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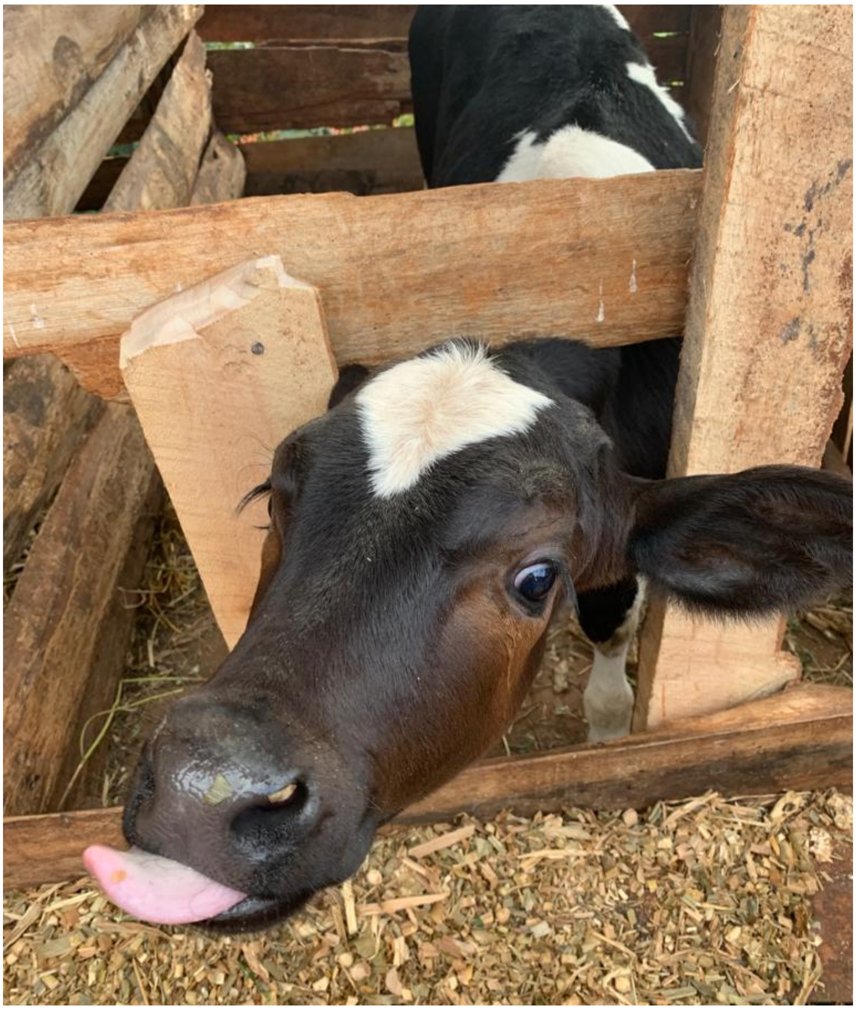
Fodder strategies and availability in Giathenge, Kenya

Final Report - SLUSE 2023



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Abstract

Low milk yield due to insufficient fodder resources poses a significant challenge for smallholder dairy farmers (SDFs) in the Central Highlands of Kenya. Most SDFs cultivate fodder and rely on rain as their primary water source. However, due to the increasing severity of drought, SDFs experience extreme difficulties cultivating sufficient fodder for a substantial milk yield. Adapting fodder strategies to cope with the drought is necessary for the future of dairy livestock. However, most SDFs are not adapting their fodder strategies and continue obtaining fodder through insufficient, conventional fodder strategies. This research analyses institutional factors and livelihood assets that determine the ability of SDFs to adapt their fodder strategies to drought, leading to sufficient fodder in terms of quality and quantity for their livestock. It uses household survey data from a sample of thirty-two SDFs in Giathenge, Kenya, along with SDF and expert interviews, a focus group discussion, and meteorological and fodder yield assessments. The findings demonstrate that barriers limiting SDFs' capability to adapt their fodder strategies are increased land fragmentation, lack of financial sources, lack of water access, and a lack of knowledge about nutritious fodder types and fodder preservation techniques. This is exacerbated and further negatively impacted by the institutional structures of long-standing agricultural norms combined with a lack of government policies and support. The study recommends that agricultural policy makers invest in training and awareness-raising programmes for SDFs to foster climate-resilient fodder strategies and improve dairy production in Giathenge.

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Villagers around Othaya, Nyeri county, hosted us and freely contributed to this report through several questionnaires, interviews, and informal communications. Their contribution is acknowledged and greatly appreciated. Special thanks go to Feliciana Wairimu Ngunjiri (Mama George), Esther Wambugu (Mama Esther) and Rose Mary Wambui Thuku (Mama David) for being such welcoming hosts and making our time in Kenya truly wonderful. Moreover, we are grateful to the chief and the community leaders in Othaya for logistical support.

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Work distribution

All authors were equally involved in all sections of this report.

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Abbreviations

CFS	Conventional fodder strategies
DS	Dry season
AFS	Adaptation fodder strategies
FB	Fodder business
FGD	Focus group discussion
FFS	Farmer Field School
HH	Household
L	Litres
LO	Livestock Officer
MCA	Member of the County Assembly
NG	Napier grass
SDF	Small-holder dairy farmer
SLF	Sustainable livelihoods framework
TKB	Teachers of the Karima Boys Secondary School
WS	Wet season

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1. Introduction

In Kenya, cows hold significant importance because of their economic, nutritional, cultural, and spiritual value. Dairy from cows accounts for 85% of all produced milk in Kenya (Sserunjogi, 2001) and the dairy industry contributes to 4% of the national GDP (Kenya Dairy Board, n.d.). Additionally, dairy is important in Kenyan diets. Annual dairy consumption per person is approximately 100 kg in Kenya, whereas the average in Sub-Saharan Africa is 25 kg (Ajak et al., 2020). This already high demand for dairy cattle products is expected to rise as the population increases (Gachuiri et al., 2017).

Smallholder dairy farmers (SDFs) are the primary dairy producers and account for 56% of the national output (Njeru, 2022). In addition to providing income, dairy, and manure, SDFs also attach additional values to having a cow (AU-IBAR, 2019). Owning a cow raises social status (Nyariki & Ngugi, 2017) and functions as an investment that can act as a risk buffer (Moyo & Swanepoel, 2010). This additional social and cultural significance makes them a vital asset in the livelihoods of Kenyan SDFs.

Despite the dependency of SDFs on milk production and their desire to own cows, they experience challenges maintaining them and producing sufficient milk. The main problem they encounter is fodder shortage (State Department of Livestock, 2019), which is intensified because of climate change-induced extreme droughts (Lukuyu et al., 2011). Since SDFs primarily rely on rainfall for their fodder cultivation, increasing heat events and changing rain patterns significantly affect fodder availability (Nalianya et al., 2020; Njarui et al., 2016; Ochieng et al., 2016). In addition to drought, declining land availability for fodder production due to population increase (Gachuiri et al., 2017; Muyanga & Jayne, 2014), lack of fodder diversification (Njarui et al., 2021), high costs of concentrates (State Department of Livestock, 2019), and lack of knowledge on preservation and storage techniques all intensify the fodder scarcity (Mbindyo, 2017; Njarui et al., 2021; Nalianya et al., 2020).

Feeding sufficient and nutritious fodder is crucial for maintaining the cow's health and ensuring high milk productivity (Cheema et al., 2011). Some SDFs experience fodder shortages to the extent that they are forced to sell their cows (FAO, 2022). Hence, with changing precipitation patterns (Mairura et al., 2021), there is an urgent need for SDFs to adapt their fodder strategies to secure their desired livelihoods.

Some SDFs are already adapting their strategies. Examples in Kenya are livestock diversification (Ngigi et al., 2020; Silvestri et al., 2012), irrigation, soil treatment, water conservation (Bryan et al., 2013; Mairura et al., 2021), crop adjustment and nutrient management (Mairura et al., 2021; Silvestri et al., 2012), and a diversification of livestock feeds (Silvestri et al., 2012). However, most SDFs are experiencing severe problems obtaining sufficient fodder. This poses the question of why some SDFs are able to improve their fodder strategies while others are not. As a result, this research aims to analyse which factors determine SDFs' ability to adopt climate resilient strategies in a context affected particularly by drought. The study is conducted in Giathenge, Kenyan Central Highlands.

2. Literature review

This section analyses the existing literature on factors impacting the ability of farmers to use agricultural adaptation strategies in response to changing weather patterns.

The primary determinant of whether SDFs adapt their strategies to climate change is their awareness of it. In this sense, farmers who are more aware and perceive climate change as a primary determinant of declining agricultural productivity are more likely to look for strategies that allow them to face the situation (Adimassu & Kessler, 2016; Mairura et al., Mustafa et al., 2018; Nalianya et al., 2020).

Such level of awareness is linked to socioeconomic and institutional factors, which either enhance or constrain the ability of SDFs to adopt new or their current strategies. Gender, education, and farming experience shape farmers' awareness. Adimassu & Kessler (2016) found that male-headed households in Ethiopia were likelier to use improved crop species than female-headed households. The results were consistent with Ali & Erestein's (2017) study in Pakistan, which found that male household heads were likelier to adopt adaptation strategies than female ones. The reason lies in men's better access to technologies and information on climate change. These gender gaps have also been confirmed by Teklewold et al. (2020) in Uganda and Tanzania, and Theis et al. (2018) in Ethiopia, Ghana, and Tanzania.

Regarding age, while Marie et al. (2020) detected a trend in Ethiopia where older people better adapted to climate change because they showed more farming experience, Ali & Erenstein (2017) found that in Pakistan young farmers and farmers with higher levels of education were more likely to adopt adaptation strategies. Both studies agreed that access to knowledge, local networks, infrastructure, and extension services played a crucial role in doing so. Accordingly, access to agricultural information and farm input, primarily through extension services and Farmer Field Schools (FFS), were significant determinants of perceptions and adaptation according to Bryan et al. (2013) in Kenya and Rondhi et al. (2019) in Indonesia.

Farmers' financial circumstances also influence the adoption of these practices. Access to credit appeared as a determinant of the adoption of soil and water conservation practices in Southern Africa (Mango et al., 2017) and Kenya (Mairura et al., 2021; Silvestri et al., 2012). Okello et al. (2020) and Adimassu & Kessler (2016) found that, both in Ethiopia and Kenya, households with more cows and higher land sizes were more likely to adapt their strategies in obtaining fodder. They reasoned that more land and livestock units available meant a higher probability to try new methods, as there was more land for cultivating traditional crops as a safe option and more livestock that could function as insurance in the event that the new strategy failed.

The available research discussed tends to concentrate on agricultural crop production rather than specifically on fodder, which is the main factor affecting the dairy situation in Kenya (State Department of Livestock, 2019). Moreover, the literature is limited in its examination of SDFs' determinants for adapting strategies in the Kenyan Central Highlands. Nevertheless, it becomes clear from the existing literature that several "common" factors increase the probability of a farmer using adaptation strategies (i.e. financial resources, awareness, and gender); others seem to be influenced by context and area-specific features (i.e. education levels and age). Taking these facts as a point of departure, and bearing in mind the multiple importances cows hold in Kenya, this study aims to examine the specific factors that influence or prevent SDFs from adapting their fodder strategies in the Kenyan Central Highlands.

3. Research question

The overarching research question of this study has been derived from the previously identified research gap in the literature: *What determines the ability of smallholder dairy farmers to obtain fodder in Giathenge, Kenya?*

The question is extensive to account for the potential socioeconomic, institutional, and environmental factors that influence the fodder availability of SDFs in Giathenge, Kenya. To evaluate such factors, three research sub-questions are proposed.

1. *What fodder strategies are used by SDFs in Giathenge?*
2. *How do assets, processes and institutions impact SDFs' ability to adapt their fodder strategies to the identified vulnerability context?*
3. *What barriers do SDFs face that affect their ability to adapt their fodder strategies?*

The first sub-question aims to provide a background analysis of the conventional and adapted fodder strategies in Giathenge. The second sub-question analyses the factors that increase the ability of SDFs to adopt the identified adaptation strategies. The third sub-question focuses on the barriers preventing SDFs from adopting these strategies that would allow them to obtain more fodder.

4. Study area

This study was conducted in Giathenge, a township shaped by soft hills and located in the Othaya sub-county (Figure 1). Othaya is one of the eight sub-counties of Nyeri County, with a size of 175 km^2 and a population of around 21,500, mainly from the Kikuyu tribe. Nyeri County is a rural district between the Aberdare Ranges and Mount Kenya in the Central Highlands of Kenya. Giathenge is 150 km north of Nairobi (County Government of Nyeri, n.d.).

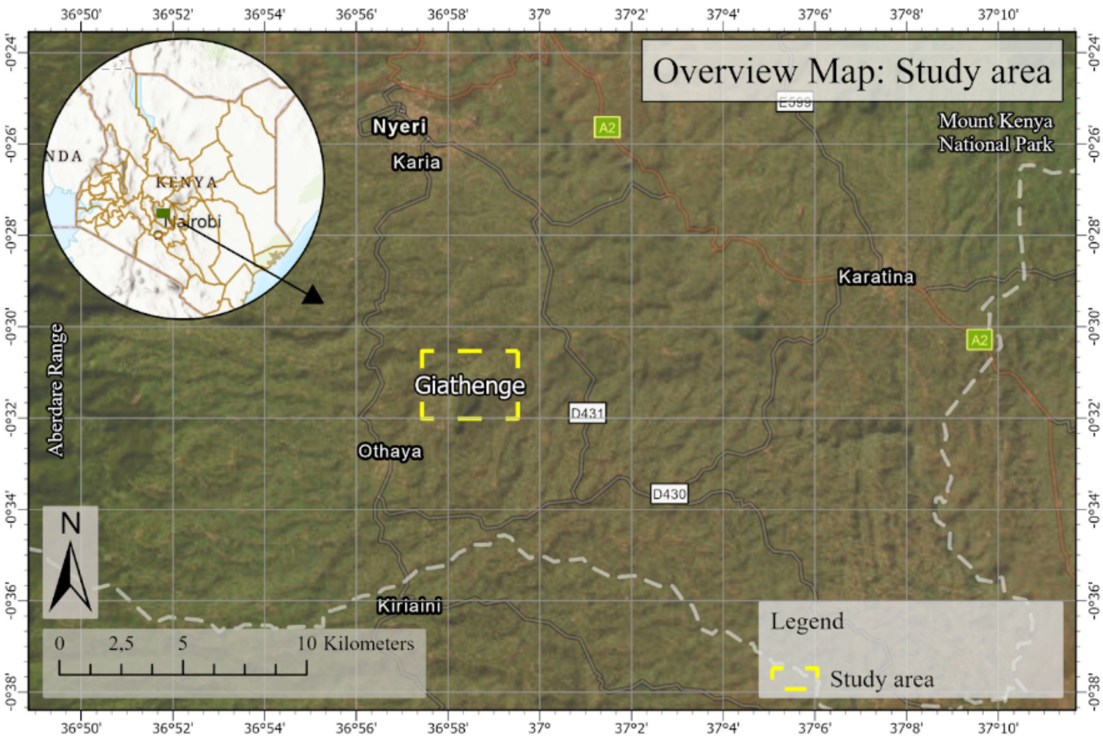

Figure 1: Overview on the study area location. The green rectangle indicates the map's extent. Source: Authors' elaboration.

The Central Highlands are well-suited for agricultural production with favourable climate conditions and fertile soils (Ngigi et al., 2020). Mean annual precipitation amounts up to 1.253 mm with a mean temperature of 18,5°C (Figure 2), a climate impacted by the El Nino Southern Oscillation. The area is inhabited by many smallholder farmers that cultivate coffee, tea, and macadamia nuts, and approximately 80% of all households own livestock for dairy production (County Government of Nyeri, n.d.). The livestock census for Othaya indicates 19.705 dairy cows and 10.580 goats, while 1.020 ha are used for growing NG and 6.500 ha for fodder shrubs (LO).

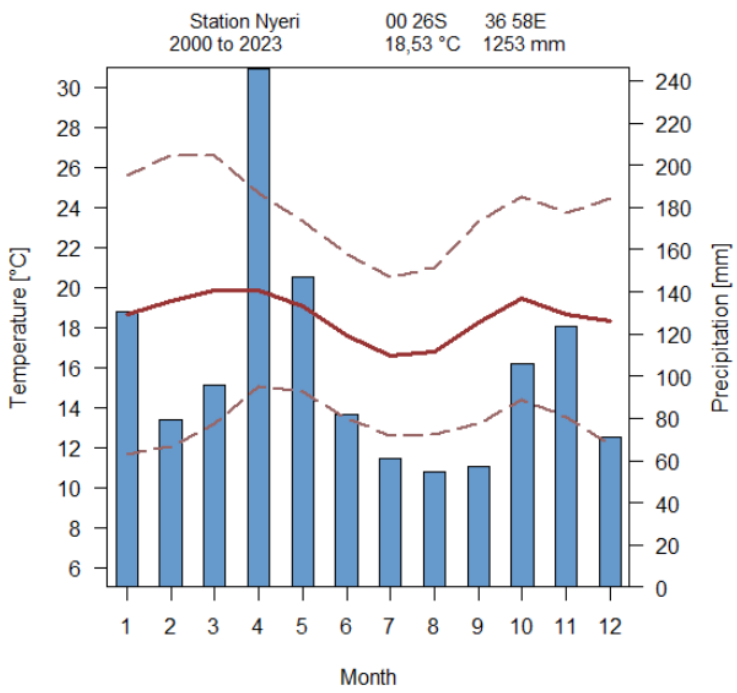

Figure 2: Average monthly temperature and precipitation trends for Nyeri County from years 2000 to 2023. The red line is the average, and the dashed lines are the maximum and minimum temperatures. Source: Authors' collaboration (data: Meteomanz, 2023).

The region has two growing seasons, each with a short and a long WS and DS. The WS is the growing season with increased rainfall, occurring from March to May and October to December (Figure 2). The study area belongs to the 20% of productive agricultural land in Kenya (World Bank CCKP 2021) and is well suited to cultivating NP and Maize (Norsuwan et al., 2014).

5. Conceptual framework

We developed a conceptual framework inspired by the Sustainable Livelihoods Framework (SLF) by Frank Ellis (2000) to guide our analysis (Figure 3).

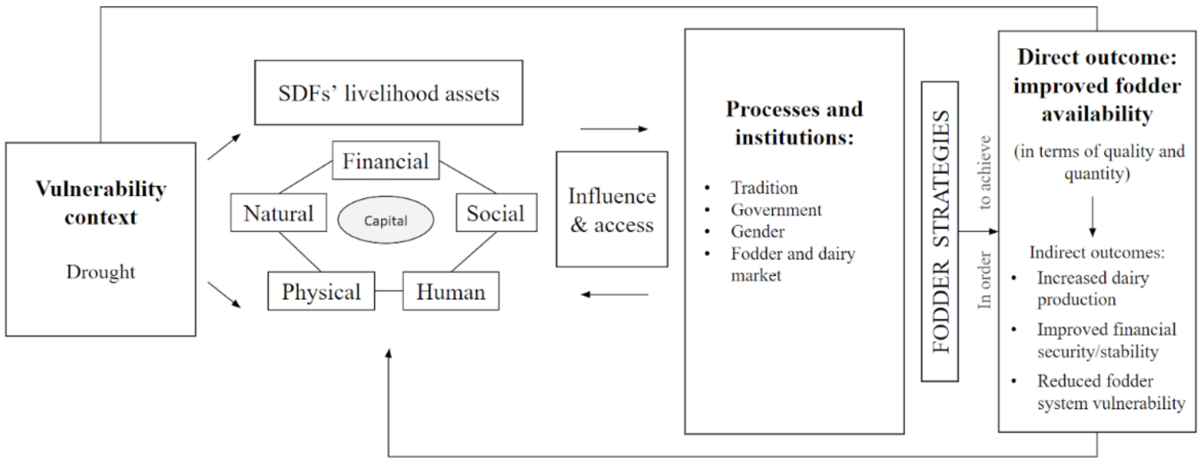

Figure 3: Schematic overview of framework. Source: Authors' collaboration, based on the Sustainable Livelihoods Framework.

The SLF is a tool for understanding the main factors that impact people's livelihoods and the relationships between them (DFID, 1999). In this context, the framework aims to understand SDFs' assets, risks, and the institutional environment that either supports or hinders their efforts to practise ideal fodder strategies (Hussein, 2002; Levine, 2014). *Fodder strategies* are defined as the strategies SDFs use to obtain fodder, directly impacting availability. *Fodder availability* is defined as the fodder SDFs have access to, to feed their dairy livestock. Based on the literature review, the framework hypothesises that the indirect outcomes include increased dairy production, and improved financial, social and cultural security for SDFs.

The vulnerability context outlines the external environment that affects farmers' assets' availability (DFID, 1999). This framework presents drought as the main shock that SDFs face in the Central Highlands of Kenya (Ochieng et al., 2016; Nalianya et al., 2020). The SDFs' livelihood assets aim to understand farmers' strengths and how they use them to increase their fodder availability (DFID, 1999). The assets are divided into five capitals: financial (financial resources to achieve fodder strategies; i.e. access to credit); social (social assets to achieve fodder objectives; i.e. networks and memberships of associations); human (skills and knowledge which enable SDFs to pursue different fodder strategies; i.e. farmers experience); physical (equipment and resources to support fodder strategies, i.e. hired labour); natural (natural resource stocks from which resource flows and services necessary for fodder obtainment are derived, i.e. SDF-owned land) (DFID, 1999; Ellis, 2000).

To assess these assets, SDFs' perceptions on various topics related to fodder are included, as they influence how SDFs react to the context (Levine, 2014). Shaping the assets are the processes and institutions, which in this framework include the agricultural tradition, government (national and the county level), gender, and market, based on Maina et al. (2019) and Okello et al. (2021).

6. Methodology

This section overviews the qualitative and quantitative methods (Table 1). Data collection took place from 3rd March to 13th March 2023. We employed social and environmental science research methods to allow for an interdisciplinary approach.

Method	Respondents
32 questionnaires	SDFs in Giathenge
6 semi-structured participant interviews with SDFs	3 SDFs with an alternative water source to rain (2 with a water pan, 1 with a water well) 3 SDFs with different water sources (1 only reliant on rain, 1 with an irrigation system, and 1 with a water pan), combined with biomass and soil quality assessment
5 semi-structured expert interviews	Agricultural livestock officer (LO) Karima Ward Member of County Assembly (MCA) Three teachers of agriculture and livestock of the Karima Boys Secondary School (TKB) Two sellers from two fodder businesses (FB)
Focus group discussion	5 Female SDF's using conventional fodder strategies
Transect walk	Observing of fodder strategies in Giathenge area
Biomass and soil quality assessment	On 3 farms, in combination with interviews. 3 assessments of Napier grass, 1 of fodder maize
GPS Mapping	From survey respondents, interviewees and transect walk
Meteorological data	Temperature and precipitation data from 2000 to 2023

Table 1: Overview of used methods in our fieldwork. Source: Authors' collaboration.

6.1 Questionnaires

Thirty-two structured questionnaires (Appendix II) with SDFs in the Giathenge area (Figure 4) were conducted, each around 40 minutes long. This was one of our primary data collection tools, as we aimed to gather standardised and quantifiable data (Rea & Parker, 2005). The set of closed-ended questions allowed us to compare respondents' answers, transfer the data quickly to the computer, and make the questionnaire less onerous for the respondents (Bernard, 2018).

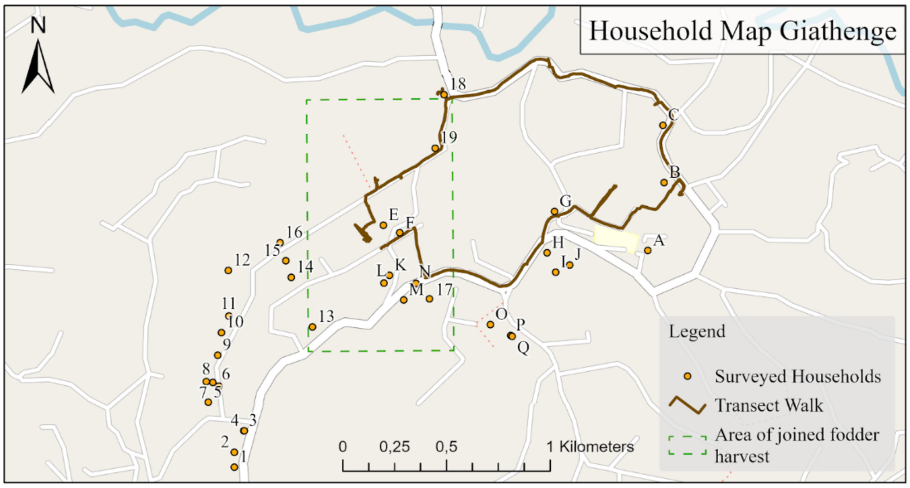

Figure 4: Data aquisition in the study area indicated in Figure 1 (yellow frame). Source: Authors' elaboration.

Our respondents owned dairy livestock and were either the heads of households or deputy decision-makers. The surveyed households were selected through random systematic sampling, selecting every second household following the perimeter road in the Giathenge region. In the case of households that were unavailable to participate (n=6) or did not have dairy livestock (n=2), the household before and after was surveyed instead.

The questionnaire's first draft was made before the fieldwork and then adapted in the field to reflect the local context. Two test questionnaires were carried out to assess the feasibility and relevance of questions by the SDFs and the translators. Afterwards, some modifications were made. Before the survey, respondents were informed of the study's objective and informed consent was sought.

The questionnaires were administered from the third to the sixth fieldwork day. The data collected from the questionnaires include household characteristics, assets of SDFs, livestock and fodder production features, and perception questions. Several questions used the Likert Scale, allowing the SDFs to indicate their attitude on given statements on a five-point scale ranging from 'strongly agree' to 'strongly disagree' (Bryman, 2016).

The data obtained from the questionnaires were collected using SurveyXact, and it was then cleaned in Excel, turning some variables into dummy variables. The analysis has been done by examining frequencies to identify trends and relationships. The statistical significance between dependent and independent variables has been assessed through t-tests (one numeric and one categorical variable) and chi-square tests (two categorical variables).

6.2 Semi-structured interviews

Eleven semi-structured interviews (guides in Appendix III) were conducted to complement the quantitative data gathered through our questionnaires and to help us better understand the social setting (Bryman, 2012). We followed an interview guide but gave the interviewee some leeway in responding, and each lasted one to two hours.

We conducted six semi-structured interviews with SDFs with different water sources to identify differences between their fodder strategies and assets. One of them had completed the questionnaire, while the others were chosen based on our observations during the questionnaires. Further, biomass and soil assessment was carried out after three of these SDFs' interviews. These were chosen because they would have us join a fodder collection for the biomass assessment.

Additionally, we conducted five semi-structured expert interviews to learn more about livestock regulations, government involvement, common fodder practices, and the fodder market from professionals in the field. These included the agricultural livestock officer (LO), Eunice Wagaki (Karima Ward MCA), three agriculture and livestock teachers from the Karima Boys Secondary School (TKB), and two sellers from two fodder businesses (FB). We developed guiding questions for these interviews to have an open conversation about fodder availability in the region.

6.3 Focus group discussion (FGD)

To better understand SDFs' perspectives and knowledge of alternative fodder strategies, a FGD with five SDFs was conducted (Appendix IV). Through their discussion and shared experiences, we learned how each participant interpreted the various factors affecting fodder availability. The method provided a chance to share why people felt the way they did by probing each other's justifications for holding a particular opinion (Bryman, 2016) and served to further the results obtained through the questionnaires and interviews. It was done during the last day of the fieldwork and lasted around two hours.

We used an open set of questions and a ranking exercise to allow the SDFs to raise issues that they considered significant but that we may not have previously contemplated. The first exercise ranked the nutritious value of different fodder types, while the questions focused on the importance of drought, water sources, institutions, and associations for fodder availability. The participants were women who also answered the questionnaires, selected through convenience sampling. Since they were all women, we included only female group members and our female translator in the FGD to create a comfortable setting. To accurately moderate the discussion, we chose for the female Kenyan counterpart to do so in Swahili while also being able to change to Kikuyu if necessary. The fact that she is a woman and shares the same cultural background as the participants helped liberate the discourse (Flick, 2022; Bryman, 2016). A student assisted the moderator with the questions while the other two took notes from the translations.

6.4 Transect walk

On the first day, we conducted a transect walk (Figure 4) with the two translators, which served as local guides. It allowed us to get an overview of the local context, and we tracked the route and selected waypoints of interest using the GPS.

6.5 Fodder yield and soil quality assessment

Figure 5: Location of households joined for fodder harvest (see Figure 4). Source: Authors' elaboration.

To examine the quantity, we joined three households (Figure 5) in their daily fodder harvest. We did this by weighing it with a spring scale. Additionally, measurements of the harvested and total area were taken. Using these measurements, the Green fodder yield was calculated as an index for productivity (method adapted from Manoj et al., 2021). Moreover, we calculated a index for feed supply in terms of fodder consumption by dividing the weight of the harvested fodder by the number of livestock and the duration of time the fodder will provide for. For livestock equivalents we used values for goats eating 1⁄6 and calves ⅛ of a cow (Interviewee 2) to perform this calculation.

Furthermore, composite soil samples of the corresponding harvested sites (three to seven sub-samples depending on the area size) were taken. The soil parameters texture, water content, pH, Nitrate-N, available Phosphorus, and Ammonium-N were analysed in Copenhagen. These parameters were chosen because they are important nutrients for plant growth. The texture was determined by the "Feel" method; Ammonium-N and Nitrate-N were analysed in KCl with a Flow Injection Analysis; soil pH in milliQ with a pH metre; and plant available Phosphorus in sodium hydrogen carbonate and added sulphuric acid again with the Flow Injection analysis (Anderson & Ingram, 1993).

6.6 GPS mapping

Global Positioning System (GPS) points and area measurements were collected with a Garmin eTrex 10. The coordinate system for all maps in this report is WGS84, visualised with ArcGIS Pro 3.0.0. By visualising the questionnaire data, spatial patterns were examined but nothing found.

6.7 Meteorological data

Temperature and precipitation trends were analysed to identify how the current drought can be attributed to climate change. The meteorological data comes from the nearby Nyeri climate station. The station was set up in 2000 (Meteomanz, 2023); thus, the available data only spans 23 instead of the necessary 30 years for climate-related investigations. A climate diagram was coded in RStudio 2021.09.0 (Appendix V.I.). Additionally, a Mann-Kendall trend test based on an autocorrelation analysis was used to assess statistically significant trends for temperature and precipitation, and a yearly precipitation distribution was created to detect data outliers (Appendix V.II).

7. Results

This chapter presents the findings from the fieldwork. It starts by providing a brief overview of the main characteristics of the questionnaire respondents and then analyses the drought as the vulnerability context impacting cultivation characteristics. Afterwards, SDFs' conventional fodder strategies (CFSs) and adaptation fodder strategies (AFSs) are identified. Subsequently, the impact of SDF's assets, processes and institutions on the AFSs is analysed.

7.1 Socioeconomic background

Characteristics	n=32		n=32
Role in household		***Education***	
Deputy decision maker	56%	Primary	47%
Head of household	35%	Secondary	18%
Other	9%	Tertiary	9%
Gender		No formal education	3%
Female	84%	Adult education	3%
Male	16%	***Main income source***	
Marital status		Cash crops	41%
Married	72%	Casual services	22%
Widowed	19%	Employment	13%
Single	9%	Handicrafts	9%
Age		Livestock for dairy	9%
> 1990	3%	Only subsistence	3%
1980-1989	25%	Livestock for meat	3%
1970-1979	16%		
1960-1969	25%		
1950-1959	9%		
<1950	22%		

Land size (in acres)	Mean	Median	Min	Max
Owned (n=32)	2,0	1,5	0,5	8,5
Rented (n=9)	0,7	0,3	0,5	3,5

Table 2: Main characteristics of questionnaire respondents (gender, household role, age, education, income, land size)

Most respondents are heads of the household or deputy decision makers (91%), female (84%), and married (72%). 47% respondents have completed primary education, and 27% have finished secondary school or higher. The average amount of land owned by respondents is 2,0 acres, and several respondents (28%) rent additional land (Table 2).

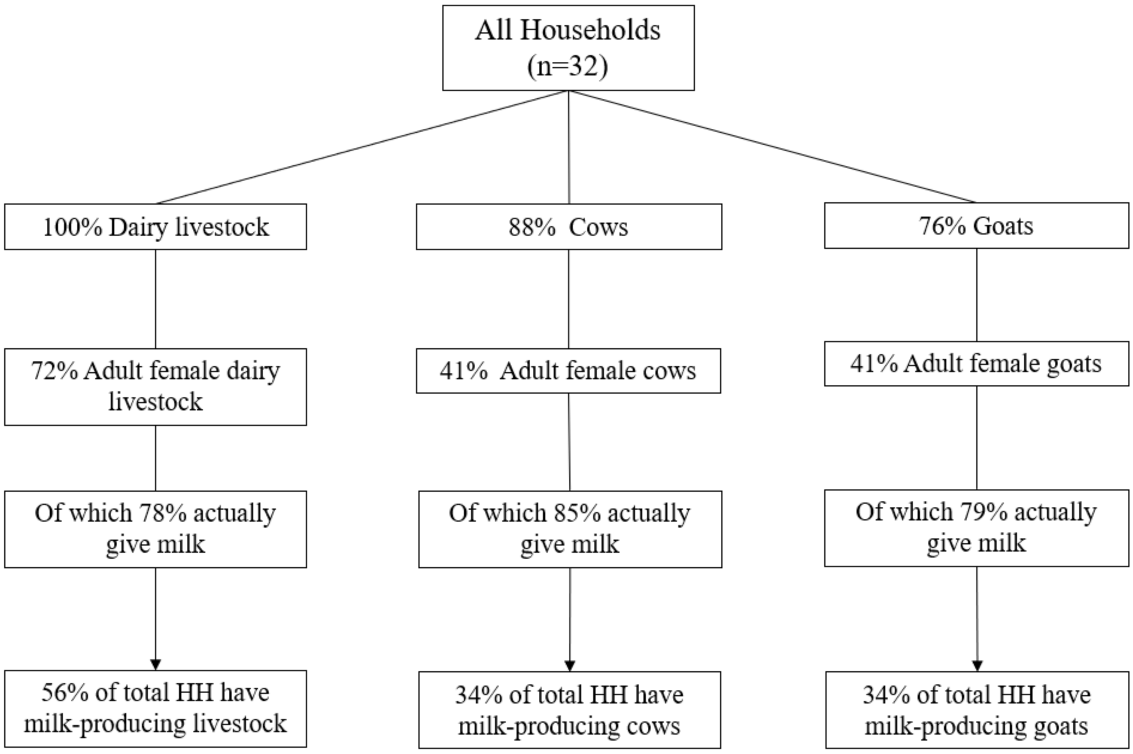

Figure 6: Percentages of dairy livestock and milk obtainment from the surveyed households.
Source: Questionnaire.

All respondents own dairy livestock, with cow ownership being slightly higher (88%) than goat ownership (76%). Just over half (56%) of the 72% of respondents with adult female livestock currently produce milk (Figure 6). Cows are primarily used to produce milk for subsistence, but sometimes they cannot due to pregnancy or malnutrition, whereas goats were frequently kept for other reasons than producing milk, such as meat.

Livestock per HH	Mean	Minimum	Maximum
Cows	0,56	0	2
Goats	0,84	0	4

Table 3: Number of dairy livestock (adult female cows and goats) per household. Source: Questionnaire.

The average number of dairy goats per household is higher than that of dairy cows (Table 3). Probably the fact that purchasing a cow is more expensive to buy, requires more space, and feed than a goat explains that if respondents have goats, they have several in comparison to cows (Figures 7 & 8).

Figure 7: Cow stable (shelters one cow).

Figure 8: Goat stable (shelters three goats).

Milk production per HH (in litres)	Mean	Median	Minimum	Maximum
Cow milk	7,4	7,0	2,0	15,0
Goat milk	1,4	1,0	0,5	2,0

Table 4: Milk production per household (only HH with milk producing cows/ goats are included in the calculation. Source: Questionnaire.

The average amount of dairy cow milk in litres is 7,4L (Table 4), slightly higher than the national average of 6L (Ajak et al., 2020). However, it is below the recommended 12L (Maina et al., 2019).

7.2 Vulnerability context: Drought

This chapter attempts to validate the severity of drought and justifies why specific fodder strategies must be adapted for future fodder production.

Most respondents (88%) experienced a decrease of more than 50% in fodder production over the previous five years. Drought was regarded as the most important cause of fodder loss by 91% of SDFs. Moreover, several experts stressed the high impact of drought on fodder availability the last two years (Interview with LO, TKB). However, this is not completely supported based on analysed weather data, which is presented below.

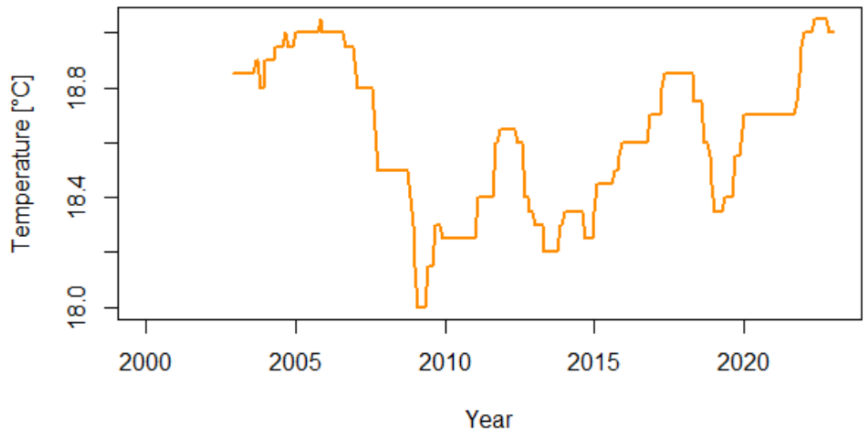

Figure 9: Floating median with a width of three years for the monthly temperatures. Source: Authors' elaboration based on meteorological data (Meteomanz, 2023).

Figure 9 shows the monthly temperature from 2003. The median temperature in the region fluctuates from 18 to 19 °C and shows peaks every 5 to 6 years. This is caused by the El Niño-Southern Oscillation. Hence, an autocorrelation within the data is present (Appendix VI.I), and the Mann-Kendall trend test cannot be conducted. Still, there is a current peak in temperatures similar to 2006.

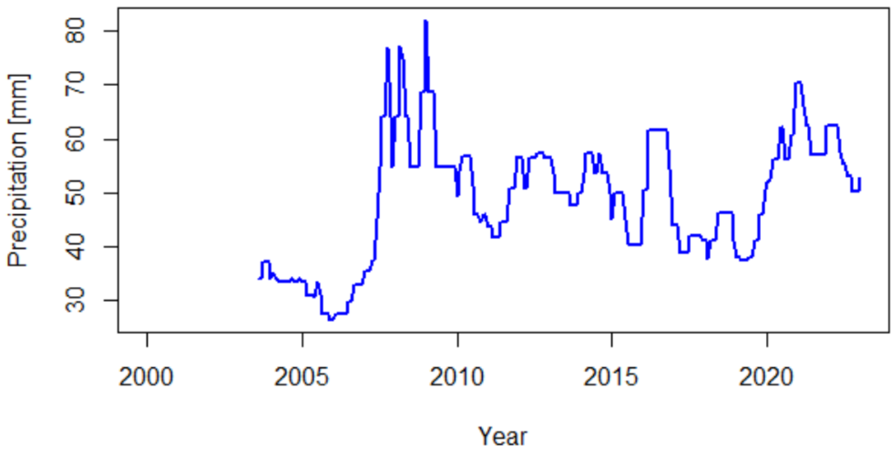

Figure 10: Floating median with a width of three years for the monthly precipitation (top) and an autocorrelation analysis with the coefficient (ACF) against the time-Lag and the 95% confidence interval in blue for the seasonally adjusted temperature data (bottom). Source: Authors' elaboration based on meteorological data (Meteomanz, 2023).

Concerning the precipitation as shown in figure 10, the data range from around 25 to 80 mm. No patterns are visible, confirming the high inter-annual variability typical for Kenya. Thus, even though an autocorrelation is not present (Appendix V.II), the Mann-Kendall test could not detect a trend for precipitation (p-value: 0,114).

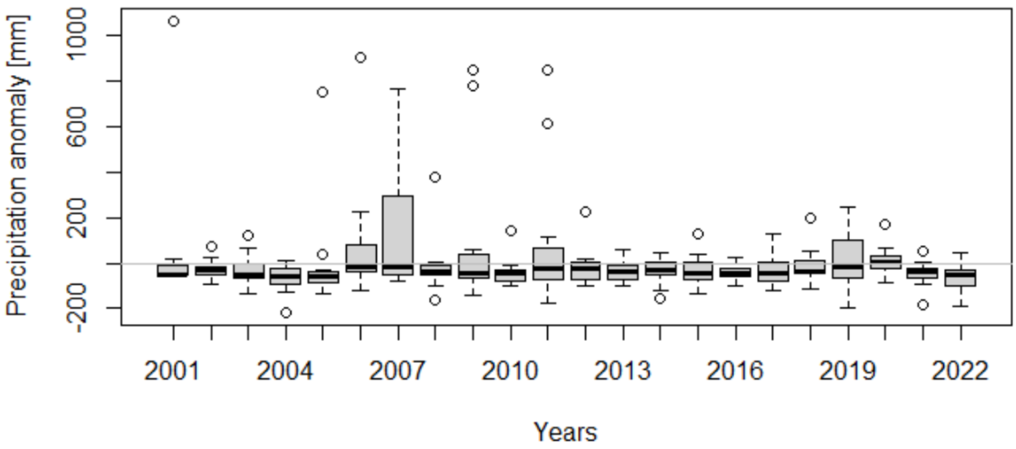

Figure 11: Precipitation anomalies as boxplots per year. Source: Authors' elaboration.

However, when looking at precipitation anomalies (Figure 11), currently a decrease in rainfall is visible. The boxplots show that until around 2012, very seldom but highly intense precipitation amounts occurred (outliers: circles). These events brought much rain into the region refilling aquifers. Without these, the meaning behind the medians (bold lines in boxes) being consistently below zero (especially pronounced for 2021 and 2022) is severe. Less precipitation water is available for harvesting fodder and to be stored in aquifers to use with wells or boreholes. This in combination with the current peak temperatures explains the drought the SDFs in Giathenge face. Even though no statistical trends could be identified, if these drought conditions continue and intense periods of precipitation continue to remain scarce, SDFs will need to adapt their fodder strategies to less water available. Biomass and soil sample assessments were carried out to determine how the fodder yields are during drought conditions.

7.3 Fodder cultivation characteristics: soil fertility and yield

This chapter contextualises the conducted biomass samples to assess how the drought currently affects the SDFs' fodder yields. Also, it examines soil parameters, as soil fertility impacts fodder yields, too (Rahman et al., 2010).

SDFs commonly practise a five-year crop rotation and the application of fertilisers (including livestock manure). This helps to keep the soil fertile and productive, which aligns with the perception of 72% of respondents who perceive their soil as fertile. However, the four soil samples taken were not too fertile, since less than 10 mg/kg phosphorus is considered a low fertility status (Hazelton & Murphy, 2016; Martius et al., 2001), which is the case for '1NG' and '3NG' (Table 5).

All the soil samples were very dry (water content of 1-2%) and had a texture of sandy loam. Ideal for the growth of Napier grass and maize is a pH value between 4,5 to 8,2 together with precipitation between 850 to 2.500 mm/a (Norsuwan et al., 2014). The annual precipitation for the study site is 1.250 mm (Figure 2). Thus, even though the phosphorus and pH values are on the low side in 1NG and 3NG, more or less acceptable growing conditions prevail (Table 5). Soil samples '2Maize' and '2NG' show higher fertility reflecting the more frequent and intense treatment with manure and a very nitrogen-rich fertiliser (UREA). Again, the higher ammonium values and not too high Phosphorus ones for soil samples '1NG' and '3NG' show the treatment with the fertiliser DAP (Di-Ammonium hydrogen Phosphate) and NPK 23.23.0 (Nitrogen, Phosphorus, Potassium) (farmer 1, 4). This illustrates the importance of soil treatment.

Soil Sample	pH-value	Nitrate-N (mg/kg)	avail. Phosphorus (mg/kg)	Ammonium-N (mg/kg)
1NG	5,94	5,98	10,70	6,46
2NG	7,04	15,47	46,13	2,71
2Maize	6,68	46,10	53,56	4,75
3NG	5,52	6,45	9,73	9,91

Table 5: Chemical soil parameters for the dried taken soil samples during the biomass assessment from three households. Source: Authors' elaboration based on the collected and analysed soil samples in the field.

Biomass sample	area of total homogenous fodder cultivation [ha]	area of harvest sample [ha]	weight of harvest sample [kg]	Green fodder yield [kg/ha]	harvest [kg]/ cow/time [h]
1 NG	0,020	0,004	4,8	1.085,727	0,200
2 NG	0,009	0,001	38	54.363,376	2,246
2 Maize	0,019	0,001	2	1.666,667	0,118
3 NG	0,111	0,024	130	5.453,020	0,734

Table 6: Data on the taken harvest samples. Source: Authors' elaboration based on the biomass assessment in the field.

The soil parameters compared to the Green fodder yield (Table 6) show the importance of sufficient soil treatment to achieve a high yield, especially concerning phosphorus (Figure 12). Still, the higher yield of ‘2NG’ is not only due to the higher fertility but also the fact that this field gets irrigated. The differences between ‘3NG’ and ‘1NG’ can be explained by the different percentage of land shadowed. An identical percentage of respondents to the questionnaire, namely 44%, agreed and disagreed that they have enough fodder to feed their livestock. This variety highlights the importance of location factors determining water demand and the potential from small-scale adaptations like providing more shadow.

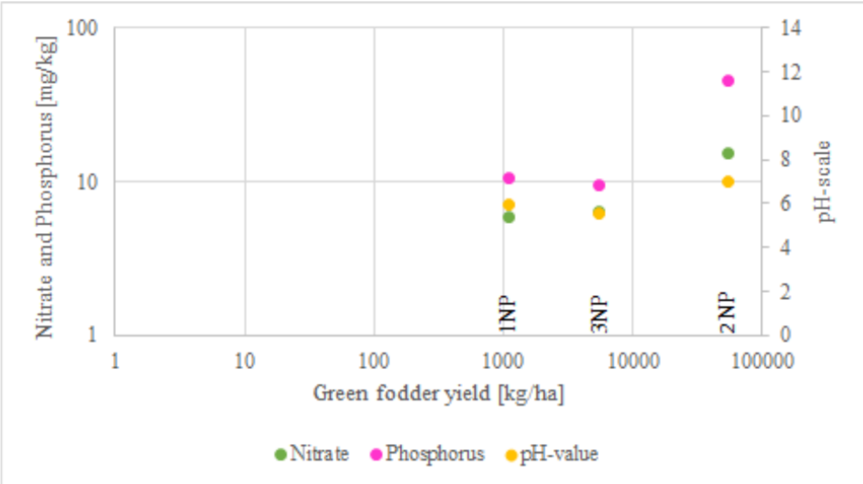

Figure 12: Chemical soil parameters in comparison to the Green fodder yield for each FC household. Source: Authors' elaboration based on the biomass and soil assessment in the field and soil assessment in lab in Copenhagen.

The capability of the harvested fodder to feed the corresponding number of livestock varies significantly between the three households (HH). A cow needs 60 to 70 kg of NG a day (Agri Farming, 2019). Only HH2 with 54 kg can reach this ideal fodder quantity, especially when including the maize (2.8 kg). This illustrates how drastic the current drought impacts the fodder cultivation. This is reflected in the 18L milk produced by the milk-producing cow of HH2 (vs. 5L HH1, 15.5L HH3). During the WS, those numbers will shift a lot. For instance, HH1 indicated to get 3 times more milk, as the harvest per unit of land will double in comparison to now (interviewee 2). Nevertheless, usually, one cow needs 0.5 acres of NG to feed on.

7.4 Fodder strategies

This section provides an analysis of observed fodder strategies used by SDFs in Giathenge. It starts with describing the conventional fodder strategies (CFSs) used by most SDFs, before identifying and subsequently analysing the used adaptation fodder strategies (AFSs), which only a few SDFs follow. This section examines the livelihood assets that promote SDFs to adopt AFSs and how these lead to fodder quality and quantity improvements. Lastly, the impact of processes and institutions on the determinant assets is analysed.

7.4.1 Conventional fodder strategies

Most SDFs in Giathenge primarily rely on their fodder cultivation (interview with LO). All of the questionnaire respondents cultivate their own fodder, and most (85%) allocate 10-25% of their land for fodder production.

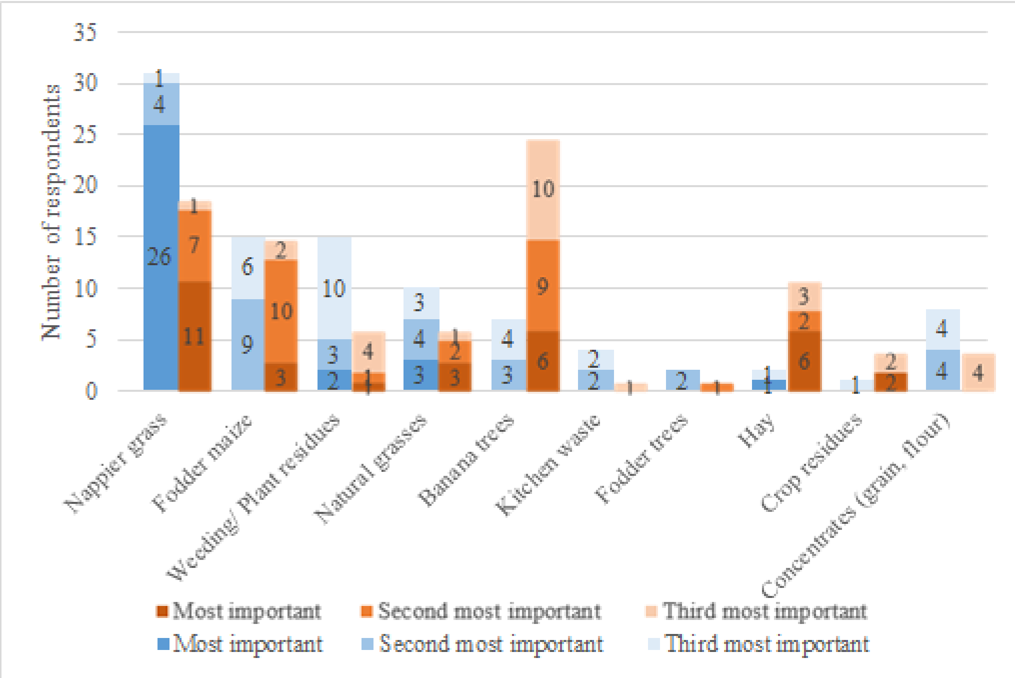

Figure 13: Most important fodder types during the WS (blue) and the DS (orange), n=32. Source: Questionnaire.

The most common types of fodder vary between seasons. During the DS, 59% of respondents indicated that NG was among the top three most important fodder types, followed by banana trees and hay. Comparatively, during the WS, 97% of respondents indicated that NG was among the top three most important fodder types, followed by natural grasses and weeds (Figure 13).

Figure 14: SDF using a panga to process fodder to feed to a goat. Source: Authors.

On average, SDFs spend 3,5h (DS) and 4h (WS) daily carrying out fodder-related tasks (Appendix VI.III). To harvest their fodder, all respondents use a panga. Most respondents harvest fodder every day, transport it by wagon or backload, and then chop it directly on the feed trough (Figure 14). The majority of respondents do not use fodder preservation (54%) or storage (60%). The SDFs who preserve and store fodder, such as using silage, hay or storing in a shed, usually do so in the WS. In the DS, the fodder on the fields is barely enough for everyday use as confirmed by the fact that only HH2 came close to being able to harvest enough for their livestock (chapter 7.3). Instead, most SDFs give their livestock just enough fodder to "survive" in this season (FGD).

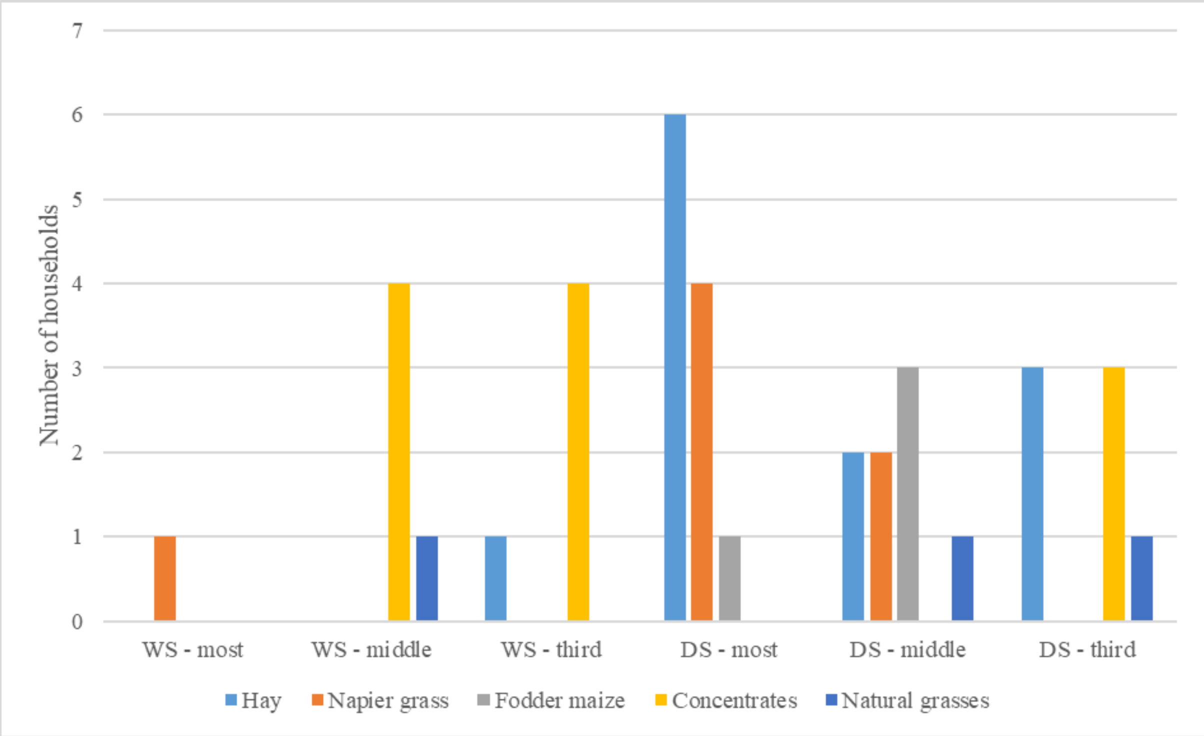

Figure 15: Fodder types purchased during the WS and DS, n=32. Source: Questionnaire.

All respondents rely on rainfall as the primary water source for their fodder crops, and only few (13%) have additional water sources. Due to the seasonal differences in fodder yield, more SDFs purchase fodder during the DS (53%) than in the WS (31%). Purchased fodder in the DS primarily supplements the quantity of fodder provided to livestock, based primarily on hay and NG. In contrast, purchased fodder in the WS are mainly concentrates, which nutritionally complement the fodder they cultivate during that time, improving the milk yield (Figure 15).

7.4.2 Adaptation fodder strategies: SDFs' livelihood assets

The AFSs that have been identified include:

1. Maize as a central fodder type for WS and DS
2. Water sources other than rain
3. Preserving fodder with silage
4. Purchasing concentrates during the WS (DS is not possible to include since barely any SDF purchases)

Per strategy, SDFs have been divided into two groups (dummy variables); SDFs who use the AFS and SDFs who do not. The means of the two groups have then been for several independent variables. These variables have been chosen based on the literature review, and are likely to positively impact the probability of SDFs to adopt a certain AFSs. Table 7 shows the p-values indicating whether the variables determine this probability.

Variable	Unit	Test type	Considering maize as a top fodder type (DS and WS) P-value	Having additional water sources to rain P-value	Preserving with silage P-value	Purchasing concentrates at the market (WS) P-value
Financial Assets						
Variety of financial sources	Number of financial sources (financial support)	T-test	DS: 0,411 WS: 0,686	0,714	0,132	0,046*
Loan access	Yes No	Chi-square test	DS: 0,604 WS: 0,489	0,087	0,117	0,601
Transportation means	Yes No (=none or backload)	Chi-square test	DS: 0,132 WS: 0,491	0,358	0,778	0,778
Dairy livestock units (adult female cows and goats)	Number of units	T-test	DS: 0,157 WS: 0,287	0,12	0,448	0,951
Social Assets						
Group membership	Dummy variable: 1=feeling part of association 0= otherwise	Chi-square test	DS: 0,163 WS: 0,264	0,218	1	0,346
Human Assets						
Age	Dummy variable: 1= >43 years old 0= </=43 years old	Chi-square test	DS: 0,783 WS: 0,682	0,882	0,820	0,820
Education	Dummy variable: 1=secondary, university, and vocational training 0= none and primary school	Chi-square test	DS: 0,280 WS: 0,694	1	1	0,102
Training on agriculture (FFSs)	Yes No	Chi-square test	DS: 0,314 WS: 0,327	0,146	0,216	0,217
Knowledge from Governmental Extension Services	Yes No	Chi-square test	DS: 0,335 WS: 0,365	0,492	0,726	0,726
Farming experience	Years	T-test	DS: 0,469 WS: 0,376	0,538	0,287	0,242
Occupation in agriculture (n=31)	Dummy variable: 1= livestock for dairy as the main income source 0=others	Chi-square test	DS: 0,955 WS: 0,241	0,16	0,145	0,849

Physical Assets						
Hired labor	Yes No	Chi-square test	DS: 0,533 WS: 0,496	0,217	0,005**	0,346
Natural Assets						
Land owned	Acres	T-test	DS: 0,929 WS: 0,459	0,191	0,270	0,271
Perception of soil fertility	Dummy variable: 1= strongly agree, agree 0=strongly disagree, disagree, neither agree nor disagree	Chi-square test	DS: 0,783 WS: 0,682	0,882	0,820	0,820
Fodder variety ***(DS and WS)***	Dummy variable: 1= Napier grass as most important fodder type 0=others	Chi-square test	DS: DS: 0,618 WS: 0,227 WS: DS: 0,125 WS: 0,361	DS: 0,788 WS: 0,581	DS: 0,217 WS: 0,399	DS: 0,217 WS: 0,399

Table 7: Determinants of exceptional fodder strategies, separated by five different capitals. Source: Questionnaire. Notes: *, ** significant at 5% and 1%, respectively.

It is assumed that SDFs who adopt AFSs have greater access to fodder than the ones following the CFSs, and that the ability to practise AFSs depends on the financial, social, human, physical and natural assets described in Table 7. Although most p-values are not statistically significant due to small sample size, the calculations of the means and percentages can provide insights into patterns and hence, possible impacts.

7.4.2.1 Adaptation strategy 1: Maize

This section examines assets that can impact the likelihood of SDFs using maize for fodder. Even though no statistically significant correlations are found for this AFS, several trends and variances in means between the two groups are identified, indicating that (a combination of) certain factors can lead to a higher probability for SDFs to adopt it.

Few SDFs identify maize as one of their top two most important fodder types to feed their dairy livestock in the DS (40%) and WS (28%). Fodder maize, however, has several advantages over NG, including a higher nutritional value, a longer lifespan, and the ability to produce a higher fodder yield (TKB; Kilimo News, 2020). In this sense, maize increases the quality and quantity of feed available to livestock. Nevertheless, the data acquired on fodder yield indicates that maize has a smaller yield than

NG per unit of land (Table 6). This is problematic in the context as SDFs are facing declining land sizes due to land fragmentation. However, this fodder yield data consisted of a small sample size (n=4), therefore, this may not be accurate to all maize cultivation in the region.

SDFs who use maize have a higher average number of income sources than SDFs who do not (2,38 and 2,05 respectively). Contradictorily, the relative number of SDFs who own a mean of transportation (indicator of financial capital) is lower for the SDFs who adopt this strategy (54%) than those who do not (79%). Therefore, based on our data, there is no relationship between financial assets and adopting maize. An explanation is that maize seeds are similar in price to NG seeds (TKB).

Being a member of an association can impact the likelihood of incorporating maize. The relative number of SDFs who consider maize an important fodder type to use (77%) are members of one or more associations, representing a higher percentage than the SDFs who do not (53%). These associations are not necessarily related to agricultural activities (such as a church or women's organisation). However, the higher percentage can be explained due to the opportunities it creates for interactions and dialogue (for instance, about fodder types), which can expand SDFs' fodder knowledge. The importance of exchanging knowledge for cultivating alternative fodder types was also highlighted with the FGD. The discussions e.g. on nutritional values of fodder types led to an outcome where the participants gained new information from one another.

As for the influence of human capital, more SDFs (68%) who follow this AFS have completed secondary school or higher than the SDFs who do not (42%). Moreover, 31% of the SDFs who use maize went to FFSs, compared to the 16% of SDFs who do not. The average years of farming experience are also higher for SDFs prioritising maize (28,1 years) than for SDFs that do not (23,5). These results indicate that SDFs with more access to farming knowledge are more likely to adopt this AFS.

In addition to maize, several fodder types contribute to a higher fodder availability than conventional fodder types like NG. For instance, millet and sorghum grow quickly (3 months), are drought-resistant, and have higher nutritional value than NG (TKB). However, only one respondent occasionally uses these fodder types. According to the TKB, this is due to a general lack of knowledge of fodder diversification, which aligns with these findings.

7.4.2.2 Adaptation strategy 2: Additional water sources to rain

Besides primarily depending on rain, 13% (n=4) respondents have other water sources. Specifically, 6% of SDFs use groundwater from a borehole and a well, and 9% use surface water from a water pan.

Even though there are no significant statistical relations between having alternative water sources to rain, some patterns have been identified, which are discussed below.

An initial investment of 18.000 Ksh is required to construct a water pan, which can hold up to 204.000 L of water and can be filled up in one night during the WS (Interviewee 3). In this sense, financial capital is relevant for acquiring alternative water sources. This aligns with our results on having 2,5 financial resources instead of the 2,1 for SDFs that rely only on rain. Half of the SDFs that use this AFS have received loans, while only 14% of those do not. Additionally, they all have means of transport, while only 18% of SDFs who rely only on rain do. Moreover, half of the SDFs who adopt this strategy hire labour, while the percentage is lower for the ones who do not (21%), confirming that the SDFs following the ESF are in a good financial situation

The units of dairy livestock tend to be higher for the SDFs following this AFS than for the ones following CFSs (averages of 2,8 and 1,2 units, respectively). This indicates that their increased water availability can be used to cultivate more fodder and, thereby, sustain more animals. Notably, dairy livestock is the primary source of income for 50% of SDFs who use this AFS, while this percentage is 19% for the SDFs who do not use it. In this regard, the SDFs relying on dairy livestock as their primary income source may favour investing more in implementing alternative water sources to sustain and bolster their own income.

Even though no difference can be detected concerning educational level, the attendance of FFSs is more popular by SDFs following this AFS (50%) than the ones relying only on rain (18%). This suggests that attendance to FFSs may be relevant for adopting the AFS and that there needs to be more education regarding rain alternatives.

The social capital is irrelevant for this AFS, as just 50% of the SDFs with additional water sources feel part of associations, while 79% of SDFs who rely on rain do. This suggests that networking and community are not determining factors in building or accessing surface or groundwater.

The natural capital of the SDFs who adopt this strategy is typically high. They tend to own larger parcels of land than those who only rely on rain (averages of 3,3 and 1,8 acres of land, respectively). However, the perception of soil fertility is similar to the ones who do not adopt the strategy. This implies that the SDFs are aware of the negative impacts on soil fertility when watering their plants and accordingly use fertiliser. This gets supported by the even more fertile soil of HH2 that uses irrigation (chapter 7.3).

Despite having greater access to water, 75% of SDFs still rank drought as the top reason for fodder loss, which is a similar percentage to SDFs who do not follow this strategy (64%). This demonstrates that even with additional water sources, the drought poses a threat to SDFs. Moreover, construction barriers lead to a limited usage time of those water sources. While interviewee 2 had to give up on a water pan because it filled up with sediment, interviewee 3's well collapsed because of a weak foundation. Surprisingly, 50% of them believe they do not have enough fodder, a similar percentage to the SDFs not following this AFS (42%). This contradicts with our biomass assessment findings, which analysed a more than tenfold yield for HH2 who have water sources in addition to rain (Table 6). This could also be a result of the higher number of livestock units they possess. SDFs of this AFS still face the threat of drought because even though they can cultivate more fodder, they also need more to feed their higher number of livestock units.

7.4.2.3 Adaptation strategy 3: Silage

The third adaptation strategy identified is using silage to preserve fodder. Of the 47% (n=15) respondents who use technology for preservation, 53% (n=8) use silage. This strategy increases fodder availability, as it can be used to preserve and subsequently store fodder during the WS to save it for the DS (interviewee 2). 43% of them tend to rely on dairy livestock as their primary source of income compared to 17% of those who do not adopt it. The 270 tons of silage in the Othaya sub-county are increasing thanks to ongoing training in NG and fodder maize conservation (LO).

SDFs using silage tend to have more years of farming experience than farmers who do not (averages of 30,9 and 23,5 years, respectively). Notably, 38% of SDFs who use the silage have attended FFSs, and 13% have received education from governmental extension services. These percentages are lower for SDFs who do not use it (17% and 8%, respectively). In this sense, human capital contributes to adopting this strategy through the farming experience and education that farmers receive.


Figures 16 and 17: Employee cutting fodder with the chaff cutter in HH 1 and silage bags from HH 10. Source: Authors.

Creating silage requires some technology, including a chaff cutter (Figure 16), silage bags (Figure 17), molasses, and a significant amount of labour over a brief period (a few days) (Interviewee 2). 63% of SDFs using silage have hired labour, while only 13% do not. Additionally, SDFs using silage are more likely to have more financial resources than those without (averages of 2,8 and 2,00, respectively). An increase in the number of adult female dairy livestock also positively affects silage utilisation (average of 1,75 compared to 1,3). This may imply that using silage assists in obtaining the greater quantity of fodder required for owning more livestock. Credit availability also influences the likelihood of implementing the strategy, as 38% of SDFs who use it have received a loan, while only 13% of SDFs do not. In this regard, physical and financial capitals are important for SDFs to adopt this strategy, but they are not the only factors.

Concerning natural capital, SDFs who own more land have an increased likelihood of using silage (2,7 and 1,8 on average, respectively). For SDFs who own more land, assuming that they can grow more fodder, it is beneficial for these SDFs to use silage to process more fodder for future uses. Regarding social capital, the same amount of SDFs who use this AFS and did not, felt like members of associations. Upholding that silage adoption is not necessarily aided by networking and a sense of community of respondents.

However, some of these results are inconsistent with farmers' perceptions on fodder quantity. Only 43% of SDFs who use silage, and 44% of SDFs who do not, believe they have enough fodder for their livestock.

7.4.2.4 Adaptation strategy 4: Purchasing concentrates

In the WS, 25% of our respondents purchase concentrates. They act as nutritional additives to fodder that generate a higher milk yield per cow (FBs 1 and 2), contributing to the availability of fodder quality. They are most frequently purchased during the WS because SDFs use them to supplement the fodder they grow (Interviewee 2). However, in the DS, since SDFs cultivate less fodder, they prioritise buying other fodder types that help fill the stomach of their livestock, like hay or NG (TKB and figure 15).

A statistical significance between SDFs who purchase concentrates and those who do not is found for one variable; the variety of income sources. The result is, however, more contradictory than expected as SDFs who purchase concentrates have fewer income sources than SDFs who do not (averages of 1,6 and 2,4, respectively). However, this variable is not necessarily an indicator of higher financial assets. Hence, a more detailed analysis of which income sources compose the average because if someone has several income sources, this can mean that they generate a small amount from (temporary) work activities. In contrast, a person with less but more income sources might generate a higher and more stable income, which seems to be the case here. Moreover, based on the visits to several fodder shops, we found that SDFs who buy concentrates have more financial means. It is often seen as an extra, and SDFs with less financial means do not prioritise them.

Concerning human capital, SDFs who purchase concentrates have more farming experience than those who do not (means 27 and 20 years, respectively). Our findings from observations and interviews also indicate the importance of knowledge obtained from formal institutions. SDFs that buy concentrates differ from the SDFs who do not, as 75% completed higher education compared to the 42% of the SDFs who do not. Moreover, 38% attended FFSs, and 13% received education from extension services, being 17% and 8% for those who do not purchase concentrates, respectively.

7.5 The role of institutions and processes

This section analyses how institutions and processes influence the fodder strategies of SDFs. Such institutions and processes include agricultural tradition, government, gender and the market.

7.5.1 Agricultural tradition

Agricultural norms and traditions are ingrained in many fodder and livestock practices. Most SDFs use practices they have been doing their whole life and see no point in changing (Interviewee 1), and 56% of respondents inherited their farming knowledge from their parents.

Moreover, many SDFs practise the same conventional fodder strategies, indicating that a culture around agriculture exists. For example, as already stated in 7.4.2.1, fodder types such as maize, millet and sorghum are more nutritious and drought resident (TKB). Still, Napier grass is by far the most commonly used fodder type and wrongly perceived as the most nutritious one (FGD). There is a lack of willingness to change fodder strategies because people have been using Napier grass in the area since 'forever' (TKB). This shows how traditional practices are deeply rooted in farmers' fodder strategies, and change is a prolonged process.

Another agricultural tradition is the decision to have cows. Interviewee 2 even stated, to keep a cow is more like keeping a pet. SDFs are hesitant to switch to other livestock strategies because the cow is deeply engraved in their culture and is part of their livelihoods by providing them with milk, manure, and in some instances, biogas. Such livestock strategies include switching to goats, as goats take shorter amounts of time to birth (5 months) than cows (9 months) and require less feed (FGD). This creates a paradox: SDFs desire to have cows but, at the same time, do not have enough fodder to feed them. SDFs explained they had cows because "Everyone does it, and it is the normal thing to do"

(Interviewee 2). When asked about abandoning cows, SDFs were very upset and answered, "I would rather starve than not be able to feed my cow" (FGD).

7.5.2 Government

The regional and county governments have limited extension services and subsidies due to financial constraints and the SDFs a lack of knowledge and physical access to these services. Only 9% of SDFs claimed that government extension services were a source of knowledge for fodder production. Governmental programs that aim to provide SDFs with knowledge and services include the National Kenya Dairy Board, which has a branch in Nyeri, the County Livestock Department, various NGO collaborations, and the Agricultural Sector Development Support Program (LO).

Moreover, there is a need to strengthen governmental support specific to water availability and access. A potential solution to the water problem is constructing boreholes and water pans (FGD). However, these two options are expensive to construct, so that SDFs would need financial support from the government (FGD). As for irrigation systems, the government currently cannot financially support them (MCA). Further, some SDFs claim that these governmental extension services only help in the WS, not during the DS (FGD). This shows that although there is knowledge about the options for increasing water availability and access, there are significant financial barriers. Often, the government lacks capacity and resources to support these improvements.

Another program in the works (2 months old) is a pipe water program from the government to supply water from the Aberdares mountain ranges (FGD). However, it has not fully developed due to lacking governmental support and infrastructure (MCA). Further, the pipe water costs 250 KSH per month, and households pay per L after that (Interviewee 2). Due to these prices, SDFs are not using this pipe water for fodder cultivation (Interviewee 3).

On the other hand, a program identified as a source of information by many farmers (22%) were FFSs. These FFSs seem to be a plausible way to bring together SDFs and share knowledge between the government and SDFs for minimal costs.

7.5.3 Gender

In Giathenge, men tend to be the household head and women the deputy decision makers, who make the decisions when the household head is absent. An exception is if the woman is a widow or single, then she is the household head. Interestingly, the majority (84%) of questionnaire respondents were women. Women usually stay home during the day doing the housework, while men usually work elsewhere.

With regards to gender roles linked to livestock tasks, feeding and milking are mainly done by the deputy decision maker (64% and 82% of the time, respectively), whereas cleaning and checking for health issues were done by the household heads (60% and 62% of the time, respectively). Moreover, during the focus group, only one woman was familiar with FFSs. This SDF had not previously informed her other female friends about FFS because sometimes men do not allow their women to join those schools. Further, the county government only offers a small department on "Youth, Women, and Gender," that does not currently offer support concerning livestock or agriculture.

7.5.4 Market

More SDFs purchase fodder in the DS (53%) than in the WS (31%); however, this is not statistically significant. The types of fodder purchased at the market also vary seasonally (Figure 15). Fodder businesses sell mainly concentrates (FBs). While NG and fodder maize are produced within the sub-county, hay is mainly imported from neighbouring countries (LO). The buying power of SDFs is currently low. Because of water scarcity the production costs are increasing and "there is no alternative other than to raise prices" (FB 1). Fodder prices have risen in both seasons. During the DS, six months ago, a bag of 70 kg of concentrates cost 2.500 Ksh, while it now costs around 2.800 Ksh, which has led to a decrease in sales (FB 2). Additionally, during the DS a 70 kg bag of concentrates is more expensive than in the WS (2.800 Ksh vs. 2.450 Ksh). Thus, there is an increase in sales during the WS (FBs); but still, the questionnaire data shows more SDFs buying fodder during the DS. This is because of the low availability of harvested fodder during the DS.

A seller needs to be certified to sell fodder to indicate that the fodder is produced locally (MCA). Only 9% of questionnaire respondents (n=3) claim to sell fodder, and they only do so during the WS. Only then, their land can provide more fodder than they need themselves (FGD). That being said, the fodder market in Giathenge among SDFs exists on a small scale. Currently, the milk yield that the SDFs' dairy livestock produces is not enough to sell milk and to receive high remuneration (FGD and Interviewee 2).

8. Discussion

In this section, we elaborate on how our main findings fit in existing literature, and how the usage of the selected framework, methods, collaboration with our Kenyan counterparts, and positioning in the field have affected our findings.

8.1 Reflection on framework

The SLF functioned as a valuable tool to identify potential factors influencing SDFs' fodder strategies. Moreover, it guided the data collection and analysis process, reminding us of our research aim and objectives. However, reflecting back on it, we did not use the framework as extensively as we would have liked. Our focus was mainly on determining livelihoods assets, and the focus on institutions and processes became a bit lost in the process. Accordingly, our findings are mostly related to the assets, which is unfortunate because we realised that several institutional factors are important determinants. In this sense, even though the study aimed for a holistic perspective, these aspects are lacking.

8.2 Reflection on methods

The sample of 32 SDFs was very small compared to our study site, which can mean that some of the correlations and relationships presented are not entirely accurate. Moreover, due to time constraints and spatial setting, the region we wanted to assess had a disproportionately low number of surveys in the north compared to the south. This restricts some of our findings, which may be geographically biased and may result in undetected correlations due to a lack of representation.

The language barrier was a huge constraint to getting the whole picture. This was particularly true for some interviews and the FGD, where the translators struggled to translate the whole discussion. Another setback with the interviews and FGD was that we had a short time for preparation. Additionally, only a few women actively participated in the discussions, and we were unsure how to include the others. This may have biases in the obtained data.

The research strived to triangulate the quantitative and qualitative methods. Even though soil and biomass assessments were made, their outcomes could have been more informative and offered a limited contribution to the research. This is because only a limited number of them could be conducted due to time constraints, incapable of entirely representing the local conditions. Furthermore, for the biomass assessment, a dry matter weight determination would have given a more comparable picture as the water content of the plants varied a lot since one field was irrigated. Still, those limitations do not explain all differences gathered.

Finally, a Seasonal Kendall test would have been necessary to detect a temperature trend besides the El Nino Southern Oscillation cycles, but insufficient data was available.

8.3 Reflection on collaboration with counterparts, ethics, and positioning

Being outsiders of the community, having Kenyan counterparts, staying with local families, and having local guides helped in understanding the area's culture and livelihood dynamics. This had some positive aspects, like the fact that we intended to document every little detail, which prevented us from taking anything we learned for granted and allowed us to learn from a fresh, unprejudiced novice perspective. However, it also led to some limitations. Our knowledge of the field was limited before going, but the little we had resulted in certain expectations that shaped how our research was designed.

The Giathenge SDFs had varying perceptions of us. While the majority seemed to consider our presence a privilege, others appeared unsure of how to respond and even suspicious. Being perceived as strangers and 'mzungus' (white people) influenced how they treated us, creating a gap between the farmers' and our positions. The majority of them were willing to participate and contribute to the study; however, the presence of university students asking questions the SDFs would not typically ask themselves or would consider as obvious led to some uncomfortable settings. Additionally, since we were outsiders, we were still determining how our research would benefit them and felt disqualified from making suggestions or offering solutions.

The collaboration with Kenyan counterparts was generally successful but became a challenge sometimes. Due to different motivations and perceptions of the research, our goals were different. Unlike us, our Kenyan counterparts were in a situation where this research did not occupy their entire days while in Giathenge; instead, it was a supplement to their lives, combined with jobs and parenting.

8.4 Reflection on findings

Extreme drought as the leading cause of fodder loss is mentioned in literature such as Lukuyu et al., 2011 and Njarui et al., 2016. This aligns with the perceptions of SDFs in Giathenge, who express that they have been suffering from extreme drought for the last two years, with the current drought being the worst one experienced in a long time. The analysis of meteorological data identified a corresponding unprecedented coincidence of high temperatures with an absence of intense precipitation events for more than a decade. Even though no trend could be detected, confirming that this coincidence will prevail in the future, implementing adaptation strategies on water scarcity are highly recommended.

The importance of financial assets, as identified in the literature by Mairura et al., 2021 and Silvestri et al., 2012, is also reflected in our findings. We found that SDFs with more financial means are likely to adopt all four AFSs. A reasonable explanation is that our identified AFSs all require financial input. It would have been interesting to analyse AFSs that require fewer financial assets, and more knowledge-related practices, such as crop rotation, to determine if financial assets also play a role. Another note is that the variables for financial assets are not necessarily reflecting the whole financial circumstances of the SDFs.

Adimassu & Kessler (2016) present the amount of livestock as an important determinant for farmers to adopt AFSs due to the financial security it generates. We found the same for AFS1 (using maize). Since cows act as a financial risk buffer (Moyo & Swanepoel, 2010), having more cows allows the farmers to make investments that would otherwise not.

Land size, also considered an essential factor by Okello et al. (2020) and Adimassu & Kessler (2016), also had a significant influence on SDFs' adoption of additional water sources to rain. These studies claim that more land provides more room for "experimentation." Based on our observation in the field, we reason that the SDFs could acquire alternative water sources due to high financial means, not so much the size of the land itself. This is substantiated by the fact that land size did not play a role for the other identified AFSs.

Knowledge acquired through (informal) education plays, as expected, a significant role in the ability of SDFs to adopt adaptation strategies. According to the literature, farmers with higher levels of education are more likely to adapt their strategies (Ali & Erenstein, 2017). We obtained different results. However, our findings show the importance of other knowledge sources, such as FFS and extension services. For many AFSs, SDFs who attended these informal education services were likely to adopt the fodder strategy. Moreover, our findings regarding farming experience are consistent with Marie et al. (2020). For AFS4 (purchasing concentrates), SDFs had more farming experience than SDFs who did not adopt this strategy, and this trend was similar for the other AFSs.

The impact of social networks is less than expected. A trend was found for the AFS1; SDFs who used AFS1 highly reported feeling part of an association compared to SDFs who did not. Our explanation for this finding is that it is not necessarily the fact of being a part of said associations but more the opportunities they create for dialogue that increase the likelihood of adopting the strategy.

An interesting finding is the high percentage of SDFs who had livestock for dairy as their primary source of income and had adopted AFSs. This makes sense because these SDFs may have a greater need to adapt and feed their livestock. However, we were unable to detect this trend in the reviewed literature. An explanation for this is that most literature did not focus on dairy farmers or fodder, but on general smallholder farmers and agricultural crop production. Nevertheless, it is an intriguing finding and can provide grounds for new research.

Lastly, due to the lack of gender variety in our data, gender did not seem to have a significant impact. Since our sample consisted mainly of females, it was not representative of the population. Therefore, it has been difficult to analyse how and to what extent gender plays a role.

Given this analysis, it is essential to note that the variables we used are not necessarily correct indicators for the asset we used them for. We chose the variables based on knowledge from the literature and observations in the fieldwork. However, these choices of variables may have influenced the outcomes. Moreover, due to a lack of experience, we could not always formulate the right questions to provide for the variable we aimed to assess.

9. Conclusion

This study aimed at determining how various socioeconomic, institutional, and environmental factors impact Giathenge SDFs' ability to adapt their fodder strategies to the current drought, which would allow them to increase their fodder availability. The conceptual framework used to assess that was based on the SLF, and it examined the influence of the SDFs' livelihood assets and institutional context on their adaptation capabilities.

The primary factors limiting SDFs' ability to adopt climate-resilient strategies in Giathenge appear to be increased land fragmentation, lack of financial sources, lack of water, and a lack of knowledge about more nutritious fodder types to NG and fodder preservation techniques. This relates to the fact that most SDFs have not received training or education from FFSs and governmental extension services. Even though the AFSs that have been described seem to be improving the situation for the SDFs who can adopt them, all sampled SDFs are experiencing drought and warmer temperatures as worrying factors for their ability to keep their livestock.

Giathenges' SDFs cannot imagine a future where their dairy livestock is not included in their livelihood. Livestock is valued in a way that goes beyond monetary worth. The fondness for keeping livestock, especially cows, is influenced primarily by tradition ("it is something that has always been done and that everyone does", from the focus group). Even though they are not usually the main source of income, they serve for purposes such as manure, milk (typically for subsistence purposes), and as an insurance safety net in the event of financial difficulties (they can give birth and SDFs can sell the calf). Goats are another type of livestock that SDFs own, but they do not hold such a value.

Abandoning livestock and shifting to more climate-resilient types of agriculture, such as cultivating avocados, is, therefore, not a good proposed solution. Solutions lie in education and increasing awareness about adaptation strategies. SDFs are open and eager to learn how to improve how they sustain such their livelihoods. *'As long as they teach us, I am willing to try other crop sources'* (FGD). Moreover, financial support in the form of low-interest loans or subsidies also appear to be an option given the high barrier of financial limitations. In this sense, actors such as the government and NGOs, can play a crucial role in the prospects of Giathenge's citizens. By providing extension services or subsidising educational programmes, SDFs can become more informed on adaptation strategies. Fodder quality and availability can also be enhanced by establishing subsidies for fodder concentrates, which would lower their costs.

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11. Appendices

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Fodder Availability in Giathenge, Kenya

Synopsis - SLUSE 2023

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1 Introduction

Agriculture plays a vital role in the livelihoods of rural dwellers in Kenya. More than 70% of the rural population is employed in the agricultural sector (FAO, n.d.), making agricultural production an essential source of income. Nationally, it contributes to 26% of Kenya's GDP and an additional 25% indirectly through linkages with other sectors (FAO, n.d.). Within the agricultural sector, dairy livestock has an important position. In Kenya, cattle are the most vital livestock and more than 85% of the milk comes from dairy cows (Sserunjogi, 2001). Smallholder dairy farmers (SDFs) are the primary producers of dairy and account for 56% of the total output in Kenya. The remaining 44% relies on large commercial farmers (Njeru, 2022).

Annual dairy consumption per person in Kenya is approximately 100 kg, whereas the average in Sub-Saharan Africa is 25 kg (Ajak et al., 2020). Further, with an increasing population, the already high pressure for cow milk is expected to increase. Despite the high milk demand, milk production in Kenya is low (Ajak et al., 2020). The low milk production is mainly caused by insufficient and poor-quality fodder (Nalianya et al., 2020). SDF's are facing challenges obtaining sufficient qualitative fodder, which is necessary for optimizing their milk production. Smallholder dairy farmers in Kenya rely on rain-fed agriculture systems (Nalianya et al., 2020); therefore, extreme weather and unpredictable weather significantly impact these systems. Extreme heat events and droughts are putting stress on the fodder system and impacting the ability for SDF's to obtain the necessary quality and quantity of fodder, and accordingly producing sufficient milk for the Kenyan population.

The discrepancy between milk demand and the ability to produce milk is a major challenge in Nyeri County. Nyeri County a rural district in the central highlands of Kenya about 153 km north of Nairobi (County Government of Nyeri, n.d.). The area is characterized by high dairy agriculture activity as approximately 80% of all households have livestock for dairy production (County Government of Nyeri, n.d.). Nyeri County is composed of eight sub-counties, with many small townships where smallholder subsistence farmers reside. An example is Giathenge, a village located in the sub-county of Othaya (County Government of Nyeri, n.d.). The (local) government has initiated programmes to increase dairy productivity, as well as local businesses that are claiming to sell high quality fodder, usually produced with innovative and new methods.

Fodder availability for SDF's in Giathenge is the focus of this research. This study aims to analyze which factors influence SDF's ability to obtain sufficient qualitative fodder for their dairy livestock. In other words, this study assumes that fodder availability differs between farmers and tries to determine what factors influence this. The Sustainable Livelihoods Framework [SLF] will be used as a tool to analyze livelihood outcomes and focuses on what factors determine these (see appendix 1 for the SLF). More precisely, it analyzes the influence of livelihood assets, core structures and processes and their interactions on the possibility of farmers obtaining sufficient qualitative fodder (see appendix 2 for the adapted SLF).

Research on low milk yield in relation to fodder availability in Kenya has been done before. However, most research focuses on the effects of fodder shortages on milk production and aims to provide possible solutions. Specific research on factors determining fodder availability for SDF's is to our knowledge, limited. In addition to the academic relevance, research on fodder availability in Giathenge will also be of societal relevance. Low milk yield is considered a severe problem in Nyeri county, as becomes evident from the previous described initiatives by the local government, and the new focus of local businesses on improving fodder. Moreover, not only attention to the availability of fodder, but also the challenges to obtain the fodder faced by SDF's are getting increased (governmental) attention. For example, Kenya's first National Fodder commercialization Conference in 2017 focussed on reviewing the fodder value chain, and identify opportunities and challenges for farmers to obtain more and better qualitative fodder. This research project can provide new insights in the factors that are determining fodder availaibiliy for SDF's in the Nyeri.

2 Research Questions and Objectives

2.1 Research question

What determines the ability of smallholder dairy farmers to obtain fodder in Giathenge, Kenya?

2.2 Objectives

1. To contextualize the current structure of the fodder system, and to analyze changes over the past five years.
2. To analyze the livelihood assets influencing farmers' ability to produce, collect, and purchase fodder of sufficient quality.
3. To assess the structural policies, regulations, and seasonal weather patterns influencing farmers' ability to produce, collect and purchase fodder of sufficient quality.

2.3 Research sub-questions

1. What is the structure of the fodder system?
2. How do capitals and structures influence farmers' ability and vulnerability to cultivate their own fodder?
3. How do capitals and structures influence farmers’ ability to purchase fodder?

The first research sub-question provides a background analysis of the fodder system in Giathenge. It explores the types of fodder and ways of production. It also analyzes the ratio of fodder being cultivated or collected by farmers in relation to being purchased from an external party. It assesses whether the current fodder quality and quantity would be ideal for livestock farmers to gain an optimal milk yield.

The second and third sub-questions analyze the determining factors for farmers to obtain fodder using the SLF. In order to do so, the fodder system is separated into the process of obtaining fodder by cultivating and collecting from public areas and obtaining fodder by purchasing. Firstly, it investigates which financial, physical, social, human and natural assets the farmers possess. Subsequently, it analyzes the impact of policies, institutions and processes on fodder cultivation and the fodder marketstructure. For a complete overview, the perception of farmers on their challenges to obtain fodder is analyzed. In addition to this, the impact of seasonality on obtaining fodder is assessed (see Appendix 3 for the detailed research matrix).

3 Methodology

The following qualitative and quantitative methods were chosen to implement the SLF. These methods allow for an interdisciplinary approach to collect data on human, social, physical, natural and financial assets of SDF's. The following section describes the proposed methods; however, these have the potential to be re-evaluated and modified in the field.

3.1 Questionnaire

Working with our Kenya counterparts, we will administer a questionnaire to obtain an overview of the assets and perceptions of SDF's in Giathenge. The questionnaires will allow us to collect quantifiable and comparable data (Bernard, 2018). Further, incorporating the Likert Scale into the questionnaire allows the SDFs to indicate their attitudes on given statements (so-called "items") on a five-point scale ranging from "strongly agree" to "strongly disagree" (Bryman, 2016). The questionnaire will be administered within the first few days in order to adapt the remaining methods upon the findings. The questionnaire will be pilot tested for its understandability and relevancy and adapted as needed. Moreover, we will thoroughly review the questionnaires with the translators to guarantee a common understanding and interpretation of the findings. We plan to conduct between 30 and 50 questionnaires, each of around 45 minutes.

We will use a systematic sampling method to collect data from every third household in the village. If residents are not at home, or not willing to participate, we will try to see if the household before or after is home and willing to answer our survey. In the case that a household has no cattle and does not produce fodder, we will administer the questionnaire to the household before or after. We will interview a household member with a sound understanding of the other members and the household structure. A draft of our questionnaire is in Appendix 4.

3.2 Semi-Structured Interviews (SSI)

SSI is characterized by an open-end approach by following a general guide of which topics to be covered (Bernard, 2018). We will conduct SSI in our fieldwork with two to four experts (livestock officers and relevant stakeholders) and five SDFs. We will contact our experts and stakeholders using our local guide, translators, and Kenyan counterparts. For SDF, we will use the questionnaire sessions as a way to get in touch. We aim to interview SDFs with varying socioeconomic statuses and natural capital to gain insight into different fodder strategies. Additionally, before or after the SSI with SDFs, we will collect a soil sample and biomass calculation. Our draft of the SSI guide can be seen in Appendix 5, with adaptable questions regarding the interviewee.

3.3 Participatory Rural Appraisal (PRA)

The highly diverse and adaptable methods from the PRA allow a bottom-up approach to include local communities in the research process by analyzing their problems and designing their own solutions (Sontheimer et al., 1999). PRA will contextualize the findings from our questionnaire and interviews. We will be using the following PRA methods throughout our stay.

3.3.1 Transect walk

The researchers will systematically walk together with an informant, in our case the translator and local guide, through the research site. Therefore, the researchers can observe, meet, listen and discuss with people (Chambers & Conway, 1992). We plan to do this on our first and second days to get an overview of the local context of our research question. To track our route and to map points of interest using the GPS. The transect walk will help us to identify key stakeholders and locations to answer our research question.

3.3.2 Participatory observation at smallholder farms

This method allows recording information through the researcher's perspective (Bernard, 2018). We will not only make observations on the farms we visit, e.g. for the questionnaires but also at our host families. We will be staying with the host family during our stay in Giathenge. Here we will be able to gain more insight into the daily lives and culture of SDFs through community events such as dinner, church services, and the Wangari Maathai day ceremony.

3.3.3 Participant observation at fodder market

A visit to the fodder market most frequented by the SDFs (data gained through questionnaires). At the market, we would gain insight into the structure of fodder purchasing and selling. This observation would also help us gain additional information about what we have learned from our interviews and questionnaires about farmers' perceptions of the quality and quantity of purchased fodder.

3.4 Global Positioning System (GPS)

The GPS will help us track the questionnaires, interviews and PRA methods. These locations of interest are important to order and structure the individual methods. Moreover, we will use the area measurement functionality of the GPS to compare and generalize the land area used for fodder cultivation and collection.

3.5 Biomass of cultivated fodder

To validate the stated values by the SDFs regarding the quantity of their cultivated fodder, the current fodder biomass of five farmers will be measured. We plan to do it similarly to Manoj et al. (2021) in consultation with the Kenyan professor for rangeland. With the SDFs, we will arrange dates with their agreement to join their normal routine to harvest a small area for our research. If possible, we want to do so for every homogenous area under fodder cultivation on their farm; however, this is something we will discover if feasible while in the field. The steps of the biomass collection are as follows. We will weigh the harvest with a spring balance. Then, we will measure the area we took each harvest sample with a tape. Further, we will take the total area of each homogenous cultivation area with GPS or measuring tape, and note down the fodder species. Then, we can estimate the total weight and, thus, the biomass. The resulting green fodder yield in quintals per hectare will indicate the availability of cultivated fodder. These steps will be conducted for each farm's five largest fodder species. The sheet for the data collection is found in Appendix 6. Moreover, these findings will help to validate and interpret the measured soil parameters.

3.6 Soil Samples

As part of the natural capital assessment, we will examine soil characteristics and fertility status to analyze the relationship between why and which fodder species is cultivated. We plan to do so for the soil of the five interviewed SDFs. In our context, the term ‘soil’ refers to the soil where fodder is cultivated. Literature values for the fodder species will be used to calculate how much phosphorus and nitrogen get removed by every harvest. This will be related to the measured soil parameters, namely **texture, pH, and available phosphorus and nitrogen**, to analyze the soil fertility and quality. The texture will be determined by the “feel” method in the field with a look-up diagram. The pH value, phosphorus and nitrogen will be measured in the laboratory in Copenhagen. The number of samples will depend on the size of the agricultural land devoted to fodder production per farm. We aim for at least one composite sample out of 10 cores for each fodder species and homogenous area (e.g. strips between fields) to achieve a reasonable comparability between the soils for each fodder species. Eventually, a **theoretical maximum potential yield** will be calculated from the measured soil parameters to estimate the amount of fodder that can be cultivated. This will help validate the biomass calculation and assess the soil’s future development. It is important to consider whether the farmers fertilize their soils as this makes the calculations inaccurate. Thus, we will try to focus our interviews on farmers that do not fertilize their soil; however, it is likely that most SDFs use fertilizers, but this will be tracked through the questionnaires.

3.7 Analysis of meteorological data

Unfortunately, the meteorological data of only one climate station has been found so far. It is located in Nyeri, which is in round about 12 km distance to Giathenge. It got set up in 2000 and is still working today (Meteomanz, 2023). Since no climate diagram could be found for this data set, a first step of the analysis is to code one with the available data, even though it won’t cover the 30 necessary years for climate analyses. Howeverl, the collaborating Kenyan professor may be able to provide better data. In general, climate parameters help to identify external stressors. In our case those stressors are linked to the fodder production. This will help to validate the information received via the questionnaires and interviews about meteorological natural hazards the fodder production faces. Based on the available data, meteorological anomalies will be calculated on a monthly resolution. For this, a floating mean will help to conduct a Mann-Kendall-Test to identify trends independent from seasonal fluctuations. Subsequently, the trend adjusted data will give information on the seasonality and combined with the trend eventually the anomalies. A correlation analysis with the recorded natural hazard events in the surveys and interviews will not only elaborate on the perception of challenges in the fodder production but also how the natural capital within the SLF gets impacted.

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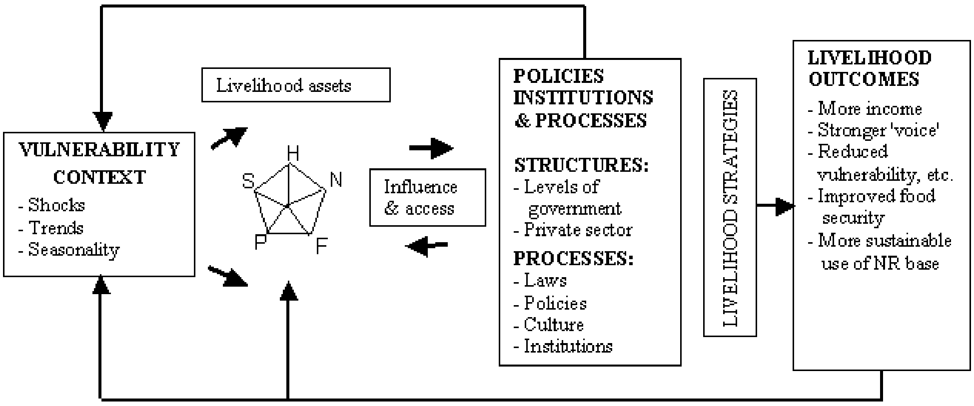
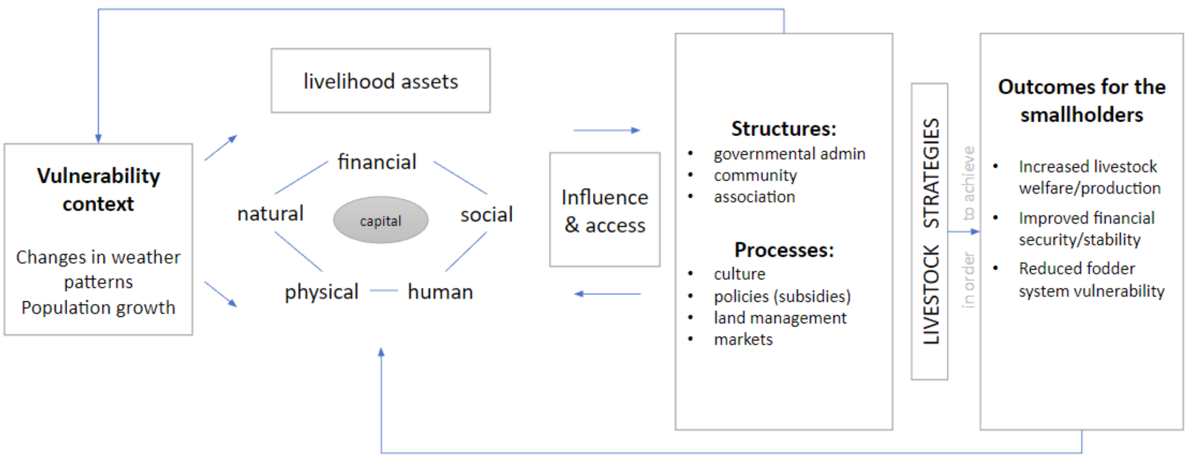
5 Appendix

1 Sustainable livelihoods framework



F = Financial capital
P = Physical capital
S = Social capital
H = Human capital
N = Natural capital

2 Sustainable livelihoods framework adapted to this research



3 Research matrix

Sub-questions	Sub-sub questions	Data required	Methods	Analysis	Possible limitations

What is the structure of the fodder system?	What are the types and characteristics of the fodder used for dairy livestock on smallholder farms?	Types and relative amount of fodder Abiotic and biotic factors of the fodder plants	Literature review Questionnaire with farmers Interview with livestock officer Literature review	Categorization of fodder types (species) and characteristics	Limited knowledge of (native) plants Distinction between fodder specifically for dairy livestock and other types of livestock may be unclear
	How much fodder is cultivated, collected, and bought?	Relative amount of fodder - cultivated - collected (not from own farm) - bought	Literature review Questionnaire with farmers Map drawing by farmers Exemplary biomass calculation of cultivated fodder by five farmers (GPS) Transect walk	Categorization of fodder origins Relative reliance on external fodder sources	Distinction between origin of fodder can be unclear (e.g. when a farmer rents land from a neighbour to cultivate) Farmers may be unsure about the exact amount of fodder they grow, collect, or buy
	What are the production strategies of the individual smallholder farmers?	Techniques and technology by farmers' fodder production	Questionnaire with farmers Semi-structured interview with farmers	Categorization of techniques of fodder production Categorization of technologies of fodder production	Not including how market fodder is cultivated
	What is the quantity of fodder necessary for an optimal milk yield?	Livestock characteristics per farm (over the last 5 years?): - Species - Number of livestock - Breed of cattle - Milk production Farmers' contentment of amount of fodder availability relative to milk yield	Questionnaire with farmers Semi-structured interviews with farmers Questionnaire with farmers Semi-structured interviews with farmers	Descriptive statistics Systematic coding/ categorization Systematic coding/ categorization Descriptive statistics	May be hard to differentiate quantity of fodder used for different animals May be difficult for farmers' to determine how much fodder they need for an optimal milk yield Contentment is abstract subjective information, may be hard to compare
How do capital and structures influence farmers' ability and vulnerability to cultivate their own fodder?	How do financial, physical, social, human, and natural capital influence farmers' ability to produce their own fodder?	F: income, remittances, loans P: technology (fertilizers, equipment, infrastructure, fodder storage, access to vehicle, access to knowledge) S: networks, association membership, livestock H: labour force, knowledge N: soil fertility, land, livestock, fodder cultivated, access to water	Questionnaire with farmers (F, H, P, N) Semi-structured interviews with farmers (S, F) Observations at smallholder farms (P) Soil sampling (pH, texture) in smallholder farms (N)	Systematic coding/ categorization Descriptive statistics	
	How do structures and processes influence smallholder farmers' ability to produce their own fodder?	Presence of governmental support programs Presence of farming education (informal and formal)	Literature review Survey with farmers Semi-structured interviews with farmers Semi-structured interview with livestock officer/ expert stakeholders	Systematic coding/ categorization Descriptive statistics	

		Associations and cooperatives prevalent in the local setting			
	How do weather abnomalies influence smallholder farmers' production capacity?	Climate parameters Cultivation changes/shifts Presence of irrigation systems	Analysis of meteorological data Questionnaire with farmers Semi-structured interviews with farmers	Seasonal diagram (calendar) of weather patterns Systematic coding/ categorization	Responses may vary depending on when we interview farmers
	What are the farmers' perceived challenges to produce their own fodder?	Perception of challenges	Questionnaire with farmers Semi-structured interviews with farmers	Systematic coding/ categorization Descriptive statistics	Opinion on what a challenge is can differ
What factors influence the farmers' ability to purchase fodder?	How does physical, social, and human capital influence farmers ability to purchase fodder?	P: Access to a vehicle, access to road S: Relationships with sellers H: Knowledge about markets	Questionnaire with farmers (P) Semi-structured interviews with farmers (S, H)	Systematic coding/ categorization Descriptive statistics	Not examining the cultivation of fodder sold at market due to time constraints
	How do structures and processes influence smallholder farmer's ability to purchase fodder?	Price of fodder Market regulation by government Perceived transparency of market and governmental policies	Literature review Questionnaire with farmers Semi-structured interview with livestock officer/ expert stakeholders Participatory observation at fodder market Semi-structured interview with fodder business person	Systematic coding/ categorization Descriptive statistics	Honesty with prices and regulations

Appendix II - Questionnaire

Questionnaire – SLUSE: Livestock, fodder and feeding – 06.03.2023

GPS point number/letter:	Translator:
Date and time:	Note taker:

Only interview in case it's the head decision maker or deputy decision maker of the household!

Introduction and statement of purpose

We are a group of seven students from the University of Nairobi and University of Copenhagen. We are conducting research on sustainable land use management system (SLUSE) as part of our master's programs. The research focuses on fodder production in Giathenge and surroundings, specifically for dairy livestock. As part of our research, we have created a questionnaire in order to collect information about the farmers' fodder and livestock practices of this region. The information collected will only be used for academic purposes and it will be kept confidential.

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

This survey should take approximately 45 minutes to complete. Responses will be kept anonymous, meaning that your names will now be mentioned in the final report.

Ask consent for participation.

Thank you very much for participating and for helping us with our research.

<u>Section A: Personal information</u>

1. What is your gender?

o Male

o Female

2. When were you born?

o > 2000

o 1990-1999

o 1980-1989

o 1970-1979

o 1960-1969

o 1950-1959

o < 1950

3. What is your marital status?

o Single

o Married

o

Widowed

4. What is the highest level of education that you completed?

o None

o Primary school

o Secondary level

o Post-secondary/ College/ Vocational training

o University degree

o Other: ______________________

Section B: Household information

5. Who is the deputy decision maker of the household (person who makes decisions when the household head is absent)?

- o Mother
- o Father
- o Spouse
- o Son
- o Daughter
- o Employee/Farm Manager
- o Other relative: ___________________________

6. Who takes care of the dairy livestock?

Task	Name
Feeding	
Milking	
Cleaning	
Bringing milk to selling place	
Checking health issues	

Codes:

1= head of household 2= spouse 3= daughter 4= son 5= employee

6= grandmother 7= grandfather 8= grandchildren 9= neighbors

7. For how many years have you practiced dairy farming? ________________ years

8. How much land does this household own? __________acres

9. How did you obtain your land?

- o Inheritance
- o Purchasing
- o Other (s): ___________________________________

10. Do you rent additional land?

- o Yes, _________acres
- o No

11. In the last 12 months, what were the 3 main income sources for your household? (mark 1 for the highest source, 2 for middle source, 3 for least source):

- o Employment (permanent with a contract)
- o Cash crops
- o Horticulture
- o Livestock rearing for meat
- o Livestock for dairy
- o Handicrafts
- o Casual services
- o Remittances (money received from other employed family member/s)
- o Only subsistence
- o Other income source, please specify: _____________________________________

Section C: Farm and livestock characteristics

12. What number and breed of dairy livestock do you keep in your household?

Livestock	***Number***	***Breeds***
Male calves (baby cow)		
Female calves		
Cows (female)		
Bulls (male)		
Male lambs		
Female lambs		
Goats (female)		
Bucks (male goat)		
Sheep		

13. Which livestock (of the above) do you value the most?

____

14. Reason for keeping dairy livestock: (rate beginning with 1 as the most important)

- o Domestic purpose (for own consumption)
- o Commercial purpose (produce milk for selling)

- Received as a gift or through inheritance
- Other (s): ________________________________

15. How many times do you feed your livestock per day? ________________times

16. How much liters of cowmilk per day do you produce? __________________liters

17. How much liters of goatmilk per day do you produce? __________________liters

18. What water sources do you have access to, to provide to your livestock?

- Ground water [borehole and shovel]
- Surface water [also rivers and streams]
- Rain
- Other (s): _____________________

19. How do you transport water for your livestock?

- Pipe water
- Backload
- Electric pump
- Wells
- Other (s): _____________________

20. How do you use your livestock waste?

- o Bio-gas
- o Organic manure
- o Sell
- o Other(s): ________________________

Section D: Fodder characteristics

21. Which were the three most important fodder types during this dry season (since August) and where did you get them from?

Types of fodder	***Own cultivation***	***Market***	***Neighbor***	***Collection on public grounds***	***Other (s)***
Napier grass					
Fodder trees					
Fodder maize					
Natural grasses					
Boma rhodes					
Banana trees					
Crop residues					
Kitchen crop residues					
Weeding/ Plant residues					
Concentrates (grain, flour…)					

Luzerne					
Calliandra					
Azola					
Hay					
Others					

22. Which were the three most important fodder types during the last wet season (before August) and where did you get them from?

Types of fodder	***Own cultivation***	***Market***	***Neighbor***	***Collection on public grounds***	***Other (s)***
Napier grass					
Fodder trees					
Fodder maize					
Natural grasses					
Boma rhodes					
Banana trees					
Crop residues					
Kitchen crop residues					

Weeding/ Plant residues					
Concentrates (grain, flour…)					
Luzerne					
Calliandra					
Azola					
Hay					
Others					

23. Which factors influence your decision on what fodder species to grow?

- o Soil erosion prevention
- o Fast growing properties
- o Cost
- o Nutritional quality
- o Water requirement
- o Drought resistance
- o Other (s): ________________________________

24. State whether you agree or disagree with this statement: The soil where I cultivate fodder is fertile.

- o Strongly agree
- o Agree

- o Neither agree or disagree
- o Disagree
- o Strongly disagree

25. What water sources do you have access to, to grow your own fodder?

- o Ground water [borehole and shovel]
- o Surface water [also rivers and streams]
- o Rain
- o Other (s): ______________________

26. *If other than rain in 25.* How do you transport the water necessary for fodder to your farm?

- o Irrigation system
- o Backload
- o Motorcycle
- o Car
- o Other (s): ______________________

27. In the past 12 months, what percentage of your land was allocated for fodder production?

- o <10%
- o 10-25%
- o 26-50%
- o 51-75%
- o >75%

28. In the highly productive season: On average, how many hours a day did you spend on fodder tasks?

- Planting ____hours
- Weeding ____ hours
- Harvesting ____hours
- Processing _____ hours
- Feeding _____ hours
- Selling ____ hours

29. In the low productive season: On average, how many hours a day did you spend on fodder tasks, in average?

- Planting ____ hours
- Weeding ____ hours
- Harvesting ____ hours
- Processing ____ hours
- Feeding ____ hours
- Selling ____ hours

30. Which technology have you used during the last 12 months for harvesting of fodder?

- No technology
- Chaff cutters
- Forage choppers
- Panga
- Sickle
- Other (s): ______________________________

31. Which techniques of fodder preservation have you used in the last 12 months?

- Silage
- Crop residue storage
- None
- Other (s): ____________________________________

32. Which technology have you used during the last 12 months for storing of fodder?

  - No storage
  - Shed
  - Other (s): ________________________________

33. State whether you agree or disagree with this statement: The fodder I cultivate has high nutritional quality.

- Strongly agree
- Agree
- Neither agree or disagree
- Disagree
- Strongly disagree

34. Where does your fodder production knowledge come from?

- Inherited knowledge from family or friends
- Governmental extension services
- Media
- Community
- Farmer's association

- Ngo’s
- Private extension service
- Farmers field school (ffs)
- Other (s): ___________________________

35. If more than 10%, what are the causes of fodder losses (mark 1 for the most, 2 for the second most, and 3 for the least significant cause)

- Pests 3
- Rainfall
- Drought 1
- Poor storage 2
- Lack of storage opportunities
- Lack of technologies
- Lack of fertilizers
- Soil erosion
- Other (s): _____________________________________

36. How do you transport purchased fodder to your farm?

- Motorcycle
- Car
- Backload (= carried on back)
- Employee
- Other (s): _________________________

o

37. State whether you agree or disagree with this statement: Over the last 5 years, I have experienced a decrease in my fodder production.

o Strongly agree

o Agree

o Neither agree or disagree

o Disagree

o Strongly disagree

38. *If "Strongly agree" and "Agree" in the previous question.* Compared to the harvest season 5 years ago, how much has the fodder harvest declined (in percentages)?

o <10%

o 10%

o 25%

o 50%

o 75%

o >75%

<u>Section E: Supporting structures</u>

39. Which financial support have you used for the last 12 months?

o Personal income

o Family support

o Table banking (chama)

o Saccos

o Banks

o Hustler fund

o M-pesa loan

40. Have you ever received a loan to conduct your dairy farming activities?

o Yes

o No

41. *If Yes in Question 39.* For what did you use your loan?

o New farming technology

o Maintenance of number of livestock

o Buy new livestock

o Cultivate more fodder

o Buy more fodder

o Employ people

o Other (s): ______________________________

Section F: Social relations

42. Do you feel a part of any of these associations and how relevant are they to livestock and fodder production?

Associations	***First most important***	***Second important***	***Third important***
Family			
Women			
Church			
Cooperative unions			

Community-based organizations			
Political parties			

43. In your view, what are the advantages of being a member of an association?

- o Greater access to farming resources
- o Greater access to farming information
- o Networking opportunities
- o Professional development
- o Other (s): ______________________________

44. How would you describe the relationship with your neighbors?

- o Very good
- o Good
- o Cordial, neutral
- o Bad
- o Non-existent

Thanks for participating! We really appreciate your help with our research.

Is there something else that you consider relevant to share?

Do you have any questions for us?

If you would potentially be interested in helping us further with a follow-up interview, with the possibility to take some soil samples of your farmland and join your harvest routine please let us know.

- o Yes
- o No

- If yes, phone number: ______________________________________

Appendix III - Interview Guides

III.I Interviewed SDFs

Table with an overview of interviewed SDFs

Interviewee Number	**Soil and Biomass Assesments**
1	1NG
2	2NG, 2Maize
3	n/a
4	3NG
5	n/a

1. What determines your choice in the type of dairy livestock you keep?
2. How long will the fodder we harvested today last to feed your livestock?
3. Which fodder mix would lead to an optimal milk yield? (more productive and healthy cow)
4. What are the main challenges that you are facing in fodder production?
5. What are the coping strategies that you are adopting?
6. Ask if they consider doing something about the following keywords and ask what their individual barriers are:
    a. Water access, storage, costs, transportation (what if drought continues?)
    b. Buying fodder
    c. Land for fodder cultivation (increase/decrease)
    d. Change of fodder species
    e. Conservation practices for fodder
    f. Choice of livestock (change to goat)
    g. Selling livestock
7. How do you treat your soil? (manure, fertilizers, crop rotation – how often, quantities)

III.II Livestock Officer

Questions about the Department of Livestock and Livestock Officer

1. What livestock areas are you (the livestock officer) responsible for? (explain your role and daily tasks)
2. Who is involved in setting of the policy / decision making for the local dairy industry?
3. What are some of the extension services (advice, training, etc.) that the county government offers to livestock farmers? Are there other livestock extension service providers in the subcounty? Are there standardization procedures for the providers? Are the farmers utilizing these services?
4. Does the county or national government offer subsidies for fodder production?
5. How is the CG assisting farmers to address the following livestock production challenges as per the county livestock strategy?
    · Low milk production
    · Inadequate forage
    · High cost of inputs
    · Diseases
6. How is the department of livestock addressing competition from other land uses within the sub-county to sustain livestock production as a county government source of revenue?

7. What are some of the livestock value chain initiatives (livestock products) undertaken by the CG to promote livestock keepers' livelihood?
8. What are the most critical concerns the livestock farmers are putting forward to your department?

Questions about farmers and livestock in Giathenge (and surrounding area)

1. Has the livestock economic activity in Giathenge changed during the last 5 years? Has dairy production increased/decreased (in livestock numbers and productivity)? How have the prices of milk changed over the past years? How are the changes influencing HH livelihood activities and assets?
    1. For the youth
    2. For the elderly
2. What are the key types of fodder produced locally? What are the alternative fodder sources and their cost? What challenges do you think farmers are encountering when producing fodder? Are there any developmental changes specific to fodder production?
3. What does the local fodder market look like and how does it work?
4. Do you believe people are buying more fodder now than 5 years ago? Why?
5. How is the fodder mix (grass/residues/trees, bought vs. cultivated fodder, quantity) changing over the year?
6. How advanced are fodder conservation practices? We heard that businesses develop where people travel from farmer to farmer to ensile their cultivated fodder. Is this happening here? How does it work?

What is the future of livestock production in the sub-county in line with County CIDP? Profitable in future?

III.III MCA

- In your opinion, what are the challenges that farmers are facing to produce fodder?
- Have there been recent CG interventions implemented to alleviate that? (fodder conservation programs) Is some type of support being set up for women, particularly?
- What are the challenges that you encounter when implementing those policies? (Which resources are lacking?)
- Do you consider that farmers are receiving enough information and training to implement their strategies and to be able to grow their own fodder? If no, what is the CG considering or planning to do about it?

Appendix IV - Focus Group

1. Rank the types of fodder in relation to their nutritious value.
2. If the drought continues, do you plan on continuing cultivating the same fodder as you do now? Follow up questions:
    a. What alternative fodder crops resistant to drought do you know?
    b. What are the constraints?
3. How do you plan to have secure access to water in the future?
    a. Knowledge about alternative options
    b. Willingness to obtain
4. What are the constraints that limit the accessibility to construct new water sources
5. If the drought continues, do you think you can abandon dairy cows farming and shift to another source of livestock (goats)?

Appendix V - Codes in RStudio

V.I Climate diagram

```
### Monthly weather data analysis

 setwd("C:/Users/ulrik/Documents/3_Masterstudium/Block 3/Livestock Strategies/climate data/ ")
 climate = read.table("monthly weather data.txt", header = T, sep = "\t", dec = ".")
 recent_weather = read.table("daily weather 2023.txt", header = T, sep = "\t", dec = ".")
 library(xts)

climate$Date = seq.Date(from = as.Date("2000-01-01"), to = as.Date("2023-01-01"), by = "month")
 climate$timestamp = strptime(climate$Date, format = "%Y-%m-%d", tz = "UTC")

 ### Temperature mean
 climate_T.xts = xts(climate$T..ÂºC., order.by = climate$timestamp)
 T_Jahresgang = aggregate(x=climate_T.xts, by = .indexmon(climate_T.xts), FUN = mean)
 T_Jahresgang = data.frame(Monat = c("Jan", "Feb", "Mrz", "Apr", "Mai", "Jun", "Jul", "Aug", "Sep", "Okt",
"Nov", "Dez"), T_Jahresgang)
 write.csv(T_Jahresgang, "T_Jahresgang.csv", row.names = F)

 ### Temperature max average
 climate_Tmax.xts = xts(climate$T..max.ave..ÂºC., order.by = climate$timestamp)
 Tmax_Jahresgang = aggregate(x=climate_Tmax.xts, by = .indexmon(climate_Tmax.xts), FUN = mean)
 Tmax_Jahresgang = data.frame(Monat = c("Jan", "Feb", "Mrz", "Apr", "Mai", "Jun", "Jul", "Aug", "Sep",
"Okt", "Nov", "Dez"), Tmax_Jahresgang)
 write.csv(Tmax_Jahresgang, "Tmax_Jahresgang.csv", row.names = F)

 ###Temperature min
 climate_Tmin.xts = xts(climate$T..min.ave..ÂºC., order.by = climate$timestamp)
 Tmin_Jahresgang = aggregate(x=climate_Tmin.xts, by = .indexmon(climate_Tmin.xts), FUN = mean)
 Tmin_Jahresgang = data.frame(Monat = c("Jan", "Feb", "Mrz", "Apr", "Mai", "Jun", "Jul", "Aug", "Sep", "Okt",
"Nov", "Dez"), Tmin_Jahresgang)
 write.csv(Tmin_Jahresgang, "Tmin_Jahresgang.csv", row.names = F)

 ### Precipitation
 climate$Prec..mm. [climate$Prec..mm. == "-"] = NA
 climate_NS.xts = xts(as.numeric(climate$Prec..mm.), order.by = climate$timestamp)
 # not working as it should:
 NS_Jahresgang = na.aggregate(climate_NS.xts, by = .indexmon(climate_NS.xts), FUN = mean)
 NS_Jahresgang = as.data.frame(aggregate(x=NS_Jahresgang, by = .indexmon(NS_Jahresgang), FUN = mean))
 NS_Jahresgang = data.frame(Monat = c("Jan", "Feb", "Mrz", "Apr", "Mai", "Jun", "Jul", "Aug", "Sep", "Okt",
"Nov", "Dez"), NS_Jahresgang)
 write.csv(NS_Jahresgang, "NS_Jahresgang.csv", row.names = F)


 ### create climate diagram
 library(lubridate)

# detect max and min value of temperature (y-axis)
 maxr <- round(max(Tmax_Jahresgang$Tmax_Jahresgang,na.rm=TRUE)+3)
 minr <- 2 * round(min(Tmin_Jahresgang$Tmin_Jahresgang, na.rm=TRUE)/2-3)

 # Barplot for precipitation
 x11(width = 500, height = 500)
 par(mar=c(6,5,5,6)+.1)

 barplot(height = NS_Jahresgang$aggregate.x...NS_Jahresgang..by....indexmon.NS_Jahresgang...FUN...mean.,
```

```
names.arg = NULL,      col = "#6699CC",      xlab = "",      ylab = "",
      axes = F,      ylim =
c(0,round(max(NS_Jahresgang$aggregate.x...NS_Jahresgang..by....indexmon.NS_Jahresgang...FUN...mean.,
na.rm=TRUE))+1),      xpd = FALSE,      xlim = c(0.5,11.5),      width = 0.5,
      space = c(0.5, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1))

 ### naming right y-axis for precipitation

 axis(side=4, # Achse und Beschriftung der Achse mit Zahlen      las=1,
      at =
seq(0,round(max(NS_Jahresgang$aggregate.x...NS_Jahresgang..by....indexmon.NS_Jahresgang...FUN...mean.,
na.rm=TRUE))+10, 20),
      ylim = c(0,
round(max(NS_Jahresgang$aggregate.x...NS_Jahresgang..by....indexmon.NS_Jahresgang...FUN...mean.,
na.rm=TRUE)))+10)
 mtext("Precipitation [mm]", side=4, line=3,cex=1)
   # mean air temperature
   mean(climate$T..ÂºC.)

## [1] 18.53899

  # mean precipitation
   sum(NS_Jahresgang$aggregate.x...NS_Jahresgang..by....indexmon.NS_Jahresgang...FUN...mean.)

## [1] 1252.784

mtext("Station Nyeri      00 26S      36 58E
 2000 to 2023      18,53 °C1253 mm", line=0.5, side=3, cex = 0.9)


 ### Plot mean temperature

 par(new=TRUE)
 plot(y = T_Jahresgang$T_Jahresgang,      x = c(1:12),      col = "#993333",      lwd = 3,      type
= "l",      ylim = c(minr, maxr),      xlab = "Month",   ylab = "Temperature [°C]",      cex.lab = 1,      xaxp
= c(1,12,11),      las = 1,   main = "",      xaxt = "t",      yaxt = "n")

 ### Plot min temperature
 lines(Tmin_Jahresgang$Tmin_Jahresgang,      col = "#996666",      lwd = 2,      lty =
"longdash")

 ### Plot max temperature
 lines(Tmax_Jahresgang$Tmax_Jahresgang,      col = "#996666",      lwd = 2,      lty =
"longdash")

 axis(side=2,      las=1,    at = seq(minr,maxr,2))
```

V.II Meteorological data analysis

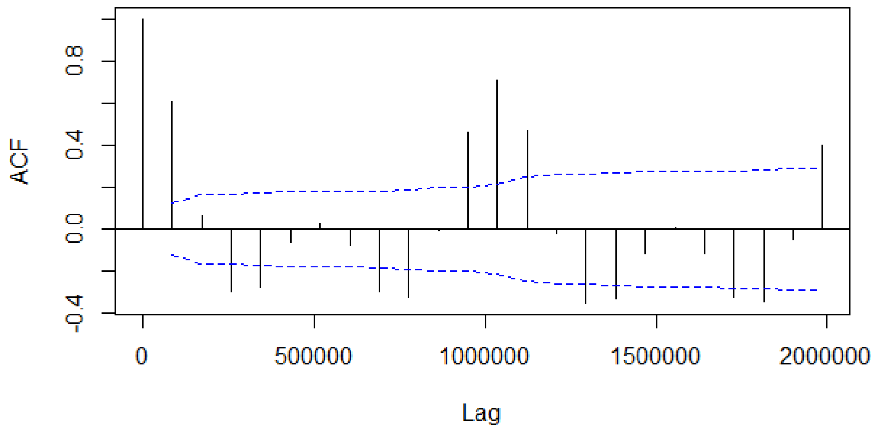
Meteorological trends were analysed by applying a floating median with a width of three years to monthly-resolution temperature and precipitation data. This helps to make long-term trends visible without the interference of seasonal dynamics. A Mann Kendall trend test was calculated to analyse the existence of a statistically significant trend for temperature and precipitation. This test has been chosen for its capability to detect monotone and linear trends, to be able to assess climate change impact for the study area. Further, an autocorrelation analysis of the seasonally adjusted (detrended) temperature and precipitation data was calculated. This validates the statistical independence of the time series from itself. This is important because if such dependence exists, a Mann-Kendall test is limited in its validity. Finally, due to the great importance of rainfall for the study area, boxplots for the yearly precipitation distribution per month were visualised to assess the data outliers..

```
### Floating median for meteorological data Nyeri 04.2023

 setwd("C:/Users/ulrik/Documents/3_Masterstudium/Block 3/Livestock Strategies/climate data/ ")
 climate = read.table("monthly weather data.txt", header = T, sep = "\t", dec = ".")
 recent_weather = read.table("daily weather 2023.txt", header = T, sep = "\t", dec = ".")
 library(xts)

climate$Date = seq.Date(from = as.Date("2000-01-01"), to = as.Date("2023-01-01"), by = "month")
 climate$timestamp = strptime(climate$Date, format = "%Y-%m-%d", tz = "UTC")


 ### Temperature floating median
 climate_T.xts = xts(climate$T..ÂºC., order.by = climate$timestamp)
 temperature.gm_median = rollapply(climate_T.xts, width = 36, FUN = median)
 temperature.gm_mean = rollapply(climate_T.xts, width = 36, FUN = mean)
 temperature.saisonalbereinigt = climate_T.xts - temperature.gm_median

 plot.zoo(temperature.gm_median, main = "Floating median (3 years) of monthly temperature", col =
"darkorange",
          lwd = 2, xlab = "Year", ylab = "Temperature [°C]",)

# Autocorrelation
 acf(na.omit(temperature.saisonalbereinigt), ci.type = "ma", main = "Autocorrelation without saisonal dynamic
for temperature")

# Significance test
 temperature.year = apply.yearly(climate_T.xts, FUN = mean)
 jahreszahlen = .indexyear(temperature.year)
 jahreswerte = coredata(temperature.year)
 cor.test(x = jahreswerte, y = jahreszahlen, method = "kendall")

# tau: -0,040; p-value: 0,785



 ### Precipitation floating median
 climate$Prec..mm. [climate$Prec..mm. == "-"] = NA
 climate_NS.xts = xts(as.numeric(climate$Prec..mm.), order.by = climate$timestamp)

 precipitation.gm_median = rollapply(climate_NS.xts, width = 36, FUN = median)
 precipitation.saisonalbereinigt = climate_NS.xts - precipitation.gm_median

 plot.zoo(precipitation.gm_median, main = "Floating median (3 years) of monthly precipitation", col = "blue",
          lwd = 2, xlab = "Year", ylab = "Precipitation [mm]",)
```

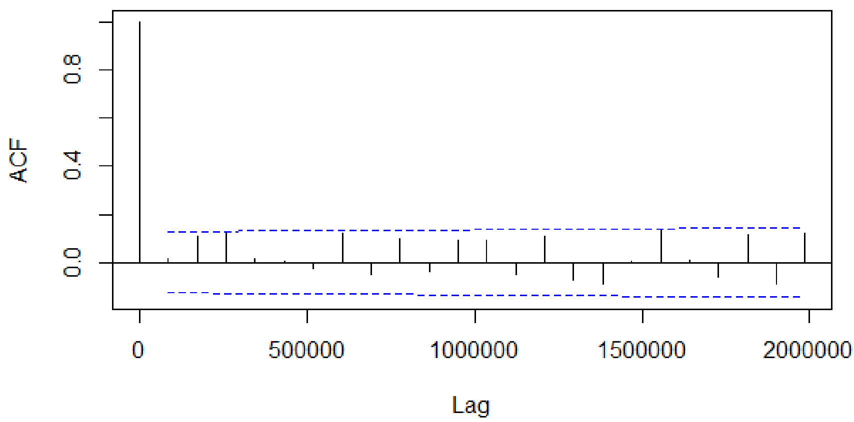
```
# Autocorrelation
 acf(na.omit(precipitation.saisonalbereinigt), ci.type = "ma", main = "Autocorrelation without saisonal dynamic
for precipitation")

# Significance test
 precipitation.year = apply.yearly(climate_NS.xts, FUN = mean)
 jahreszahlen_NS = .indexyear(precipitation.year)
 jahreswerte_NS = coredata(precipitation.year)
 cor.test(x = jahreswerte_NS, y = jahreszahlen_NS, method = "kendall")

# tau: -0.241; p-value: 0,1137


 ### NS Anomalies
 climate_NS_yearly = as.data.frame(split(climate_NS.xts [13:276],f="years"))
 NS_anomaly = t(apply(climate_NS_yearly, 1, function(x) x-mean(x)))
 write.csv(NS_anomaly, file = "NS_anomaly.csv", row.names = F)

 NS_anomaly.xts = xts(as.vector(NS_anomaly), order.by = climate$timestamp[13:276])
 plot(NS_anomaly.xts, type = "h", auto.grid = FALSE, xlab = "Months", ylab = "Precipitation anomaly [mm]")

boxplot(NS_anomaly, xlab = "Years", ylab = "Precipitation anomaly [mm]", names=c(2001:2022))
 abline(h=0, col = "grey")
```

Appendix VI - Result section

VI.I Meteorological Data - Autocorrelation Analysis



Autocorrelation analysis for temperature: Correlation coefficients (ACF) do not stay within the 95% confidence interval (blue dotted line) - an autocorrelation is present

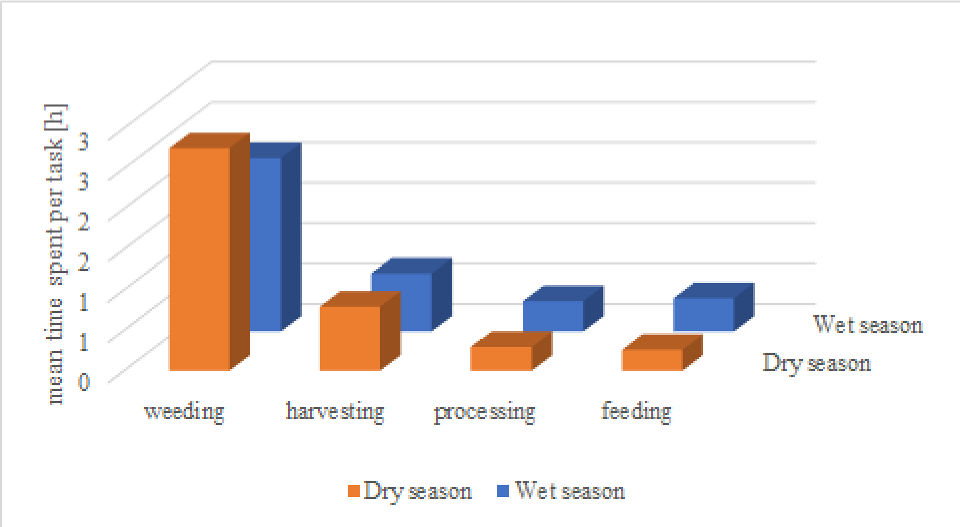


Autocorrelation analysis for precipitation: Correlation coefficients (ACF) stay within the 95% confidence interval (blue dotted line)

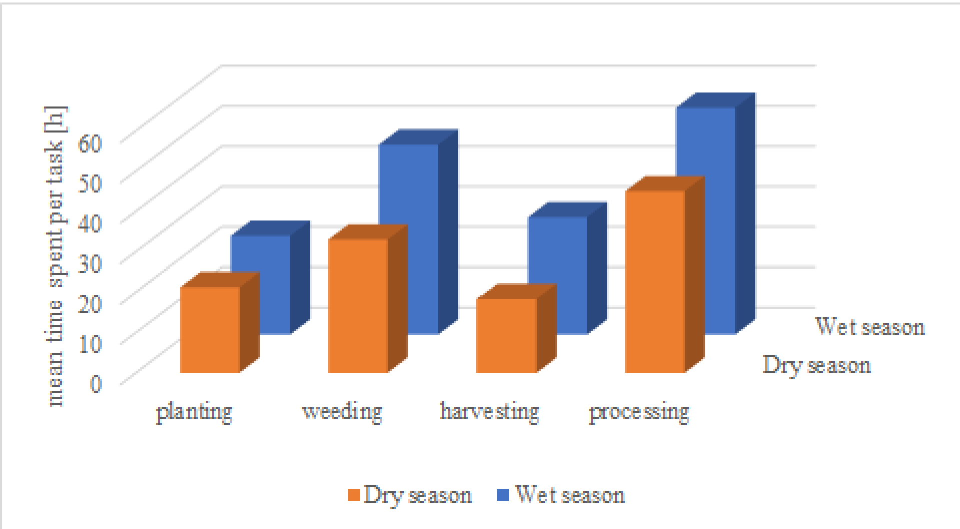
VI.II Soil sample analysis

Nitrate is a source of nitrogen and produces chlorophyll. Ammonium functions as a nitrogen fertiliser but makes the soil more acidic, as can be seen in the pH values. The development of the root system and the leaves is stimulated by phosphorus, and it increases the resistance against illnesses and stress factors.

VI.III Statistical Analysis Labour Effort



Time spent on daily tasks per season. Source: Authors' elaboration



Time spend on seasonal tasks related to fodder per season. Source: Authors' elaboration

		Wet season					Dry season				
		planting	weeding	harvesting	processing	feeding	planting	weeding	harvesting	processing	feeding
daily tasks	mean*	/	2,14	0,72	0,38	0,41	/	2,75	0,79	0,29	0,26
	SD*	/	0,69	0,53	0,61	0,55	/	0,50	0,51	0,30	0,28
	min	/	1,00	0,17	0,04	0,04	/	2,00	0,17	0,00	0,04
	max	/	3,00	2,00	2,00	2,00	/	3,00	2,00	1,00	1,00
	n	/	7	16,00	18,00	23,00	/	4,00	14,00	17,00	21,00
seasonal tasks	mean*	24,41	47,03	29,00	56,20	/	21,23	33,00	18,33	45,00	/
	SD*	31,57	55,65	24,45	32,74	/	32,20	21,90	14,67	/	/
	min	0,50	6,00	6,00	16,00	/	0,50	10,00	4,00	45,00	/
	max	112,00	180,00	72,00	105,00	/	112,00	80,00	42,00	45,00	/
	n	22,00	16,00	7,00	5,00	/	13,00	10,00	6,00	1	/

Statistical values for the time [h] the SDFs' tasks linked to dairy livestock take (* of all data bigger than zero). Source: Authors' elaboration