

# Socioeconomic Factors Influencing the Adoption of *Cenchrus ciliaris* among the Pastoralist Communities in South Baringo, Kenya

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## Abstract

Land degradation poses significant threats to food and environmental security globally. In arid and semi-arid lands (ASALs), livestock production is an important and significant livelihood. Unfortunately, overstocking and overgrazing have diminished pasture availability, and thus adversely impacting on the sector's contribution to food security for many ASAL communities. The Global Environment Facility's Small Grants Program in its quest to combat soil erosion, deforestation, and *Prosopis juliflora* invasion in the Lake Bogoria Landscape, Baringo County, Kenya has supported the establishment of *Cenchrus ciliaris* (buffel grass) since 2018. Despite its introduction and establishment, the socioeconomic factors influencing its adoption remain undocumented. This study evaluated these factors in three administrative wards, namely: Ilchamus, Mochongoi, and Marigat of Baringo South Sub-County. Data was collected from 103 households using a semi-structured questionnaire, key informant interviews (KIIs), and Focus Group Discussions (FGDs). Our results revealed that *Cenchrus ciliaris* adoption has partially reduced soil erosion and deforestation, improved livelihoods and environmental conservation. Nearly 50% of the respondents have established 2 to 5 acres of buffel grass pasturelands on their farms. The level of education of the respondents for had a significant association with the participants' knowledge regarding the advantages of pasture production for environmental conservation ( $\chi^2 = 16.93$ ;  $p < 0.05$ ). Nearly 90% of the respondents linked buffel grass to improved livestock production in the study area ( $\chi^2 = 77.71$ ;  $p < 0.05$ ). Adoption of the grass was also correlated with the level of education ( $\chi^2 = 18.3$ ;  $p < 0.05$ ) as was Gender ( $\chi^2 = 3.8$ ;  $p < 0.05$ ). Tertiary teaching and research insti-

tutions have played a major role in the adoption of this grass in the study area, and as per the KIIs and FGDs, the underlying reasons behind increasing adoption of the grass are its tolerance to ecological stress and high productivity under low rainfall amounts. The challenges to the adoption of the grass include lack of certified seeds, damage of the young pastures by livestock due to the communal land tenure system, and extreme dry weather conditions. Provision of certified seeds, community mobilization and capacity building, and strengthening the *Cenchrus ciliaris* value chain are recommended as practical strategies of enhancing livestock production and environmental conservation in Kenya's ASALs.

## Keywords

*Cenchrus ciliaris*, Pasture, Ecology, Conservation

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## 1. Introduction

Arid and semi-arid zones experience low, erratic rainfall (up to 700 mm annually), periodic droughts, and varying vegetative cover and soils. Rainfall in arid zones averages up to 350 mm, with 50 - 100% inter-annual variability, while semi-arid zones see up to 700 mm [1] with 20 - 50% variability. Livelihoods in these areas rely on pastoralism and rain-fed agriculture, leading to unpredictable outputs [2]. Droughts, degraded rangelands, and restricted grazing access cause severe livestock feed shortages, making ASAL communities, often low-income, vulnerable to food and nutrition insecurity. Climate change exacerbates these challenges, with the Horn of Africa experiencing seven major droughts in the past decade, devastating pastoral livelihoods [3] [4].

In Kenya, arid and semi-arid lands (ASALs) cover 89% of the country, housing about 14 million people and 70% of the national livestock herd. Arid areas rely on pastoralism, while semi-arid areas engage in agropastoral activities, rain-fed and irrigated agriculture, bio-enterprises, and tourism [5]. ASALs are crucial to Kenya's tourism sector, contributing 10.4% to the GDP. Recognized under Vision 2030, these lands and the livestock sector are key to economic growth, necessitating pasture production. The depletion of natural resources is a major concern, with the UN estimating that 1.2 billion hectares of land are moderately degraded, one-fourth of which is in Africa [6].

Environmental degradation, including soil erosion and climate change, directly impacts agricultural productivity and food security [7]. Globally, degradation claims six million hectares of agricultural land annually, with 16% affected by soil issues. Water erosion is the most significant, accounting for 56% of degraded land. In Africa, five to six million hectares are degraded each year. Poor farming practices in developing countries lead to soil loss, nutrient depletion, and ultimately, land degradation, resulting in low productivity, food insecurity, and poverty. Desertification is driven by overgrazing, population growth, deforestation, and climate change [8]. The Lake Bogoria Landscape faces severe envi-

ronmental challenges, including resource conflicts, human-wildlife conflicts, and unsustainable practices, threatening its ecosystem services. Its unique geology and biodiversity make it vital locally and globally.

Despite its international importance, the Lake Bogoria Production Landscape faces severe environmental degradation due to unsustainable resource use and harmful catchment-wide practices [9]. Root causes include poverty, poor land management, overstocking, weak traditional management, and rapid agricultural expansion. Overgrazing and reliance on synthetic fertilizers have degraded arable lands [10]. Conventional farming and extensive chemical use have led to soil acidity and pest resistance. Although pasture technologies like *Cenchrus ciliaris* and *Eragrostis superba* show promise, adoption among pastoral communities remains slow. Understanding the factors hindering adoption is crucial for addressing land degradation and food security in Baringo [11]. The Global Environment Facility's Small Grants Program in its quest to combat soil erosion, deforestation, and *Prosopis juliflora* invasion in the Lake Bogoria Landscape, Baringo County, Kenya supported the adoption and establishment of *Cenchrus ciliaris* (buffel grass) since 2018 amongst the local agropastoralist communities [12].

It is against this background that this study was conceptualized to assess socio-economic factors that influence the adoption of *Cenchrus ciliaris* grass species among the pastoralist communities. The findings from the study contribute new knowledge on factors influencing the adoption of *Cenchrus ciliaris*, thus informing the relevant bodies on interventions that can increase its uptake that will ultimately improve livestock production and enhance environmental conservation practices.

## 2. Research Methodology

### 2.1. Description of the Study Area

The Study area is located in the Eastern (Gregory) Rift Valley in Central Kenya. It is an open savannah bushland/woodland environment with an elevation varying from 970 m at the lake surface to over 2200 m above sea level [13]. A variety of dryland woody species characterize the vegetation including *Commiphora* (Myrrh), *Acacia xanthophloea* (Fever tree), *Balanites aegyptiaca* (Desert date) although two introduced species, *Prosopis juliflora* (Mesquite) and *Opuntia ficus indica* (Prickly pear cactus), have become invasive and now occupy vast tracts of land in the lowlands. Grass species includes red oat grass (*Themeda triandra*), Maasai lovegrass (*Eragrostis superba*) while herbaceous plants include the african wild basil (*Ocimum gratissimum*). Many of the lowlands are now used for irrigation, farming and grazing.

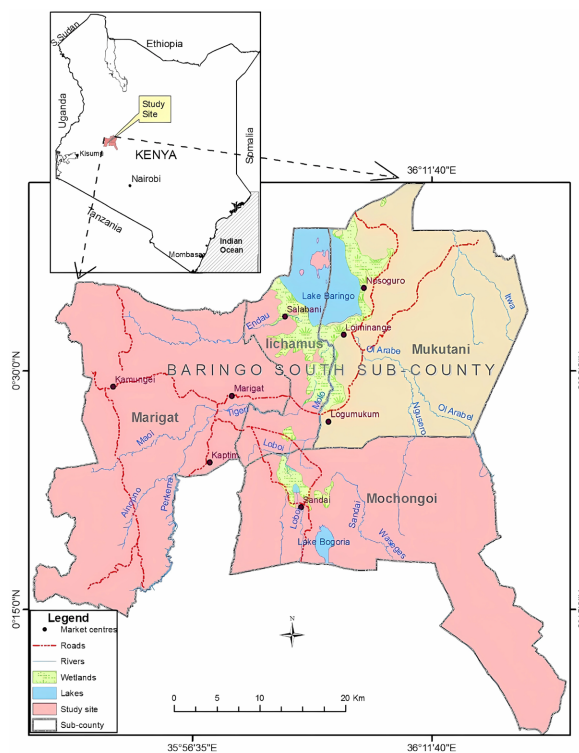
The topsoil was formed in the early Holocene as a lakebed, during a period when Lake Baringo and Lake Bogoria (just to the south) formed a single lake [13]. The soils are an unconsolidated silty loam, with varying contents of silt and clay but almost no sand. These soils and the surrounding highlands are now subject to high rates of sheet, wind, and gully erosion due to a mixture of soil

properties, lack of undergrowth, persistent winds and high-intensity downpour [14]. Because of this erosion, the region has been subject to many different land rehabilitation projects, which have all failed, and it attracted a lot of research from various disciplines concerned with the degradation and the paleoecology of the environment [1].

The study was conducted in the semi-arid reaches of Baringo South Sub-County of Kenya, (also herein referred to as Lake Bogoria Landscape) within three wards (Ilchamus, Mochongoi and Marigat). The area covers the rangelands inhabited by these communities. It falls within agroclimatic zones IV and V, at an average altitude of 900 - 1200 m above sea level [14]. Climate can generally be described as hot and dry (22 - 24°C). Rainfall is low, erratic, unreliable in both space and time 300 - 700 mm, and bimodal in distribution.

The study area borders Laikipia County to the East, Turkana to the North, and Elgeyo-Marakwet to the West. The dominant ethnic groups in Baringo South Sub-County are the Pokot, Tugen, Ilchamus and Endorois, who are all agropastoralists, and have value livestock very much. It has two distinct weather patterns, with temperatures in the southern part ranging between 25°C during the cold month (June and July) and 30°C during the hot months (January and February). It receives rainfall amounts of between 1000 m - 1500 m and m annually in the highlands and 600 m in the lowlands. It lies between longitude 35.602° - 36.277°E and latitude 0.541 - 0.723°N at an altitude ranging between 870 and 2499 m above sea level [13].

The following map in **Figure 1** describes the study area in the country.



**Figure 1.** Map of baringo county showing the study areas.

## 2.2. Study Population

The target population for the study included all household heads of the agropastoralist communities within Ilchamus, Mochongoi and Marigat wards of Baringo South Sub-County, Baringo County. The villages within the Sub-County was divided into clusters where stratified random sampling was applied to select the participants in the study. Additionally, local administrative leaders, opinion leaders and local informants included the chiefs from the region, leaders representing various women groups, officials from non-governmental organizations operating in the region, religious leaders, youth groups and members of the council of elders from the communities formed the key informants (**Table 1**).

**Table 1.** Characteristics of the population in the study area.

<b>Location Parameter</b>	Headcount Index: % of people below the Poverty line	Poverty Gap as % of Poverty Line	The severity of Poverty as % of Poverty Line	Wealth Gap index as % of Poverty Line	Mean Expenditure	Ginni Co-efficient	County Contribution to national Poverty	Total Population
Kimalel	38.5	7.5	1.9	61.1	2400	0.290	0.009	4072
Marigat	45.2	10.1	3.0	64.7	3530	0.383	0.034	12,753
Salabani	83.8	28.2	11.9	10.4	1280	0.255	0.023	4725
Ngambo	68.7	14.6	4.1	21.9	1680	0.244	0.022	5324
Ilchamus	59.2	12.1	3.2	30.4	1850	0.263	0.011	3298
Sandai	54.6	11.2	3.0	34.9	1930	0.271	0.008	2564
Kapkuikui	52.2	9.8	2.6	39.8	2030	0.269	0.003	1080
Loboi	51.4	11.8	3.5	51.5	2180	0.326	0.006	2126
Kimondis	44.8	9.5	2.7	53.5	2250	0.296	0.004	1357
Ilngarua	54.1	10.2	2.6	34.7	1950	0.258	0.008	2555
Ewalel Soi	56.8	11.8	3.3	39.5	2000	0.286	0.005	1364

Source: BCG, 2015.

## 2.3. Research Design

A descriptive cross-sectional design was used among households to assess ecological and socioeconomic factors influencing the adoption of *Cenchrus ciliaris* grass. By use of this design, a sample of 103 respondents was selected, and semi-structured questionnaires were administered to household heads. Focused group discussions (FGD) and key informant interviews (KII) were also conducted. Further, personal observations were used to gather information on the establishment and management of *Cenchrus ciliaris* among the selected households.

## 2.4. Target Population and Sampling

A social survey was used for data collection through the administration of the questionnaire, oral interviews and focus group discussions (FGD). Data was col-

lected from 103 households. For this data, simple random sampling was used to select household heads. Stratified random sampling technique was preferred for this study as it ensured equal chances for every household in the study area being included in the sample [15].

$$n = NC^2/C^2 + (N - 1) e^2$$

$$n = 100$$

where,

- n** the size of the sample; N is the size of the population;
- C** the coefficient of variation (30%);
- e** the standard error 0.05%.

## 2.5. Key Informant Interviews and Focused Group Discussion Data

For qualitative data, KII and FGD participants were selected purposely based on their willingness to participate in the study. The strategy was used because it enabled us to get people who were in a better position to provide us with the relevant information. KII respondents included those groups and individuals that had adopted *Cenchrus ciliaris* pasture production. Owing to ethnic and gender stereotypes, the focus group discussants were drawn along ethnic and gender considerations to encourage and ensure free and active participation in the discussions.

A total of 20 key informants were selected based on their level of knowledge about the community and knowledge about production of *Cenchrus ciliaris* grass species. In addition, four Focus Group Discussions consisting of 6 to 8 participants per FGD group were conducted based on their willingness to participate in the study. The two tools Key informant interviews (KIIs) constituted opinion leaders, Ministry of Agriculture, Livestock and Fisheries personnel, Staff in the Ministry of Wildlife and Tourism, Kenya Wildlife Service, Kenya Forestry and Research Institute, representatives of development partners working within the study area, and local county administrators. By the end of the study, a total of four focused group discussions had been conducted.

## 2.6. Validity and Reliability of the Data Collection Instruments

Checking validity of the data collection instruments was done before they were applied in the main study. There were a number of proposed activities that were carried out in order to validate these data collection tools. Additionally, randomization, the use of a research design and statistical analysis that are appropriate to the types of data to be collected were used to assess validity and reliability. Pilot testing was carried out in Emining Ward, an area with similar agroclimatic and socioeconomic conditions, and where *Cenchrus ciliaris* had been adopted for livestock production. The sample size for the pilot test was 10% of the total target sample.

In the pilot testing, fifteen questionnaires were administered. Validity was tested using experts knowledgeable in pasture and livestock production, whereas

reliability was tested using Cronbach's Alpha. The necessary adjustments to the tool were made based on the findings from the pilot study.

## 2.7. Data Processing and Analysis

Data from the questionnaire were coded and handled using Statistical Package for Social Sciences (SPSS) software (version 22). Descriptive statistics were used to present the results in graphs and tables, whereas inferential statistics by use of Pearson Chi-Square method were done to determine the relationship between socioeconomic, ecological conditions, and adoption of *Cenchrus ciliaris* production. For the FGDs and the KII, the audiotapes of the discussions and the interviews were carefully transcribed. After the data was transcribed and translated, it was coded using theme analysis, and following keywords, key concepts, or reflections using respondents' exact words and analyzed manually for common themes. The codes were finalized, written and illustrated with some quotations from the original text to communicate its meaning better.

## 3. Results and Discussions

### 3.1. Results

#### 3.1.1. Socio-Economic Characteristics of Study Participants

One hundred and three respondents participated in this household survey within the selected wards (Ilchamus, Mochongoi and Marigat). In terms of gender, 54.4% of the respondents were males (**Table 2**). Eighty-eight percent of the respondents were farmers whereas only 7.8% had formal employment (**Table 2**). Additionally, 36% of the respondents had attained primary level of education while 7.8% had obtained a university-level education (**Table 2**).

**Table 2.** Characteristics of respondents that participated in the study.

Characteristics	n	%	Characteristics	n	%
<b>Respondents' age</b>			<b>Education level</b>		
18 - 25	21	20.4	None	2	1.9
26 - 35	40	38.8	Primary	38	36.9
36 - 45	27	26.2	Secondary	36	35.0
46 - 55	12	11.7	College	19	18.5
Above 56	3	2.9	University	8	7.8
<b>Occupation level</b>			<b>Household size</b>		
Farmer	91	88.3	1 - 5	35	34.0
Pastor	2	1.9	6 - 10	53	51.5
Formally Employed	8	7.8	11 - 15	14	13.6
Casually Employed	2	1.9	Above 16	1	1.0
<b>Respondents' Gender</b>					
Male	56	54.4			
Female	47	45.6			

### 3.1.2. Pasture Establishment and Adoption

Eighty-six percent of the respondents owned a grazing land whereas 24% of the grazing lands were communally owned. The majority of respondents (69%), reported owning between 1 - 10 cows. Additionally, nine percent owned between 21 - 30 cattle. Contrary to our expectation, 18% of the respondents did not own any cattle.

In terms of the size of grazing land, most respondents (47%) had access to two to five acres. Twelve percent of them had more than 11 acres, while 39% reported that the distance to the grazing fields was between two and five kilometers from their households. Only 8% had to travel a distance of more than 5 kilometers to the grazing lands. Eighty-three of the respondents reported buying pastures for their livestock during the dry periods of the year when grazing lands were bare and could not support their animals.

In terms of training on pasture establishment, 23% of the respondents received it from early adopters within their community, while only 1% received it from teaching and research institutions such as Egerton University (EU), Kenya Agricultural and Livestock Research Organization (KALRO), and the Kenya Forest Research Institute (KEFRI). The main types of pasture for most respondents (65%) was open grazing fields, followed by maize stalks (12%), and with only 1% citing silage as their main type of pasture.

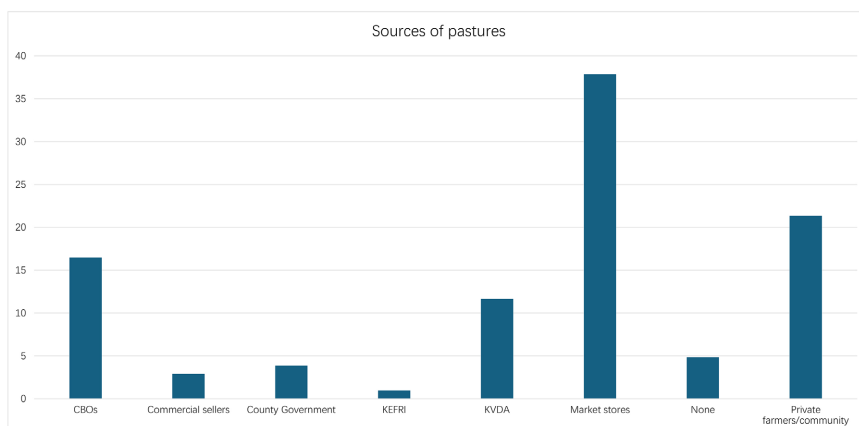
During times of crisis, farmers opt for alternative types of pastures for their livestock. The majority (41%) use maize stalks/pods, followed by tree leaves/pods (26%) and hay (21%). *Prosopis juliflora* (locally known as Mathenge) seeds and open grazing were the least cited as types of livestock feed.

Eighty-six of the respondents had knowledge of the contribution of pasture production to environmental conservation (**Table 4**). The types of pasture establishments varied, with 13% practicing furrow farming, 8% practicing round-basin farming, while the rest practiced terracing and afforestation. Despite their knowledge of the contribution of pasture establishments to environmental conservation, 70% of the respondents reported not practicing any pasture production establishments and depends on free grazing fields.

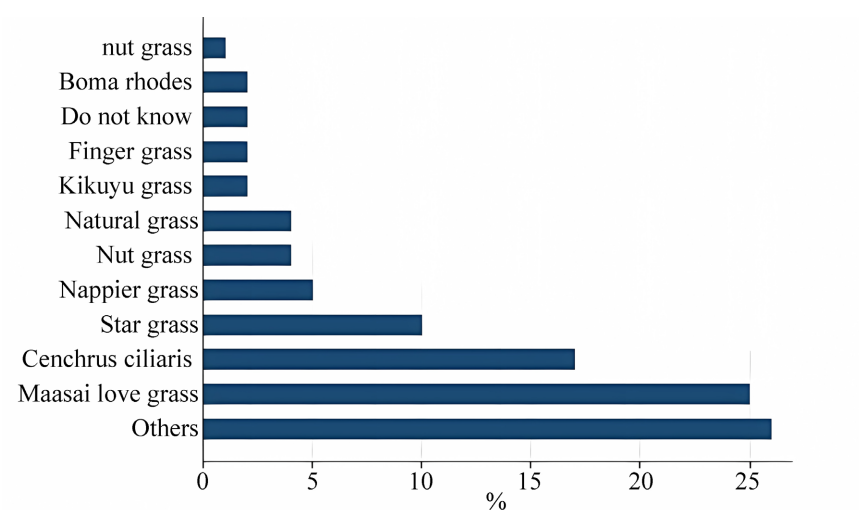
The majority of people (49%) paid more than Kshs 200 for a bale of pasture. Thirty-eight percent of the respondents indicated that they purchased their pastures from market stores in the adjacent towns and trading centres (**Figure 2**). Only 1% of the respondents indicated KEFRI as the source of pastures (**Figure 2**).

The main pasture grasses in the study area were Maasai love grass (*Eragrostis superba*), buffelgrass (*Cenchrus Ciliaris*) and star grass (**Figure 3**).

At least 30 participants (29% of the total) identified the benefits of pasture production in preventing soil erosion. Similarly, 25% of the participants recognized improved animal production as a result of pasture utilization. Additionally, 17% of them acknowledged the income generated from pasture production, while only 7% recognized its potential for improving soil fertility. Only one percent of them identified the reduction of conflicts as a benefit of pasture production (**Table 3**).



**Figure 2.** Sources of pasture versus the number of respondents within the study area.



**Figure 3.** Types of pasture grass species in the study area.

**Table 3.** Environmental conservation measures through pasture within the study area.

Activities done for soil conservation	Freq.	Percent	Benefits of pasture production	Freq.	Percent
Afforestation	20	19.42	Environmental aesthetic value	4	3.88
Building gabions	1	0.97	Improved animal production	26	25.24
Building gabions	4	3.88	Improvement of soil fertility	7	6.80
Constructing boreholes	3	2.91	N/A	6	5.83
Educating the community on pasture establishment	13	12.62	Prevention of soil erosion	30	29.13
Help in fencing of farms	2	1.94	Provides thatching grass	11	10.68
None	13	12.62	Reduced conflicts	1	0.97
Providing capital/seeds to the famers	11	8.74	Source of income	18	17.48
Training farmers	35	33.98	<b>Total</b>	<b>103</b>	<b>100.00</b>
<b>Total</b>	<b>103</b>	<b>100</b>			

**Table 4.** Pasture adoption and establishments.

Characteristics	n	%	Characteristics	n	%
<b>Grazing land ownership</b>			<b>Main sources of pasture</b>		
Yes	89	86.4	Communal land	10	9.7
No	14	13.6	Hay	4	3.9
<b>Type of ownership</b>			Maize stalks	12	11.6
Communal	25	24.3	Open grazing fields	67	65.1
Lease	4	3.9	<i>Prosopis juliflora</i>	2	1.9
Owner	69	67.9	Silage	1	1.0
Not specified	5	4.0	Other tree leaves/pods	7	6.8
<b>Size of grazing land</b>			<b>Alternative pasture during crisis</b>		
0 - 1	22	21.4	Tree leaves/pods	27	26.2
2 - 5	49	47.6	Hay	22	21.4
6 - 10	20	19.4	Maize stalks/pods	42	40.8
More than 11	12	11.7	Open grazing	1	1.0
<b>Does household buy pasture</b>			Pastoralism	4	3.9
Yes	85	82.5	Prosopis seeds	1	1.0
No	18	17.5	Silage	3	2.9
<b>Cost of pasture per bale</b>			None	3	2.9
0 - 50 Kshs	1	1.0	<b>Pasture production establishments</b>		
51 - 100 Kshs	6	5.8	Afforestation	1	1.0
101 - 150 Kshs	3	2.9	Furrow farming	13	12.6
151 - 200 Kshs	43	41.8	Round basin farming	8	7.8
More than 200 Kshs	50	48.5	Terracing	2	1.9
<b>Training bodies on pasture establishment</b>			Natural grass	2	1.9
CBOs	17	16.5	Gulley	2	1.9
Government/Ministries	3	2.9	None	72	69.9
Community/Neighbors	4	3.9	Others	3	2.9
Egerton University (Chemeron)	1	1.0	<b>Number of cattle owned</b>		
KVDA	12	11.7	0	18	17.5
KEFRI	39	37.9	1 - 10	71	68.9
NGOs	22	21.3	11 - 20	3	2.9
<b>Distance to primary source of pasture</b>			21 - 30	9	8.7
0 - 1 Km	26	25.2	61 - 70	2	1.9
1 - 2 Km	29	28.2			
2 - 5 Km	39	37.9			
More than 5 Km	9	8.7			

Regarding soil conservation activities in the study area, 34% of them mentioned the importance of providing training to farmers on establishing pastures for environmental benefits.

Twenty percent highlighted the significance of afforestation, while 13% believed that educating farmers would be beneficial. Nine percent suggested providing farmers with capital or seeds to support their efforts in soil conservation. The least common suggestions were building gabions, mentioned by 1%, and fencing farms, mentioned by 2%. Thirteen percent did not propose any specific activity to aid farmers in conserving soil.

### 3.1.3. Relationship between the Socio-Economic Factors and Adoption of Pastures

Pearson's Chi-square tests were conducted to assess if there was a relationship between specific socio-economic factors and the establishment of pastures. Our findings indicate that there was a significant association observed between the respondent's gender and their establishment of pasture lands ( $\chi^2 =$  of 3.8;  $p =$  0.05). The level of education of the respondents had a significant association with the participants' knowledge regarding the advantages of pasture production for environmental conservation ( $\chi^2 =$  16.9344,  $p <$  0.05).

Our results also indicated a significant association between gender and land ownership, highlighting gender disparities in agricultural productivity. Secondly, the findings revealed that the education level of respondents significantly influenced their knowledge about the benefits of pasture production for environment protection. Higher education levels were associated with a greater awareness and understanding of the benefits of sustainable land management for environmental conservation.

There was however no association between the educational level of the participants and their preference for specific body or institutions to receive pasture training ( $\chi^2 =$  18.2859;  $p >$  0.05).

### 3.1.4. Key Interviews and Focused Group Discussion Data

A total of twenty (20) key informant interviews (KIIs) were conducted with various individuals representing major stakeholders in the pasture and livestock production. Additionally, four focus group discussions (FGDs) were conducted involving community members; two of which involved community-based organizations. Based on these findings, the following information was obtained.

The primary occupation reported by the majority of respondents was agropastoralism. The commonly cultivated crops included maize, melon, green grams, and pawpaw. Land ownership in the community is communal, although each household has designated demarcations ranging from 2 - 5 acres. The primary pasture species utilized for livestock feeding included maize stalks, *Cenchrus ciliaris* (buffel grass), *Leucaena leucocephala* (a legume tree), bean straws, and *Acacia seyal* barks.

The qualitative analyses revealed that *Cenchrus ciliaris* was used as a pasture due to its various benefits, as reported by the respondents. For instance, 32.4% of

the participants mentioned its ability to be drought resistant, while 45.6% noted that it helps in preventing soil erosion. Additionally, 12.7% highlighted its minimal management requirements, 37.8% mentioned its role as a source of income, and 9.5% pointed out its function in moderating crude protein levels. Furthermore, 15.9% reported that *Cenchrus ciliaris* is easy to harvest, 50.8% noted its ability to increase livestock production, and 19% mentioned its quality as hay. Finally, 25.4% of respondents recognized *Cenchrus ciliaris* for its potential use as thatch grass, showcasing its versatility and value as a pasture option.

The use of *Cenchrus ciliaris* for thatching was also reported by some male FGD respondents saying:

“We adopted this grass species owing to its great benefits not only in livestock and environmental protection but also for thatching our houses,” Male Key Informant respondent in Marigat.

However, the grass species was reported to be extinct due to overgrazing in the study area (Ilchamus, Mochongoi and Marigat wards) and the surrounding areas as mentioned by one female KII participant: “*Cenchrus ciliaris* is an indigenous grass species which was there before but due to overgrazing, it became extinct and we can only access its seeds in areas such as Kapedo.”

Similar to quantitative findings, indicating the use and prevalence of Maasai love grass in the region were corroborated by the key informants. Other types of grass pasture reported by the key informants included Boma Rhodes and Star grass which was mentioned as being good for water conservation.

Focus group discussants reported that they had received training on pasture establishment from a variety of community-based organizations. The training sessions included topics such as pasture establishment and management, adopting paddocking methods to reduce overgrazing, harvesting quality seeds, managing *Prosopis juliflora*, and proper planting timings for *Cenchrus ciliaris* to prevent competition from unwanted grass species. These trainings were aimed at improving the community’s knowledge and skills in pasture management, ultimately leading to healthier pastures and increased livestock productivity. The information provided in these sessions was valuable in ensuring sustainable and efficient pasture establishment practices within the community. They also indicated that they received expert guidance and training on establishment of *Cenchrus ciliaris* from the local tertiary teaching and research institutions.

During the drought season, respondents reported alternative ways to get pasture for their livestock, with 11 of them moving their animals to graze near wetland areas around the community. Another option was buying hay from market stores, with 9 key informant interview respondents stating that the cost ranged from Kshs 350 - 400. Additionally, 2 participants mentioned practicing nomadism, where they moved their animals to areas with better pastures around wetland and mountainous areas. A small number of participants, including the Nasinya Women Group, mentioned receiving assistance in adopting *Cenchrus ciliaris* as the primary type of pasture in their homes. They received seeds and a milling machine from institutions such as Egerton University and other wom-

en self-help groups.

### 3.1.5. Challenges Hindering the Establishment and Adoption of Pastures

Respondents reported to have faced a number of challenges when it came to establishing pastures on their land. One major issue was the lack of knowledge on the benefits of pasture establishments, with many respondents having a limited understanding of the advantages associated with growing pastures. Illegal grazing by livestock in certain areas also posed a problem, as unauthorized grazing disrupted the growth and development of the vegetation. Financial constraints were another barrier, as many respondents cited a lack of resources to purchase the necessary seeds for pasture establishments. Access to quality seeds was also a challenge, with a limited availability of high-quality seeds making it difficult to establish productive pastures.

Overgrazing was a common issue, with pastures often subjected to excessive grazing by livestock, leading to the degradation and depletion of the vegetation. The communal land ownership structure further complicated matters, creating social and logistical complexities that discouraged the establishment of pastures. Social-cultural issues, such as traditional beliefs and practices, also hindered the adoption and success of pasture establishments. Unpredictable rainfall patterns were a significant factor affecting pasture establishments, as the irregular nature of rainfall impacted the availability of water for the growth and maintenance of pastures.

Government policies were reported as hindrances to pasture establishments, with the preference for tree-related research over grass-related research limiting the promotion and development of pastures. Additionally, the invasive nature of *Prosopis juliflora*, locally known as Mathenge, posed a significant obstacle to the successful establishment of pastures. Overall, respondents faced a myriad of challenges that hindered their ability to establish healthy and productive pastures on their land.

The qualitative analysis of the transcripts revealed several noteworthy recommendations. Firstly, it was suggested that there should be a focused effort in creating awareness amongst farmers regarding the best practices for establishing pastures. This would involve providing farmers with training and education on the most effective methods for pasture establishment.

In addition, community mobilization efforts should be implemented to highlight the benefits of *Cenchrus ciliaris*, a specific type of grass. This would involve educating the community about the advantages of utilizing this particular grass species for pastures. Furthermore, it was suggested that access to certified seeds of *Cenchrus ciliaris* should be increased. This would involve making high-quality and genetically verified seeds more readily available to farmers. To ensure effective implementation of pasture technologies, it was recommended that organizations should actively seek to establish linkages and partnerships with other individuals or groups working towards the adoption of *Cenchrus ciliaris*. This collaboration would promote knowledge sharing and the exchange of best practices.

To support farmers in this endeavor, it was deemed necessary to assist them in finding markets for their pasture seeds. By connecting farmers with potential buyers, it would enable them to sustain their activities and generate income. Finally, it was suggested that the formation of cooperatives would play a crucial role in enhancing the growth and sustainability of pasture technologies. By coming together and pooling resources, farmers can benefit from collective decision-making, shared resources, and increased bargaining power.

## 3.2. Discussion

### 3.2.1. Pasture Establishment and Adoption

The study findings suggest that livestock keeping is a common practice among the community, as indicated by 86% of respondents owning grazing land. This aligns with previous research that has shown livestock farming to be a prevalent activity in similar rural communities [16]. The preference for private ownership of grazing land, with 68% of fields being individually owned, further supports this conclusion. The majority of respondents reported owning between 1 - 10 cattle, indicating that livestock farming is predominantly small-scale. The availability of grazing land is another important factor for livestock farmers, and the findings suggest that a moderate amount of land is accessible to a significant proportion of respondents. About 47% reported having access to 2 - 5 acres of grazing land, while a few reported having more than 11 acres. This indicates a higher availability of land for a smaller proportion of farmers, which could potentially affect the overall productivity and profitability of livestock farming in the community [17].

The distance to grazing fields is also a factor that can impact livestock farming, and the findings suggest that the proximity of grazing land is relatively convenient for a significant number of farmers. However, few respondents reported that the distance to grazing fields was more than 5 kilometers, which could pose logistical challenges for livestock management [18]. This highlights the importance of considering the accessibility and proximity of grazing land when designing support programs and interventions for livestock farmers.

The fact that the majority of respondents reported buying pastures at some point for their livestock suggests that the available grazing land might not be sufficient to meet the dietary needs of the livestock year-round. This emphasizes the need to improve pasture production and management practices by incorporating grass species such as *Cenchrus Ciliaris* in order to ensure a sustainable and reliable source of feed for livestock [19].

Open grazing fields were cited as the main source of pasture by a majority of respondents, indicating a reliance on natural pastures for livestock feeding. This finding is consistent with that of [20]. Maize stalks were also mentioned as an additional feed source, suggesting the utilization of crop residues. However, silage was cited by only 1% of respondents, indicating its limited use as a pasture source which further suggests that there may be opportunities to promote the use of silage as a more reliable and consistent feed source for livestock.

During times of crisis, when alternative pastures are needed, respondents reported using maize stalks/pods as the most commonly used alternative. This indicates that farmers adapt to different feed sources when their usual pastures are not available, highlighting their resourcefulness in finding suitable feed substitutes. Tree leaves/pods and hay were also mentioned as alternative pastures, further emphasizing the need for diverse and accessible feed sources for livestock [21].

The findings also suggest that farmers have a good level of knowledge around pasture production for environmental awareness. This is encouraging, and suggests that farmers are aware of the importance of sustainable pasture management practices [22]. However, it is concerning that a significant proportion (70%) of respondents reported not practicing any pasture production establishment. This could indicate a gap between knowledge and implementation, emphasizing the need for further support and training in pasture production techniques that protect the environment.

The findings also highlight the cost and sources of pasture for the majority of respondents which suggests that a significant proportion of individuals had to spend a substantial amount of money to acquire pasture. On the other hand, only 1% of the respondents reported that they were able to buy pasture for a cost ranging from 1 - 50 Ksh. This indicates that a very small percentage of individuals managed to find cheaper alternatives or perhaps had access to their own pasture without incurring significant expenses. Incorporating sustainable pasture practices could help sort this issue and further protect the environment [23].

When examining the sources of pasture, it is interesting to note that a majority of respondents mentioned purchasing it from market stores in the nearby trading centres. Market stores can be seen as convenient sources where one can easily buy the required pasture. This high percentage suggests that these stores are either widely available or preferred by the respondents due to factors such as convenience, variety, or quality. On the other hand, only a few respondents reported buying pasture from local research and livestock development centres. This low percentage implies that local centres might not be a popular or commonly utilized source for purchasing pasture when it should be the case.

The findings also indicated that Maasai grass and *Cenchrus Ciliaris* are the most commonly planted pasture grass species by farmers in the region, with Maasai grass being the most popular choice. This suggests that these grass species are well-adapted to the local conditions and are preferred by farmers for their livestock. Studies conducted on grass species diversity and their nutritional composition in pasture systems. It was found that different grass species have varying nutritional values, affecting livestock performance and health. This highlights the importance of selecting suitable grass species for livestock feeding. A different study by [24] investigated farmers' perceptions and preferences for different grass species in grazing systems. They found that farmers considered factors such as palatability, persistence, and adaptation to local conditions when

choosing grass species for their livestock. It is interesting to note that a larger group of respondents cited different varieties of other local grasses as the main ones for their livestock. This highlights the diversity of grass species that farmers rely on in the region, indicating a more varied approach to pasture management. The preference of *Cenchrus Ciliaris* over other grasses may also mean that farmers are aware of its value, that includes environmental conservation.

The findings also reveal that a significant number of respondents recognize the benefits of pasture production. The majority of respondents attribute the benefits to prevention of soil erosion and improved animal production. This indicates an understanding of the importance of sustainable land management practices for both environmental and economic reasons [25]. Interestingly, only a small percentage of respondents contributed the benefits of pasture production to improved soil fertility and reduced conflicts. This suggests that there may be a need for further education and awareness on the potential impacts of pasture production on soil and environmental conservation in the region. Our study findings are consistent with that of [26] that examined the ecosystem services provided by pastures, including soil erosion control, carbon sequestration, and water regulation. They emphasized the role of well-managed pastures in delivering multiple benefits to both livestock and the environment. A different study by [27] assessed the economic benefits of pasture-based livestock systems. They found that pasture-based systems contribute to increased income and reduced production costs for farmers, while also providing ecosystem services and improving animal welfare.

In terms of activities recommended for soil conservation, the majority of respondents suggested training on pasture establishment as a key activity. This reflects the recognition of the importance of proper pasture management in preventing soil erosion and maintaining soil health [28]. Other suggested activities include afforestation, education, provision of capital or seeds to farmers, and the building of gabions and fencing. [29] conducted a study on soil conservation strategies in agricultural landscapes. They highlighted the importance of implementing a range of practices, including afforestation, erosion control measures, and sustainable land management, to preserve soil quality and prevent erosion. They also explored farmers' perceptions and adoption of soil conservation practices. They found that training and education programs, along with financial support and policy incentives, are crucial for promoting farmers' engagement in soil conservation activities [30]. These results are similar to the current study findings.

These recommendations demonstrate a variety of approaches to soil conservation, indicating the need for a multifaceted approach that considers the specific needs and challenges of the local context. However, it is concerning that a significant number of respondents did not suggest any specific activity for soil conservation. This may indicate a lack of awareness or understanding of the importance of soil conservation practices or a disconnect between current practices and knowledge.

### 3.2.2. Relationship between Socio-Economic and Adoption of *Cenchrus ciliaris*

Pearson's Chi-square test was used to determine if there was a significant association between socio-economic factors and adoption of pastures. While examining the association between the gender of the respondents and the ownership of pasture land, there was a significant association realized at a Chi-square value of 3.8. This implies that there is enough evidence to suggest that gender influences the likelihood of owning pasture land. Various studies have examined the association between socio-economic factors (e.g. gender and education) and land ownership or adoption of specific pastures.

A study by [25] investigated the role of gender in the adoption of agroforestry practices in Nepal. The authors used chi-square tests to examine the association between gender and adoption. Similar to the example provided, they reported significant associations between gender and specific agroforestry practices based on the chi-square test results. Another study by [29] examined gender differentials in agricultural productivity in Kenya, covering aspects such as land ownership and other socio-economic factors. The study reported significant association between gender and land ownership, highlighting gender disparities in agricultural productivity.

Secondly, the findings revealed that the education level of respondents significantly influenced their knowledge about the benefits of pasture production for environmental protection. The Chi-square test statistic of 16.93 with a p-value less than 0.05 suggests that there is a statistically significant association between education level and knowledge about the topic. This finding is consistent with previous research conducted on similar topics. For example, a study by [30] examined the relationship between education level and environmental knowledge in the context of sustainable farming practices. The findings indicated that individuals with a higher education level had a better understanding of the ecological benefits of sustainable farming methods compared to those with lower education levels. This suggests that education plays a crucial role in enhancing knowledge and awareness of environmental protection strategies.

Another study investigated the influence of education on individuals' knowledge of sustainable land management practices. The results revealed that higher education levels were associated with a greater awareness and understanding of the benefits of sustainable land management for environmental conservation. These studies support the idea that education level plays a crucial role in shaping individuals' knowledge and awareness about environmental protection strategies, including pasture production. The more educated individuals are, the more likely they are to possess knowledge about the benefits of pasture production for environmental preservation.

### 3.2.3. Key Informant Interviews and Focused Group Discussion Findings

The qualitative analysis revealed that the use of *Cenchrus ciliaris* as a pasture was attributed to its benefits such as drought resistance, soil erosion prevention, minimal management requirements, and the ability to generate income through

seed sales. Additionally, it has moderate crude protein levels, is easy to harvest, can increase livestock production, and has uses as hay and thatch grass.

However, the grass species was reported to be extinct in the study area due to overgrazing. Respondents also mentioned the use of Maasai love grass (*Eragrostis superba*), Boma Rhodes (*Chloris gayana*), and Star grass (*Cynodon dactylon*) as alternative pasture options. Various community-based organizations provided training to the community on pasture establishment and management, paddocking method adoption, seed harvesting methods, managing *prosojis juliflora*, and proper planting timings for *Cenchrus ciliaris*. The choice of grass species to combat desertification is influenced more by its contribution as a source of forage for livestock than its contribution for rehabilitation purposes.

During drought seasons, respondents mentioned alternative ways of getting pasture for their livestock, such as moving animals to wetland areas, buying hay from market stores, and practicing nomadism. Some respondents, particularly the Nasinya Women Group, received support from institutions like self-help group Africa and Egerton University to establish *Cenchrus ciliaris* as the main pasture species in their households. A similar study in Burkina Faso shows that prolonged droughts leads to forage scarcity and forces the pastoralists communities to develop multiple strategies to maintain livestock production. These strategies includes forage conservation practices like grass mowing, woody species pods collect, crop residues conservation, purchase of hay and cottonseed cakes and use of *Senna obtusifolia* as a supplementary food and feed [31]

Challenges in pasture establishment mentioned by respondents included a lack of knowledge on its benefits, illegal grazing, financial constraints, lack of access to quality seeds, overgrazing, communal land ownership, social-cultural issues, unpredictable rainfall patterns, government policies favoring trees over grasses, and the invasion of *Prosojis juliflora*. Recommendations from the qualitative transcripts included creating awareness and training farmers on best pasture establishment practices, mobilizing the community on the benefits of *Cenchrus ciliaris*, increasing access to certified seeds, creating linkages with organizations doing similar work, assisting farmers in finding markets for their pasture seeds, and forming cooperatives to enhance growth and sustainability of pasture technologies [22] [32].

Our study findings and recommendations align with similar work in the field of pasture establishment and management. Previous studies by [9] [20] [33] have also highlighted the benefits of specific grass species, such as drought resistance, soil erosion prevention, and income generation. They also identified challenges related to seed availability, grazing practices, and government policies. Additionally, recommendations for awareness creation, training, and forming cooperatives are common in similar studies.

Furthermore, a study by [34] on the influence of farmers' social networks on their training choices might also be relevant. This research showed that farmers were more likely to seek training from institutions recommended by their peers or trusted individuals within their social networks. This could potentially explain

the association found between the type of pasture grass species and the desired training provider. It is possible that the respondents sought training from institutions that were known to specialize in the particular grass species they were planting, based on recommendations from their network.

A study by Goba *et al.* (2022); Shinde *et al.* (2019); Twinamatsiko *et al.* (2020); Zone (2015) [7] [27] [33] found that the use of specific grass species, including *Cenchrus ciliaris*, had similar benefits such as drought resistance and soil erosion prevention. They also identified challenges related to seed availability and grazing practices, which align with the findings of the current study. The study recommended the promotion of these grass species through awareness creation and training programs. Another study examined the challenges faced by farmers in establishing pasture. The study found that financial constraints, lack of access to quality seeds, and communal land ownership were common challenges, which are also mentioned by the respondents in the current study. The study recommended increasing access to certified seeds and forming cooperatives to enhance the sustainability of pasture technologies, consistent with the recommendations of the current study

The impact of the Global Environment Facility/Small Grants Programme (GEF/SGP) in pasture establishment and livestock production in the study area has been significant, as it has provided funding to enhance livestock production and environmental conservation through established Community-Based Organizations (CBOs) and line ministries. Studies have highlighted the crucial role of CBOs in promoting sustainable pasture management, emphasizing the importance of training programs and forming partnerships with organizations with similar goals.

## 4. Conclusions and Recommendations

### 4.1. Conclusions

In summary, the socioeconomic characteristics of households in the study area were found to significantly influence knowledge about the benefits of pasture production for environmental protection. Education level and the size of pasture land owned by respondents were associated with pasture harvest per year and the number of cattle owned.

Additionally, there was a significant relationship between socioeconomic characteristics and the adoption of *Cenchrus ciliaris* grass in the study area. Respondents who received support from research and teaching institutions as well as local social networks to establish *Cenchrus ciliaris* as the main pasture species in their households were more likely to adopt it. Challenges in pasture establishment included financial constraints, lack of access to quality seeds, and communal land ownership.

### 4.2. Recommendations

Based on the findings of this study, two research recommendations can be made to inform future research and interventions for sustainable land management in

the region. First, stakeholders should consider selecting grass species such as Buffel grass and Rhodes grass, for livestock feeding. These grass species have been found to be suitable for the environmental conditions in the area and can help both support livestock nutrition and promote sustainable land management practices. Secondly, training, education programs, financial support, and policy incentives are crucial for promoting farmers' pasture establishment and by extension engagement in soil conservation activities.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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