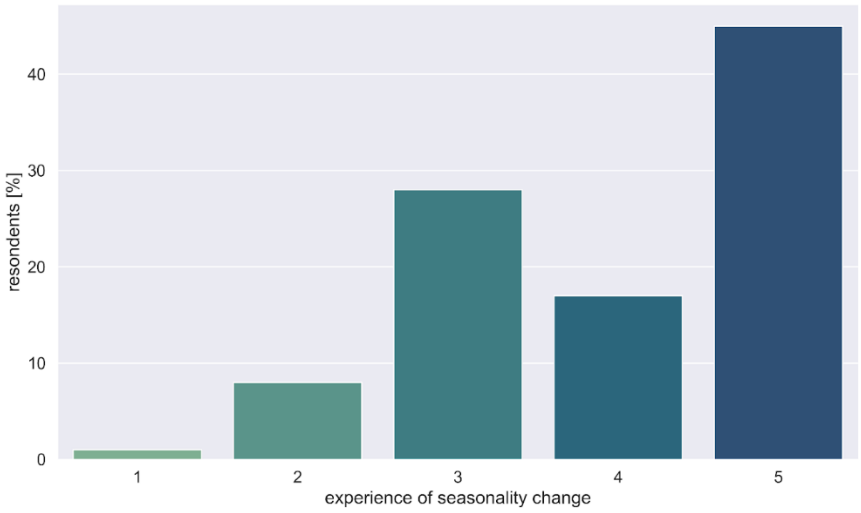

Figure 8: Perception of change in growing seasons within the sample (n=60), with 1 meaning low experience and 5 meaning a high experience of change (Survey)

The irregularity of seasons, experienced by local farmers, can also be observed in seasonality metrics. Figure 9 shows the trends in SOS and LOS experienced in the study area. For most of the area, no significant trend could be calculated. Thus, the trends showed a highly irregular pattern. There are, however, few areas where a significant trend exists, which vary within the study area. The western, woody parts exhibit an earlier SOS, in some parts up to ten days earlier. Areas dominated by agriculture further to the east, experience a delayed SOS of up to ten days (fig. 9a). The Thuti village, located in the western part, exemplary shows these trends with an average delay in SOS of five days (fig. 9b).

This pattern continues in the LOS trends. While the western woodlands experience a shorter LOS, the sparsely vegetated areas within them, as well as the agricultural areas to the east show a longer LOS (fig 9c). Within Thuti the LOS was extended by around two days. Therefore, it can be said that the woodlands experience an earlier SOS, while the LOS is decreasing. The agricultural areas to the east experience a later SOS, but also an increase in LOS (fig. 9d).

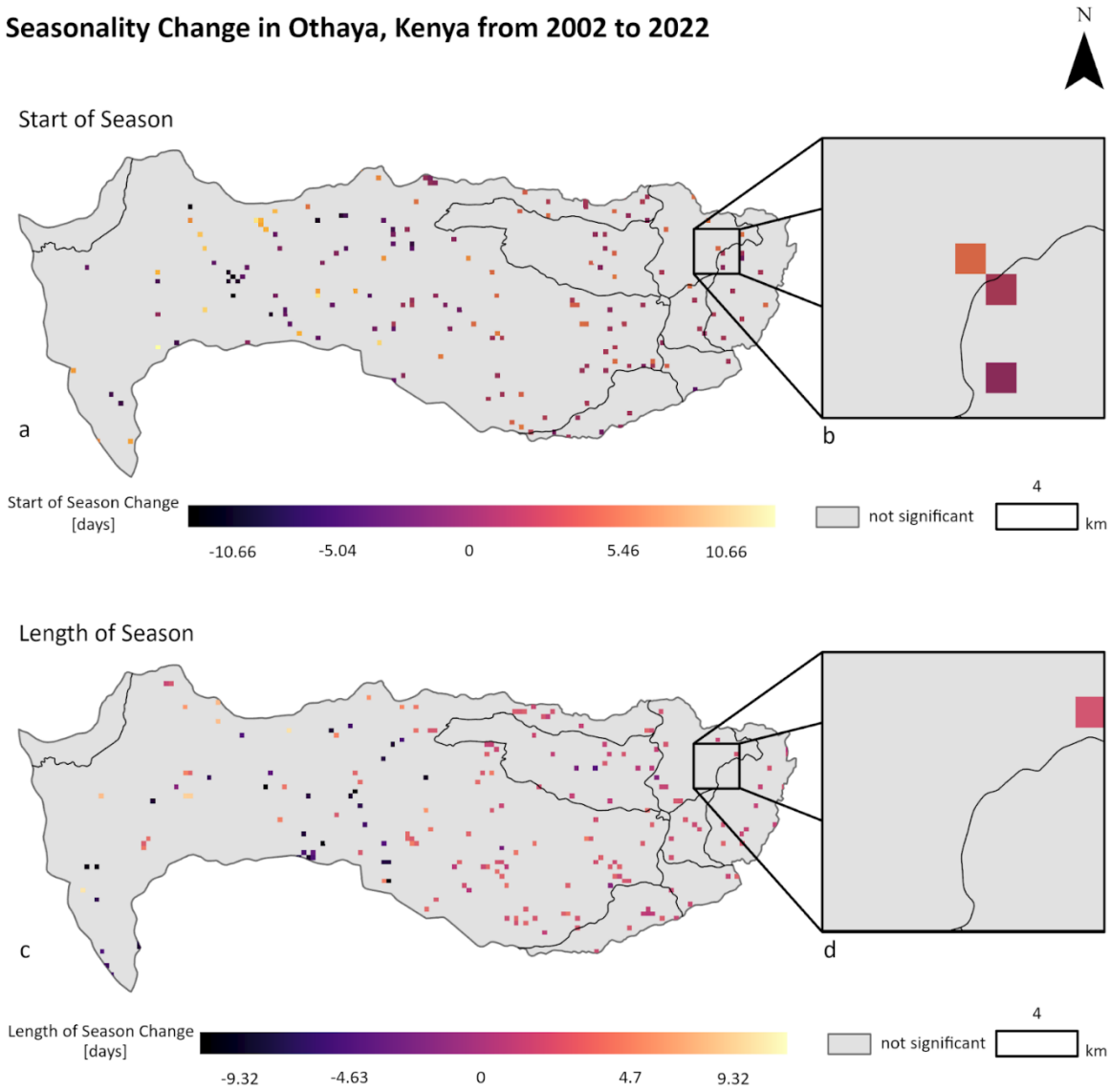

Figure 9: Change in Start and Length of Season within the sub county of Othaya. Each pixel represents a trend (Seasonality-Analysis).

4.2.3 Land Cover Change

The changes in seasonality as well as the increased drought led to changes in land cover, identifiable through the Land-Cover-Classifications. Both classifications achieved good accuracies, with 82% of the classified pixels being correctly classified for 2016 and 88% for 2022. While most classes were classified unambiguously, the classes of tea and maize suffer from frequent misclassification. Another, but less frequent misclassification took place between woody vegetation and coffee fields. A large area of the Karima Forest, for example, was falsely classified as coffee in 2016. These classificatory errors propagate into the change classification.

Therefore, each classification has to be viewed with their corresponding accuracy in mind. The accuracy matrix for the individual classes is available in the appendix (R1). Thuti falls within a highly fragmented part of the sub county. The coffee and low vegetation and other crops classes are dominant. This trend of diversity of crops was even better captured in the survey with 92%, 88% and 88% of respondents planting bananas, coffee and maize respectively. This trend will be described more in section 4.2. In the South-East the Karima Forest forms a larger area of closed, woody vegetation (fig. 10). A large scale, interactive map is available *here*.

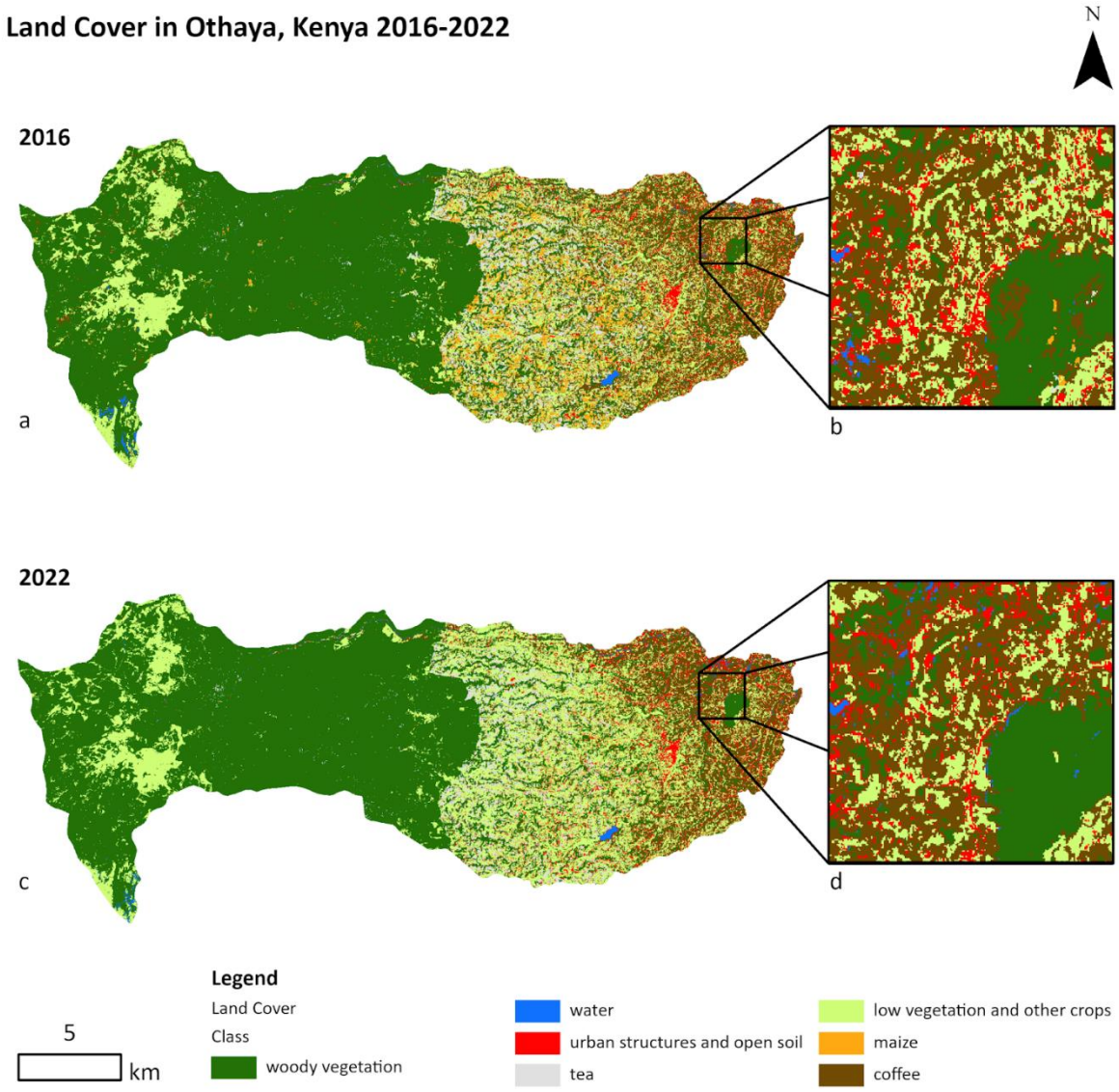

Figure 10: Land Cover in Othaya between 2016 and 2022 (Land-Cover-Classification)

Between 2016 and 2022, the Eastern part of the sub county experienced dramatic changes, as shown in figure 11a. According to the accuracies of the maps above, the accuracy of the change detection is 72 % ($Accuracy_{2016}$ x $Accuracy_{2022}$). While the Western part of the sub county,

according to the classification, experienced almost no changes, the tea zone suffered great losses in maize and tea. The coffee zone shows a more complex pattern. While there are some coffee farms in the study area that have been abandoned, new coffee fields emerged in different locations. Still, the trend of the area used for coffee production is decreasing, with most areas formerly covered by coffee, now being covered by low vegetation/other crops or woody vegetation (fig. 11). This change was not captured in the survey as there has only been a marginal decrease in farmers planting maize, coffee or tea. When interviewed, farmer 2 said that she had uprooted most coffee trees, but that she still kept some. So, although the survey indicates no change, the Land-Cover-Classification does, as the decrease in coffee trees leads to a decrease in area covered by them.

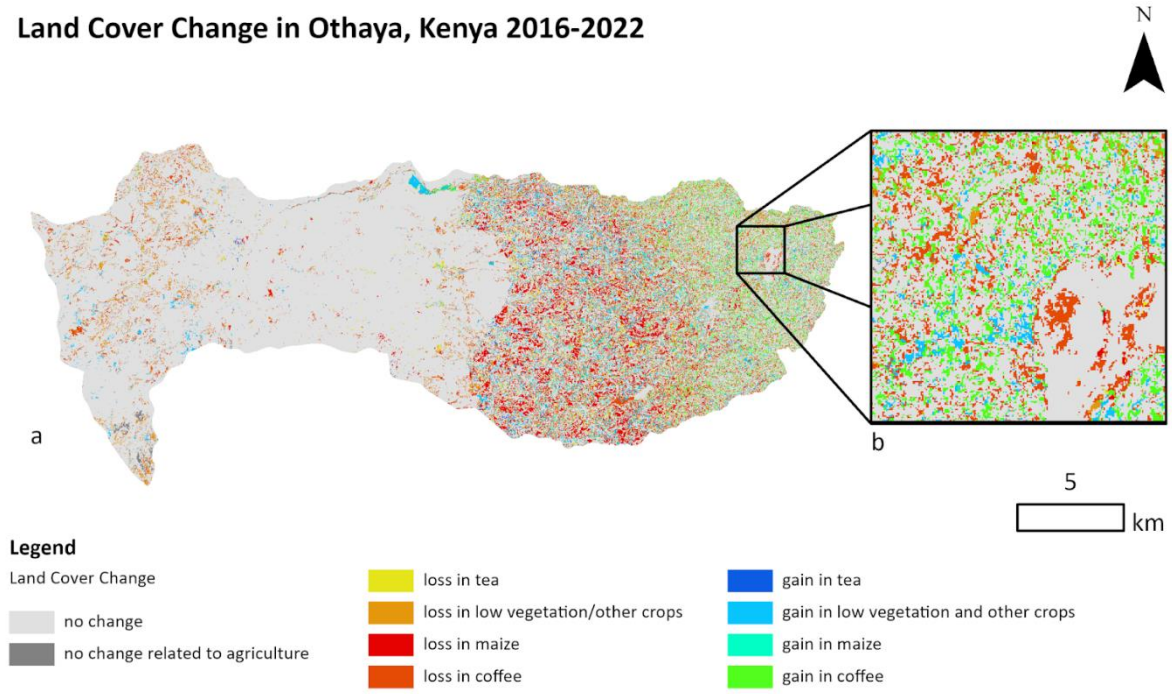

Figure 11: Land Cover Change in Othaya (Change detection)

Figure 12 quantifies the changes in land cover observed in the entire sub county. There has been an increase of forest cover by 12 km², which could result from the encroachment of trees in the Aberdare National Park. The increase could also come from an increased plantation of avocado and macadamia trees on the fields, as the interview with the AO indicated (AO). There are, however, significant losses in the agricultural land cover classes. The area covered by tea decreased by 1.84 km², the area covered by maize by 11.12 km² and the area covered by coffee by 17.36 km². These changes were barely captured by the survey, as farmers hardly abandoned any crops, but rather scaled them back in favour of other ones.

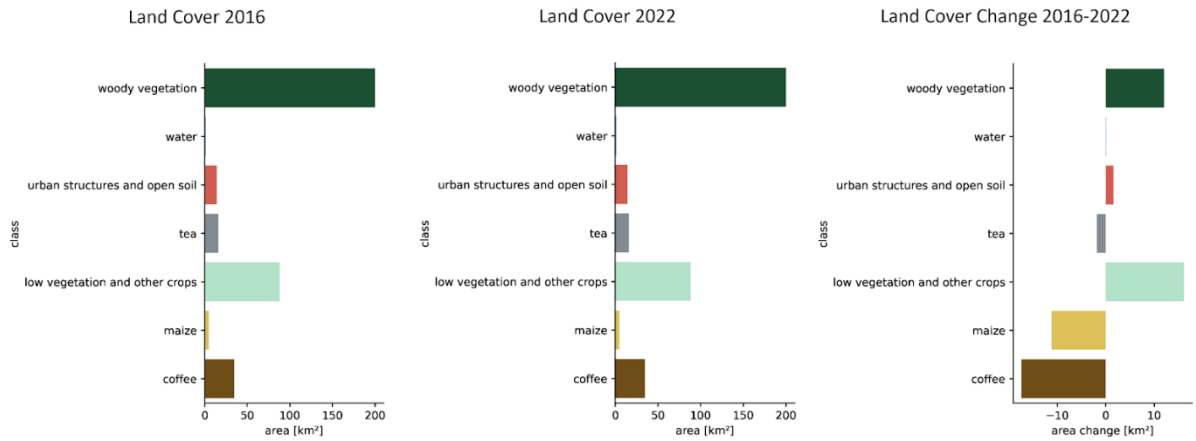

Figure 12: Change in Area of land cover classes (Change Detection)

There has been a reduction in area used for cash crops, while the share of woody vegetation as well as low vegetation and other crops has increased. Different perspectives were shown by the farmers and the AO. On one hand, farmers agreed that the reduction was not only on cash crops production but on all the crops: *"they all decreased, tea, maize and coffee. very much maize and coffee" (farmer 1)* and *"all of the crops are affected and yields have gone down" (farmer 2)*. On the other hand, the AO stated that the production of coffee and tea has almost stayed the same, but that there was also a strong decrease in maize production (AO). This discrepancy, however, may result from a different understanding of terminology by the interviewed, with the AO referring to quantitative crop production and the farmers also taking crop quality into account.

4.3 Smallholder's Adaptation to Climate Change

4.3.1 Crops and Crop Production

During the survey, the diversity in crop cultivation was captured by testing for changes in the types of crops grown in the study area, compared 10 years ago, 5 years ago and the last 12 months (fig. 13). T-tests revealed no significant differences regarding the diversity of crops the farmers were asked about (t-test, $p > 0.1$, table 2).

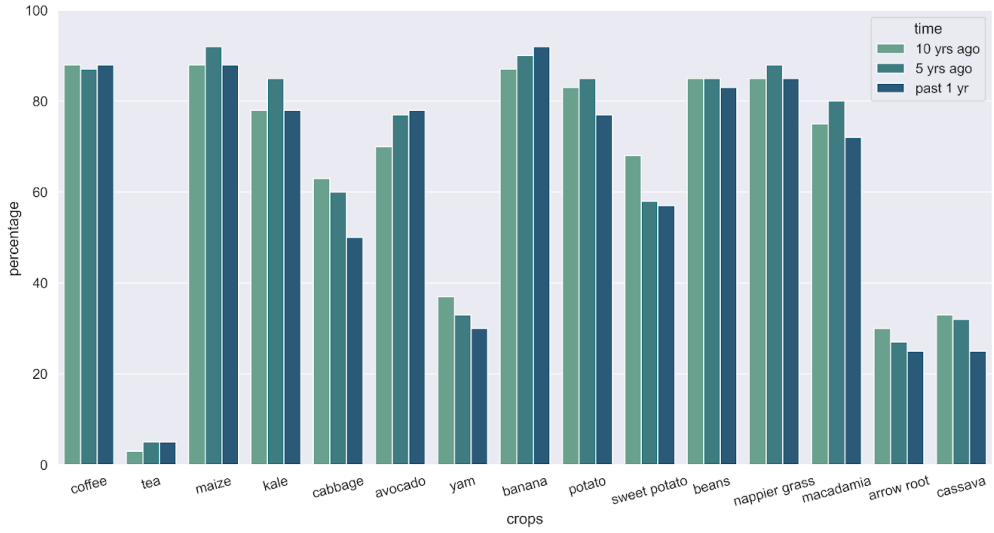

Figure 13: Percentage of the different cultivated crops throughout the analysed years (10 years ago, 5 years ago and the past year) in the surveyed households (survey)

Table 2: average, standard deviation and p-value of crop diversity in the different analysed years (survey)

	Crops	t-test (p-value)
5 y	10.11 ± 8.51	0.56
1 y	9.80 ± 9.21	0.69
10y	10.03 ± 11.72	

Significance level: 0.05

Nevertheless, it was observed that all the mentioned crops were cultivated in the area (fig. 12). Chi-square tests were also conducted with the aim to detect any significant changes in the composition of crops grown in each farm, in the past five and ten years, but they, too, revealed no significant differences ($\chi 2$-test, $p > 0.1$, table 3).

Table 3: p-value obtained through chi-square tests of each analysed crop when comparing now to 5 years ago and now to 10 years ago (survey)

Crops	X^2-test (p-value)		Crops	X^2-test (p-value)	
	1 y - 5 y	1 y - 10 y		1 y - 5 y	1 y - 10 y
Coffee	0.78	1.00	Banana	0.75	0.37
Tea	1.00	0.64	Beans	0.80	0.80
Maize	0.54	1.00	Napier Grass	0.59	1.00
Suma Wiki	0.34	1.00	Macadamia	0.28	0.67
Cabbage	0.27	0,14	Arrow Root	0.83	0.53
Avocado	0.82	0.29	Cassava	0.41	0.31
Yam	0.69	0.43			
Banana	0.75	0.37			
Irish Potato	0.24	0.36			
Sweet Potato	0.85	0.18			

Significance level: 0.05

However, some of the interviews captured the implementation of new seed varieties. The AO stated that:

> *"One of the practices we are promoting is the change of the coffee seeds, from traditional varieties that are very susceptible to CBD disease and frost to tolerant varieties."*

The Agriculture Officer was not alone in mentioning the introduction of new seeds. Some farmers also discussed this topic. Farmer 1 for example, started using improved seeds 5 years ago: *"You can't plant that maize that takes maybe 4-5 months. You're supposed to grow maize that takes around 3 months to grow." (Farmer 1).*

This was supported by interviewee 3: *"We have changed maize seeds; the variety grows faster." (Farmer 3)*. Despite these statements, the survey did not show significant differences on the implementation of this agricultural practice through the years (Table 4). This could be explained, as the survey indicated, by a lack of finances and knowledge for 71% and 43% of the respondents, respectively (fig. 14).

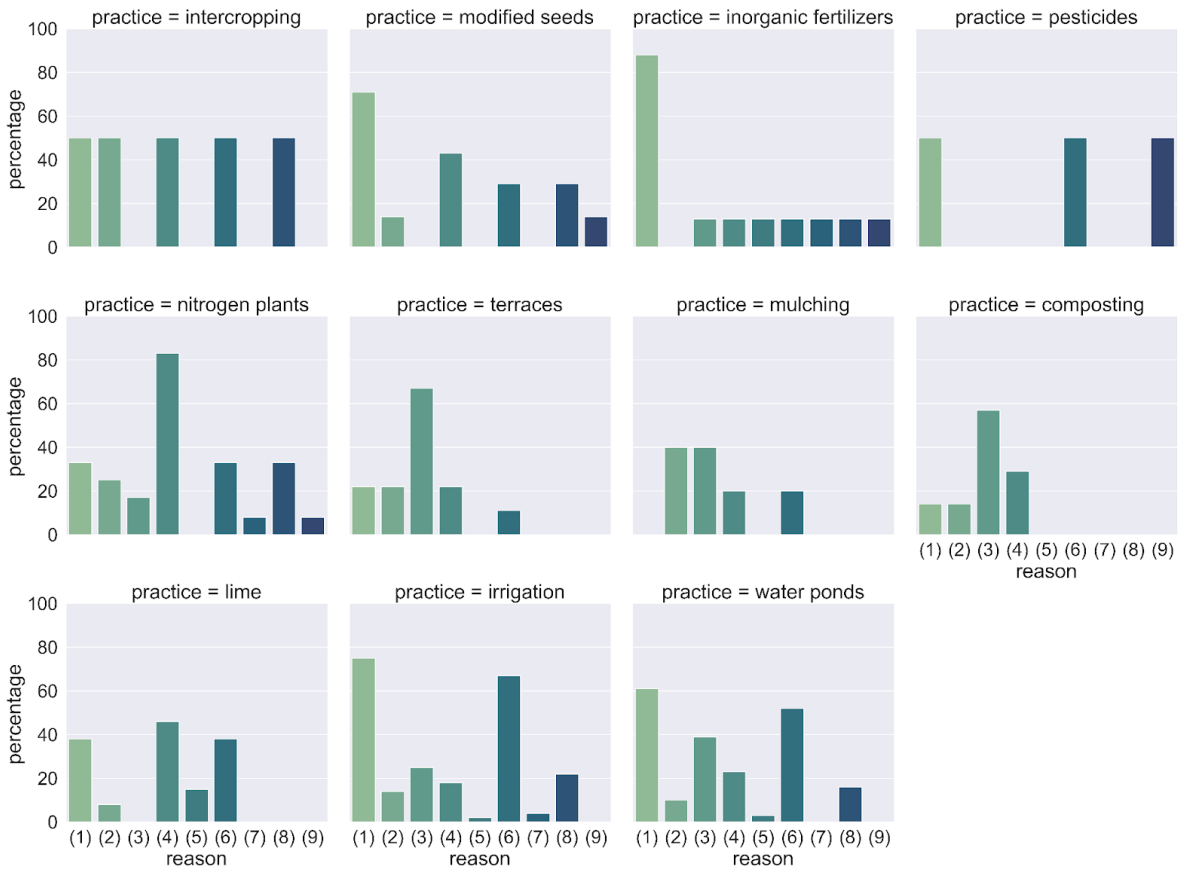

Figure 14: Reasons for not using a certain practice with (1) too expensive, (2) too time consuming, (3) too labour demanding, (4) too knowledge demanding, (5) too uncertain, (6) no access to resources, (7) legislation barriers, (8) lack of support, (9) too high (survey)

In summary, no significant changes in crop diversity were found. However, awareness and implementation of new *technologies* like seed varieties seems to have increased heavily. The main barriers in relation to crops correspond to the *financial* and *human capitals* of the farmers. To overcome the lack of *human capital*, using the internet for further education was proposed as an opportunity by farmer 1.

4.3.2 Agricultural Practices

Changes in agricultural practices were also analysed (fig. 15). No significant differences in the diversity of implemented practices five years ago compared to present-time were found (t-test, $p > 0.1$, table 4), but a significant change was found, comparing present-time with 10 years ago (t-test, $p < 0.05$, table 4). Therefore, chi-square tests were conducted to determine which specific practices had changed. The tests showed significant increases in tilling, mulching (χ2-test, $p < 0.1$, table 5), lime addition and water-capture-ponds (χ2-test, $p < 0.05$, table 5). Water-

capture-ponds and mulching are water-related technologies, which are most important in terms of dealing with water scarcity. Indeed, farmers heavily rely on water:

> *"What the government should do now… We have roads, the next thing they should do is do whatever they can do to supply water. If everybody can get water for irrigation (...) so people can do work, and they can survive well. (...) Let them prioritize water" (farmer 2).*

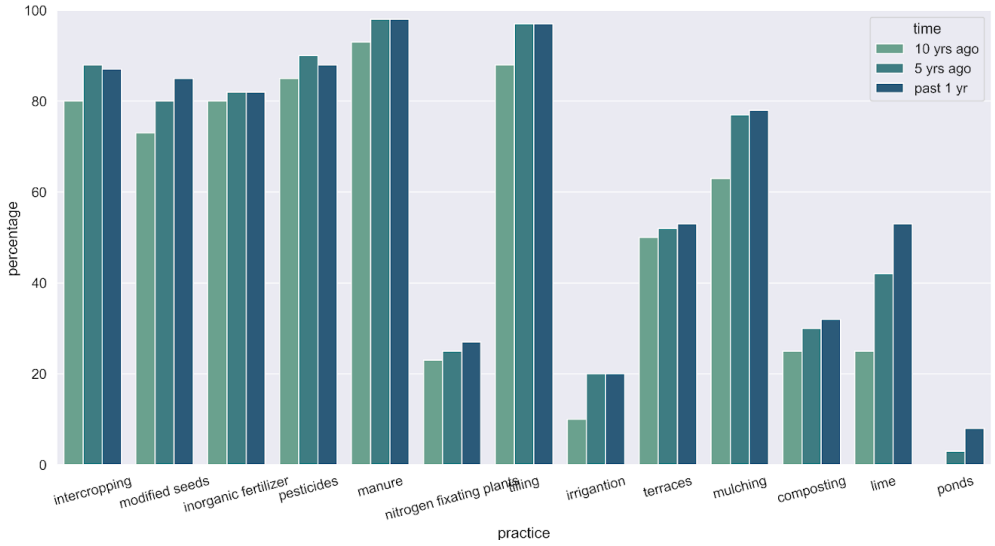

Figure 15: Percentage of the different implemented agricultural practices throughout the analysed years (10 years ago, 5 years ago and the past year) in the surveyed households (survey)

Table 4: average, standard deviation and p-value of agricultural practices diversity in the different analysed years (survey)

	Agricultural practices	t-test (p-value)
5 y	7.83 ± 3.86	
		0.41
1 y	8.13 ± 4.15	
		<0.05**
10y	7.05 ± 5.03	

**Significance level: 0.05

Table 5: p-value of each analysed agricultural practices when comparing now to 5 years ago and now to 10 years ago (survey)

	X^2-test (p-value)	
Agricultural practices	**1 y - 5 y**	**1 y - 10 y**
Intercropping	0.78	0.33
Seeds	0.47	0.12
Inorganic fertilizer	1.00	0.82
Pesticides	0.77	0.59
Manure	1.00	0.17
Nitrogen fixating plants	0.83	0.67

	X^2-test (p-value)	
Agricultural practices	**1 y - 5 y**	**1 y - 10 y**
Tilling	1.00	**0.08***
Irrigation	1.00	0.13
Terraces	0.85	0.71
Mulching	0.83	**0.07***
Composting	0.84	0.42
Limestone	0.20	**<0.05****
Water capture ponds	0.24	**<0.05****

Significance level: **0.05

*0.1

4.3.3.1 Water related technologies

The demand for water solutions was captured by the survey, which illustrated that 85% and 51% of the farmers in the study area wished to use irrigation and water-capture-ponds, respectively, as a part of their agricultural practices. Thus, even though the survey only showed a significant increase in water-capture-ponds, the data likewise indicates that irrigation systems are needed.

This could be explained by, aside from the obvious relief it could provide their farming, the perceived impacts it would have on soil fertility. Farmer 3 stated:

> *"The irrigation has a positive impact on the soil fertility. The plant will be boosted just because there is water in the soil. Irrigation has a really positive impact; the system is more efficient and effective. There is more production." (Farmer 3)*

However, the soil tests did not show any significant differences between irrigated and non-irrigated soils (χ2-test, $p < 0.05$, table 6). This therefore counteracts the statement above, but does not invalidate it. This discrepancy will be discussed later in the report.

Table 6: Average, standard deviation and p-value of the different analysed soil properties (pH, electrical conductivity (EC), soil organic matter (SOM) and total N) for irrigated and non-irritated systems (soil samples)

Treatment	pH	EC (ds/m)	SOM (%)	Total N (%)
Irrigation	5.26 ± 0,05	0.117 ± 0.00	2.01 ± 0.73	0.21 ± 0.01
Non irrigation	5.64 ± 0,07	0.056 ± 0.00	2.09 ± 0.13	0.23 ± 0.00
p-value	0.47	0.38	0.84	0.62

Significance level: 0.05

Another opportunity was presented by Farmer 1:

> *"When it is raining there is a lot of water that goes to waste, so if there is maybe a way farmers can be helped to get those water ponds, and then to get access to dam liners, you'll be able to irrigate"*

This raises the question why, despite their obvious benefits, there was no significant increase in irrigation systems. Both the AO and the MCA agreed that there are potentials in water capture. The MCA explained that: *"When the rain comes, it rains too heavily, and they can collect water at that time" (MCA)*. Furthermore, she explained how she is trying to "push" different authorities to develop water-related solutions:

> *"In my area, they are a bit slow coming here for a borehole: But we are pushing so much for it, but we think the best thing we shall do is tapping our water from Aberdare. (...) so that it will come down to our Othaya sub county (...) and our neighbouring county." (MCA)*

She explained further that getting water from the mountain range of Aberdare is a long-term solution. She believes that *"the most affordable thing we can do very fast is, offering them dam liners, and, they do the small ponds." (MCA)*

However, she admitted that for some of the farmers with lack of assets it would be difficult to be provided with ponds and dam-liners. She explained*: "They are not affordable to them at this time, the way the economy is. Even if we try to advise them 'do dams', it's not affordable for them." (MCA).*

This statement was also supported by the survey which showed that the lack of financial resources is the main barrier in terms of irrigation systems implementation (fig. 14). Of all respondents, 75% expressed that the main reason they could not adopt irrigation was that it was too expensive, closely followed by the lack of access to water (67%). Similarly, for water-capture-ponds, 61% deemed it too expensive and 52% saw the lack of access to water as another barrier (fig 13). The farmers socioeconomic background was analysed to see if there were patterns for farmers who express a lack of financial resources depending on their age, educational level and number of household members. No significant differences were found ($\chi 2$-test, $p > 0.1$, table 7).

Table 7: Relationship of socioeconomic variables and financial barriers (survey)

	X^2-test (p-value)
Socioeconomic variables	Too expensive
Age	0.21
Educational level	0.31
Members on the household	0.57

Significance level: 0.05

Still, lack of finances was a barrier all the interviewees commented on. The MCA explained that the government is not able to provide financial support for irrigation. The Agriculture Officer added that *"there is a lack of funds for the government, this is the main reason why there are farms that are not getting subsidies" (AO)* and that *"there is a lot of emphasis on climate smart agriculture but if there is no funding then it cannot work"*.

Farmer 1 explained that *"it is expensive and we don't have the government support". (Farmer 1)* This suggests that she believes there is a lack of institutional responsibility and financial barriers regarding water-related technologies. Farmer 2 and his mother also commented on the effects finances had on the speed of adaptation. They explained that "*if you have enough money, you can even do it within 3-4 weeks (...) but if you don't have enough money, do it bit by bit" (Farmer 2)*, implying that if you do not have enough, the implementation process is long, delaying the relief that irrigation could bring farmers. Regarding the installation of the dam liners, they explained further that it: *"costs a lot of money" (Farmer 2).* These experiences align well with the MCA admitting that it is not possible for all farmers to implement water-related

technologies. During the interview regarding lack of financial resources for irrigation, farmer 1 mentioned a solution she felt should be implemented:

> *"Maybe you can contribute some amount of money and the government can contribute some amount of money, so that we can help each other. Irrigation is expensive and that's why we want the government to help the farmers. If they can start for us or maybe we cut the costs (...) half, it will be possible." (Farmer 1)*

This shows that she views farmer-institution collaboration as an opportunity for farmers to obtain the necessary technologies to provide them with the relief needed.

Farmer 2 and his mother also highlighted the loan barriers present, saying that *"farmers are complaining about the high interest rate of the loans." (Farmer 2)* However, they believe there is still an opportunity where farmers should form groups, register and remain active, to provide them with more opportunities, for example, increasing their likelihood of getting loans for groups.

This was also found in the survey, where the importance of collaboration around agriculture was high as 82% of the surveyed farmers are a part of an agricultural group. The potential of the agricultural groups was also something the AO elaborated on during the interview: *"We are expecting farmers to form 100 coffee groups that should meet twice a month." (AO)* Clearly, the local institutions also emphasize the collaborations between farmers as an opportunity for adaptation.

This was supported by farmer 3 who stated that for him, the opportunity lies in the creation of groups between farmers. He believes that not enough farms are providing education to other farmers (farmer 3). He further explained that the farm where he works has the aim of providing education to neighbouring farmers, thus contributing to the creation of new agricultural groups. Farmer 2 also aligns with this. She is part of an agricultural coffee group and on the advantages of this, she explains: "They also educate us. They bring people to educate us for free. They think the education is very helpful. More than a thousand farmers are part of this". (Farmer 10008).

In addition, farmer 2 furthermore explained the importance of the collaboration in between farmers facing similar problems by the creation of informal communities:

"We help one another. When there is rain, we help one another to rear our cows, we talk with them, we advise one another, we sit down, we discuss things. When is time for planting, what type of maize are you planting, are you planting cabbage, are you planting Sukuma wiki, what kind of food are you giving your animals?" (Farmer 2)

Thus, collaborating with likeminded farmers can be an opportunity for farmers with lack of resources. However, the interview with farmer 1 indicated that collaboration with the neighbours is not necessarily an easy opportunity as a result of potential trust issues (farmer 1). On this barrier farmer 2 commented:

"That one belongs to minister, to MP." "When he comes, does he ask me, do you have food? No? Then why can I go and talk to him? Why should I? It's better I talk to those ones [talking about her neighbours in a similar situation as her], better than him". (Farmer 2)

Evidentially, it is an opportunity for farmers to collaborate and unite to increase climate change adaptation. However, the data also shows that there are barriers for the collaboration in terms of trust and socio-economic differences.

Besides a lack of available financial, natural and social resources, lack of knowledge was also identified as a main barrier in regards to adopting new practices. Although the surveys did not highlight this as much, with 23% of respondents identified lack of knowledge as a reason for not being able to install water-capture-ponds, and 18% for irrigation systems, the interviews showed it remained an important factor.

Therefore, conducted to test for any significant relations between farmers expressing lack of knowledge as a barrier, and those who did not, with their socio-economic status. Again, no significant differences have been found (χ2-test, $p > 0.1$, table 8).

Table 8: Relationship of socioeconomic variables and knowledge barrier

	X^2-test (p-value)
Socioeconomic variables	Too knowledge demanding
Age	0.92
Educational level	0.29
Number of household members	0.76

Significance level: 0.05

This was observed, when farmer 1 expressed her concerns about the impossibility of using the water provided by the government for irrigation:

> *"The barrier that we can see is that the government doesn't allow people to do irrigation with the water that they are giving people, that is the biggest problem" (...) "even I'm able to pay the water that I'm using at home. I can also be able to pay the water that I will be using to irrigate, but if there isn't that law, I can do it."*

When asking why that was, she explained *"we don't understand why" and "even if you ask, they don't have that concrete answer to tell you why" (Farmer 1).* It was later discovered that the reason for this is that the water for household use is chlorinated. The MCA seemed to be aware of the knowledge barrier, when she explained: *"Household water cannot be used for farming, because it's chlorinated, that's what they don't know." (MCA)*

Additionally, farmer 1 expressed other barriers facing irrigation, relating to governmental communication and support which she believes can provide a big opportunity to adapt to climate change. She explained:

> *"In rural areas, most of the farmers are not aware the irrigation they are supposed to use. So, we still go back to the agricultural department, the ministry of agriculture, that they are supposed to be giving out extension officers, to come and educate farmers: what they are supposed to be doing because of the landscape of their lands, maybe you can use drip irrigation or whichever way. But they are supposed to be educated".*

This shows that the farmers hold governmental institutions responsible for helping and guiding them. However, the farmer does not feel that the institutions are living up to this responsibility, as they do not physically visit the farms.

This miscommunication was also highlighted in an incident which happened during our presentation meeting the 14th of March.

> After our presentation, a heated discussion on subsidies and support started as the agricultural officer stated that it is the farmers own fault if they do not receive the subsidies. Several farmers disagreed and argued that the agricultural office was responsible for the number of subsidies that the farmers were given (field notes).

One can see that the lack of communication is not only affecting the farmer's knowledge, but also their financial resources. The survey supports this, as only 15% of respondents had received financial support from the government in the past five years. As the farmer 1 stated: *"If there is no awareness, you wouldn't be interested in something you are not aware of. The government should play part" (farmer 1).* During the survey, the importance of some sources for agriculture-related knowledge were identified. When asked to rank the top three most useful sources, the following were found: radio (75%), TV (73%), and word of mouth (30%). This could serve as a way to solve communication and lack of institutional personnel issues.

The frustration that the farmers have because of the non-present institutions was articulated by MCA and the AO: *"There is a lack of funds for the government, this is the main reason (...) We used to have officers on every unit, now we are only 7 officers for the 22.000 farmers of the county." (AO).* Thus, illustrating that they do not see themselves as powerful enough to change the situation due to the lack of resources. Instead, they argue that the lack of support and their limited ability to reach out to the farmers is a product of less prioritization from the governmental institutions.

To sum up, regarding agricultural practices, it is clear that *technologies* like irrigation and water-capture-ponds are not accessible for many farmers, due to lack of personal financial and knowledge resources, and the lack of governmental support in terms of education and economic aid. Furthermore, the lack of communication and cooperation between farmers and institutions, or simply between farmers, may also contribute to the inability to adopt these practices. In relation to the framework, this can be seen as the farmers being heavily interested in optimizing their *Physical Capital*. Before doing so, there are a number of barriers and opportunities related to their *Human* and *Financial Capital* as well as related to the farmers *Social Relations* with the local *Institutions.* Thus, it is clear that these elements are heavily interrelated to the optimization of the *Physical capitals*.

4.3.3.2 Alternative water related practices

As there are several barriers for the farmers in order to implement water-capture-ponds and irrigation, other water related practices are encouraged by the government (AO). Mulching and tree planting are examples, and relate to water retention in the soil.

Mulching proved to be a practice which had a significant increase over the past 10 years. This can be attributed to institutions and their guidance. Indeed, the MCA has been recommending

the implementation of this practice to help farmers who do not have access to other technologies. She said:

> *"What I do, for those small farmers, I encourage them to do mulching." (...) to not suffer a lot of water loss" (...) "I advise them on digging (...) when it's dry, so that when it comes to rain, (...), your farm will hold some water." (MCA)*

The MCA emphasizes that it is possible to do a lot with some more traditional agricultural practices such as digging, tilling and mulching to make the soil as resistant to drought as possible. This aligns with the received information from the AO: *"We are advising them on water conservation by doing terraces, cover crops, mulching (...) and water harvesting." (AO).*
This can partly explain the significant increase in mulching. However, some farmers remain unable to adopt this practice. A reason for this, as discussed during the interview with farmer 2, is the lack of water, a biophysical barrier, which was also highlighted in section 4.2:

> *"Mulching, without water? Without rain? you cannot mulch, without rain." "We mulch the soil when it is watered." "When it is dry like this way, you cannot do mulching." (Farmer 2)*

Another reason as to why certain farmers may not be able to implement this change could be attributed to the lack of time and labour resources. The survey results showed that 40% of the respondents attributed these two reasons as their barriers for implementing mulching (fig. 14). However, it is important to note that knowledge was another mentioned barrier for 20% of the respondents.
In this case, the government and local administrations have been promoting other water related practices: although not captured during the survey, a recurring topic during the interviews was that of tree planting.
The Land-Cover-Classification indicated that tree cover has increased in the region specifically on the crop fields (Fig. 4). This is in line with the indications received by farmer 1, that various regional and national institutions have been advocating. Farmer 10002 explained: *"we have been told by the government to add a lot of trees" (Farmer 2)*, a statement supported by the MCA and AO during their interviews, where emphasis was placed on the government promotion of the planting of shading trees (MCA and AO). However, farmer 1 highlights a reason

which could explain why an even bigger increase in tree planting has not been observed, or why certain farmers do not follow these guidelines. When asked if she understood the reasoning behind this advice, she explained *"I really don't understand, but the government has been saying that we should add the trees that have been there because cutting of trees is affecting the way we get rainfall" (Farmer 1)*. This highlights again the lack of communication between institutions and their strategies, and the individual farmers. This theme seems to be a recurring reason for the slow adaptation of farmers, or for the inability of farmers to adapt.

To sum up, from the results above, it can be summarized that some actors identify mulching and tree planting as alternative water related practices that the farmers can implement to strengthen their Physical Capital and to adapt to climate change. However, the farmers identify several barriers when using these practices. The most central is the Natural Capital asset, water, as it is fundamental for mulching to work. Moreover, there is also a lack of Human Capital in terms of knowledge and labour, which are barriers to the implementation. In this context, the communication between the farmers and Institutions regarding their Laws and Policies and strategies is problematic. Therefore, it is an opportunity to improve this Social Relation.

5 DISCUSSION

5.1 Results

The goal of this report was to describe the effects climate change has had on the study area, how farmers have adapted to them, and which barriers and opportunities they are facing during the process of adaptation. The most prominent effect is the increase of drought, which was broadly covered in the corresponding literature (Tesfahunegn et al., 2016; Ochieng et al., 2016; Kogo et al., 2021).

Furthermore, the Seasonality-Analysis and corresponding interviews revealed, as Maiura et al. (2021) and Kogo et al. (2021) found, that the area suffers from a change in growing seasons, which tend to start later and last longer, although this research found the extent of this change to vary considerably through the study area. Although they did not quantify the degree of change, the five day delay in SOS is in line with the findings of Wainwright et al. (2021). The trend in LOS on the other side, indicates an acceleration of change. Cook and Vizy, (2012) predicted an extent of LOS by 20 days by 2040, which, according to this report, has already half been reached. Nevertheless, comparisons between these studies and this report must be carefully made, as the analysis is based around different methods and spatial resolutions.

The Land-Cover-Classification as well as the interviews further showed that drought and seasonality change lead to a decrease in agricultural land, which is contradictory to the trend observed by the classification of Mwangi et al. (2020), who observed a general increase of cropland. It is necessary to highlight that their study has used different data, classes and a different time frame ending in 2017, thus missing the years where drought was most severe. These severe years with a decrease in cropland as well as some fields remaining idle described in this report, is further substantiated by many (Whitmarsh and Capstick, 2018; Rojas-Downing et al., 2017). Moreover, the classification showed an increase of tree-cover, mainly on fields, which was supported by our interviews and corresponds to the findings of Omambia et al. (2009), who described the beginning of the tree planting initiative already back in 2009. The implementation of said initiative was also captured by Stefanovic et al. (2019).

The survey further showed that adaptation to these changes through changes in crops did not take place on a significant level, which contradicts the findings of Musafiri et al. (2022). They identified a diversification in crops as a way of adaptation, however, no crops were abandoned or introduced significantly during the observation period, nor did the diversity of crops change to a significant level. Whether there has been no adaptation through change of crops, or it took place before the observation period started, has to remain unanswered, although the latter is

implied through literature (Kogo et al., 2021). But, as the interviews implied, there has been a change through the adoption of new, drought resistant seeds, also described by Stefanovic et al. (2019).

In terms of practices related to water, only the implementation of water-capture-ponds and mulching saw a significant increase. The introduction of water-capture-ponds for irrigation is in line with the findings of Musafiri et al. (2022), while increase for mulching has not been captured by any publication examining the region so far. Although there has been irrigation on some farms, there was no significant difference between the soil property of irrigated and non-irrigated farms, which contradicts the findings of Chachar et al. (2020), Kaduyu and Musinguzi, (2021) and Tessema et al. (2023). An explanation could be that due to the water shortage, as most of the tested fields have not been watered for several months, which equals out the difference in soil properties (Chachar et al., 2020)

The reasons for the implementation/non implementation of certain adaptation measures are manifold, with a lack of knowledge and financial resources as the main ones, besides from the obvious constrained environmental resources. This is a pattern found throughout the corresponding literature (Mairura et al., 2021; Shackleton et al., 2015; Odwori, 2022; Asokan et al., 2020). Many publications further state that although systems to educate farmers about drought resistant crops or loans for irrigation systems exist, these are described as highly inefficient and lacking the necessary range (Asokan et al., 2020; Odwori, 2022). This was also found in this report. There is an agricultural administration that provides agricultural extension, but not nearly enough to reach the broad majority of farmers, an unfortunate situation, recognized by both farmers and officers. Attributing this inefficiency to corruption as stated by Odwori (2022) did not happen during our fieldwork. The reasons for that remain unclear as surveys and interviews were not aimed at capturing structures of corruption.

In summary, one can say that the interviewed farmers largely saw barriers as a lack of support by the government in general, which incorporates lack of finance and knowledge, as providing these capitals is largely seen as the task of the government through extension programs and loans.

To change this, some farmers in Thuti wish for the provision of extension programs. This could help to install the necessary irrigation system, as well as educate the farmers about climate change mitigation (Asokan et al., 2020; Odwori, 2022). Additionally, they wish for financial support to implement irrigation systems, with the government taking over all costs or a part of it by providing boreholes or construction material. However, this would mean the mobilization of significant financial and personal resources by the government (Mairura et al., 2021).

Another opportunity identified during this report is the potential of networks between farmers to educate each other about ways to adapt or cooperate on large scale investments like irrigation systems, which highlights the importance of social relations.
In summary it can be said that the findings presented in this report largely comply with the existing state of literature. There are some contradictions which can, however, largely be attributed to the characteristics of the study area or the use of different methods.

5.2 Methods

The Seasonality-Analysis succeeded in capturing the changes in growing seasons experienced in the area. Although it produced a result similar to those found in literature, the outcome could be affected by the chosen trend operator. Although it was needed to reduce the influence of erroneous measurements, it also leads to a more conservative estimate of change (Eastman et al., 2020). The sub county was classified with a satisfying accuracy that is in the range of similar classifications conducted in the area (Mwangi et al., 2020), while mapping the area in greater classificatory detail. This achievement can be attributed to the use of STMs over raw data. Both analyses are severely limited through the spatial resolution of the used imagery. The complex small-scale agriculture provides a challenge for classification and Seasonality-Analysis, through the mixing of different surface covers within a pixel. Upcoming systems with higher spatial resolution, such as drones, could in combination with STMs pave the way to a more detailed description of land cover and seasonality change. Lastly, the different spatial extent of satellite-based analysis and survey/interviews hinders the comparability of both. Although needed to ensure a valid result, more advanced imaging systems could help closing this gap.
As presented in the results section, the soil samples did not reveal any significant differences. This was an unexpected result, as studies highlight the impact of irrigation on soil fertility, through various soil properties. This could be related to the methodology behind the samples: the sample size, strategy and the analysis in the laboratory; or it could be explained by how irrigation was used at the field level. Multiple of the sampled farms had been using irrigation sparingly. They had either only been using it once a week, or had actually not used it in months. Had all farmers been using irrigation on a daily basis, the results would have been significant. However, this remains a result which unpacks the use of irrigation in the study site. It can be inferred that although some farmers have access to irrigation, the degree to which they can use it may not be enough to help their production and may not help provide relief.

Although the survey helped us get a deeper understanding of the livelihoods, decisions and context of the farmers, it failed to capture certain nuances or details. This was to some degree anticipated, and the interview guides were therefore designed to bring those to light. For example, the survey was not able to highlight any significant changes in terms of crops. This was an unexpected result. Instead, the interviews highlighted that the farmers tended to grow crops using modified seeds, and did not completely change the crops grown.

An element which we believe would have enriched this analysis, lies in the proportion of crops grown on each farm. The Land-Cover-Classification revealed some general trends in regards to the decrease of maize and coffee in particular. This was complemented by the interviews, where the farmers and officers agreed. On the other hand, the survey results showed no significant decreases in any crops, as it only looked at categorical crop composition. We believe this could be explained by two reasons: there is a difference between lower yields and less crops grown, a nuance which may have gone unnoticed; and in the surveys and interviews, we failed to extract information regarding the proportion of crops grown in each farm, compared to previous years. However, we also recognise that situations like these are natural, and inevitable with methods like surveys, which in turn highlight the advantages of triangulating and validating statements through multiple methods. The particular data and perspectives from the applied methods have impacted the way we have interpreted and analysed our data. Therefore, the interdisciplinary approach of this study has given us the ability to capture more nuances and thereby get a deeper understanding of the phenomena than it would have been with less or only one of the disciplines.

Overall, we believe our methods remain a good fit and enable us to answer our research questions thoroughly. Certain details and nuances could have been added, leaving us with further research opportunities. A reason behind the strength of the methods producing useful results, comes from the collaboration with the University of Nairobi, which this project allowed. Had we not been able to collaborate with local guides and students, a lot of the data and results would have gotten lost or modified in translation. They allowed us to tailor our survey questionnaire and interview guide, so that fit the local context, which we lacked an understanding of. This collaboration was therefore a great learning experience, which we believed to have been fruitful in a number of ways. The differences of cultures, disciplines and positionalities in our group only made the final report stronger.

6 CONCLUSION

The aim of this report was to understand how farmers have been affected by climate change, and which barriers and opportunities they face in order to adapt. It was shown that the area experienced increased drought and more irregular growing seasons which lead to a decrease in land used for agriculture. There were no significant changes in the crop composition at the farms, but an interest in implementing more resistant crop varieties was found. Moreover, an increased implementation of relevant water conserving practices like water ponds or mulching as well as a heavy interest in irrigation were identified. The implementation of these agricultural practices was mainly hindered by a lack of knowledge, finance and institutional support. Other barriers such as the lack of trust and poor social relations as well as constrained environmental resources were also identified. Thus, it can be concluded that even though the area is heavily impacted by climate change, adaptation to these changes is urgently needed, but the lack of assets restricts the farmers in their capability to adapt. Therefore, providing these assets, first and foremost education and financial aid, should be a priority. More extension officers, better communication between institutions and farmers, as well as networks between farmers, all have the potential to help them adapt to climate change. Besides, it is found that loans with low interest rates, subsidized materials such as dam liners, or even shared costs in projects between farmers and the government for the creation of boreholes, can as well be opportunities for improved adaptation.

Implementing the proposed recommendations in the given context is a quite complex process and whether these changes turn out successful remains unclear. Fighting water scarcity through more boreholes or by retrieving water from nearby mountain ranges as proposed in this report might be an obvious solution; whether these sources can provide enough water for a sustainable long-term solution, however, is unclear. Therefore, further studies should seek to gain a deeper understanding of the relations between smallholder farmers/the relations between them and the administration as well as the water resources in the area. They should assess the feasibility of the proposed recommendations to ensure the future of agriculture and farmers in Thuti and the sub county of Othaya.

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APPENDIX

O1 Table of Applied Methods

METHOD	DETAILS
SEMI STRUCTURED INTERVIEW	7 Interviews with Key Informants
SURVEY	60 respondents
SOIL SAMPLING	5 samples from irrigated, 7 from non-irrigated, composite samples of 10 subsamples per field. 0-20cm
SEASONALITY ANALYSIS	240 images of EVI with 250x250m ground resolution
LAND COVER CHANGE DETECTION	53 (2016), 57(2022) images of STMs with 10x10m ground resolution

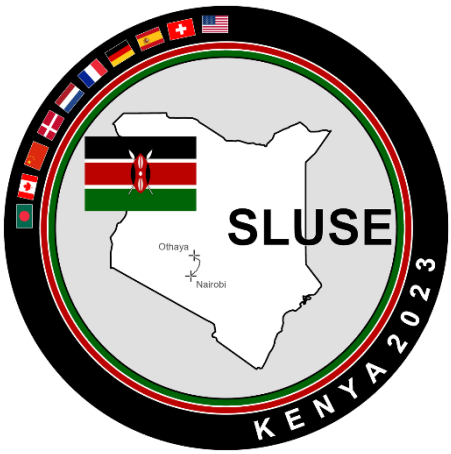
O2 Final Synopsis

SLUSE SYNOPSIS

Agricultural Production and Climate Change

Field site: Thuti, Kenya

February & March 2023



Research Topic: **Climate Variability and Smallholder Agricultural Practices**

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1 Introduction

Agricultural products make up a considerable part of the Kenyan economy, with tea and coffee contributing the most to the country's GDP (Karuni 2020). Climate change, however, had a considerable impact on the country's agricultural sector. Changing rain patterns and growing seasons are posing a threat to Kenyan agricultural production, as the unfavorable conditions lead to lower crop yield (Kogo et al. 2021). Rain events tend to be heavier and less predictable (Nathan et al. 2020), and the growing season is getting longer, resulting in a higher production of unprofitable biomass (Kogo et al. 2021).

The degree to which these changes are perceived by the Kenyan farmers and how they adapt to/mitigate these changes differs greatly throughout the community of Kenyan farmers (Mairura et al. 2021) and is influenced by social, institutional and geophysical factors (Musafari et al. 2022). Therefore, a broad variety of responses and strategies to cope with the challenges posed by an increased climate variability exist (Ochieng et al. 2020). This study therefore aims to research the agricultural practices that farmers implement to adapt to climate variability, and identify barriers and opportunities of their adoption.

2 Background

2.1 Major Historical and Current Trends in Society

The agricultural landscape found in the Nyeri area today was mainly shaped by colonial history. Before the British colonization of the Nyeri area, the population was divided into a number of relatively autonomous communities. In the 1890s, a series of catastrophes hit the communities provoking considerable depopulation. During that time, British colonizers found out that the Nyeri region was very profitable and easy to conquer because of the soil's good fertility and the low population living there. Once the British had colonized the rural communities were forced to relocate. It was then when they were assigned to the "native reserves" mainly located in marginal lands. During this colonial period, the Kikuyu in the native reserves got involved in cash crop production for distant markets. However, they were banned from producing the most profitable crops because the white settlers were the ones wanting to have its exclusivity (Bates, 1989; Tignor, 1976) .

The post-colonial era was marked with major agricultural upheavals. The sector was liberalized meaning that anyone was able to grow whatever it wanted. However, some instructions from the extension officers to follow remained. Land availability started dwindling and the president Kenyatta called on people to buy the land. The 1990's marked the worst interval in the agricultural transformation of the district as most farmers were suffering from political interferences that were leading to the farmer's collapse (Owuor et al., 2009).

The period starting in the 2000s is marked with a relief to most farmers, mostly due to the creation of some farmer's support structures such as the Agricultural Finance Corporation and Kenya Farmers association, and the emergence of credit institutions. However, the coffee sector is still under a lot of pressure because of political interference (Owour et al., 2009).

2.2 Legislative Context

Climate Change and its effects on agriculture have long been in the focus of kenyan lawmakers. The Climate Change Act from 2016 places duties on the national and county governments to mainstream climate change responses into development planning, decision making and implementation and to respond in other ways to climate change (National Council for Law Reporting, 2016). Furthermore, acts were passed to create funds to finance climate change programmes and climate smart practices (National Council for Law Reporting a, 2019). To regulate land use planning in the agricultural context, the Physical and Land Use Planning Act was passed in 2019. It establishes principles and guidelines that every entity involved in physical and land use should promote sustainable land use in the face of climate change (National Council for Law Reporting b, 2019). In the context of this study, the legislative context is important to consider, as it influences the decision making of local farmers.

Legislation around land tenure, in the context of this study, is also relevant to consider. The relevant customary laws to consider, in the context of this study, relate to land tenure. In the 1950s, land consolidation schemes were initiated on a large scale, where a registration of titles and ownership was put in place. This meant that once the land and its owner had been registered, the customary laws no longer had to be followed, as it used to prior to this scheme. This led to the Registered Land Act of 1963. Individual tenure titles were therefore strengthened (Coldham 1979). The Kenyan Constitution of 2010 states that the land in Kenya is divided into public,

private and community land, where different legislation apply to each category (Doshi et al, 2014). In Nyeri county, most of the land is privately owned, usually by men, and over 85% of farmers hold title deeds (COUNTY GOVERNMENT OF NYERI, 2018). For the context of the study, this means that the farmers which we will survey and interview, will most likely be the owners of the land on which they are cultivating, and therefore, will be free to adopt and change their practices as they see fit.

3 Problem statement

This study departs from the above mentioned socio economic, environmental and historical context, and studies the Central Highlands of Kenya, particularly the village of Thuti. Several studies have been focusing on trends in the Central Highlands of Kenya. Mairura et al. (2021) and Musafiri et al. (2022) examine to what degree farmers' perceptions on climate variability influence their ability and likeliness to adapt their practices to the climate variability. Mairura et al (2021) suggests that perceptions of climate change are influenced by environmental, institutional and socioeconomic factors, and that adaptation of practices result in increased use of fertilizer and manure, terraces, trees and crop rotation. Musafari et al. (2022) indicates that in addition to the household head's gender, age, education, arable land, livestock owned etc., perceived climate change is also a factor for the adoption of "climate smart agriculture". In addition, a previous SLUSE project has studied the factors determining the farmers soil and soil management in Thuti (Møller et al, 2014). This project builds upon these studies but differentiates from them, as it combines the quantitative data from natural science with the qualitative data from interviews with farmers and other key actors in the region. Thus, the project aims to produce new knowledge on farmers' barriers and opportunities to adapt agricultural practices to climate variability, which is an aspect that is not a central focus point in the above mentioned studies. In addition, comparing the study's results to the previous studies gives material to find similarities and differences to discuss and reflect upon. To add to this research gap, many studies have investigated land use change (Mwangi et al., 2020) and change in seasonality (Cook and Vizy, 2012) in the region, however, they lack the necessary spatial detail and detail in land cover classes to make a meaningful contribution to the effects climate variability had on smallholder agricultural practices. To do so, the following research question, as well as sub questions and methods are proposed:

How has climate variability influenced smallholder agricultural practices and soil fertility in Thuti, Kenya, since 2016?

-What are the effects of climate variability on growing seasons and land cover?
-Which changes in agricultural practices have farmers implemented to adapt to climate variability?
-What impacts have these changed agricultural practices had on soil fertility?
-Which barriers do farmers face in relation to agricultural practices when adapting to climate variability?

Due to this study's framework and the resources available, the study location is delimited to Thuti village. Furthermore, the methods applied to answer the research question suggest a fairly short time frame as the data relies on the involved actors memory, as well as the imager's spatial resolution available for the land cover classification. Thus, the study covers the period from 2016-2023.

4 Methods

4.1 Survey

In order to answer our research questions thoroughly, different methodological approaches will be used in triangulation. Household surveys are one of these. This research will aim to collect answers from the household heads of around 40 households, in the Thuti village and surroundings. The survey will present a majority of close ended questions, as this leads to the significant advantage of making analysis clearer, and the survey will avoid question types that cloud this analysis process, such as double barreled, vague, or leading questions (Rea and Parker, 2005). The survey will blend factual and perceptual questions, including what farmers do, own and think. The way in which the households will be selected will follow a simple systematic sampling method (Henry 2009), where for example, households on every accessible street within a certain radius of the research base will be counted, and every 3rd house will be chosen. In the event that the selected household is unable to participate, the "2nd" household will be selected. In the same manner, the "4th" will be selected in the event that the "2nd" cannot participate. This method will be adopted for its ease of adoption and because it will tend to select more equally within the population. The survey will be conducted with the SurveyXact tool, and will be analyzed on Microsoft Excel. Chi square tests, t-tests or correlation tests will be carried out depending on the variables we are doing the statistical analysis on. For example, farmer's

perception of climate variability and their adoption of certain practices will be analyzed in a chi square test.

4.2 Interviews

To answer the sub-questions, we find it useful to conduct a number of semi-structured interviews with farmers. These will mainly be based on the data and patterns that we will identify from the survey. The interviews give us a chance to get a better understanding of the patterns and the underlying drivers (Brinkmann, 2020). The explorative nature of the semi-structured interviews will also allow us to touch upon other important aspects of the phenomena and be led into unexpected elements of the phenomena (Brinkmann, 2020).

To ensure the interviews will not give us a distorted picture of the phenomena, it is important that the respondents represent the different types of farmers with regard to socio-economic status and agricultural practices. Therefore the respondents will be chosen through a purposeful sample (Scheyvens, 2014). Prior to the interviews, a classification of different farmers groups will therefore be made and a relevant farmer of each group will be chosen. The interview guides will be customized according to the particular interviews. We expect them to contain both general questions, which will be similar and comparable in between interviews, as well as more concrete and particular questions and topics suitable for the particular cases (Brinkmann, 2020).

Aside from interviewing farmers, we plan to interview other key informants, such as the agricultural officer or representatives of farmer cooperative groups, to get a deeper understanding of the effects of climate variability in the study region.

4.3 Soil Analysis

Some studies highlight the impact of agricultural practices on soil fertility, for example the use of inorganic fertilizer on the soil's pH, carbon content and nutrient content (Odendo et al., 2009; Mairura el al., 2007). Thus, we will do a quantitative analysis of the farmer's soil quality focusing on the main soil parameters analyzed in these studies. We plan to carry out the soil sampling on the same farms on which we will conduct the semi structured interviews, after we

have identified the major trends from the survey. We will proceed to choose the sampling sites on each farm with a systematic sampling, as it ensures spatial coverage.

On each farm, we aim to collect 10 soil samples which we will combine through compositing, in order to have a final homogeneous sample to analyze in the lab. When sampling, topography will be taken into account and a description of the site will be noted, in order to account for any potential variability in our observations. These samples will be selected based on the topography and in similar conditions, at depths from 0 to 20 cm depth (Mairura el al., 2007). Afterwards, they are going to be air-dried and sieved for measuring the main parameters. These are going to be: soil organic matter and nutrient analysis (N, P and K) which show the nutrient status of the soil for plants, and pH and conductivity which influence the habitat of soil organisms (Jin, J.W., et al. 2011). Once the data is obtained, a comparative analysis of the different soil parameters will be conducted.

4.4 Seasonality Analysis and Change Detection

Multiple analyses making use of earth observation data will be conducted. First, a timeseries of the MOD13A2.061 Terra Vegetation Indices 16-Day Global 250 m product's EVI band (Didan et al., 2015) covering the years from 2002 to 2022 will undergo a seasonality analysis. The longer timeframe is needed to ensure the validity of the analysis. By looking at the temporal variation in EVI (Enhanced Vegetation Index) as a measurement of vegetation productivity, this analysis can extract seasonal parameters like length of season (LOS), start of season (SOS) from the EVI timeseries (Eklindh & Jönsson, 2010). The integral (INT) under each season can also be extracted, giving an estimate of the total biomass produced in each season. A Theil-Sen-Median Trend will be calculated for each parameter, to see whether there has been any significant change in either LOS, SOS or INT (Eastman, 2022). This will provide information on how seasonal parameters, and therefore growing seasons in the area of interest changed and whether there are temporal and spatial patterns. The change in growing season serves as a proxy for climate variability, defined as the anomalies in temperature and precipitation deviating from the climate's mean (America's Climate Choices, 2010), as they are directly and solely dependent on climate. The results will further be correlated with data on precipitation to see what the effects of anomalies (droughts etc.) on seasonal parameters are.

A land cover change detection will be performed, to assess the impact climate variability may have had on land cover. Two images of the area of interest from 2016 and 2022 will be classified. To reduce the influence of clouds and ensure continuous coverage, all images available for each year will be combined into a composite. To make use of the temporal variation within the timeframes, spectral temporal metrics will be calculated. This allows the classifier to recognise the needed land cover classes (Pflugmacher et al, 2019). The proposed classes are: coffee, tea, corn, other crops, forests, human disturbances and water. By comparing the two resulting land cover maps, it can be determined if there has been change in the spatial and quantitative distribution of land cover classes. To make sure the observed changes are related to climate variability, the results will be triangulated with the results of the interviews and surveys.

2.5 Planned collaboration with counterparts

During an introductory online meeting with the Kenyan students; prior to our departure, we established a discussion regarding our research themes. While in the meeting, we discussed several aspects of the research objectives, and the meeting showed that both parts of the group have a fairly similar understanding of the theme as well as the research questions and approaches. The similarities gave us a good platform to have constructive dialogue on our collaboration in the different aspects of the field work. We reflected upon the differences that we have regarding culture, scientific background etc., and agreed that these differences have the potential to be our strength during this process. Specifically, we planned to create the questionnaires and interview guides together as well as conducting the survey and the interviews together. Furthermore, we planned to maintain open and continuous constructive discussions, so we are well prepared and can contribute and collaborate with each other during the process.

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Appendix:

A1 *Matrix*

Sub questions	Data needed	Methods	Analysis	means of verfication / triangulation	Considerations / limitations
What are the effects of climate variability on growing seasons and land cover?	Modis EVI time series Sentinel 2 MSI STM (2017+2022) Meterological data (for correlation with seasonality parameters)	1. **Remote Sensing** (seasonality analysis, trend analysis) 2. **Land Cover Classification** Change detection 3. **Household surveys** (Perceptions on Climate Variablity) 4. **Meterological databases** (rainfall, drought, correlation)	Savitzky-Golay --> Theil Sen Median Trend --> Man Kendell Sig. test Random Forest Classifier	Use of **meteorological databses** **Ground truth** data accuracy assessemnt	Clouds Data availability in present and past
Which changes in agricultural practices have farmers implemented to adapt to climate variability?	Land Cover Classifications + Change detection Information on smallholder's agricultural practices	1. **Household surveys** 2. **Interviews** 3. (**PRA** - Mapping)	Transcribing and coding of interviews Statistical analysis fo survey responses (means, medians, t tests etc.)	**Transect walks / participative observation**	Memory Willingness to participate
What impacts have these changed agricultural practices had on soil fertility?	pH, conductivity, nutrient availability (N, P and K) and soil organic matter (SOM)	1. **Soil sampling and analysis** 2. (**Houshold Surveys** - Farmers perceptions of their soil) (3. Transect walk)	Statistics methods (comparing the different farm's soils depending on the applied farming practices)	Literature	Compositing: loss of variability information Sampling technique may vary from person to person Physical environment Potential rainfall during study
Which barriers do farmers face in relation to agricultural practices when adapting to climate variability? (Maybe include oppertunities)	A specific framework/theory to structure the analysis (in process)	1. **Interviews** 2. (Household survey) 3. (PRA Transect walk)	Transcribing and coding of interviews Statistical analysis fo survey responses (means, medians, t tests etc.)	Literature	Thruthful answers? Does the data from the interview allign with the data we got from the Survey and soil samples? And how do we discuss it doesn't?

A2 Survey draft:

Intro:

We are a group of students from the University of Copenhagen and the University of Nairobi, who have come to Kenya to learn about agriculture, climate change, and how to do a research project. We have created this survey to get an understanding of your agricultural practices, the impacts of climate change and the socio-economic context of the households we survey.

This survey will take approximately **25 minutes** to complete. The purpose is purely educational, and it is **not linked to any other institution or organization** other than the University of Copenhagen and the University of Nairobi.

Your names will not be mentioned in the final report, meaning your answers are **anonymous**.

The data will be **stored safely**, where only us, the students, have access, and it will be deleted once we are finished with this course.

Are you willing to proceed with this survey?

Questions for our survey

During the past 7 years = Since Uhuru Kenyatta was elected for the second time (2017) (the second time he was elected).

Personal questions

- The respondents name? (X)
- The respondents age? (X)
- The respondent's gender (male / female / other)
- The respondent's education level (primary school, middle school, secondary school, university, vocational training)
- Number of household members (including children and the respondent) (1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10+)
- The respondent's number of children (0 / 1 / 2 / 3 / 4 / 5 / 6 / 7+)
- Does the respondent hope their children will pursue agriculture in the future? (yes/no)
  → If yes, why?
  → If no, why?

Farming questions

- Farming experience of the respondent (0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35 …)
- How big is your household's farm, in acres? (x)
- Is the land owned by you (or your family)? (yes/no)
- Did you hire labor to work on your farm in the last 12 months (yes/no)
  → if yes, how many people? (1, 2, 3, 4, 5, 6+)
  OR → If yes, for how many months? (1,2,3,4,5,6,7,8,9,10,11,12)
- Do you have livestock? (yes/no)
  → If yes, what animals (and how many?) (goats, chickens, cows, pigs, sheep, rabbits)(Table)
- Do you and other farmers in the village share agricultural knowledge with each other? (yes/no)

Perception questions :

- Have you felt the effects of climate change since Uhuru's second period? (1-5, 1 have not felt them at all, 5 felt them a lot)
- How have you experienced climate variability: cross all that apply (no experience / increased drought / increased flooding / changes in growing seasons / increased pests & diseases / intense rain - damage to crops / lower yields / other)
- How fertile do you consider the soil on your farm compared to the soil in other farms in the village (1-5, 1 not fertile at all, 5 very fertile)
- Has rainfall been more unpredictable than usual? (1-5, 1 don't agree at all, 5 agree completely)
- To what extent do you agree with this statement: there has been a change in the growing seasons since Uhuru's second period? (1-5, 1 don't agree at all, 5 agree completely)
- To what extent do you agree with this statement: I have had to change my agricultural practices since Uhuru's second period due to climate change? (1-5, 1 don't agree at all, 5 agree completely)
- Do you believe that the changes you have implemented are successful in respect to climate variability? (yes/no)

Knowledge / Advice and Support questions

- Have you participated in agricultural extension programs since Uhuru's second period?
  → If yes, who has participated (household head or other).
  → And in what program? (name of program)
- Which sources do you most often use to gain information about agriculture? (ranking)

Source	Do you use it? (yes/no)	Ranking
TV		
Radio		
Internet		
Newspaper		
Word of mouth		
Agricultural groups		
Extension Programs		

Authorities		
Other:		

- Is the respondent part of an agricultural cooperative group? (tea group, coffee group, other, no)
- Did you receive agricultural subsidies before Uhuru's second period? (yes/no)
- → Has the amount of agricultural subsidies changed since Uhuru's second period? (Increased, decreased, no change)
- Did you receive free seedlings before Uhuru's second period? (yes/no)
- → Has the amount of free seedlings changed since Uhuru's second period? (Increased, decreased, no change)
- Did you receive non-financial support to adapt your agricultural practices to climate variability before Uhuru's second period?
- → Have you had any non-financial support regarding adaptation to climate variability after Uhuru's second period?
- Did you receive financial support to adapt your agricultural practices to climate variability before Uhuru's second period?
- → Have you had any financial support regarding adaptation to climate variability after Uhuru's second period?

Agricultural practices

- Which crops have you been growing the past 12 months? (cross all that apply)

Coffee	Cabbage	Potatoes (irish)	(Fodder) trees
Tea	Avocado	Sweet potato	Macadamia
Maize	Tomatoes	Beans	Arrowroot
Kale	Onion	Nappier grass	Cassava
			Other (specify which)

- Which crops have you started producing since Uhuru Kenyatta was elected for the second time? (cross all that apply)

Coffee	Cabbage	Potatoes (irish)	(Fodder) trees

Tea	Avocado	Sweet potato	Macadamia
Maize	Tomatoes	Beans	Arrowroot
Kale	Onion	Nappier grass	Cassava
			Other (specify which)

- Which crops have you stopped producing since Uhuru's second period? (cross all that apply)

Coffee	Cabbage	Potatoes (irish)	(Fodder) trees
Tea	Avocado	Sweet potato	Macadamia
Maize	Tomatoes	Beans	Arrowroot
Kale	Onion	Nappier grass	Cassava
			Other (specify which)

- What agricultural practices have you been using the past 12 months? (cross all that apply)

Agroforestry	Organic fertilizer	Nitrogen fixing plants	Irrigation
Intercropping	Inorganic fertilizer	Cover crops	Terraces
Monocropping	Pesticides	Contour Farming	Fallow periods
Modified (improved) seeds	Use of manure	Tilling	Other (specify which)

- Which of these practices have you stopped using since Uhuru Kenyatta was elected for the second time? (cross all that apply)

Agroforestry	Organic fertilizer	Nitrogen fixing plants	Irrigation
Intercropping	Inorganic fertilizer	Cover crops	Terraces
Monocropping	Pesticides	Contour Farming	Fallow periods
Modified (improved) seeds	Use of manure	Tilling	Other (specify which)

- Which of these practices have you started to implement since Uhuru Kenyatta was elected for the second time? (cross all that apply)

Agroforestry	Organic fertilizer	Nitrogen fixing plants	Irrigation

Intercropping	Inorganic fertilizer	Cover crops	Terraces
Monocropping	Pesticides	Contour Farming	Fallow periods
Modified (improved) seeds	Use of manure	Tilling	Other (specify which)

- Are there any practices that you would like to use, but cannot:

Agroforestry	Organic fertilizer	Nitrogen fixing plants	Irrigation
Intercropping	Inorganic fertilizer	Cover crops	Terraces
Monocropping	Pesticides	Contour Farming	Fallow periods
Modified (improved) seeds	Use of manure	Tilling	Other (specify which)

  → when selected, a drop down will appear: why: (too expensive, too time consuming / too labor demanding / too knowledge demanding / too uncertain / too difficult access to products / legislation barriers / lack of support group / other)
- Which 3 practices do you perceive as the most helpful in terms of yield security? (Ranking top 3)
- Have your sowing times changed by more than a week since Uhuru's second period? (yes / no)

  → If yes, for which crops?

Coffee	Cabbage	Potatoes (irish)	(Fodder) trees
Tea	Avocado	Sweet potato	Macadamia
Maize	Tomatoes	Beans	Arrowroot
Kale	Onion	Nappier grass	Cassava
			Other (specify which)

- Have your harvest times changed by more than a week since Uhuru Kenyatta was elected for the second time? (yes / no)

  → If yes, for which crops?

Coffee	Cabbage	Potatoes (irish)	(Fodder) trees
Tea	Avocado	Sweet potato	Macadamia
Maize	Tomatoes	Beans	Arrowroot
Kale	Onion	Nappier grass	Cassava

			Other (specify which)

Outro:

We would like to thank you very much for taking the time to help us with this survey.

Do you have any questions for us?

Do you accept that we get in contact with you if we would like to talk to you some more, and maybe take some soil samples on your farm?

→ If yes, could we please have your phone number so we can contact you again?

A3

Research timeline:

M1 Survey

Jambo!

We are a group of students from the University of Copenhagen and the University of Nairobi, who have come to Nyeri County to learn about agriculture, climate change, and how to do a research project. We have created this survey to get an understanding of your agricultural practices, the impacts of climate change and the socio-economic context of the households we survey.
This survey will take approximately 20 minutes to complete. The purpose is purely educational, and it is not linked to any institution or organization other than the University of Copenhagen and the University of Nairobi.
Your names will not be mentioned in the final report, meaning your answers are anonymous.
The data will be stored safely, where only us, the students, have access, and it will be deleted once we are finished with this course.
Are you willing to proceed with this survey?

0. Identification Number

_____

Respondent Information

1. The respondents name?

_____

2. The respondents age?
(1) ❍ 0-19
(2) ❍ 20-29
(3) ❍ 30-39
(4) ❍ 40-49
(5) ❍ 50-59
(6) ❍ 60-69
(7) ❍ 70+

3. Gender
(1) ❍ Male
(2) ❍ Female
(3) ❍ Other

4. Education level
(1) ❍ Never went to school
(7) ❍ Adult education
(2) ❍ Primary school
(3) ❍ Secondary school
(4) ❍ College
(5) ❍ Vocational Training
(6) ❍ University

5. Number of household member (Including respondent and children who currently lives in the house)

_____

6. Number of children (who lives in the household)

_____

7. What is your main source of income?
(1) ❍ Agriculture
(2) ❍ Business
(3) ❍ Wages/Salary
(5) ❍ Remittances
(6) ❍ Government Support
(7) ❍ Pension
(4) ❍ Other _____

Farming Questions

8. For how many years have you practiced farming?
(1) ❍ 0-5
(2) ❍ 6-10
(3) ❍ 11-15
(4) ❍ 16-20
(5) ❍ 21-25
(6) ❍ 26-30
(7) ❍ 31-35
(8) ❍ 36-40
(9) ❍ 40+

9. How big is your farm (in acres)?

_____

10. What is the land tenure of your farm?
(2) ❍ Bought
(3) ❍ Rented
(4) ❍ Family land
(6) ❍ Hired
(5) ❍ Other _____

11. How fertile do you consider your soil compared to your neighbours' soil?
(1) ❍ Worse
(2) ❍ Same
(3) ❍ Better

11.1 Have you heard that you can check your soil fertility in the agricultural department?
(2) ❍ Yes
(3) ❍ No

12. Which type of farming do you engage in?
(1) ❑ Cash Crops
(2) ❑ Subsistence farming
(3) ❑ Livestock
(4) ❑ Other _____

12.1. What animals?
(3) ❑ Cows
(4) ❑ Pigs
(5) ❑ Sheep
(1) ❑ Goats
(8) ❑ Geese
(2) ❑ Chicken
(6) ❑ Rabbits
(7) ❑ Others _____

Perception Questions

13. Have you ever heard about climate change?
(2) ❍ Yes
(3) ❍ No

14. How much do you think changes in temperature affect crop production, on a scale of 1 (lowest) to 5 (highest)?
(2) ❍ 1
(3) ❍ 2
(4) ❍ 3
(5) ❍ 4
(6) ❍ 5

15. How much do you think changes in temperature affect livestock production, on a scale of 1 (lowest) to 5 (highest)?
(1) ❍ 1
(2) ❍ 2
(3) ❍ 3
(4) ❍ 4
(5) ❍ 5

16. How have you felt the effects of climate change in the past five years on a scale from 1-5? (1 lowest - 5 highest)
(1) ❍ 1
(2) ❍ 2
(3) ❍ 3
(4) ❍ 4
(5) ❍ 5

17. Have you experienced any of the following?
(1) ❑ no experience
(2) ❑ increased drought
(4) ❑ changes in growing seasons
(5) ❑ increased pests and diseases
(7) ❑ lower yields
(8) ❑ other _____

18. Has rainfall been more unpredictable than usual in the past 5 years?
(2) ❍ Yes
(3) ❍ No

19. To what extent do you agree with this statement, on a scale of 1 (lowest) to 5 (highest): There has been a change in the growing seasons in the past 5 years?
(2) ❍ 1
(3) ❍ 2
(4) ❍ 3
(5) ❍ 4
(6) ❍ 5

20. Do you agree with this statement: I have had to change my agricultural practices in the past 5 years, due to climate change. (Scale: 1 lowest - 5 highest)
(2) ❍ 1
(3) ❍ 2
(4) ❍ 3
(5) ❍ 4
(6) ❍ 5

Knowledge / Resources / Support Questions

21. Do you receive information about the weather?
(2) ❍ Yes
(3) ❍ No

22. Which sources do you use for agricultural information?
(1) ❑ TV
(2) ❑ Radio
(3) ❑ Internet
(12) ❑ Phone (SMS / Text message)
(4) ❑ Newspaper
(5) ❑ Word of Mouth (talking with neighbours)
(6) ❑ Agricultural Groups
(7) ❑ Received Extension Programs / Government support
(8) ❑ Authorities
(9) ❑ Education from friends/family
(11) ❑ Church
(10) ❑ Other _____

22.1. Which sources do you find most useful? (name up to 3)
(1) ❑ TV
(2) ❑ Radio
(3) ❑ Internet
(12) ❑ Phone (SMS / Text message)
(4) ❑ Newspaper
(5) ❑ Word of Mouth (talking with neighbours)
(6) ❑ Agricultural Groups
(7) ❑ Received Extension Programs / Government support
(8) ❑ Authorities
(9) ❑ Education from friends/family
(11) ❑ Church
(10) ❑ Other _____

23. Are you part of an agricultural group or Sacco?
(2) ❑ Coffee group
(3) ❑ Tea group
(5) ❑ Other _____
(6) ❑ No

24. Have you received financial support (for example: agricultural subsidies) in the past 5 years?
(2) ❍ Yes
(3) ❍ No

24.1. Has the amount changed in the past 5 years?
(1) ❍ Increased
(2) ❍ Decreased
(3) ❍ Not changed

25. Have you received non-financial support (for example free seedlings) in the past 5 years?
(2) ❍ Yes
(3) ❍ No

25.1. Has the amount changed in the past 5 years?
(1) ❍ Increased
(2) ❍ Decreased
(3) ❍ Not changed

26. Which crops have you been growing the past 12 months?
(1) ❑ Coffee

(2) ❑ Tea
(3) ❑ Maize
(4) ❑ Kale (Sukuma wiki)
(5) ❑ Cabbage
(6) ❑ Avocado
(7) ❑ Yam
(8) ❑ Banana
(9) ❑ Potato (Irish)
(10) ❑ Sweet potato
(11) ❑ Beans
(12) ❑ Nappier grass
(14) ❑ Macadamia
(15) ❑ Arrow root
(16) ❑ Cassava
(17) ❑ Other _____
(18) ❑ None

27. Which crops did you grow 5 years ago?
(1) ❑ Coffee
(2) ❑ Tea
(3) ❑ Maize
(4) ❑ Kale (Sukuma wiki)
(5) ❑ Cabbage
(6) ❑ Avocado
(7) ❑ Yam
(8) ❑ Banana
(9) ❑ Potato (Irish)
(10) ❑ Sweet potato
(11) ❑ Beans
(12) ❑ Nappier grass
(14) ❑ Macadamia
(15) ❑ Arrow root
(16) ❑ Cassava
(17) ❑ Other _____
(18) ❑ None

28. Which crops did you grow 10 years ago?
(1) ❑ Coffee
(2) ❑ Tea
(3) ❑ Maize
(4) ❑ Kale (Sukuma wiki)
(5) ❑ Cabbage
(6) ❑ Avocado
(7) ❑ Yam
(8) ❑ Banana
(9) ❑ Potato (Irish)
(10) ❑ Sweet potato
(11) ❑ Beans
(12) ❑ Nappier grass
(14) ❑ Macadamia
(15) ❑ Arrow root
(16) ❑ Cassava
(17) ❑ Other _____
(18) ❑ None

29. What agricultural practices have you been using the past 12 months?
(2) ❑ Intercropping
(4) ❑ Modified / improved seeds
(6) ❑ Inorganic fertilizer
(7) ❑ Pesticides
(8) ❑ Manure
(9) ❑ Nitrogen fixating plants
(12) ❑ Tilling
(13) ❑ Irrigation
(14) ❑ Terraces
(18) ❑ Mulching
(19) ❑ Composting
(16) ❑ Limestone

(21) ❑ Water capture ponds
(17) ❑ Other _____
(20) ❑ None

30. Which agricultural practices did you use 5 years ago?
(2) ❑ Intercropping
(4) ❑ Modified / improved seeds
(6) ❑ Inorganic fertilizer
(7) ❑ Pesticides
(8) ❑ Manure
(9) ❑ Nitrogen fixating plants
(12) ❑ Tilling
(13) ❑ Irrigation
(14) ❑ Terraces
(18) ❑ Mulching
(19) ❑ Composting
(16) ❑ Limestone
(21) ❑ Water capture ponds
(17) ❑ Other _____
(20) ❑ None

31. Which agricultural practices did you use 10 years ago?
(2) ❑ Intercropping
(4) ❑ Modified / improved seeds
(6) ❑ Inorganic fertilizer
(7) ❑ Pesticides
(8) ❑ Manure
(9) ❑ Nitrogen fixating plants
(12) ❑ Tilling
(13) ❑ Irrigation
(14) ❑ Terraces
(18) ❑ Mulching
(19) ❑ Composting
(16) ❑ Limestone
(21) ❑ Water capture ponds
(17) ❑ Other _____
(20) ❑ None

32. Are there any practices that you would like to use, but cannot:
(2) ❑ Intercropping
(4) ❑ Modified / improved seeds
(6) ❑ Inorganic fertilizer
(7) ❑ Pesticides
(8) ❑ Manure
(9) ❑ Nitrogen fixating plants
(12) ❑ Tilling
(13) ❑ Irrigation
(14) ❑ Terraces
(18) ❑ Mulching
(19) ❑ Composting
(16) ❑ Limestone
(21) ❑ Water capture ponds
(17) ❑ Other _____
(20) ❑ None

32.1. Why? (Intercropping)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

32.2. Why? (Modified / Improved Seeds)

(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.3. Why? (Inorganic Fertilizer)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.4. Why? (Pesticides)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.5. Why? (Manure)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.6. Why? (Nitrogen Plants)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.7. Why? (Tilling)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group

(10) ❑ Health reasons
(9) ❑ Other

33.8. Why? (Terraces)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.9. Why? (Mulching)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.10. Why? (Composting)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.11. Why? (Limestone)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.12. Why (Irrigation)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding
(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

33.13 Why (Water Pond Capture)
(1) ❑ Too expensive
(2) ❑ Too time consuming
(3) ❑ Too labour demanding
(4) ❑ Too knowledge demanding

(5) ❑ Too uncertain
(6) ❑ No access to resources
(7) ❑ Legislation barriers
(8) ❑ Lack of support group
(10) ❑ Health reasons
(9) ❑ Other

34. Do you believe that the changes you have implemented will help your production?
(2) ❍ Yes
(3) ❍ No
(4) ❍ Have not made changes

35. Have your planting times changed by more than a month, in the past 5 years, due to climate change?
(2) ❍ Yes
(3) ❍ No

36. Have your harvesting times changed by more than a month in the past 5 years, due to climate change?
(2) ❍ Yes
(3) ❍ No

37. Have you experienced harvesting losses due to climate change?
(2) ❍ Yes
(3) ❍ No

37.1. For which crops?
(1) ❑ Coffee
(2) ❑ Tea
(3) ❑ Maize
(4) ❑ Kale (Sukuma wiki)
(5) ❑ Cabbage
(6) ❑ Avocado
(7) ❑ Yam
(8) ❑ Banana
(9) ❑ Potato (Irish)
(10) ❑ Sweet potato
(11) ❑ Beans
(12) ❑ Nappier grass
(14) ❑ Macadamia
(15) ❑ Arrow root
(16) ❑ Cassava
(17) ❑ Other _____
(18) ❑ None

38. Do you hope your children will pursue agriculture in the future?
(2) ❍ Yes
(3) ❍ No
(4) ❍ It is their choice

38.1. Please explain why
_____
_____
_____
_____
_____
_____

OUTRO

We would like to thank you very much for taking the time to help us with this survey.
Do you have any questions for us?
Do you accept that we get in contact with you if we would like to talk to you some more, and maybe take some soil samples on your farm?

M2 Interview Guide

General questions:

1. What do you think has been the biggest challenge in the past 5 years, due to climate change?
2. How does climate change affect the way you do agriculture?
3. How has the weather changed over the past 5 years?
    1. Does this affect the way you do agriculture? If so, how?
    2. Does this affect growing seasons? If so, how?
    3. Has the temperature affected the quality of your crops? explain
4. How often does it rain?
    1. When it rains, how is the rain compared to before (time, intensity, amount)?
5. Which crops do you grow that rely the most on water?

With Water Capture

6. When and why were you able to implement water capture in your farm.
    - Did you receive any support for implementation (government/irrigation. (***Loans, schemes, SACCO or government support)***
    - How much did it cost?
    - How long did the implementation take?
    - Who helped in the design of the water capture system?
    - what is the main source of water for the water capture, (***is it drilled borehole, river, rain or any water catchment area***)
    - Do you think water capture has helped you during climate change? If yes, how?
    - Has the implementation of the water capture changed your choice of crops?
    - What is the consumption of water on a daily basis and has it changed over time due to climate change
7. What are some of the challenges that you have experienced with farming despite having a water capture pond?
8. Has the water capture pond changed any of your agricultural practices?

Without Irrigation

1. What do you think has been the biggest challenge in the past 5 years, due to climate change?
2. What would it mean to your production if you had access to irrigation?
3. Has the lack of irrigation influenced:

a. your choice of crops? (& proportion of crops grown)

4. Have you implemented any kind of practice that could be similar to irrigation, such as water capture ponds or tanks (make sure that the tanks are used for agriculture and not for water consumption)? If not, why?

5. What are the biggest challenges / barriers you are facing in relation to irrigation? ***(In relation to labour, financial support, knowledge and resources)***

6. And how do you think these can be solved?

7. Have you heard of any irrigation funding opportunities?

a. How do you think the government is helping the situation?

how would you like the government to help you?

Without Water Capture

1. Do you know what a water capture system is? If not, would you like to have one?
2. What are the biggest challenges / barriers you are facing in relation to implementing water capture? ***(In relation to labour, financial support, knowledge and resources)***
    1. And how do you think these can be solved?
    2. Have you heard of any opportunities that support water harvesting techniques?
3. Have you implemented any other water storage technique in your farm such as water tanks (make sure that the tanks are used for agriculture and not for water consumption)? If not, why?
4. What would it mean to your production if you had access to water capture in this era of climate change?
5. How do you think the government is helping the situation?
    1. How would you like the government to help you?

M3 Interviews

1. Interview with Karima Ward, MCA

12.57: **barriers/challenges:** “there are so many (challenges). “Weather patterns have changed, they cannot forecast when to plant” (...) “They plant knowing their seedlings dry up, so they have got that loss which is a big challenge.”
13.30: **challenge:** because of climate change: “when they used to harvest, is not the time they are harvesting, so they are suffering hunger (...) They used to know “by September we shall be harvesting maize”, so they realize September is here (...), the maize has not arrived the time of harvest, so we are suffering hunger”
14.06: **challenge:** “it's becoming hotter everyday” so they are finding water even harder, it is becoming hard for them. They use a lot of time to concentrate on finding water, and not concentrating on the farm and farming, so they are facing that challenge”

We didn't ask about this in our interview, but from the other groups she mentioned changes they are pushing for and encouraging farmers to do:
12.06 “on agriculture department, we are trying to see whether we can. You’ve seen some farmers to fishery, farming fish, we are introducing that. You can do fish farming, you can do pig rearing, you can do poultry, for at least your day-to-day earnings (as we await the payment of the coffee)”
She also mentioned fish farming as an opportunity alongside dams. (21.02, refer to RQ3)

14.31: **challenge**: Barrier: “also they are finding a challenge they would like to find water for irrigation” “the government is not able to supply at this time, but everyone is crying out “we need water for irrigation”, which is, so expensive.” rain, irrigation, pipes and all that, and getting water for irrigation all the way from Aberdare is not easy for county government, or even national government, as the way the economy is”.
15.00: **barrier**: They would like to have dam liners. They are not affordable to them at this time, the way the economy is. Even if we try to advise them “do dams”, it's not affordable for them.”
15.32: **barrier and opportunity:** Have you done efforts to present a bill on drilling boreholes for irrigation in your ward: “Yes i have done so, but, (...) on their priority (list), where will they go? In my area, they are a bit slow coming here for a borehole: But we are pushing so much for it, but we think the best thing we shall do is tapping our water from Aberdare. Our area MP they were there the other day, trying to get a dam from Aberdare, so that it will come down to our Othaya sub county (...) and our neighbouring county. But that one will not stop us from at least trying to do some borehole within the ward.”
16.45: **opportunity:** “But I think the most affordable thing we can do very fast is, offering them dam liners, and, they do the small ponds.”
17. 46 **Opportunity:** “When the rain comes, it rains too heavily, and they can collect water at that time”.
18.24 **Opportunity**: (idk when she was elected?) “At times they feel that if they are not recognised, but now when they were electing me, they were like “let's elect one of our own, an agronomist, who will get to know our problems”.
19.55: **opportunity if things work out:** “that one we shall be implementing when (...) the committee that has been made, through the county, that’s what they will be doing, they will

provide us dam liners, they do biogas because of the climatic change, they will work on the tree, like eucalyptus, they will change the tree to trees like pine that can attract rain, but eucalyptus it has been done all over and it has been affecting climate change". "But I cannot assure directly, like right now I will provide them dam liners, because the budget was very small, we had just a budget of 13.5M per ward, so having (..) infrastructure department, education department, so you could not be able to."
21.02: **barrier**: (size of land for dams) "it shall be a challenge for those who have a small size of the land, but a bit you can do it, and at the same time you do the fish farming in the same pond, so it's an alternative"
22.06 "Household water cannot be used for farming, because it's chlorinated, that's what they don't know."
22.38: **barrier**: we can just do ponds (...), borehole is something we can do, but we cannot do the tapping of the water from the river for the whole irrigation system, that one we can only collaborate with the national government, of which they are ready to do it because of the climate, the way it has change."
23.05 **Barrier and proposed solution:** "there is a tank that you can see near to the forest, it's very big" "those one it was made for irrigation, but where is this water which is not chlorinated? So, they worked on the tanks, but they never worked on the source". "First work on where water comes from, they we build the tanks" "we also have another tank at Watima, the other side, still in Karima, we even have pipes, but the tank is not being used, because they never first worked on where the source of the water will come from".
31.14: **proposed solution:** ((how will you help the poor farmers make necessary changes): "what I do, for those small farmers, I encourage them to do mulching." (...) "if you plant Sukuma wiki and you do spinach, then you do mulch, to not suffer a lot of water loss" (...) "it will be able to keep water during the rainy seasons" "again, another thing I normally advise them, is on digging. Some farmers they are just doing herbicides or weeding. When you do herbicides (...) you didn't break the hard parts, so when it rains, water will not enter inside, so it will just come and pass" (like cement ground), so I advise them on digging, practice on digging on January and February, prepare your farms, not with herbicides, but do the (..) maximum tilling (...) when it's dry, so that when it comes to rain, (...), your farm will hold some water. Then do mulch."
33.17 **barrier**: how she spreads knowledge: "I used to go around; my work was fieldwork". (Implying she cannot do that anymore)

1. Interview with Agricultural Officer

2:57: Challenge. It has happened for the 5th season that they don't have harvested. We also have the issue of insect pests because it is very dry.
3:40: Opportunity. E-subsidy program. There is a program for coffee farms supported by the government. The farmer pays 60% and the government pays 40%. There are also fundraisers for some food crops.
5:05: Opportunity. Commercialization of avocado. For the last 5 years there has been an increase of this major crop for export. Cash crops have changed from coffee to avocado. There has also been the introduction of chia seed, but in a very small scale. We are promoting two crops: macadamia and avocado.
7:40. Barrier. The avocado grows better in the tea growing zone rather than in the coffee zone.
8:10: Barrier. The price of macadamia in the global market is going down after corona.
8:32: Opportunity. We are recommending to diversify crops. Have avocado + tea.

9:07. Opportunity. A new practice that has adopted is the use of herbicide in coffee, avocado, maize, beans and horticulture. Compared to the cost of labour, it is cheaper to use herbicide. PCPB regulates the use of herbicides.
11:28. Opportunity. We are advising them on water conservation by doing terraces, cover crops, mulching of coffee, construction of dams, and water harvesting. We are also advising them about the crops to plant. We recommend the seeds of different companies. Recommendation of maize, beans and root crops (cassava, Irish onions, sweet potatoes) and vegetables. We recommend these crops because we are not expecting so much rain, and these crops don't need so much rain.
15:16. Barriers. We have no irrigation program in Karima. The avocados are drying up, even coffee is drying up.
16:13. Barrier. There has not been any research carried out in this area because it is not considered the most dried subcounty.
17:48. **Opportunity.** Climate smart agriculture has just begun in coffee. One of the practices they are promoting is the change of the coffee seeds, from traditional varieties that are very susceptible to CBD disease and frost to tolerant varieties. In coffee producing instead of using water, ecopalpa is used. They are also using the promotion of solar dryers and also solar water conservation, shading trees.
22:00 —> **Challenge.** Because of climate change, there is a time, January, we expected to be sunny, warm but
What affects now the teas is the frost, affected on January.
22:50. **Opportunity.** With maize we have introduced the maize insurance to prevent farmers of the lost issued by climate change.
Challenge. We only implement the strategy of the government; we don't come with new things.
The e-subsidy, the crop insurance, the irrigation they are issued because of the ambition 2030, the issues of **food security**.
25:45. **Challenge.** If there is no support there is no so much, I can do. But if we are supported by the projects, the sub county has done very well on implementing them. We depend on the county government, national government and the stakeholders. There is not much you can do when you do not have funds. Sometimes the farmers refuse visits or the activities.
C. **Challenges.** I think the climate has seriously changed for the last 5 years, actually the last time they had a good harvest was in 2019. From 2020, the seasons have changed a lot. You see, the irrigation updates are not enough, it is only to supplement the rains, so farmers must rely on the weather information.
29:00. Opportunities. We do provide weather information. We provide two programs, one called: —-- and another one supported by E-fund and the other one by —. LISTEN TO IT, I DONT UNDERSTAND.
30:00: Opportunities. Brochures are produced by rain. About rains, what should they plant, what will grow… Those things are on many TV programs, on newspapers, on some text messages, production of those brochures, word of mouth. Sometimes it depends on the source and information
32:30. Challenges. A farmer cannot afford to farm if he is not getting any profit, unless there is something done by the government to support agriculture.
Our farmers have always been cash crops, they were all alone. In fact, subsidies have been introduced recently because of the effects of climate change that are affecting farmers seriously.
36:00. **Barrier.** There is a lack of funds for the government, this is the main reason while there are farmers that are not getting subsidies. 10 years ago, we used to have a lot of officers but right now the employment has gone down. We used to have officers on every unit, now we are only 7 officers for the 22.000 farmers of the county. It is every sector that is affected of this

cutting of funds, not only the agricultural sector. We cannot reach all the farmers. Actually, our target is to reach 4000 farmers a year.
42:35. Opportunity. We are expecting farmers to form a 100 coffee groups that should meet twice a month. KSAP program - support to coffee farmers (https://www.kosap-fm.or.ke/).
44:24. Barrier. We report to the government weekly that we need more staff.
45:00. Opportunity. We collaborate with farmer cooperative, Kenya Tea Climate Agency (https://www.gafspfund.org/projects/ktda-climate-smart-solution-supporting-tea-industry-east-africa), 3 factories, agrochemical companies, department of livestock, NGO Nairobi water farm (https://iwa-network.org/upper-tana-nairobi-water-fund/)
47:00. **Production of coffee** in the last 10 years. The production has been constant. Tea also. Maize, however, is going down but avocado is increasing.
48:00. Challenges. There is a lot of emphasis on climate smart agriculture but if there is no funding then it cannot work.
54:00. **Barrier/opportunity.** Soil fertility is a big issue. In three minutes, you can get the results of your soil fertility. You have to pay a small fee. Not all of them know that these exist, less than 1% have come. They are not coming because of other issues and priorities.
55:19. **Opportunities.** Only the well-up farmers who are able to use soil amendments, even for manure, purchasing manure is expensive.

2. Interview with farmer 100002 (farmers w/o irrigation)

2.55: “Before we used to have the months that we are expecting the rains to come, but nowa-days it (rain) is unpredictable, so that is a challenge”
3.10: “The weather has changed”
3.16: “Yeah, it affects a lot” (rain on growing seasons)
4.15: “The rainfall is not enough” long rains used to be in April to May, but now it is not enough
4.15: “There is no more rainfall from May upwards” (this is a change)
4.23: Maize, Irish potatoes, bananas, avocados, (relies most on water)

7.12: they lack of irrigation is influencing her choice of crops
7.52: they now plant crops that grow faster: “there is lack of water. Normally we grow like beans, you know they take short time, maybe it’s, let’s say, 2 months. And then there is maize. You can't plant that maize that takes maybe 4-5 months. You're supposed to grow maize that takes around 3 months to grow. That's what we normally do. And then there are sweet potatoes, they don't take long, they don't consume a lot of water, that's what we do. Irish potatoes also don't take a lot of time, maybe less than 3 months, they’ll grow.”
8.40: “not yet” (when asked if they do things differently, if they have adapted their practices)
9.25: You have to change because of the climate change (talking about seeds)
9.46: They used improved seeds, started 5 years ago
22.42: She thinks having money is the only reason why some people have irrigation and some don't. Distance to roads or rivers or contact with the government or part of a Sacco does not play a part.
24.50: she has never visited the agricultural officer’s office, “because we just cultivate the usual things, we haven't decided to go a bit higher and maybe plant tomatoes or horticultural things, we do our farming the usual way that we have been used to from where we are born. They follow short rains and long rains.

30.26: “the things that we are doing differently is growing trees, because we have been told by the government to add a lot of trees because of the rainfall”. “I really don't understand, but the government has been saying that we should add the trees that have been there because cutting of trees is affecting the way we get rainfall”

4.55: **Challenge**: “how we grow the crops that we are used to; we are being affected, because we can’t get the yields that we are used to”
5.24: **Challenge:** When you have access to irrigation, production will be very high. But when there is no rainfall, there will not be nothing water for irrigation.
6.09: **Barrier:** “the water that is given to the household is only for household use, if you cultivate with it or if you irrigate things, you will be prosecute” “The neighbours will tell the authorities that you are using the water to irrigate”
9.00: **Barrier:** “People are not even aware that you are supposed to do mulching on maize”
9.00 (they normally only do on Irish potatoes)
11.15 **Barrier**: “it is expensive and we don't have the government support” (for why she hasn't implemented other ways to capture water for irrigation)
10.10: **Opportunity:** She uses the internet to go through and look for ways to improve her agriculture. That’s how she found out about the seeds. She said that it depends on your interest in agriculture, the more interested you are the more you will go out and learn to improve.
10.39: “I went to Kenya E-carry / Ikaria (??), I bought beans seeds, from there, because they are good”
11.20: **Barrier:** “you know when we are in rural areas, getting like dam liners, because maybe you will be having water ponds, it’s a challenge”
11.50: **Opportunity** on how to get water: “When it is raining there is a lot of water that goes to waste, so if there is maybe a way farmers can be helped to get those water ponds, and then to get access to dam liners, you’ll be able to irrigate”
12.34: **Opportunity:** the government side, is the one which is important, because maybe farmers are not aware and they would like to cultivate food. You see, now, they are supposed to be going around, like the way you are doing, they come and tell us “We want to help you people with digging water ponds and getting dam liners” but, maybe you can contribute some amount of money and the government can contribute some amount of money, so that we can help each other. But now there is no way you will be helped, how are you going to get those water ponds?”
13.16: **Barrier**: “maybe some areas but not this area, I haven't heard of this area” (when asked if she knew of any future programs in the works, with the aim to provide dam liners or water ponds)
13.53 **Barrier and proposed Solution:** The barrier that we can see is that the government doesn't allow people to do irrigation with the water that they are giving people, that is the biggest problem” Because you see like now, even I’m able to pay the water that I’m using at home, I can also be able to pay the water that I will be using to irrigate, but if there isn't that law, I can do it.”
14.31: **Barrier**: “we don't understand why” (when asked why the government says they can’t use the water to irrigate), also she says there is water all around, there are rivers, so she doesn't understand why she can’t use the water provided for agriculture too.
15.06 **Barrier:** “even if you ask, they don't have that concrete answer to tell you why” (when we asked if she made an effort to ask why to the government)
15.30: **Opportunity**: She believes that with access to irrigation, she could go back to the yields she had 10 years ago
15.54: **Barrier:** “in rural areas, most of the farmers are not aware the irrigation they are supposed to use, so we still go back to the agricultural department, the ministry of agriculture,

that they are supposed to be giving out extension officers, to come and educate farmers, what they are supposed to be doing because of the landscape of their lands, maybe you can use drip irrigation or whichever way, but they are supposed to be educated to minimize the use of water.
16.30: **Barrier**: "it requires much labour" (about irrigation)
18.40: **Barrier:** The growth of the population she believes is a challenge related to the size of lands, because it gets split. She says a lot of people want to live the urban life even if they are in rural areas, so a lot of land is idle (empty, fallow, not used)
19.38 **Barrier:** She stopped growing coffee 20 years ago because of the government, because she couldn't get paid anything, she was getting 5 shillings for a kg. of coffee.
20.20: **Barrier and proposed Solution**: "irrigation is expensive and that's why we want the government to help the farmers. If they can start for us or maybe we cut the costs (...) half half, it will be possible" -> She emphasized again the lack of knowledge, that officers should come, look at the land, and say whether they need a borehole, drip irrigation or water ponds. For example: they drill the whole and farmers buy the dam liners and we should you how to use them.
21.03: **Barrier:** "If there is no awareness, you wouldn't be interested in something you are not aware of". "The government should play part"
23.10: **Barrier and opportunity**: "there is, but like I said there before, the awareness of the farmers" (about whether or not there are loans). She thinks again the extension officers should spread the message about this and explain how to get a loan.
28.05: **Barrier**: she sees from the internet and the media, that farmers are complaining about the high interest rate of the loans.
25.50: **Barrier:** They don't understand why extension programs have stopped, maybe it depends on each county.
28.25: **Barrier:** says the price of fertilizers, after the government subsidies, is still very high (3500 KES)

3. Interview with farmer 100008 & mom (w/ irrigation)

3:04: the biggest challenge from the past 5 years is water
4:47: They have felt strong effects of climate change on their agriculture. All of the crops are affected and yields have gone down. "Everything is drying now".
7.29: "There is drought everywhere"
7.36: "In terms of pests, no" (when asked if there was an increase)
7.44: "The quality is poor, poor, poor. Especially for the napier grass, maize"
17.57: "there are so many challenges nowadays"
18.18: "if people can get water, people can stay a bit better" "water is life, water is everything, because you can live without money, but with water, you can live, because you can grow something, and then you eat, without going to buy, so you can survive"
18.19: **challenge** "even the cows are dying" (use to be source of nutrition and income)
18.53: interesting "even the atmosphere is also affecting the health of the people" "small children are always sick (...) because of the weather, the dust"
25.25: "this year is the worst, the worst. Even we are asking, are we going to survive with these cows?"

3:55: they installed the water capture pond more than 5 years ago
4:12: the water used for their irrigation system comes from the river

8.25: they have not changed the crops they are planting
12.15: the water pond has really helped with this period of climate change
12.20: a lot of farmers are coming to their farm to buy some vegetables, because they know they have enough water to grow them. It's good for business for them.
23.50: **adaptation / changes bc of climate change:** "this drought is about five years" "the rest of the years we have never felt it, because we have been with food in the stores, like me I have never bought maize. But for these three years, I have bought. I have never bought Napier grass for my cows, and I have been having 5 or 6 cows. I have sold them now. So, I'm feeling it! We have never given these banana leaves and banana trees, we have never used them, and we are using them now (for fodder). So, we are feeling it. Going to the market to buy everything, fetching food for the cows (..) sincerely we are feeling it."
26.35: **adaption:** "now if you feel that change and there is no rain, what are you going to do my friend? There is nothing you can do. What you can do, is just look at God, you call "God now come, this is your time. Just come and take over now"".

8.40: He got the water capture pond idea 10 years ago, when he was in college, and used to go fishing himself as a hobby. Then he learnt about this, and when donors were giving dam liners, he approached them.

5:53: **barrier:** "the main reason was to do some fishing, but it was not supported by the government" "there was a group that was supposed to support that fishing project, but they did not support fully" "so what happened is after we dug the fish pond, we are using it to irrigate some part of the land, just a portion, so don't irrigate (...)"
6.40: "not really" (when asked if they were provided support to start the fish pond project) "They only provided the papers" (dam liners)
8.14: **opportunity:** Macadamia is one of the things on his farm which hasn't been affected that much
9.35: **barrier:** "there was some fee you had to pay, 3000 shillings" (So they still had to pay for something for the dam liners???)
10.10: **barrier:** "it costs a lot of money" (dam liners)
10.40 **opportunity:** (about providing dam liners) "the idea is good" "even if it is a small portion of the farm that you irrigate, it will help a lot"
11.10 **barrier:** "she (MCA) won't be able to provide for all farmers" **opportunity:** "maybe to groups"
13.00 **barriers:** their costs for irrigation were high. "You have to do the pipping, from here up to down there" "it was not done within a day, it has been done continuously (...) it's not complete. (...) "we need more pipes" 14.04 "if you have enough money, you can even do it within 3-4 weeks" "but if you don't have enough money, do it bit by bit"
14.29 **barrier:** "it took a lot of time because we had to do it manually, we had no money to pay for laborers so we were working with him (the son). So, you work day by day until you complete" "Then getting the pipes to take the water down there is another process, because you still need money (...) so you have to wait, to get that money, to drop these pipes down there"
15.03: **opportunity:** "it's a process, but if supported by the government or any other company, you can do it as soon as possible, as quickly as possible"
15.25: **barrier**: "if I'm told to ask, I can ask somewhere" (sounds like she didn't know where to ask for help for irrigation)
15.33: "the support that the government give us is just that paper, nothing else" "that program did not last for long" "we did not know the actual company that was doing the work, we were being told "it is the government that is funding", by somebody that brought those papers

16.23: **barrier:** everyone can build a pond, it just takes time and labour, but the problem for small scale farmers is the price of the pipes and the paper (dam liners)
16.50: **opportunity:** "what one can do is harvest this one (the rainwater) during the rainy seasons, you can get these gutters and you can take it to the pond. So, you can have enough water." The same with the water that is captured in the tanks
17.20: **barrier:** "challenges are so big, so much, we have so many challenges" "no rain, no money, without money, no food, without money, no work. Without rain, no food." "People are staying at the same level of poverty".
17.50: **barrier:** "whether you have these little things in your chamber, people are coming to steal, because they are hungry"
19.37: **opportunity:** "what the government should do now. We have roads, **the next thing they should do, is do whatever they can do to supply water.** If everybody can get water, for irrigation, not for drinking, there is a lot of water for drinking (...) at least, every village, because there are so many rivers, so, people can do work, and they can survive well. "And even the economy will drop (I think she meant do better) because that challenge of going to import food somewhere, it will stop"
20.45: opportunity: "let them prioritize water" (the gov)
"Let them prioritize water" (20.45)
21.14: **barrier:** "Mulching, without water? Without rain?" "You cannot mulch, without rain" "we mulch the soil when it is watered" "when it is dry like this way, you cannot do mulching" (in response to the MCA's suggestions)
21.33: **opportunity:** "first of all, supply water, then, the litter I will get, I will start mulching, because evaporation is very high, isn't it. Even you go to rivers, there is no water, they are almost drying up, because evaporation is very high. It is a good idea but, during this time, it will not succeed. They cannot succeed nowadays, unless it rains"
22.19: **opportunity:** "if they do it during rainy season, it will be okay, because if they supply that water for irrigation, me I come and construct my dam there. I will harvest my water with tanks." she is saying the competition for water won't be so high if some are able to use water capture ponds, others tanks, while irrigation is being installed for everyone. But it has to be done during rainy seasons.
23.00: **opportunity…?** "It is not all farmers that have plenty of land to do irrigation, some even doesn't have a portion like this one, so it's very few who are going to use this water. But those who have water, they will supply others with food"
27.15 about politics: "Here politics is usual. That one is usual. And we enjoy it. We just enjoy it on TV, when we see them fighting one another. Because you know, the government has nothing else to do, because the president on the throne now, has taken from the worst. So, to (...) pull that government up, it will need a lot of time, (...) and a lot of challenges, so there must be this noise." 28.30: "me, I have trust in it. I have 100% trust, because I know, after these challenges, everything is going to be settled." "It must take time"
30.30 **barriers and opportunities:** "that one belongs to minister, to MP." "When he comes, does he ask me, do you have food? No? Then why can I go and talk to him? Why should I? Its better I talk to those ones, better than him" (talking about her other neighbours in a similar situation as her). "I am comfortable with those people there because they are of my standard".
31.20 "we help one another. When there is rain, we help one another to rear our cows, we talk with them, we advise one another, we sit down, we discuss things. When is time for planting, what type of maize are you planting, are you planting cabbage, are you planting Sukuma wiki, what kind of food are you giving your animals? (...) what insecticides are you using? We interact, yes".
32.10: **opportunity:** they are part of the coffee society, which help them. They provide them insecticide with the system of credit for example. She will pay it during the payment time. Same for fertilizers. They also educate them. They bring people to educate them for free.

They think the education is very helpful. More than a thousand farmers are part of this she believes.
→ 33.17 **barrier:** they received education but not about irrigation or water capture ponds. But she hopes the gov will do it soon. Nowadays they need to figure it out by themselves. They can only rely on the small amount of knowledge they got from school. She studied agriculture.
34.45: **opportunity:** the TV is where they sometimes get information about groups that can provide education to them.
36.25: **opportunity and barrier:** if someone can provide even a loan, and you pay little by little, you can help yourself. But she was not aware of any loans nowadays that people can take for irrigation. She believes people can go out and get loans, and if they organize a group and register it, she can get money from somewhere else. She thinks there is an opportunity. She thinks it's not easy, the group has to be registered and active, then they can get a loan.
37.50 barrier: "greenhouses are too expensive, very expensive, very expensive (...) you need more than one hundred thousand to construct a greenhouse" (...) "But with a dam it is less."
44.17 **barrier:** She is saying that harvesting water will depend on one's interest and capability. It is possible someone will be provided with dam liners but will not want them because they do not want to work or they are not interested, and they may only want a tank.

4. Interview with farmer 200017 (w/ irrigation, "high tech")

1:10. Challenge The water level has gone down. The rainfall has changed a lot during this 3 last years. This affects the crops we do here. We have expected march harvest but because the maize has not received enough water. The temperature affects the crops: the maize, the avocado. If the temperature is too high or too low it puts stress in the crops.
4:20. Challenge We expect long rain from march-April to mid may, and short rains from October to November. But the rain has changed drastically, it rains one or two days. After a prolonged drought, when it rains it rains heavier.
5:55. Opportunity. Cassava and yam are drought resistance, the challenge we have is that there are some animals that come and break the crops. Coffee needs some moisture. Another challenge we have when it comes to vegetables is that the animals are hungry and come to eat the food.
7:47. Challenge. The challenge is water. There has been more damage from animals than before. Pests is another challenge, that is why we spread pesticides. There was a challenge of a coffee disease for the smallholders' farmers but they came with a very good item.
11:21. Opportunity. They spread a pesticide for controlling the diseases. It is better to control than to cure. This control was spread from extension programs coming from the agricultural officer.
11:38. Challenge. This is the first year of irrigation. We shift from rain-fed to irrigation because of the climate change challenge. Also, we wanted more harvest.
12:30. Opportunity. We have changed of maize seeds; the variety grows faster. 5 months for the short rainfall.
12:36. Irrigation cost. 3M ash. 1.8 to dig the borehole, to install the pipe itself, the dam…
16:20. Irrigation labour. It took about 2 weeks of work. After setting up it is necessary to have 3 workers to control it and make this farm run. Some specialists came here and design the irrigation system for them. It is a personal investment; he has not used any help from the government.

19:14. Water used by the system. Every day the system uses around 10.000 L. It changes during the season. When it becomes the rainy season, we can maybe use 5.000 L. We can store the water if it rains a lot.
21:36. **Opportunities.** Since we planted the maize, we have been using this irrigation system all the days and it has been successful. There is much success, at least there is some maize we can sell. Before there was not much production, and they had the challenges of pests, no water. But right now, there is a big change.
23:02. Challenges. Sometimes there is too much pressure from the water to the pipes.
23:44. Opportunities. The deep irrigation was set when the crops were already planted. We want to develop as an extension centre. Becoming an extension centre, they want to —--> (don't understand)
27:26. Opportunities. We prioritize growing coffee, because there is already a market, so we do not have the stress of having to find a market. Coffee is number 1.
We are planning to grow tomatoes and cash crops in the greenhouses.
28:00. Avocados are profitable. The challenge for the farmers is that they do not have much water to irrigate it.
29:00. Opportunities. Greenhouses are a new technology, when using it you have more production. You can plant a lot of plants in a small portion, in a big field you cannot squeeze them, simply because there is the challenge of some diseases. When in the greenhouse you do not have that many challenges and you can control the pests and the diseases. Greenhouse is a very big solution.
30:00. Barrier. Implementing a greenhouse is a bit costly. But I know some groups that have some joints together. They joined funds and built one greenhouse. After some time, and getting the profit from the first one, they can build a second one.
30:37. Opportunity. In an open field you have to use much more water because of the sun, but inside, it is a few litters of water that you use.
31:10. Effects of irrigation. The irrigation has a positive impact on the soil fertility. The plant will be boosted just because there is water in the soil. Irrigation has a really positive impact; the system is more efficient and effective. There is more production.
35:00. This land is 5 acres, about 3 acres receive irrigation.
36:30. Socio-economic different status. Some farmers are doing very great, but not that great, because if you go to other areas, you can see that they are doing better.
Challenges:

- Language barrier
- Awareness problem

These big problems can be caused because of lack of group work.
The main problems are: cooperation, group-work and education. Even if they get some finances, if they are not educated it is not going to be useful. Before getting these finances, they have to be educated on what they want to do, how they have to start.
46:48. Challenge. We do not have farms that do extension programs in this area. We are missing farms that offer extension programs.
40:31. Challenge. The farmers do not want to get help from the extension officers. They are willing to help farmers but farmers do not want to get help from. They are already comfortable with what they do. The government should try to implement more extension programs.

5. Interview with Soil Guy

Drought in addition to, low productivity due to acidic soil, acidity is easily compensated for, by testing

Improvement through: testing, lime, organic manure or compost

Barrier: Lack of Knowledge: no awareness of the importance of soil fertility ergo no need for testing ⇒ more advertisements, more use
Barrier: lack of testing facilities. 2 machines in Nyeri (although still under maximum capacity 300 sample per year)
Opportunity: Testing scheme. Soil testing with officers can provide farmers with advice on which crops to plant where/which practices to use. Can't solve problem of drought, but at least compensate for acidity, knowledge gap can be closed, as offices will interpret the result if needed
Barrier: price 300KES per sample

6. SPG Interview with Solar Panel Guy.

2:30: At the moment it is not wet, and there are so many pests.
3:00: Some of our boreholes are almost dried up.
4:17: The coffee is drying up [...] and so the quality reduces, and the prices will be lower.

6:00: Since 2018 we have the irrigation and the Solar Panels to power the irrigation

7:03: **Barrier:** The initial cost of instalment is quite high, but after that it is manageable.
9:10: **Opportunity:** Instead of fetching water from the river, which is quite time consuming, they can have our water directly [...] and we are also taking water from the [Changa]dam.
10:20: **Opportunity:** Our founder started the initiative, because he wanted to have irrigation on his farm and therefore, he had to ask the others for permission to run the water through their farms [...] so he allowed them to use some of what was passing through [...] otherwise they pay.
13:10: They are Paying nothing????
15:50: The irrigation is helping a lot to keep track of production
21.50: for irrigation (farmers) they can get loans.
23.34: **Opportunity:** If we are doing the irrigation for them, they will take their coffee to us instead of the cooperatives [...] and we will pay them for the coffee at a competitive price
24:30: If you sell coffee to the cooperatives, it goes to the factory and they depend on government support, we do not.
25:18: If you sell to us, you'll get more money????

M3 Code

```
//%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%
// THE EFFECTS OF CLIMATE VARIABILITY ON SMALLHOLDER AGRICULTURAL PRACTECIES IN THE SUBCOUNTY OF OTHAYA,
KENYA - LAND COVER CLASSIFICATION


// Carl Stadie, UCPH, MSc Geography and Geoinformatics, grx152@alumni.ku.dk
//%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%



// MODIFIABLE VARIABLES



var aoi = ee.FeatureCollection('users/CarlStadie/aoi_othatya'); // define aoi as county borders



var start_date_1 = '2016-01-01';                            // define time frame for 2016
var end_date_1 = '2016-12-31';


var start_date_2 = '2022-01-01';                            // define time frame for 2016
var end_date_2 = '2022-12-31';


var cloudfilter = 0;




// FUNCTIONS


// Cloudmask function to mask clouds in all images


function cloudmask_sentinel_2(image) {

        var qa = image.select('QA60');                              // selcect proper Quality band

        var cloudbitmask = 1 << 10;
        var cirrusbitmask = 1 << 11;

        var mask = qa.bitwiseAnd(cloudbitmask).eq(0).and(           // filter according to encoded bits
                qa.bitwiseAnd(cirrusbitmask).eq(0));

        return image.updateMask(mask).divide(10000)                 // devide by 10 000 to get reflection
as float
        .select("B.*") // copy all bands
        .copyProperties(image, ["systm:time_start"]);               // copy all image properties
}


// add NDVI


var add_ndvi = function ndvi(img) {
var nd = img.normalizedDifference(['B8', 'B4']).rename('NDVI'); //compute ndvi as additional band


  return img.addBands(nd);                                  // add computed band to every image
};




// IMAGE COLLECTIONS


// Querry 2016
```

```
var s2_2016 = ee.ImageCollection('COPERNICUS/S2_HARMONIZED')  // image collection of sentinel 2 corrected
for atmospheric influences
  .filterBounds(aoi)                                        // filter for images within the aoi
  .filterDate(start_date_1, end_date_1)                     //filter for images within the time frame
  .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 20))      // filter for images with less then 20% cloud
cover to save computing time
  .map(cloudmask_sentinel_2)                                //apply cloudmask funtion
  .map(add_ndvi);                                           //apply ndvi function


//print(s2_2016, 'REPORT collection 2016');


// Querry 2016


var s2_2022 = ee.ImageCollection('COPERNICUS/S2_HARMONIZED')  // image collection of sentinel 2 corrected
for atmospheric influences
  .filterBounds(aoi)                                        // filter for images within the aoi
  .filterDate(start_date_2, end_date_2 )                    //filter for images within the time frame
  .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 20))      // filter for images with less then 20% cloud
cover to save computing time
  .map(cloudmask_sentinel_2)                                //apply cloudmask funtion
  .map(add_ndvi);                                           //apply ndvi function


//print(s2_2022, 'REPORT collection 2022');



// calculate STMs


var STM_2016 = s2_2016.select('B2', 'B3', 'B4', 'B5', 'B6', 'B7', 'B8', 'B9', 'B10', 'B11', 'B12',
'NDVI').reduce(ee.Reducer.percentile([10, 25, 50, 75, 90])).clip(aoi);
print(STM_2016, 'STM 2016');                                // for each band and pixel selct the
10/25/50/75/90 Percentile



var STM_2022 = s2_2022.select('B2', 'B3', 'B4', 'B5', 'B6', 'B7', 'B8', 'B9', 'B10', 'B11', 'B12',
'NDVI').reduce(ee.Reducer.percentile([10, 25, 50, 75, 90])).clip(aoi);
print(STM_2022, 'STM 2016');                                // for each band and pixel selct the
10/25/50/75/90 Percentile






// IMAGE CLASSIFICATION


// Classification 2016


var training_data_2016 = STM_2016.sampleRegions({           // sample STM values at training points
        collection: training,
        properties: ['lc'],
        scale: 10,
        tileScale:2
});


//print(training_data_2016.limit(10), 'training_data_2016')


var bands = STM_2016.bandNames();                           // define wich bands to use for classification


var classifier_2016 = ee.Classifier.smileRandomForest(100).train({
  features: training_data_2016,
  classProperty: 'lc',
  inputProperties: bands                                    // train classifier using random forest with
100 decision trees
});


var classified_2016 = STM_2016.classify(classifier_2016);   // apply classifier to iamge
```

```
//print(classified_2016, 'classified 2016')


// Classification 2022


var training_data_2022 = STM_2022.sampleRegions({           // sample STM values at training points
        collection: training,
        properties: ['lc_2022'],
        scale: 10,
        tileScale:2
});


//print(training_data_2022.limit(10), 'training_data_2022')


var classifier_2022 = ee.Classifier.smileRandomForest(100).train({
  features: training_data_2022,
  classProperty: 'lc_2022',
  inputProperties: bands                                    // train classifier using random forest with
100 decision trees
});


var classified_2022 = STM_2022.classify(classifier_2022);   // apply classifier to iamge


//print(classified_2022, 'classified 2022')




// ACCURACY ASSESSEMT


// Accuracy 2016


var validation_2016 = classified_2016.sampleRegions({       // sample class vaulue from classified image
  collection: validation,
  properties: ['lc'],
  scale: 10,
  tileScale:2
});


//print(validation_2016, 'REPORT validation 2016')


var Accuracy_2016 = validation_2016.errorMatrix('lc', 'classification');
print(Accuracy_2016, 'ERROR MATRIX 2016');                  // compare classified value to observed ground
truth
print(Accuracy_2016.accuracy(), 'OVERALL ACCURACY 2016');


// Accuracy 2022


var validation_2022 = classified_2022.sampleRegions({       // sample class vaulue from classified image
  collection: validation,
  properties: ['lc_2022'],
  scale: 10,
  tileScale:2
});


//print(validation_2022, 'REPORT validation')


var Accuracy_2022 = validation_2022.errorMatrix('lc_2022', 'classification');
print(Accuracy_2022, 'ERROR MATRIX 2022');                  // compare classified value to observed ground
truth
print(Accuracy_2022.accuracy(), 'OVERALL ACCURACY 2022');
```

```
// ADD RESULTS TO MAP


var count_sentinel_2016 = s2_2016.select('B1').count();     // number of observations
var count_sentinel_2022 = s2_2016.select('B1').count();     // number of observations


Map.addLayer(count_sentinel_2016.clip(aoi), {min: 0, max: 40, palette: ['007fff', 'ff0000']}, 'S2 2016
count', false);
Map.addLayer(count_sentinel_2022.clip(aoi), {min: 0, max: 40, palette: ['007fff', 'ff0000']}, 'S2 2022
count', false);


var sentinel_param = {bands: ['B4_p50', 'B3_p50', 'B2_p50'], min: 0, max: 0.35}; // visualisation parame-
ters for image composites


Map.addLayer(STM_2016.clip(aoi), sentinel_param, 'true colour composite 2016', false); // example image
from 2016
Map.addLayer(STM_2022.clip(aoi), sentinel_param, 'true colour composite 2022', false); // example image
from 2022



var palette = ['145a32', ' 5dade2', ' e74c3c', ' 808b96', ' abebc6', ' f4d03f', ' 7e5109']; //woody, water,
urban, tea, low, corn, coffee, palette for classified images


Map.addLayer(classified_2016.clip(aoi), {min: 1, max: 7, palette: palette}, 'Land Cover Classification
2016'); // classified image for 2016
Map.addLayer(classified_2022.clip(aoi), {min: 1, max: 7, palette: palette}, 'Land Cover Classification
2022'); // classified image for 2022




// ADD SLIDER


var left_map = ui.Map();
var right_map = ui.Map();


var LCC_2016 = ui.Map.Layer(classified_2016.clip(aoi), {min: 1, max: 7, palette: palette})
var LCC_2022 = ui.Map.Layer(classified_2022.clip(aoi), {min: 1, max: 7, palette: palette})


var layer_2016 = left_map.layers()
var layer_2022 = right_map.layers()


layer_2016.add(LCC_2016)
layer_2022.add(LCC_2022)


var label_2016 = ui.Label('2016');
label_2016.style().set('position', 'top-left').set('fontWeight', 'bold').set('fontSize', '20px')


var label_2022 = ui.Label('2022');
label_2022.style().set('position', 'top-right').set('fontWeight', 'bold').set('fontSize', '20px')


left_map.add(label_2016)
right_map.add(label_2022)


var slider = ui.SplitPanel({
  firstPanel: left_map,
  secondPanel: right_map,
  orientation: 'horizontal',
  wipe: true
});


ui.root.clear()
```

```
ui.root.add(slider)


var linkpanel = ui.Map.Linker([left_map, right_map])


left_map.setCenter(36.93, -0.5826, 12);                              // center map on area of interest (aoi)
right_map.setCenter(36.93, -0.5826, 12);                             // center map on area of interest (aoi)


// ADD CHARTS


var data_2016 = ee.List([188, 1.25, 12.63, 17.80, 71.83, 15.72, 52.25]);     // area of lc classes in sqkm


var chart_2016 = ui.Chart.array.values(data_2016, 0, 0)                      // coloumn chart
  .setChartType('ColumnChart')
  .setOptions({
        title: 'Area of Land Cover Classes in 2016',
        color: ['273746'],
        hAxis:
                 {title: 'Class', titleTextStyle: {italic: false, bold: false}},
        vAxis: {
        title: 'Area [km²]',
        titleTextStyle: {italic: false, bold: false}
        },
        });



var chartPanel_2016 = ui.Panel({                                             // define position of panel on
UI
  style: {
        position: 'bottom-right',
        padding: '8px 15px',
        width: '800px',
  }
});
chartPanel_2016.add(chart_2016);                                             // add chart to panel


right_map.add(chartPanel_2016);                                              // add panel to map


var data_2022 = ee.List([200, 1.36, 14.25, 15.96, 87.94, 4.6, 34.89]);       // area of lc classes in sqkm


var chart_2022 = ui.Chart.array.values(data_2022, 0, 0)                      // coloumn chart
  .setChartType('ColumnChart')
  .setOptions({
        title: 'Area of Land Cover Classes in 2022',
        color: '#273746',
        hAxis:
                 {title: 'Class', titleTextStyle: {italic: false, bold: false}},
        vAxis: {
        title: 'Area [km²]',
        titleTextStyle: {italic: false, bold: false}
        },
        });



var chartPanel_2022 = ui.Panel({                                             // define position of panel on
UI
  style: {
        position: 'bottom-right',
        padding: '8px 15px',
        width: '800px',
  }
});
chartPanel_2022.add(chart_2022);                                             // add chart to panel


right_map.add(chartPanel_2022);                                                      // add panel to map


var data_change = ee.List([12, 0.11, 1.62, -1.84, 16.11, -11.12, -17.36]);
```

```
var chart_change = ui.Chart.array.values(data_change, 0, 0)
  .setChartType('ColumnChart')
  .setOptions({
        title: 'Area of Land Cover Class Change between 2016 and 2022',
        color: '#273746',
        hAxis:
                {title: 'Class', titleTextStyle: {italic: false, bold: false}},
        vAxis: {
        title: 'Area [km²]',
        titleTextStyle: {italic: false, bold: false}
        },
        });



var chartPanel_change = ui.Panel({
  style: {
        position: 'bottom-right',
        padding: '8px 15px',
        width: '800px',
  }
});
chartPanel_change.add(chart_change);


right_map.add(chartPanel_change);




// ADD LEGEND


var legend = ui.Panel({
  style: {
        position: 'bottom-left',
        padding: '8px 15px'
  }
});


var legendTitle = ui.Label({
  value: 'Land Cover Class',
  style: {
        fontWeight: 'bold',
        fontSize: '18px',
        margin: '0 0 4px 0',
        padding: '0'
        }
});


legend.add(legendTitle);


var makeRow = function(color, name) {


        var colorBox = ui.Label({
        style: {
        backgroundColor: '#' + color,

        padding: '8px',
        margin: '0 0 4px 0'
        }
        });


        var description = ui.Label({
        value: name,
        style: {margin: '0 0 4px 6px'}
        });


        return ui.Panel({
        widgets: [colorBox, description],
        layout: ui.Panel.Layout.Flow('horizontal')
        });
};


var palette = ['145a32', '5dade2', 'e74c3c', '808b96', 'abebc6', 'f4d03f', '7e5109'];
```

```
var names = [ '0: woody vegetation',
                  '1: water',
                  '2: urban structures and open soil',
                  '3: tea',
                  '4: low vegetation and other crops',
                  '5: maize',
                  '6: coffee'


];


for (var i = 0; i < 7; i++) {
  legend.add(makeRow(palette[i], names[i]));
  }

left_map.add(legend);


// EXPORT IMAGES



/*
var projection = classified_2016.select('classification').projection().getInfo();


Export.image.toAsset({
  image: classified_2016,
  description: 'classified_2016',
  crs: projection.crs,
  crsTransform: projection.transform,
  region: aoi
});


Export.image.toAsset({
  image: classified_2022,
  description: 'classified_2022',
  crs: projection.crs,
  crsTransform: projection.transform,
  region: aoi
});
*/
```

R1 Accuracy matrix

2016

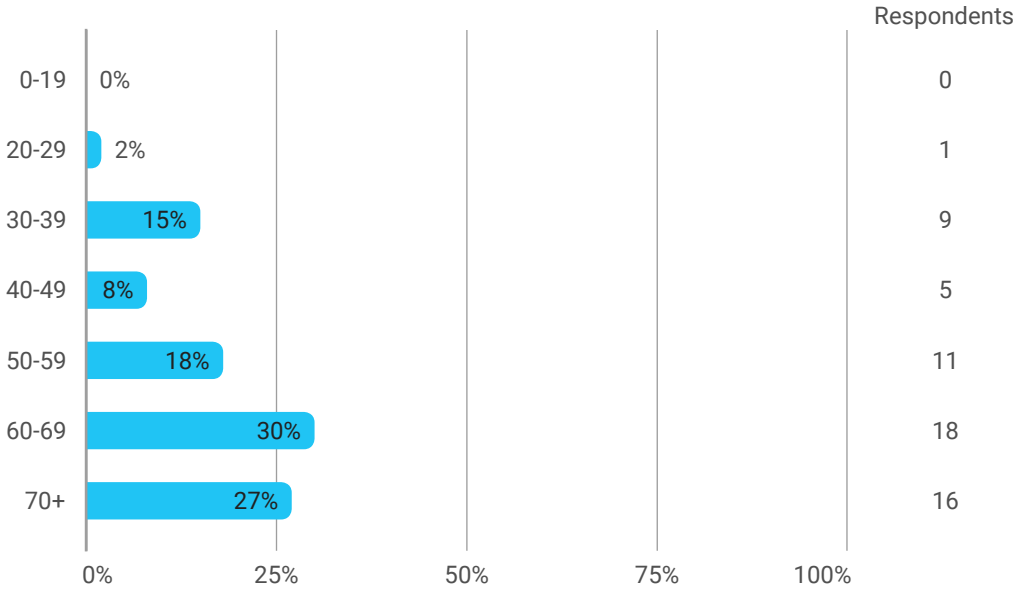
Overall Accuracy = 81.7%		observed 2016						
		woody vegetation	water	tea	urban structures and open soil	low vegetation and other crops	maize	coffee
predicted 2016	woody vegetation	10	0	0	0	0	0	1
	water	1	7	0	0	0	0	1
	urban structures and open soil	0	0	9	0	1	0	0
	tea	0	0	0	8	0	4	0
	low vegetation and other crops	0	0	1	0	11	0	0
	maize	0	0	0	3	1	12	1
	coffee	1	0	0	0	0	0	10

2022

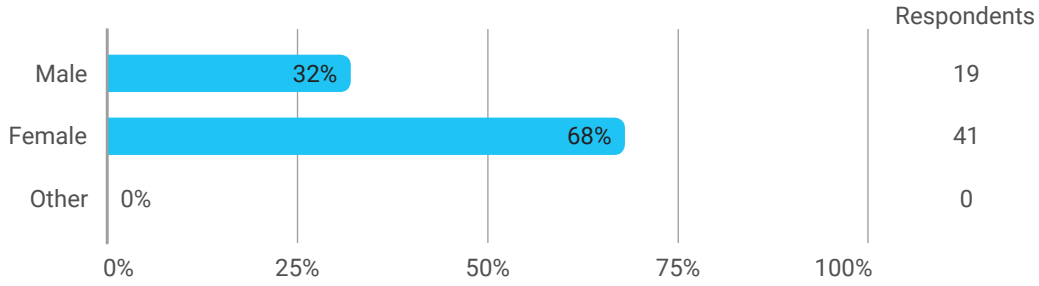
Overall Accuracy = 87.8%		observed 2022						
		woody vegetation	water	tea	urban structures and open soil	low vegetation and other crops	maize	coffee
predicted 2022	woody vegetation	12	0	0	0	0	0	1
	water	0	9	0	0	0	0	0
	urban structures and open soil	0	0	10	1	2	0	0
	tea	1	0	0	12	0	0	0
	low vegetation and other crops	0	0	0	0	13	0	0
	maize	0	0	0	3	0	7	0
	coffee	0	0	0	0	2	0	10

D1 Survey Results

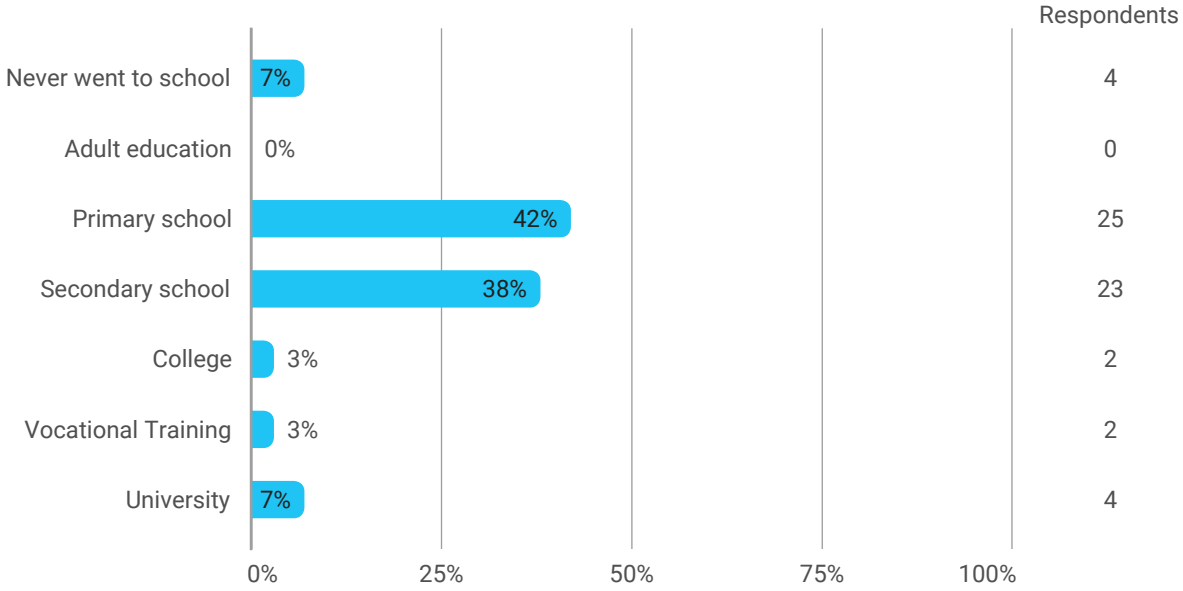
2. The respondents age?



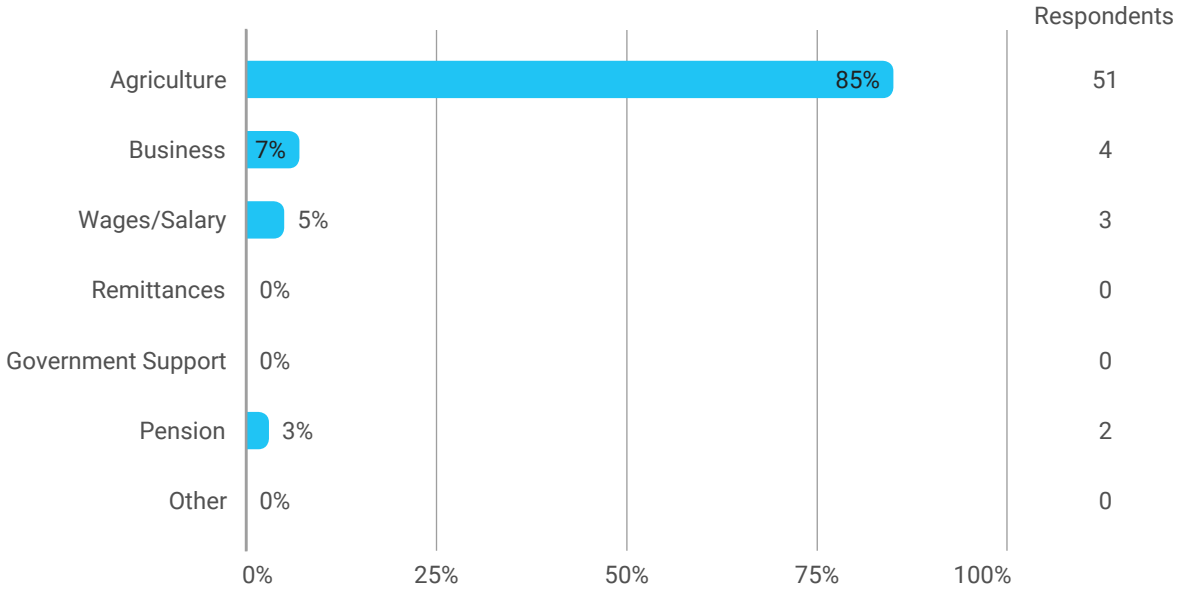
3. Gender



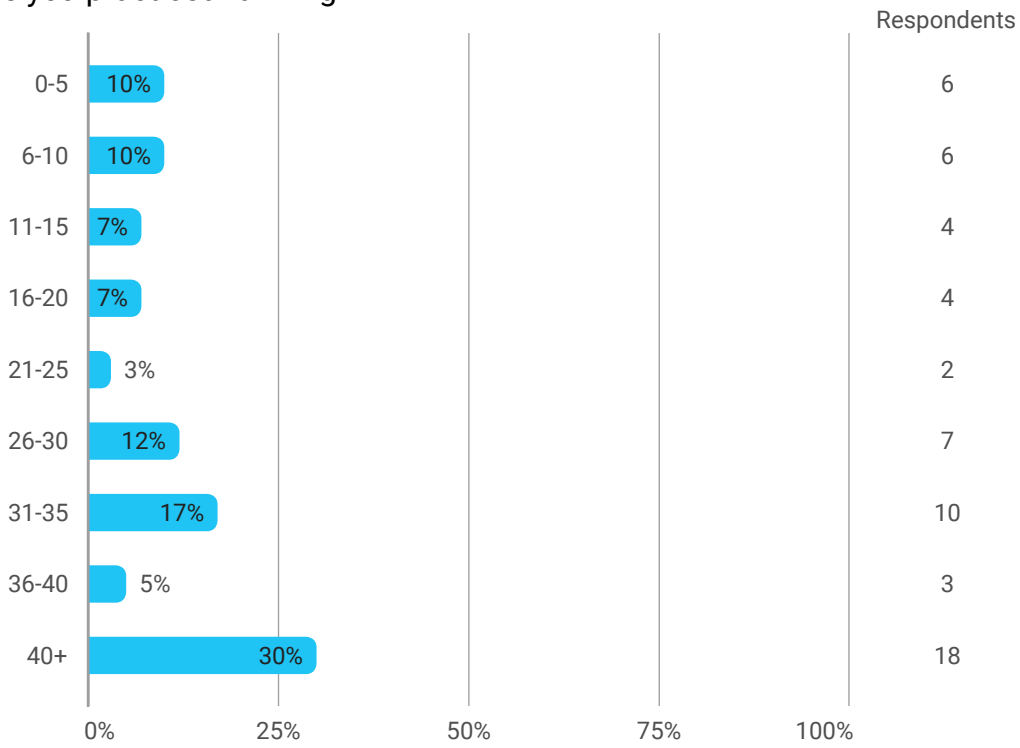
4. Education level



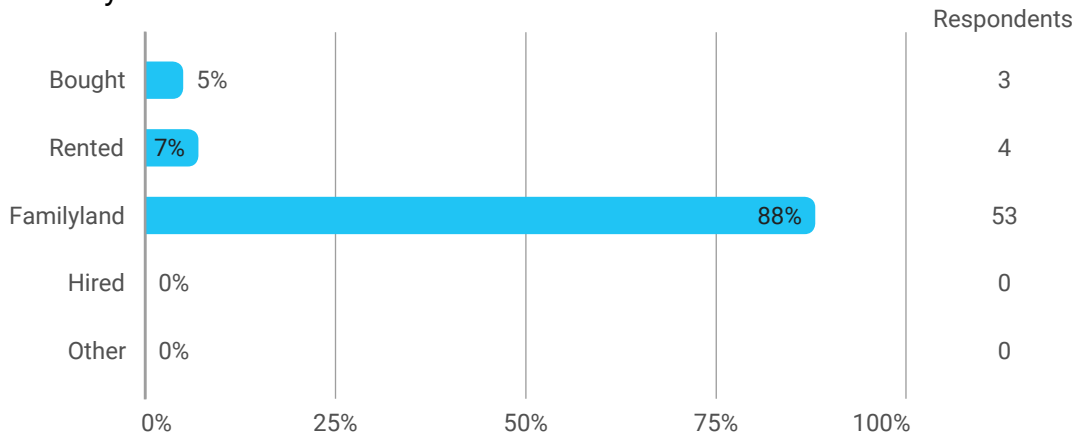
7. What is your main source of income?



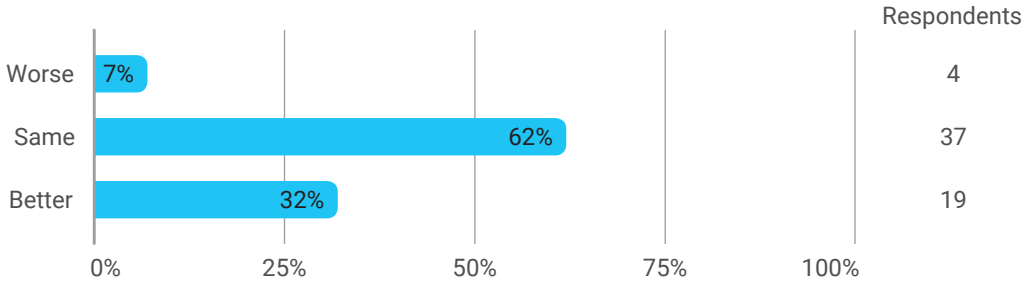
8. For how many years have you practiced farming?



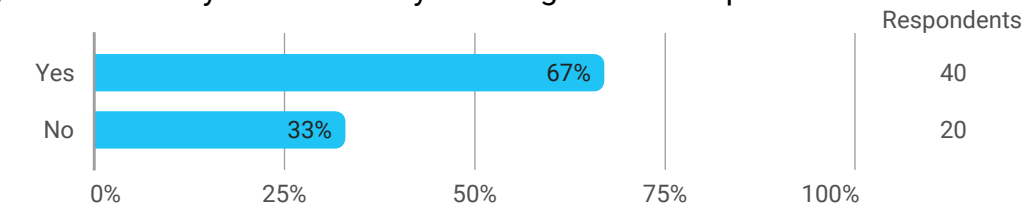
10. What is the land tenure of your farm?



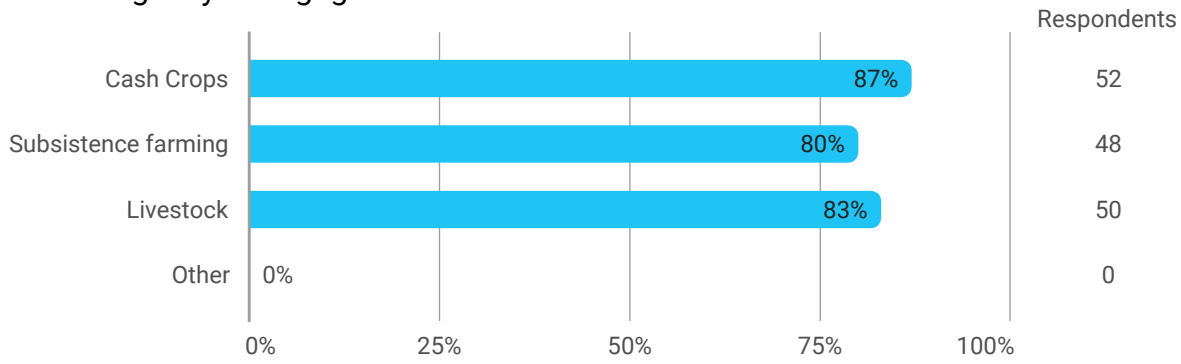
11. How fertile do you consider your soil compared to your neighbours soil?



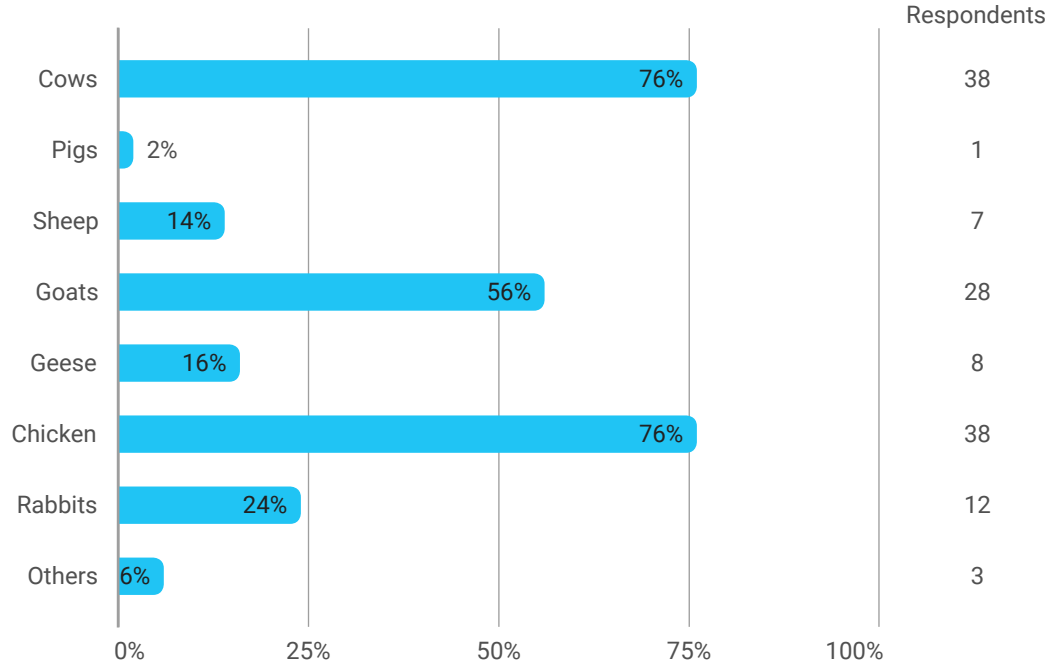
11.1 Have you heard that you can check your soil fertility in the agricultural department?



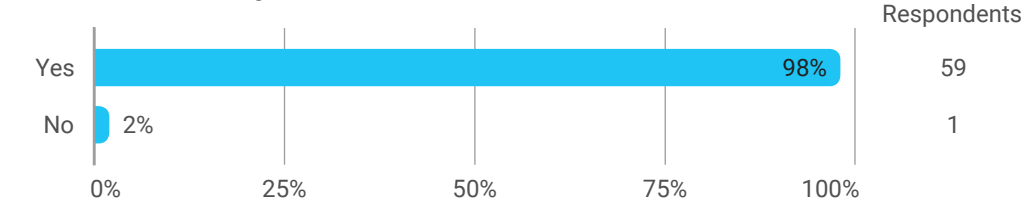
12. Which type of farming do you engage in?



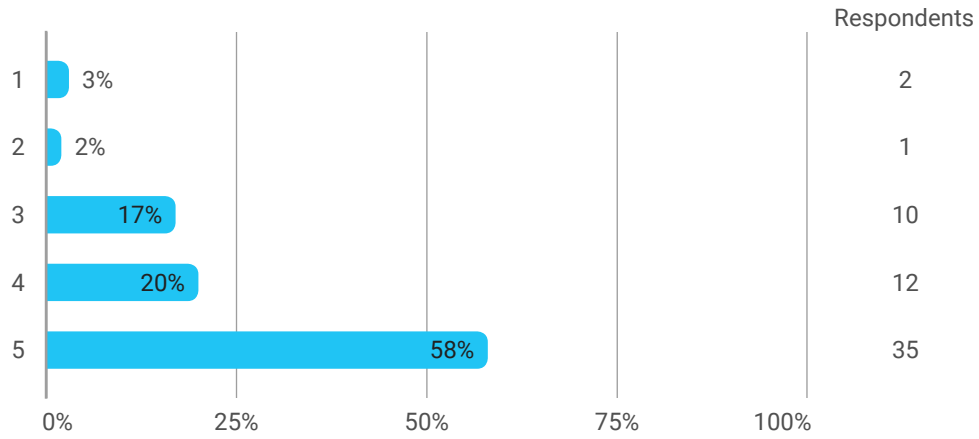
12.1. What animals?



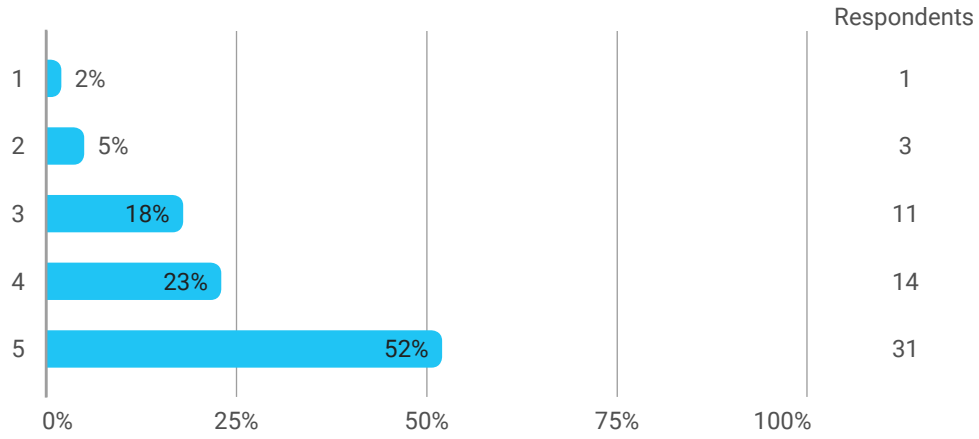
13. Have you ever heard about climate change?



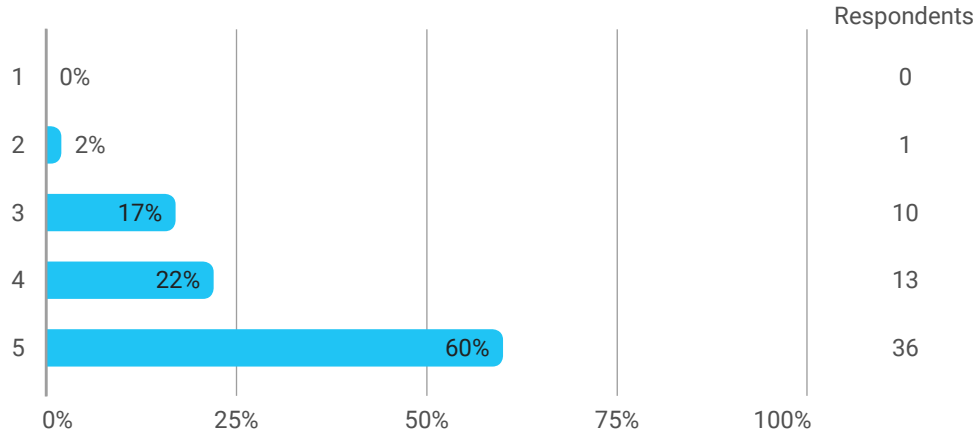
14. How much do you think changes in temperature affect crop production, on a scale of 1 (lowest) to 5 (highest)?



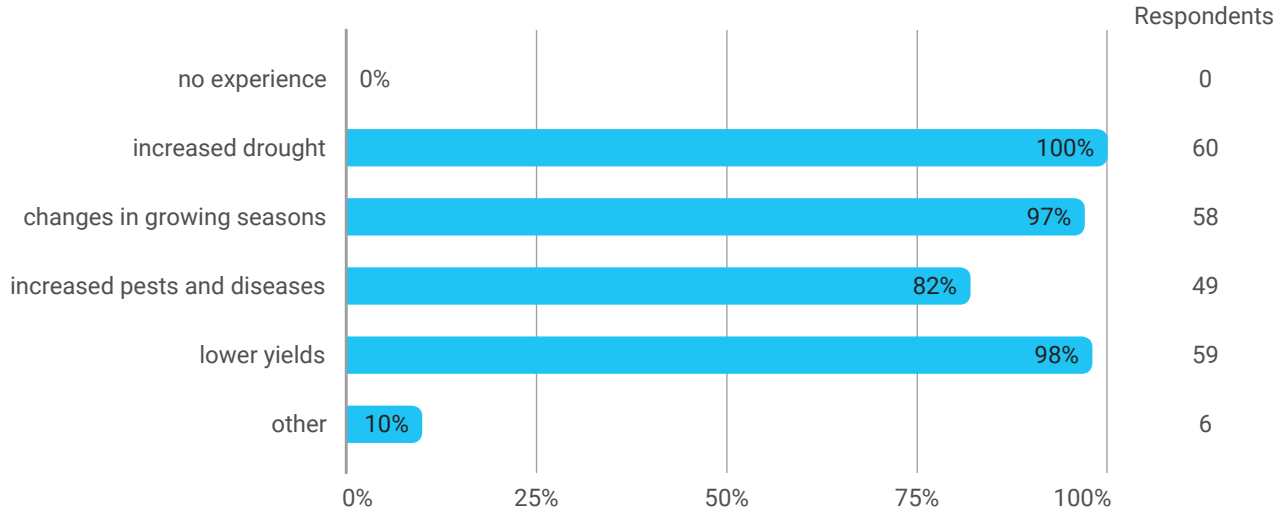
15. How much do you think changes in temperature affect livestock production, on a scale of 1 (lowest) to 5 (highest)?



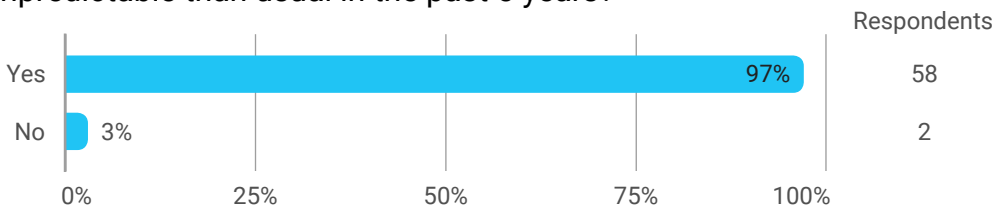
16. How have you felt the effects of climate change in the past five years on a scale from 1-5? (1 lowest - 5 highest)



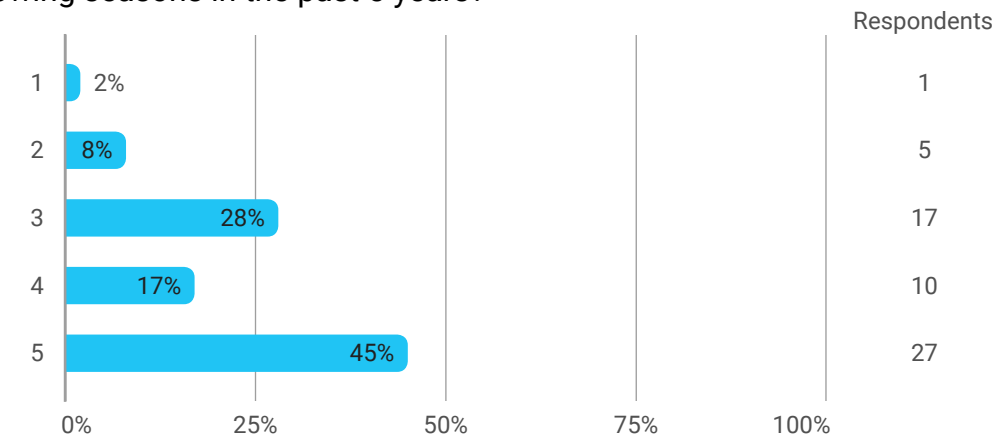
17. Have you experienced any of the following?



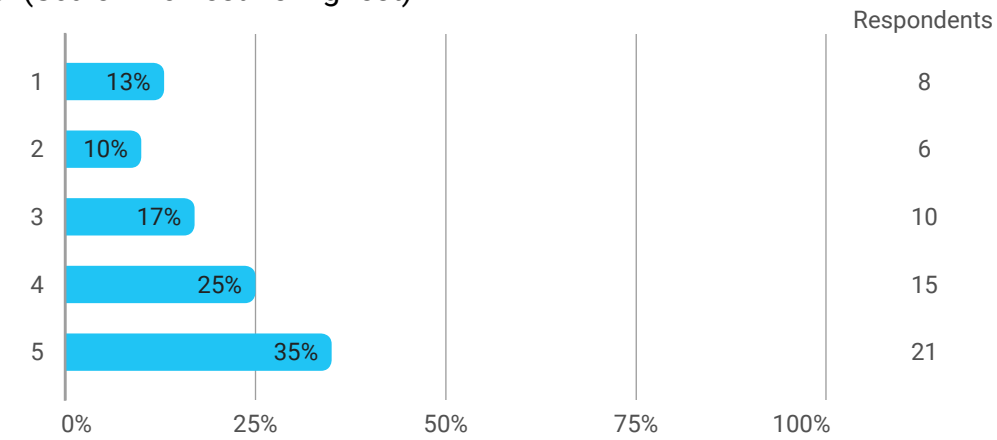
18. Has rainfall been more unpredictable than usual in the past 5 years?



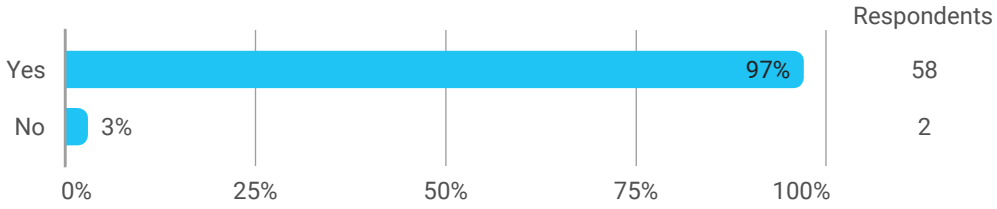
19. To what extent do you agree with this statement, on a scale of 1 (lowest) to 5 (highest): There has been a change in the growing seasons in the past 5 years?



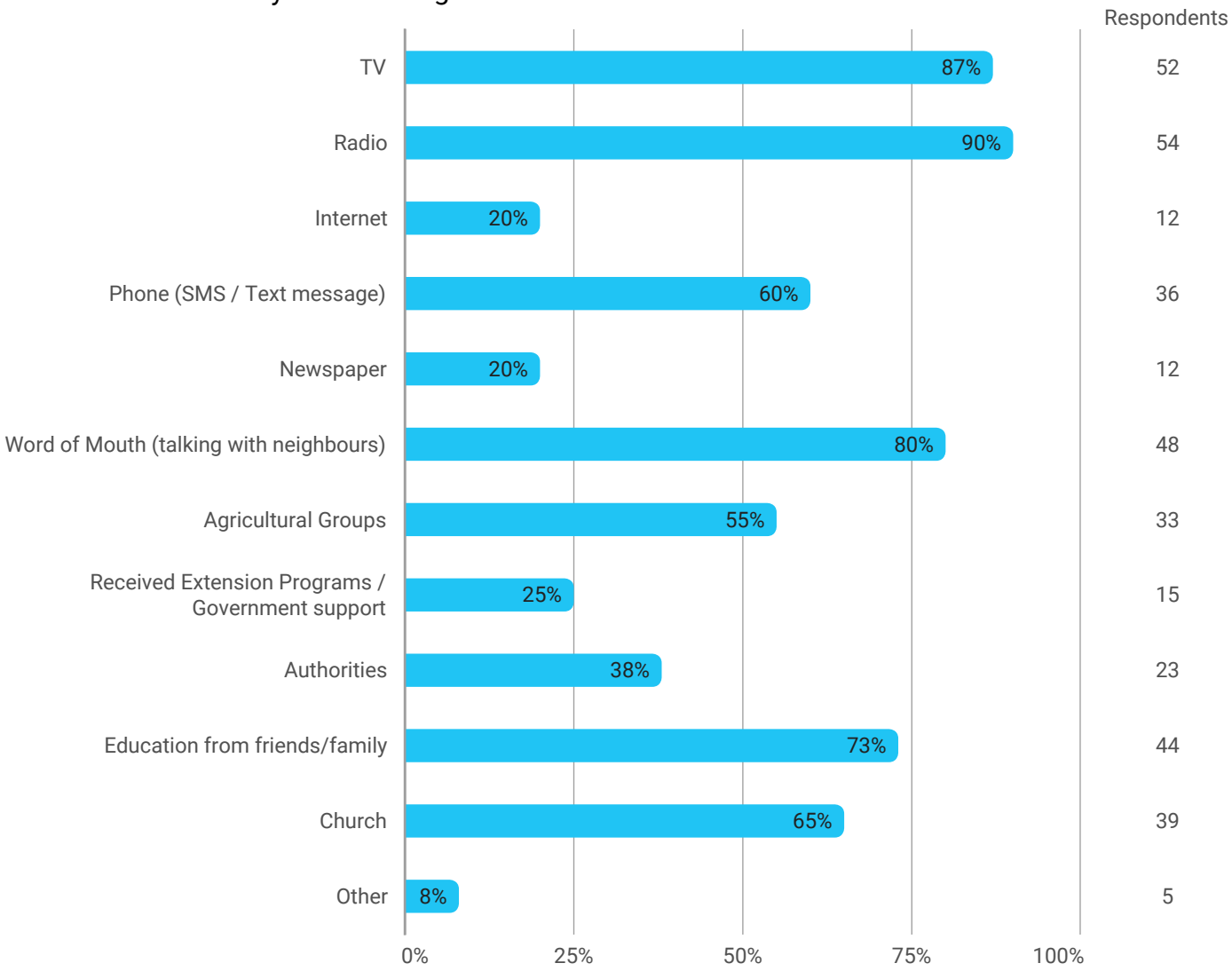
20. Do you agree with this statement: I have had to change my agricultural practices in the past 5 years, due to climate change. (Scale: 1 lowest - 5 highest)



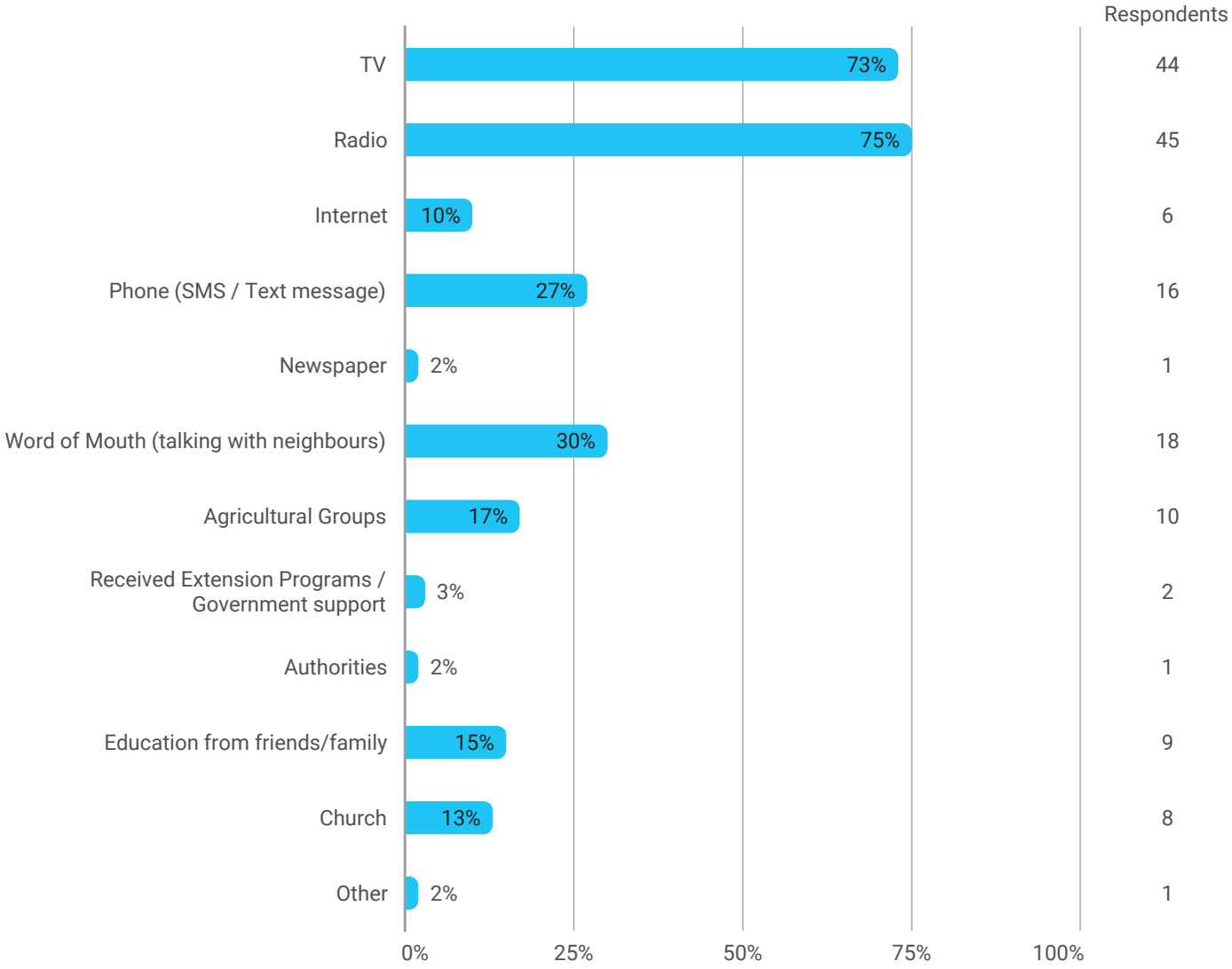
21. Do you receive information about the weather?



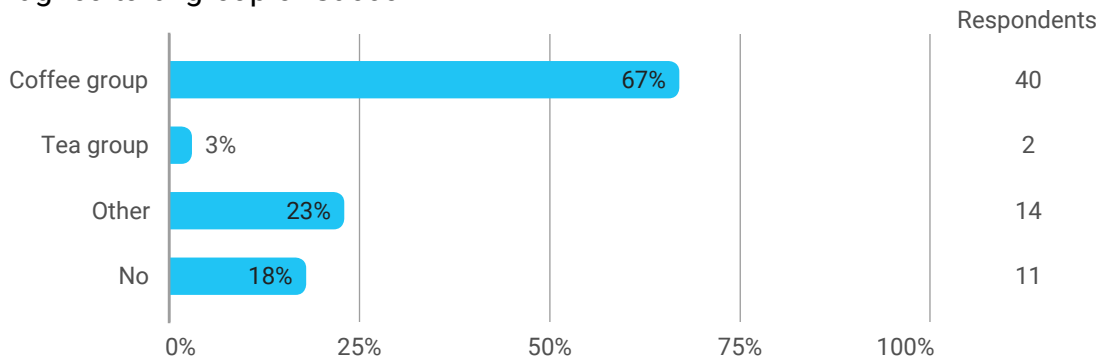
22. Which sources do you use for agricultural information?



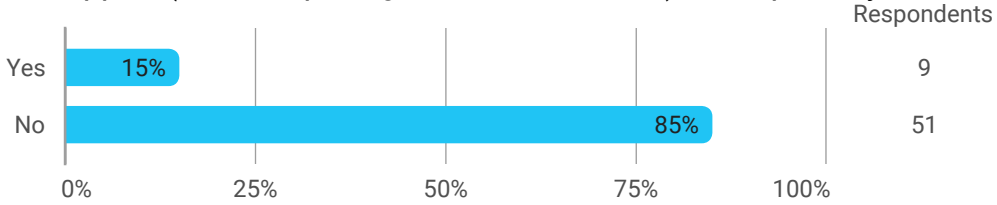
22.1. Which sources do you find most useful? (name up tot 3)



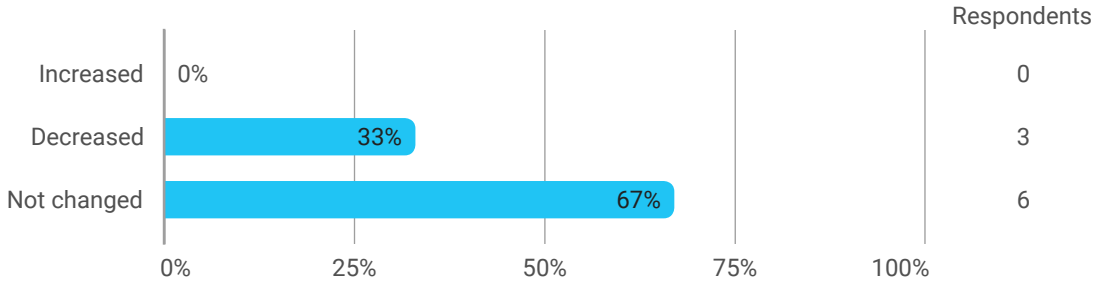
23. Are you part of an agricultural group or Sacco?



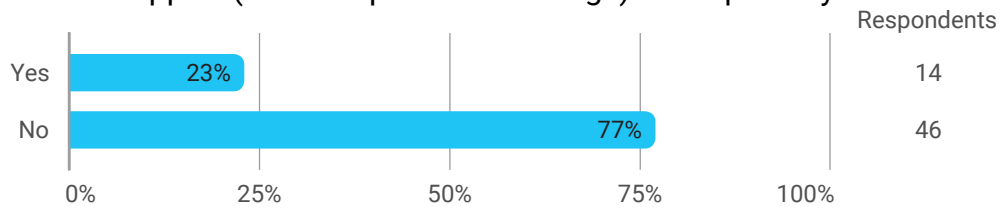
24. Have you received financial support (for example: agricultural subsidies) in the past 5 years?



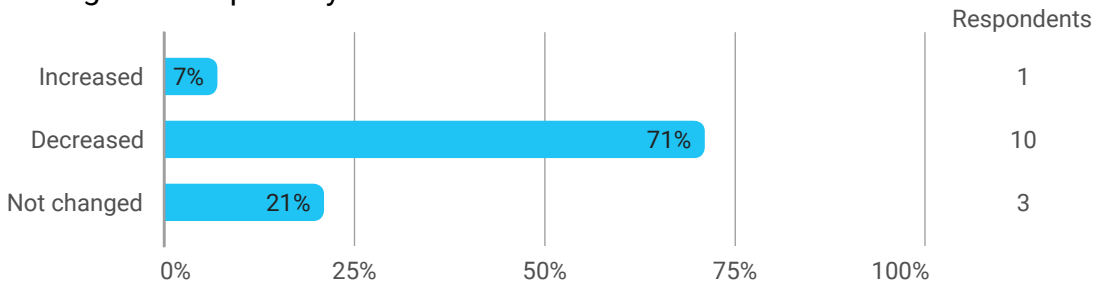
24.1. Has the amount changed in the past 5 years?



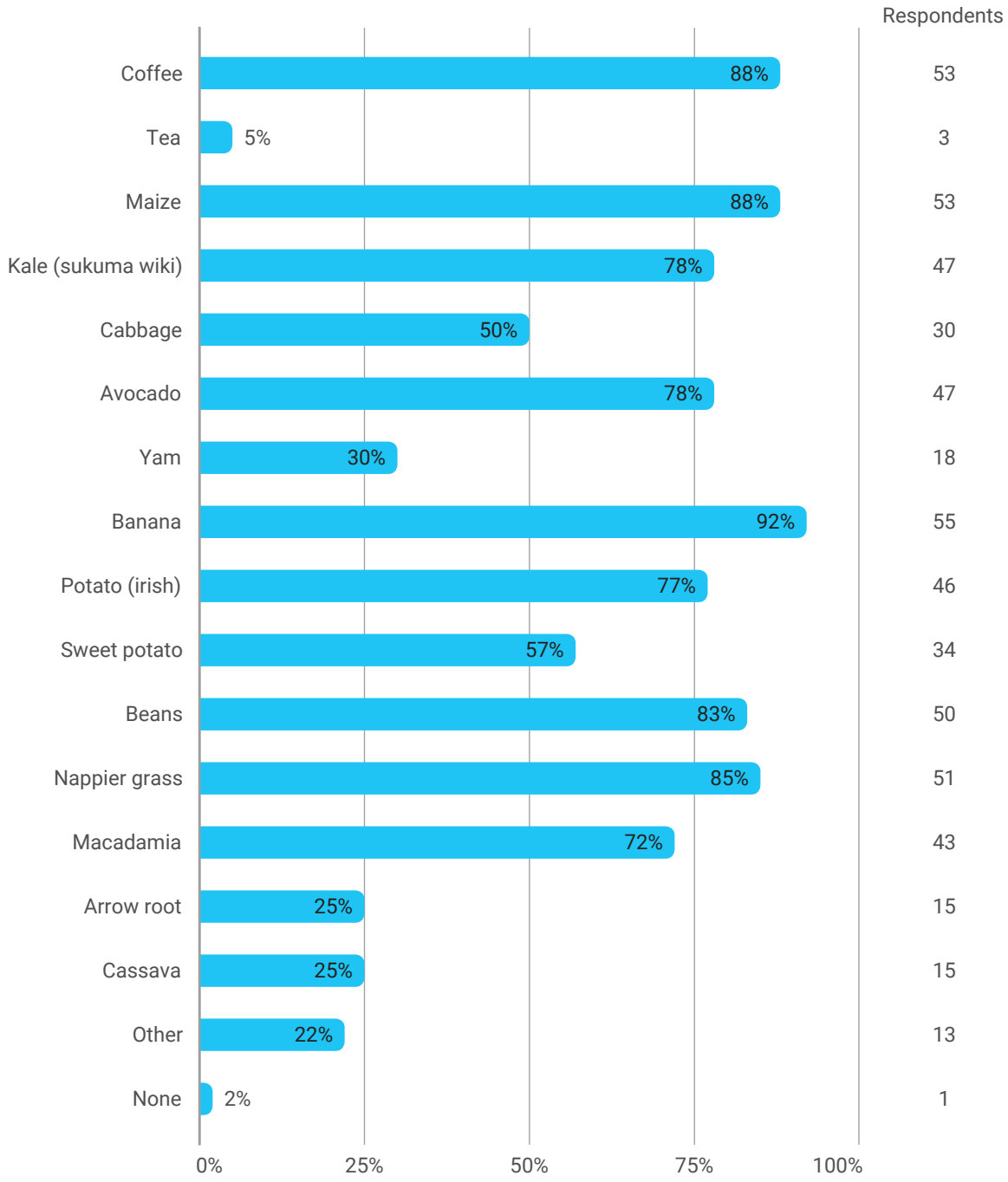
25. Have you received non financial support (for example free seedlings) in the past 5 years?



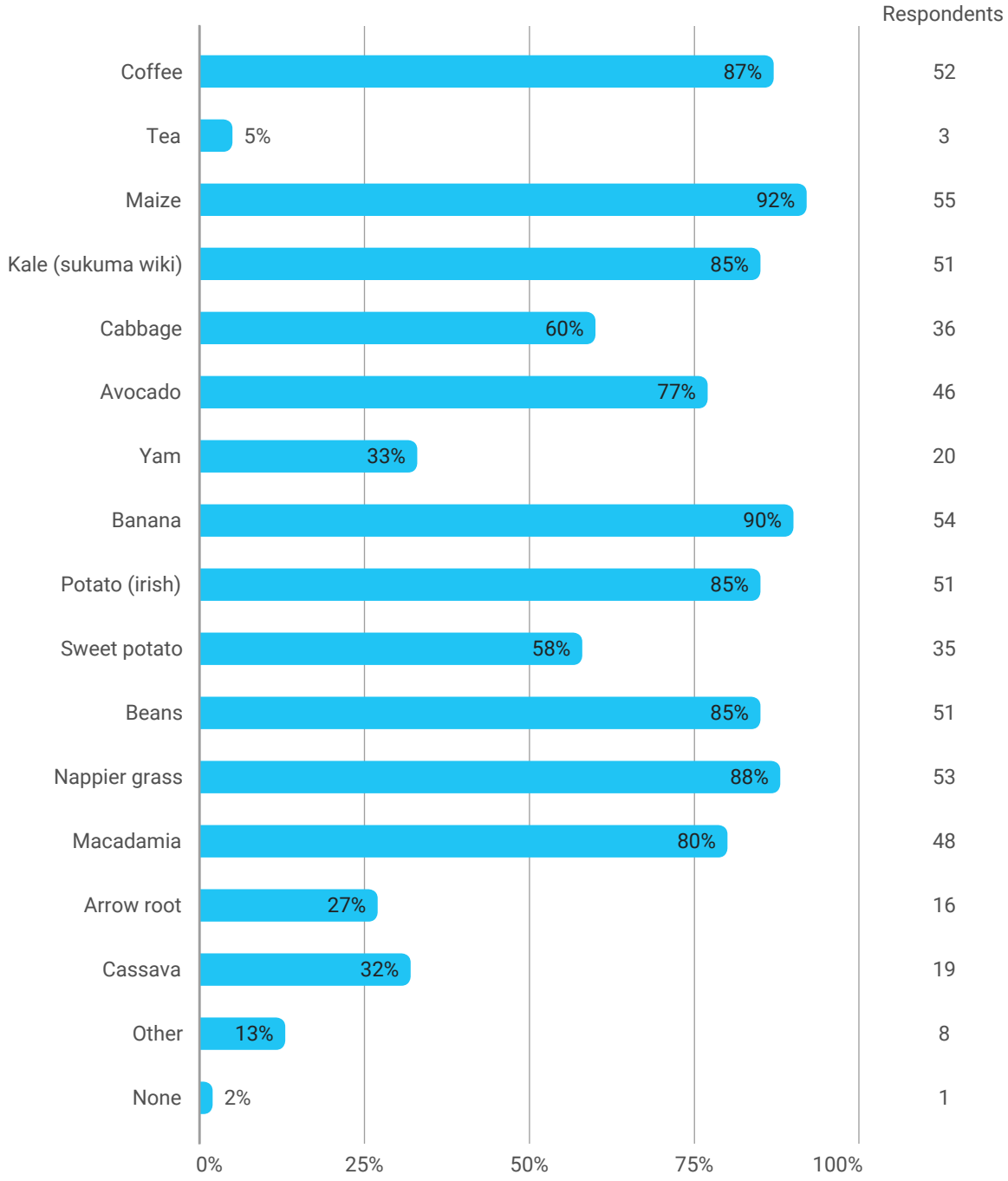
25.1. Has the amount changed in the past 5 years?



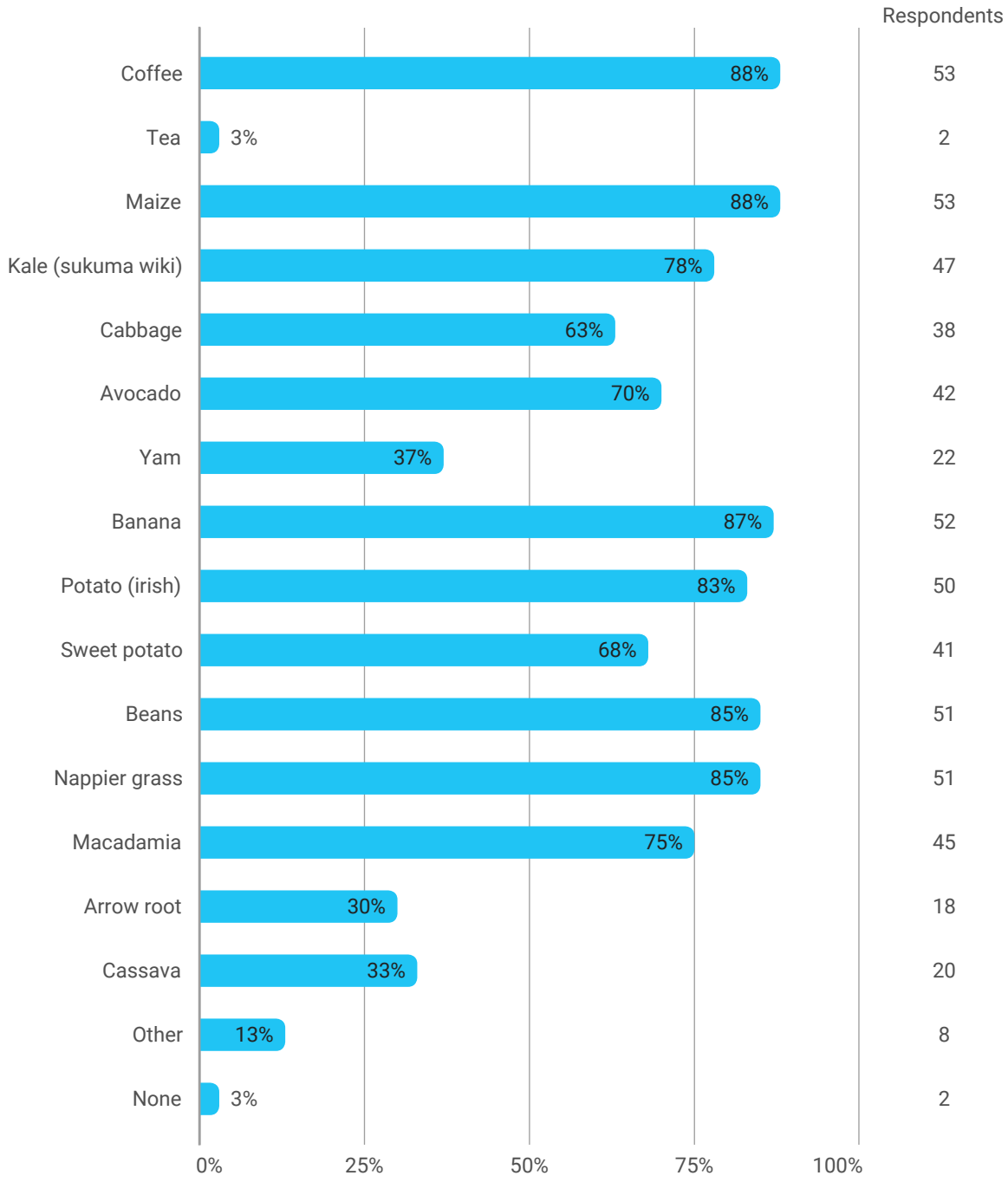
26. Which crops have you been growing the past 12 months?



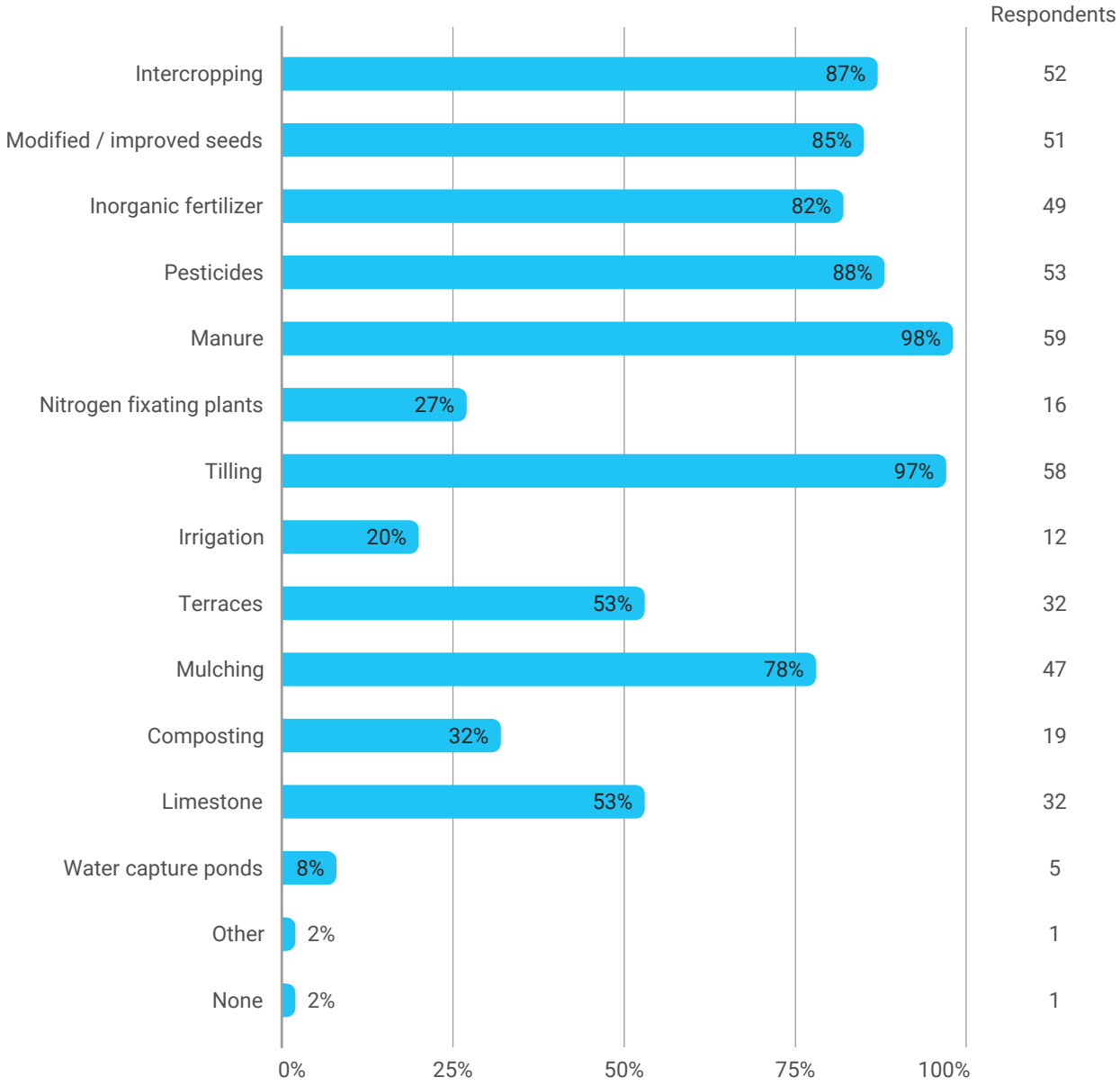
27. Which crops did you grow 5 years ago?



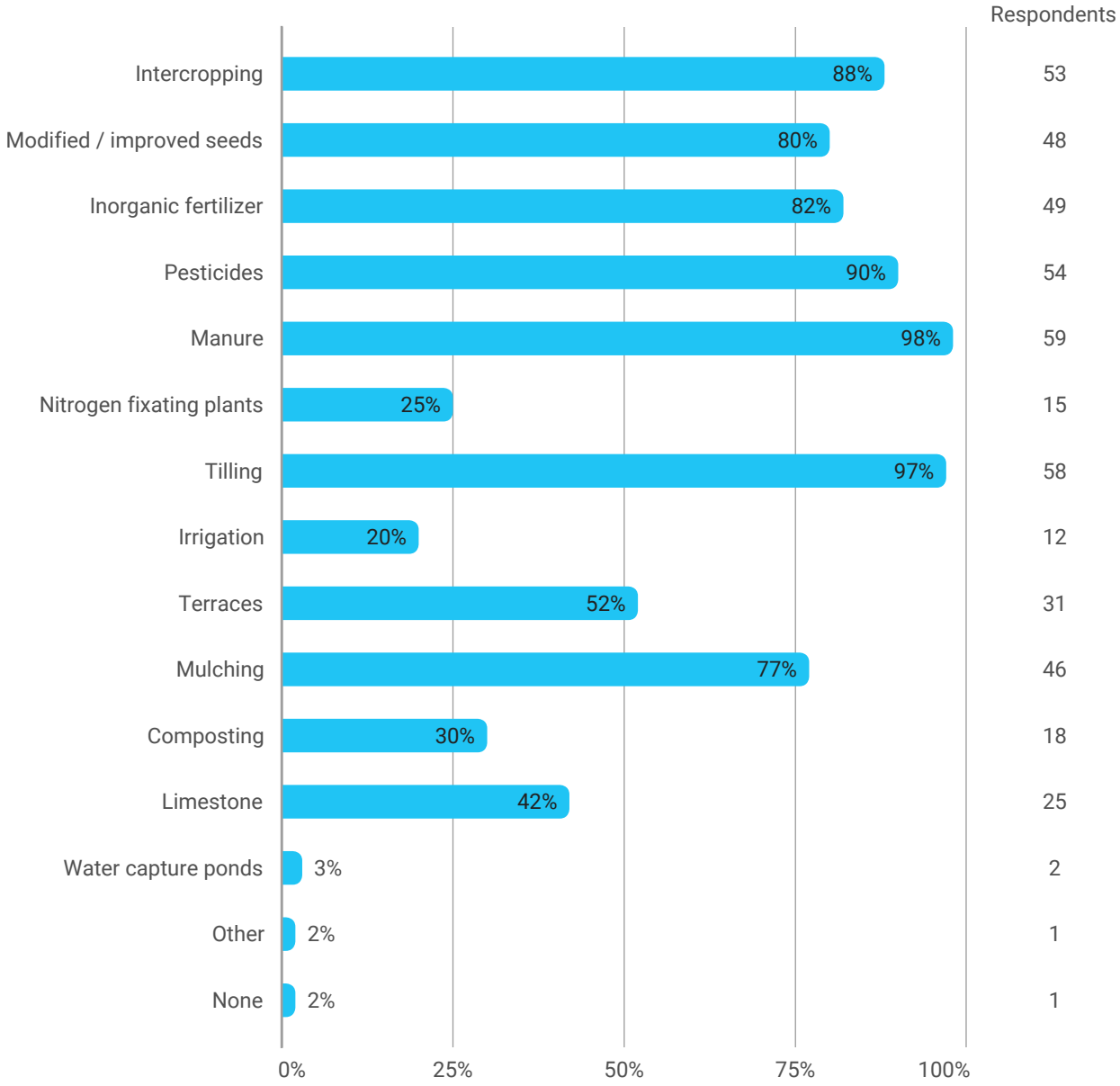
28. Which crops did you grow 10 years ago?



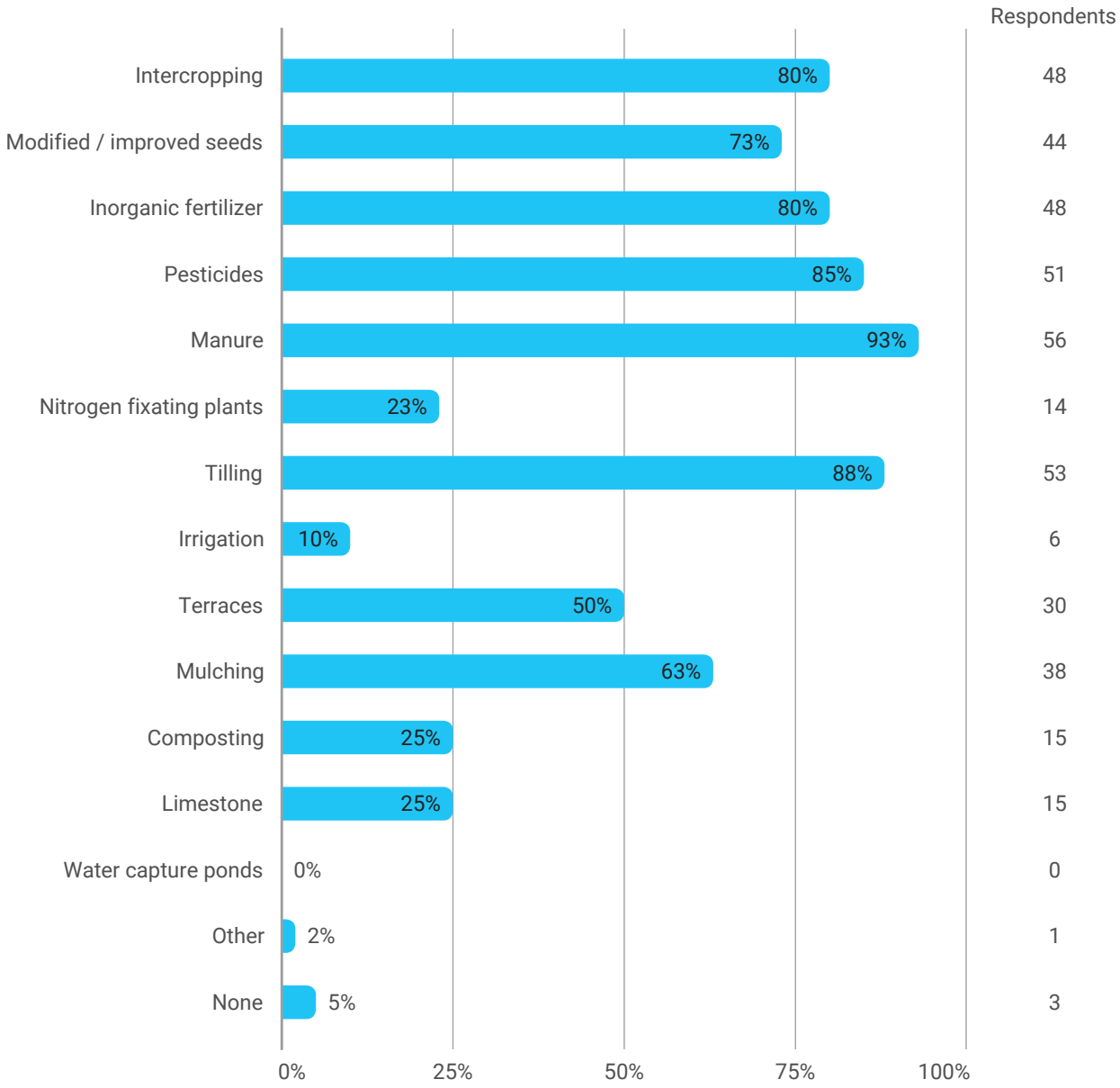
29. What agricultural practices have you been using the past 12 months?



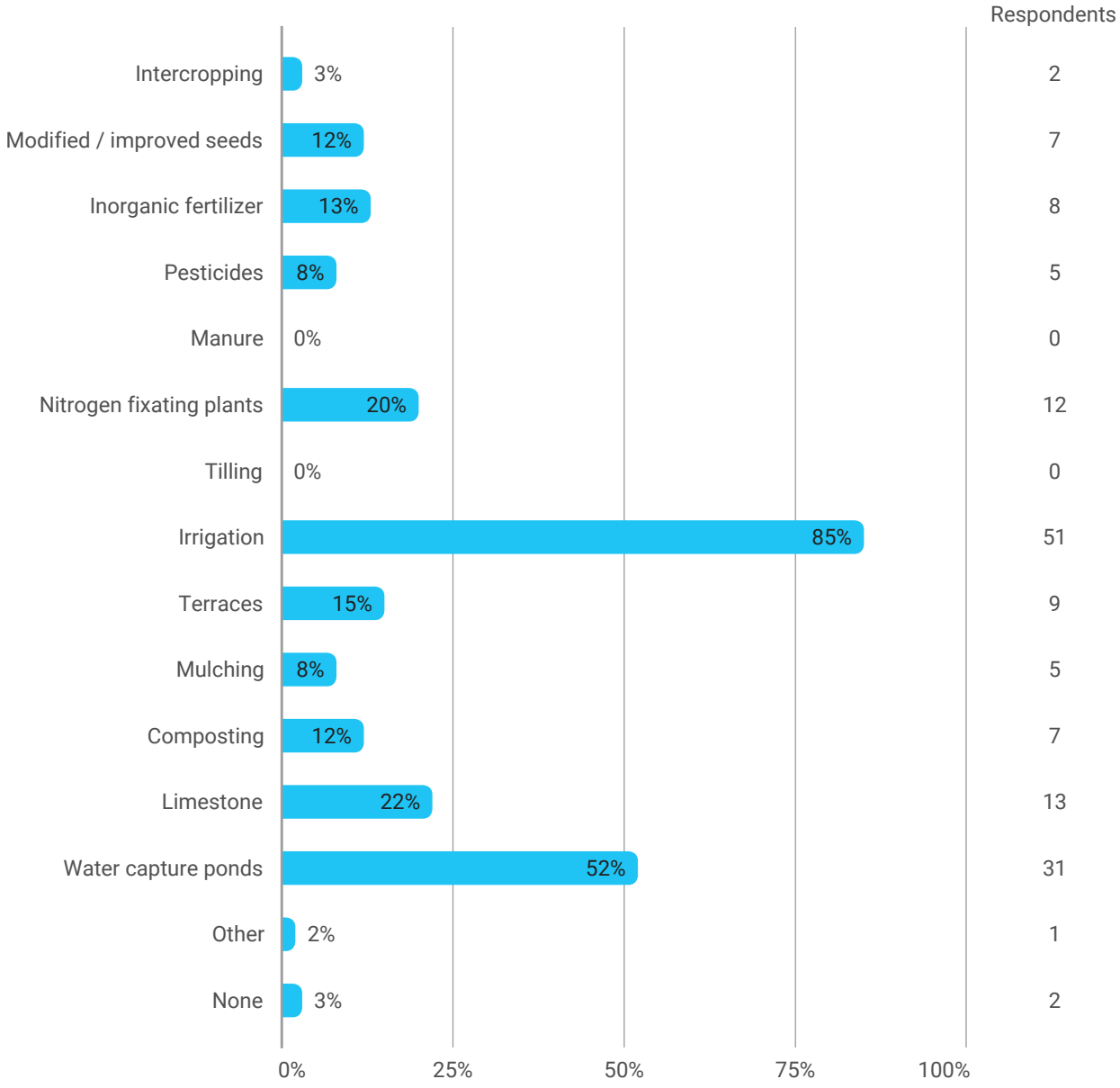
30. Which agricultural practices did you use 5 years ago?



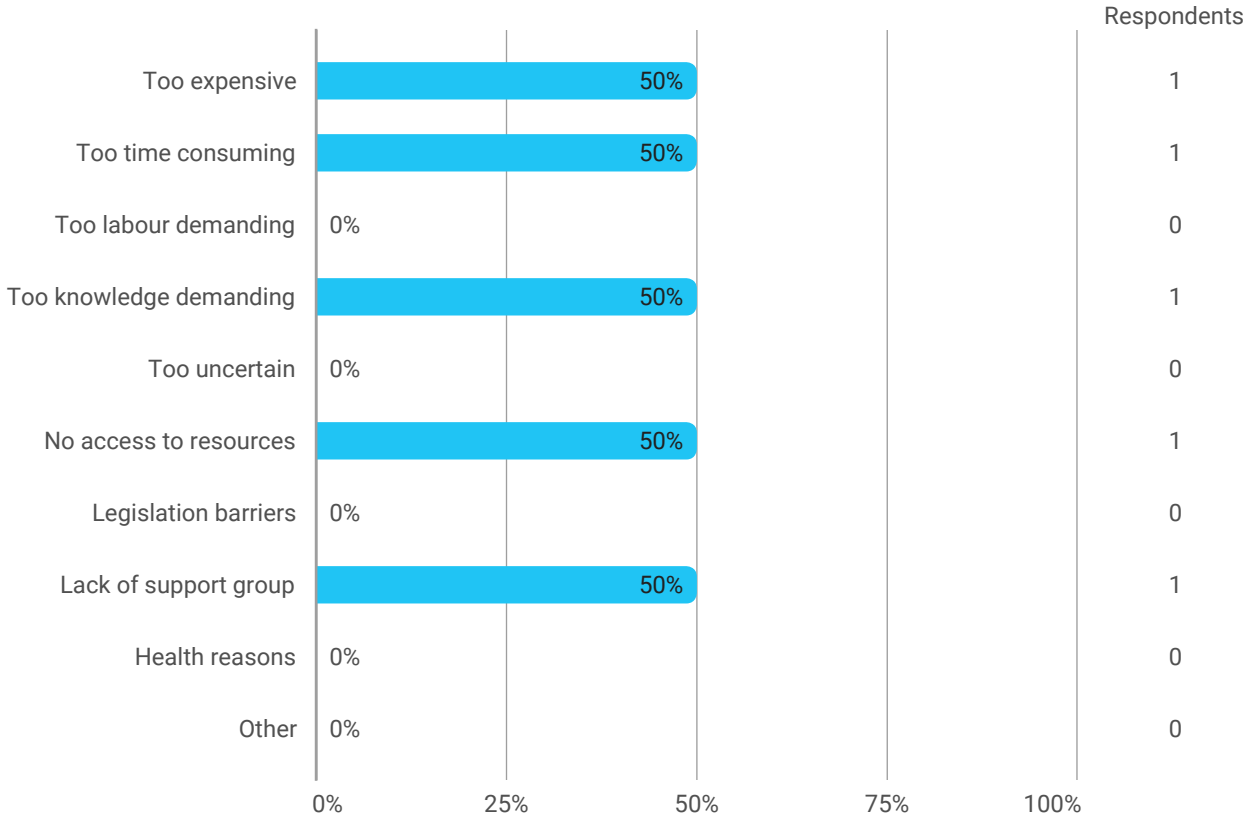
31. Which agricultural practices did you use 10 years ago?



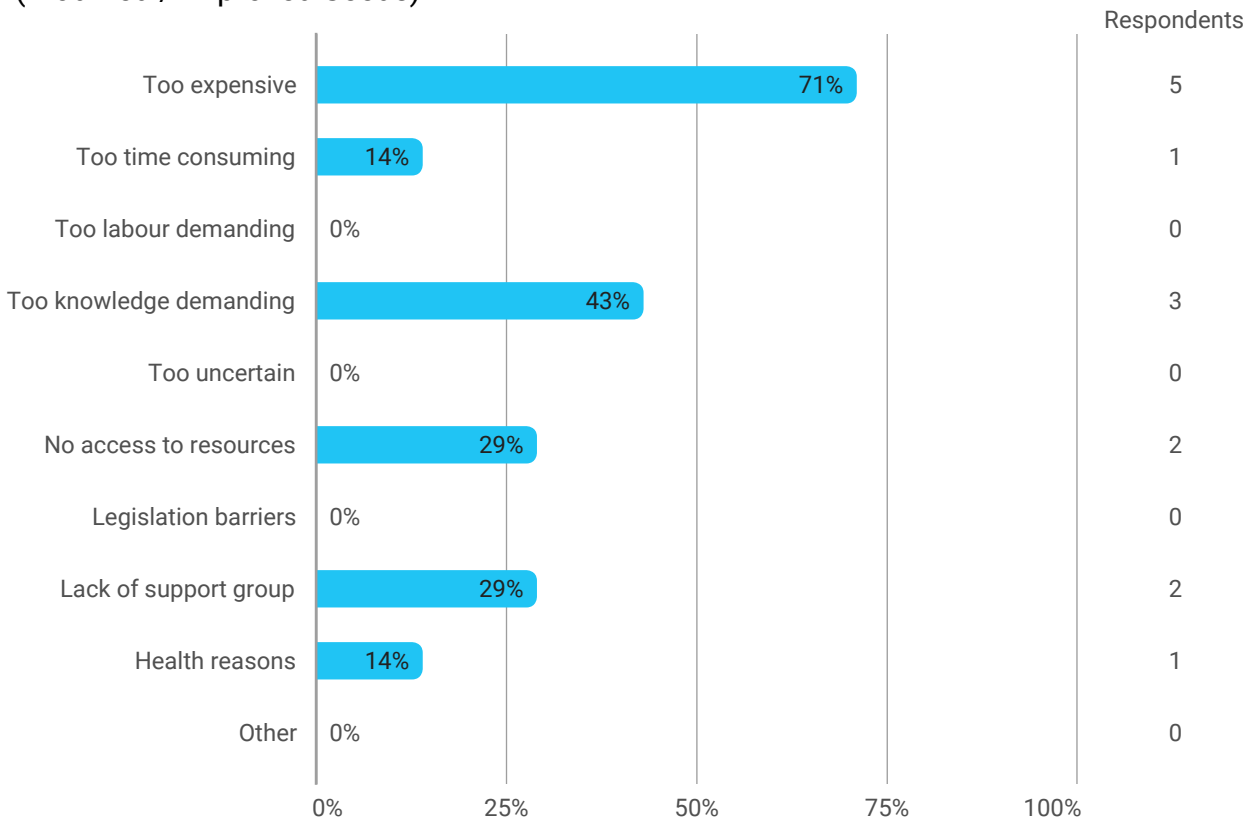
32. Are there any practices that you would like to use, but cannot:



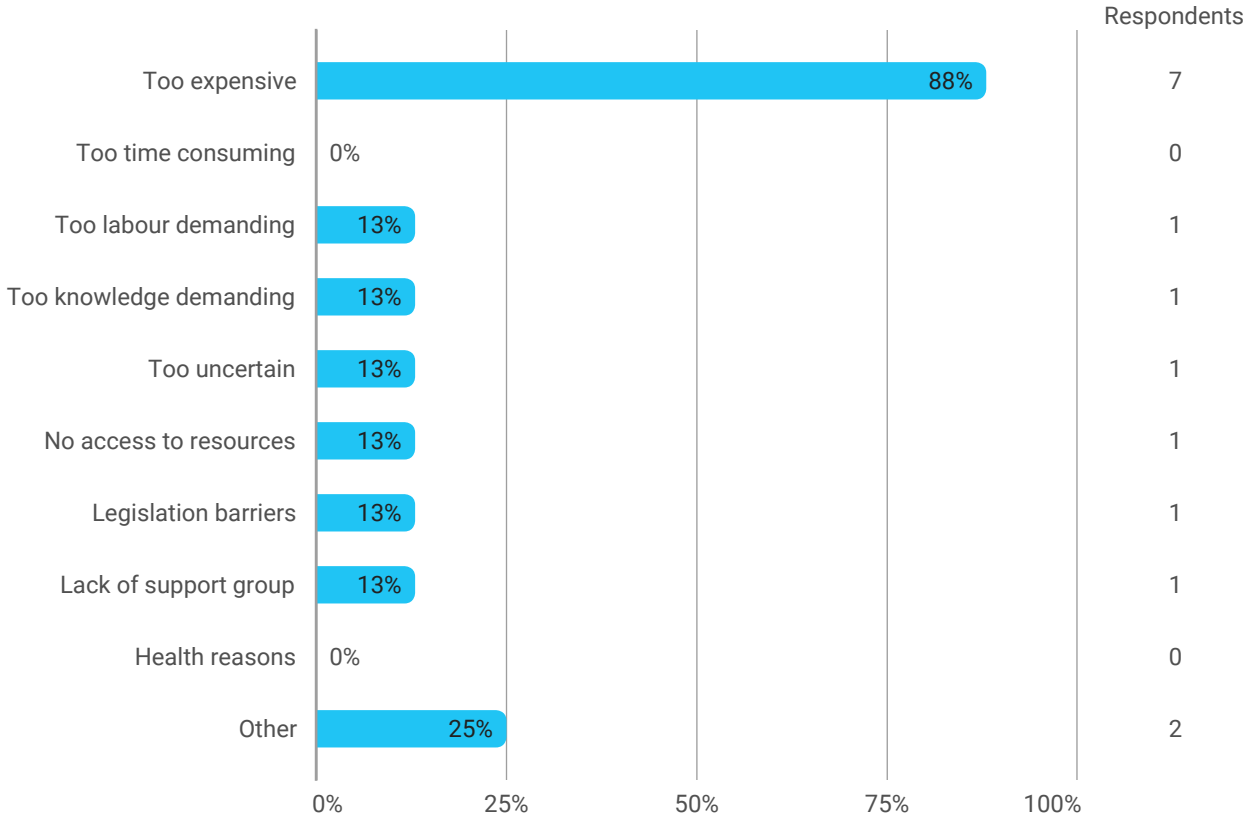
32.1. Why? (Intercropping)



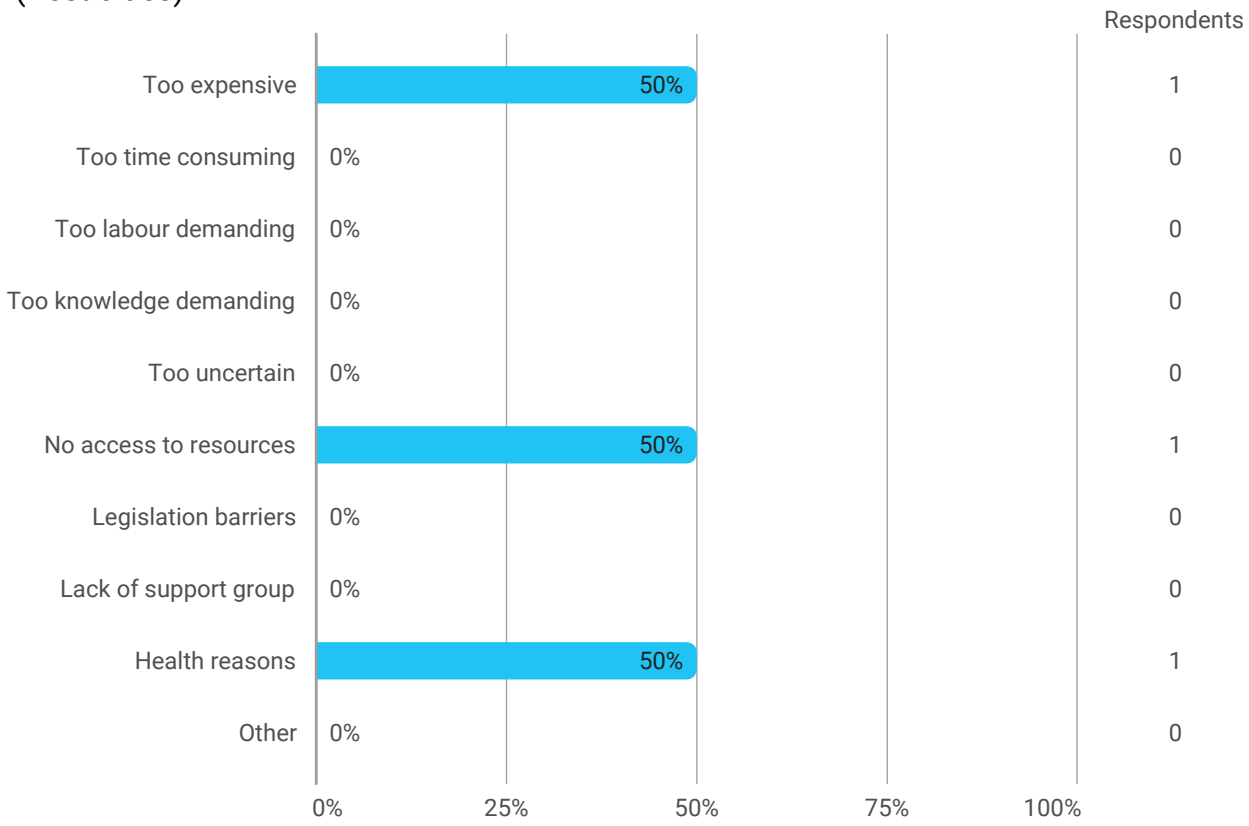
32.2. Why? (Modified / Improved Seeds)



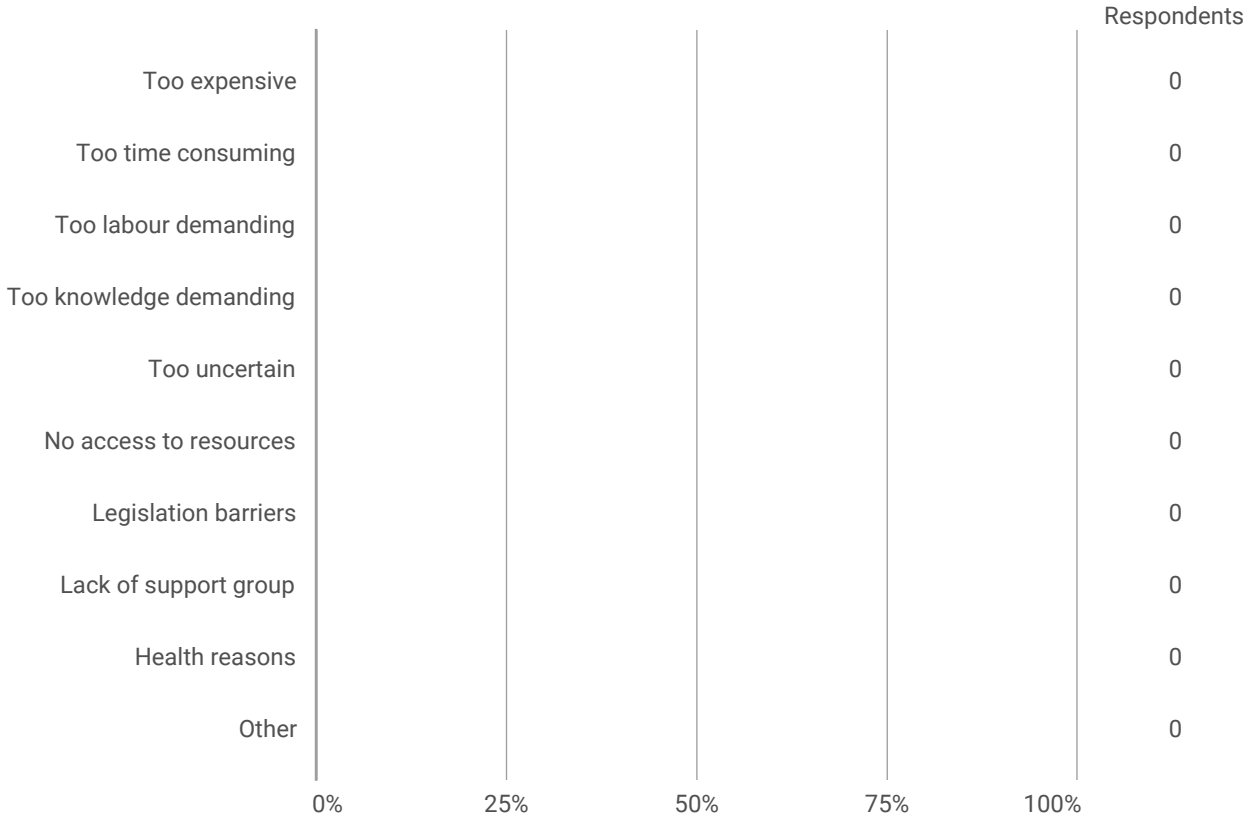
33.3. Why? (Inorganic Fertilizer)



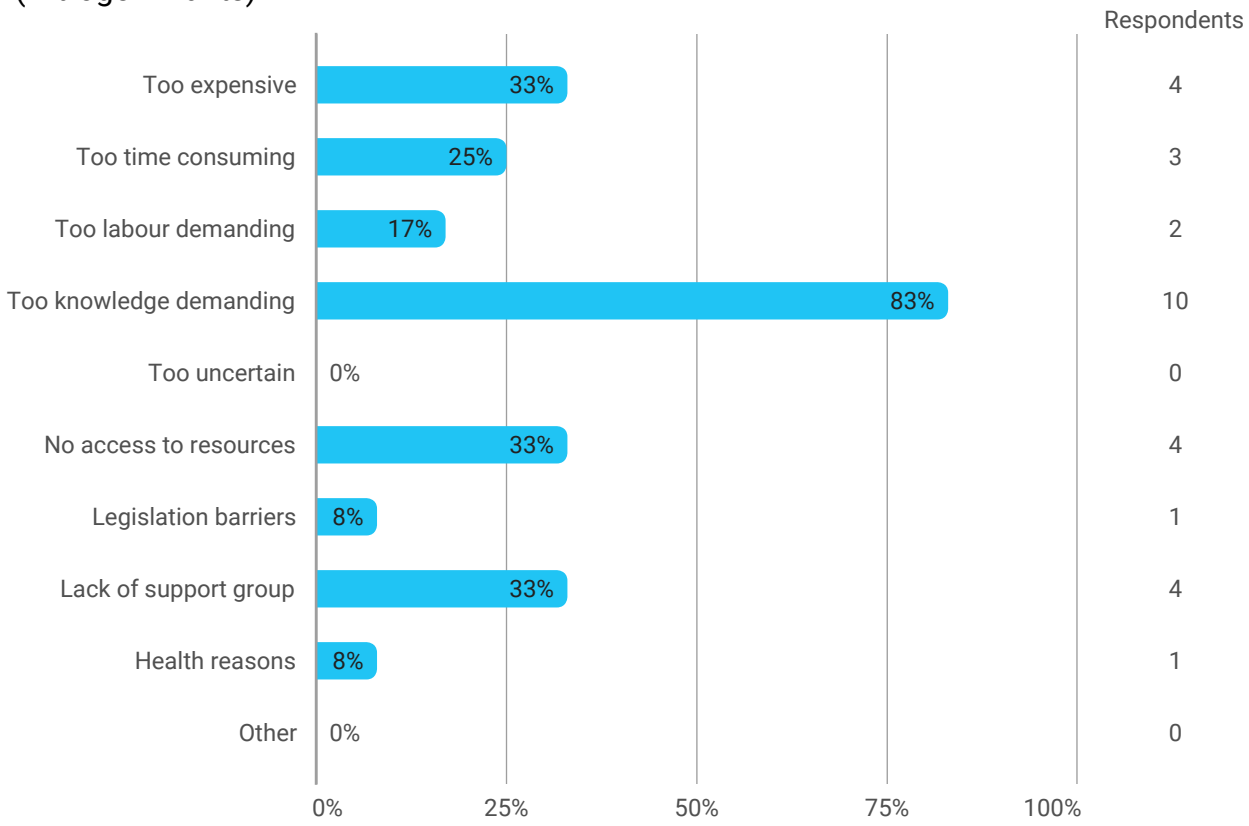
33.4. Why? (Pesticides)



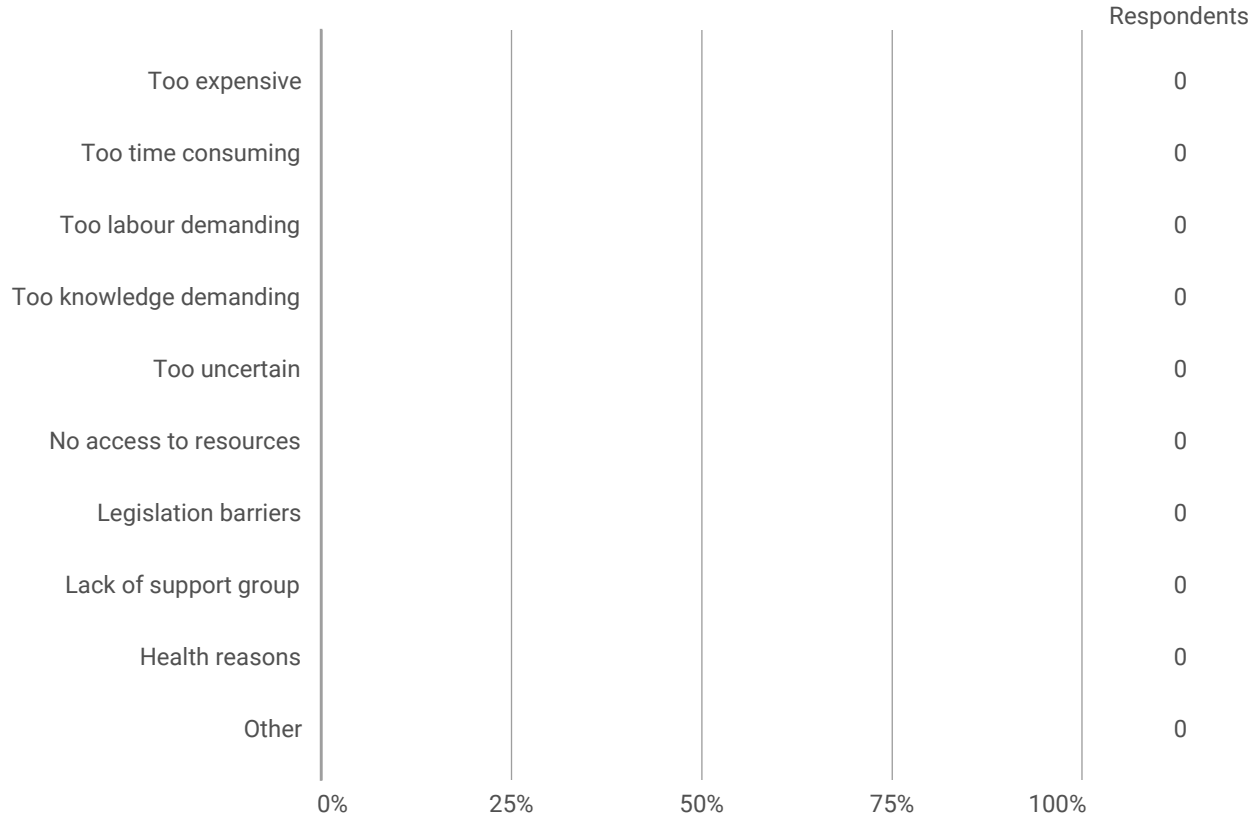
33.5. Why? (Manure)



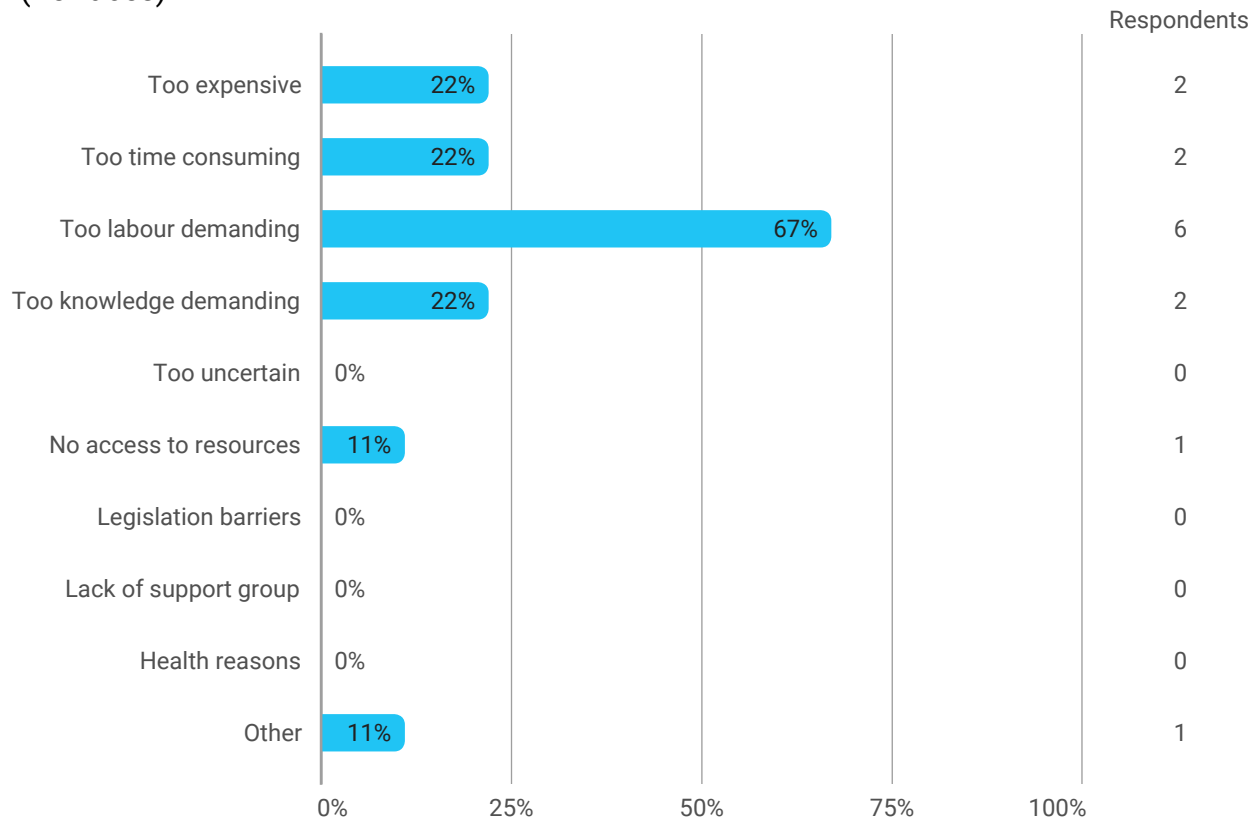
33.6. Why? (Nitrogen Plants)



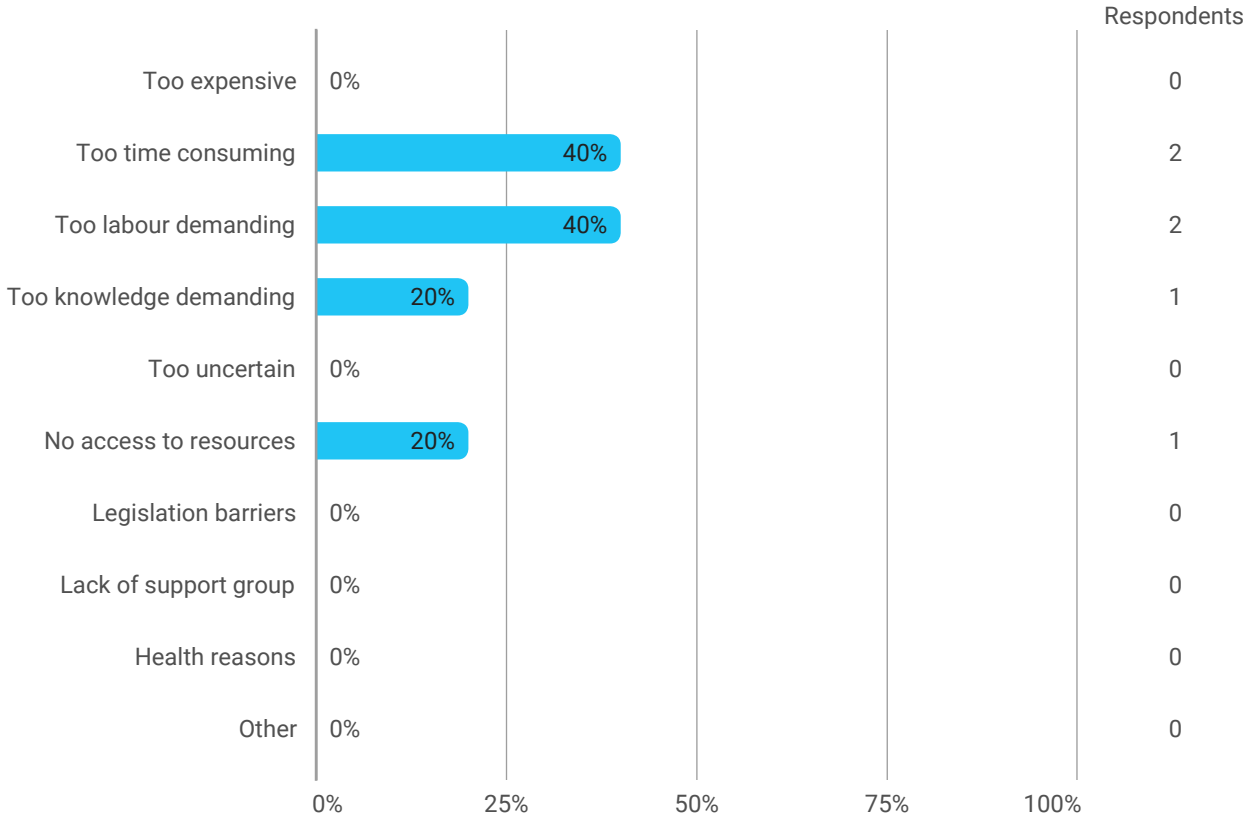
33.7. Why? (Tilling)



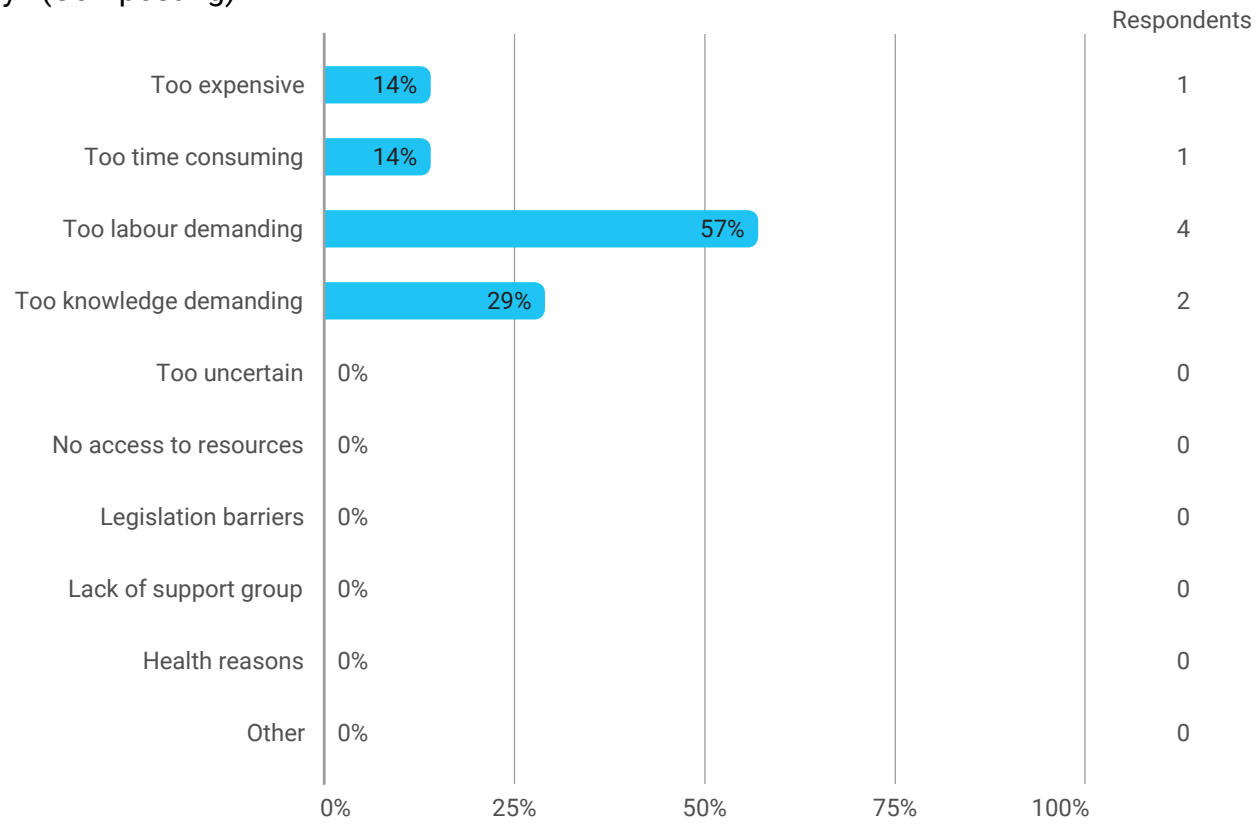
33.8. Why? (Terraces)



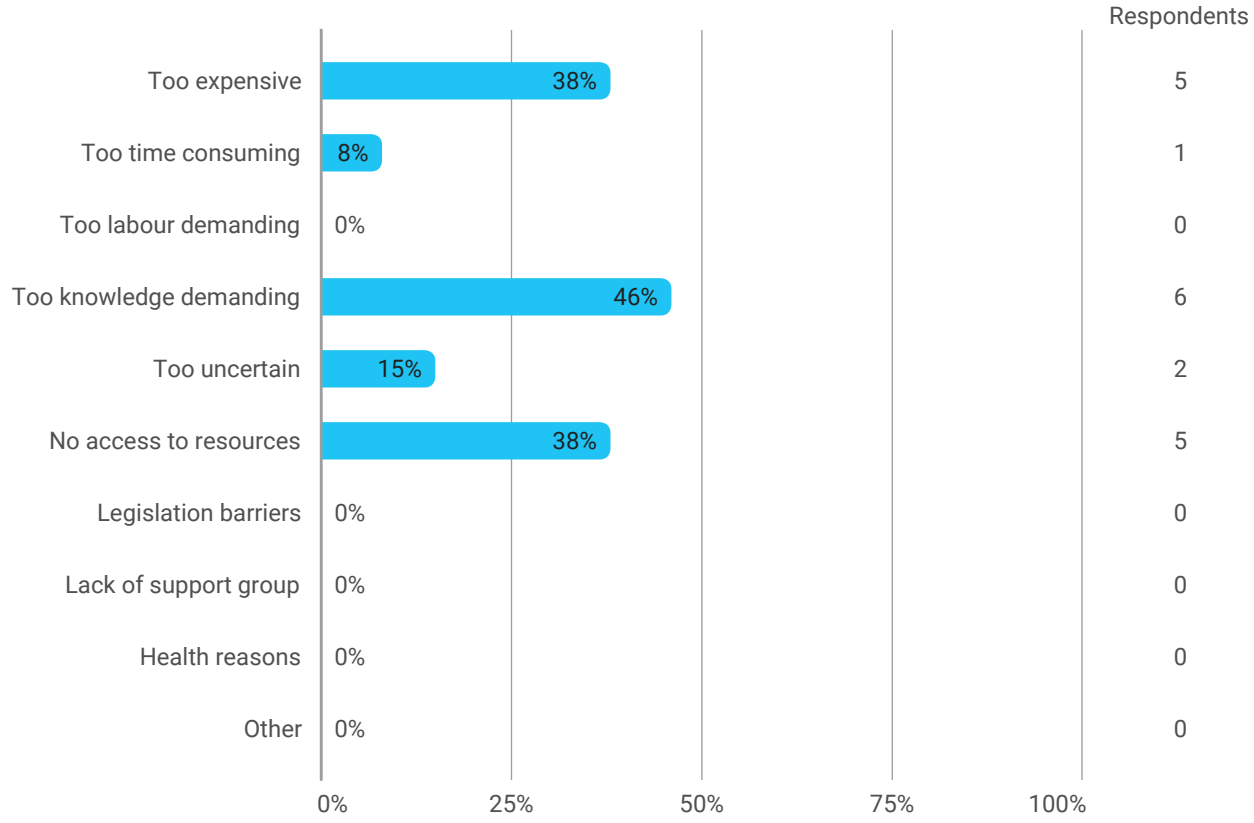
33.9. Why? (Mulching)



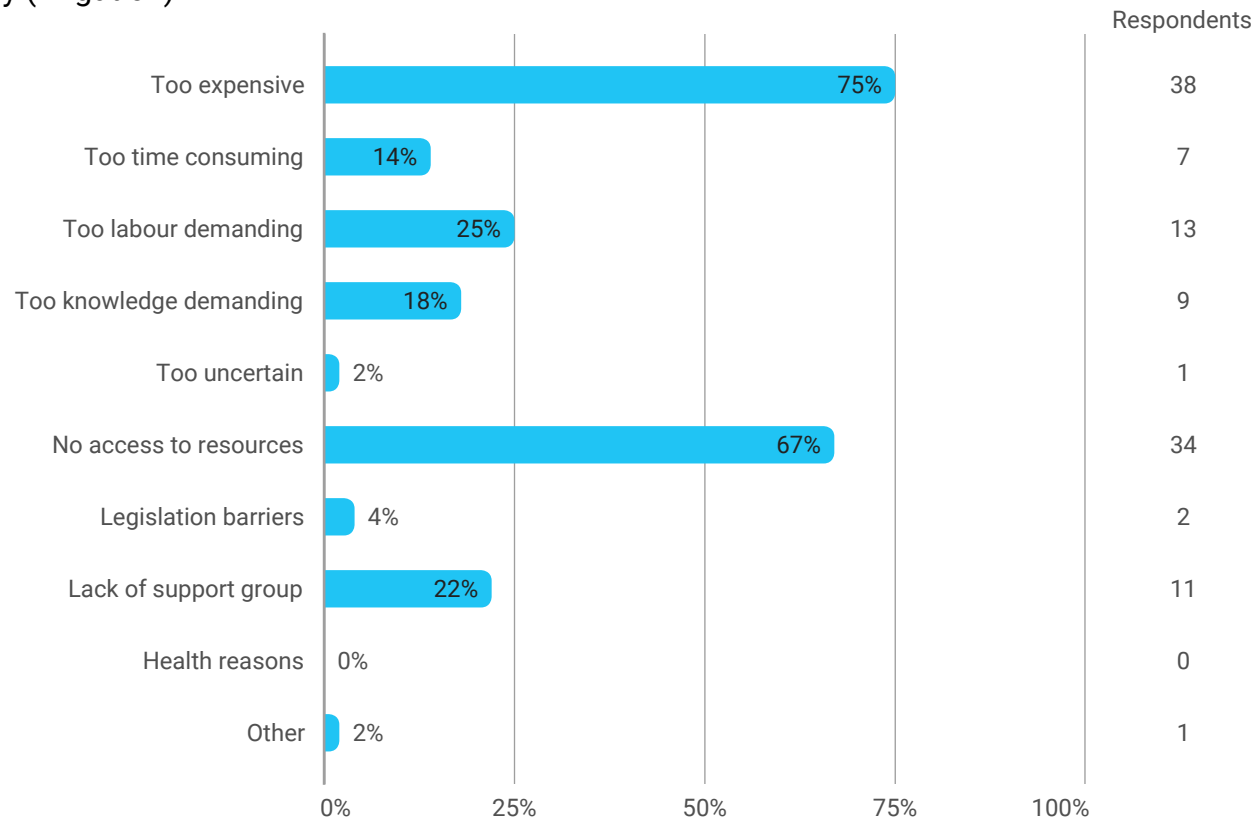
33.10. Why? (Composting)



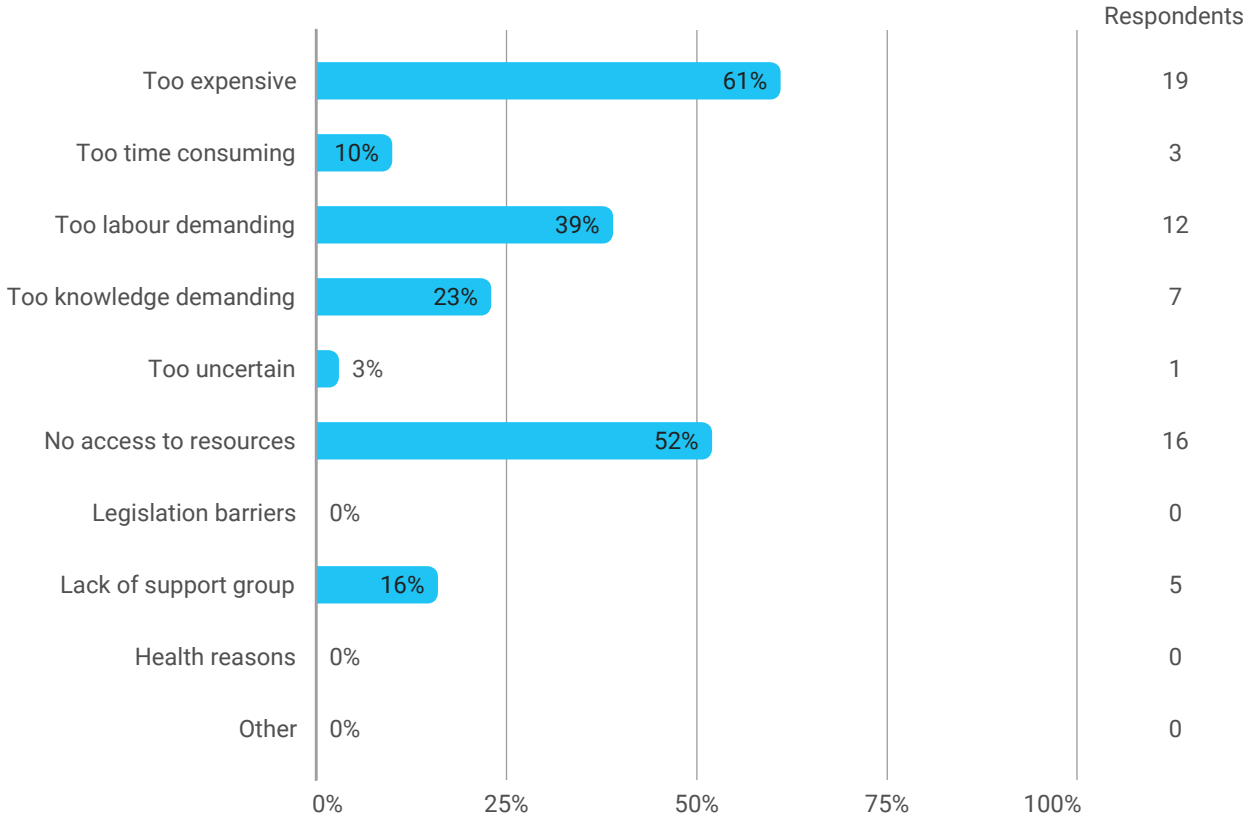
33.11. Why? (Limestone)



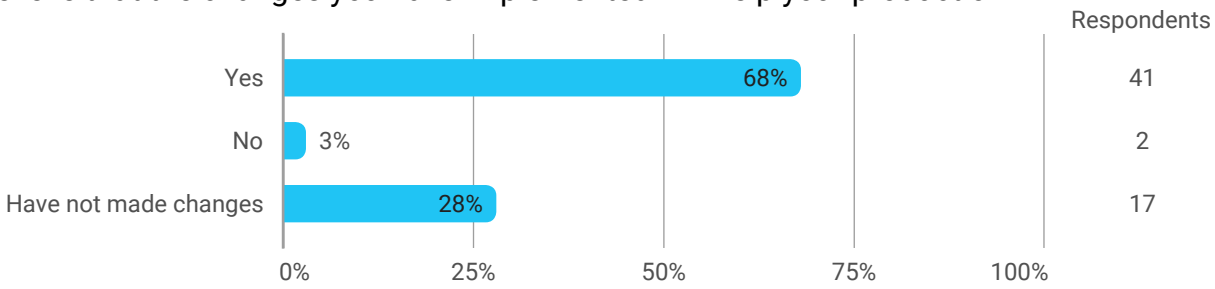
33.12. Why (Irrigation)



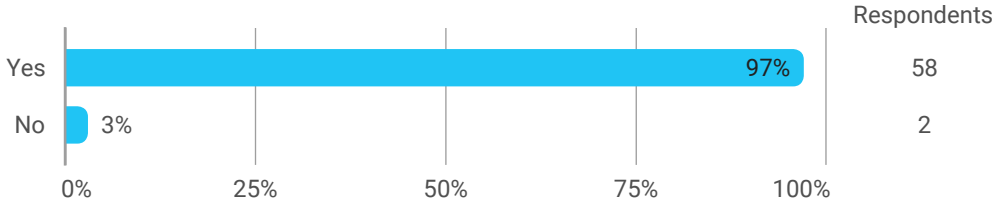
33.13 Why (Water Pond Capture)



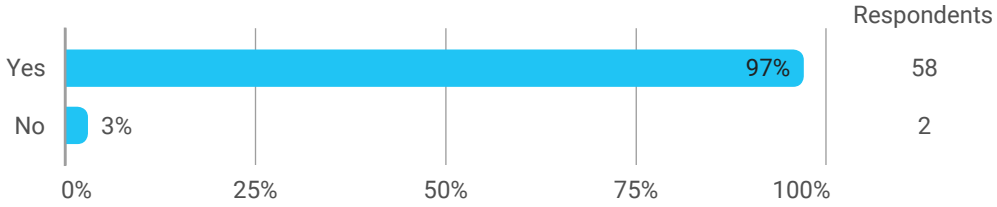
34. Do you believe that the changes you have implemented will help your production?



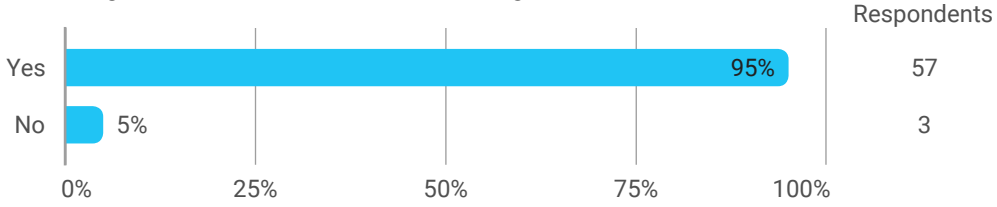
35. Have your planting times changed by more than a month, in the past 5 years, due to climate change?



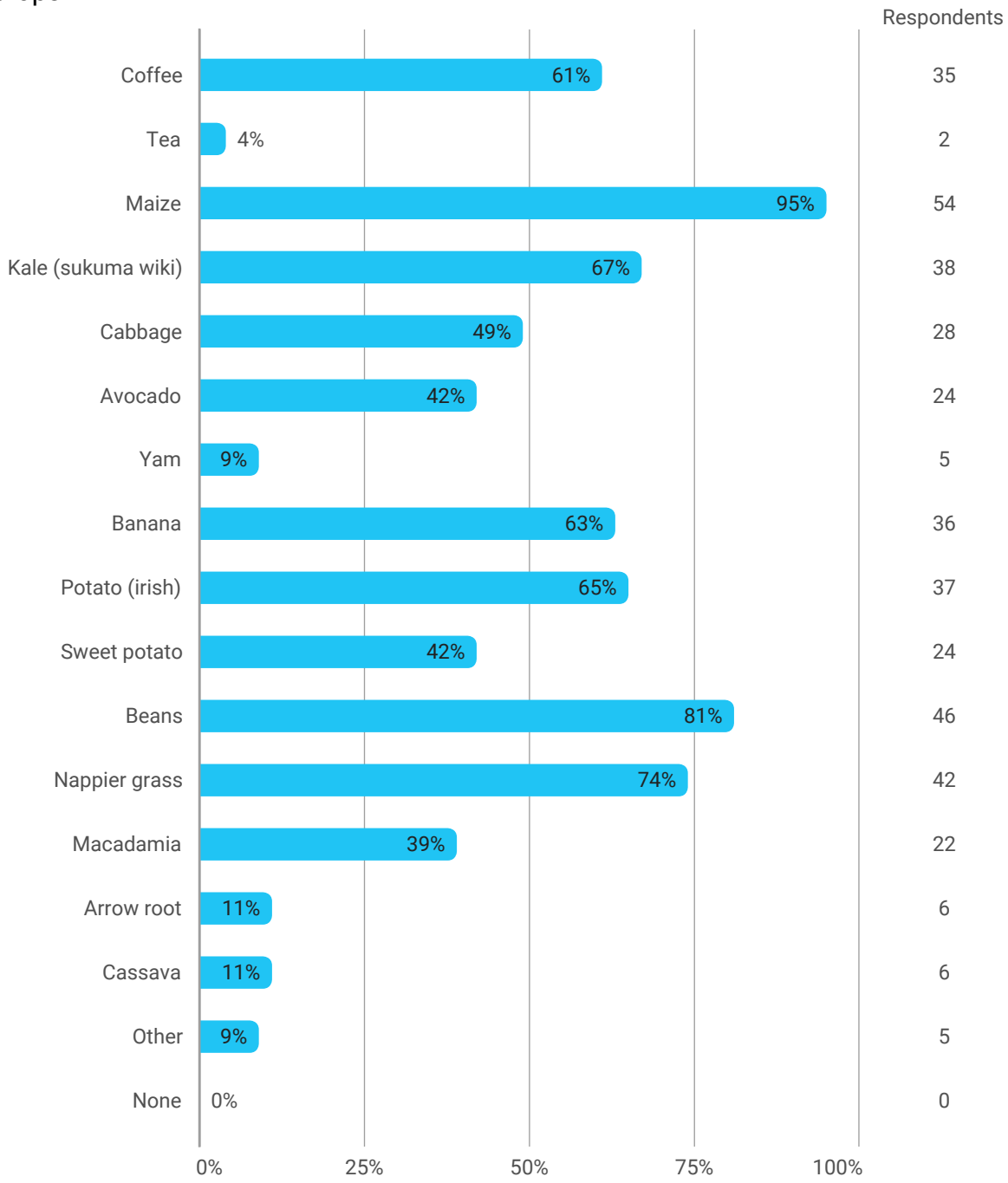
36. Have your harvesting times changed by more than a month in the past 5 years, due to climate change?



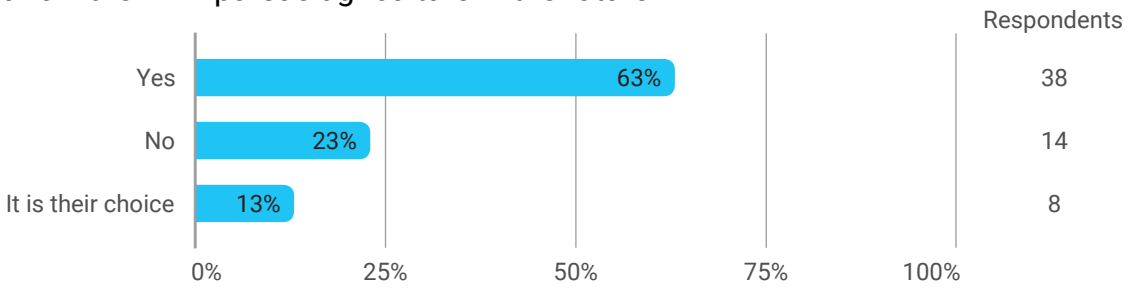
37. Have you experienced harvesting losses due to climate change?



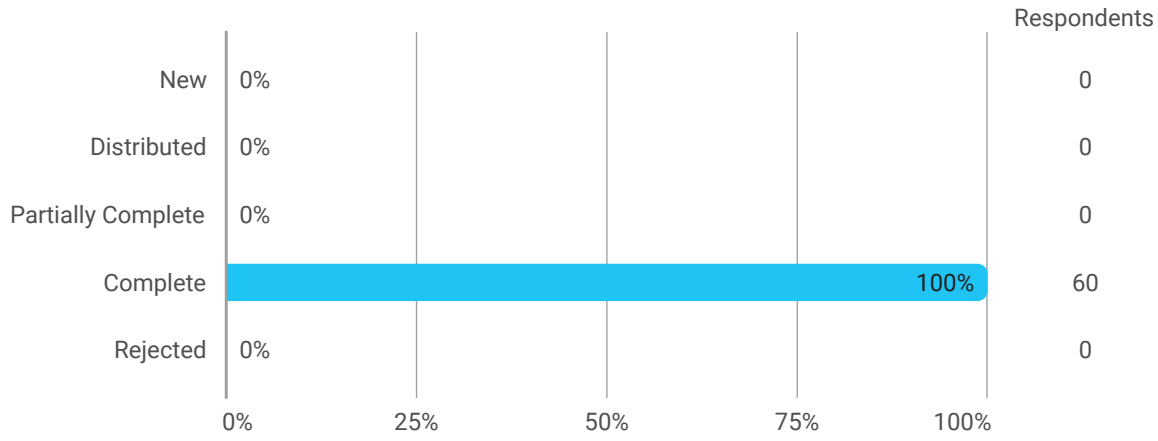
37.1. For which crops?



38. Do you hope your children will pursue agriculture in the future?



Overall Status


Respondents
New
0%
0
Distributed
0%
0
Partially Complete
0%
0
Complete
100%
60
Rejected
0%
0
0%
25%
50%
75%
100%