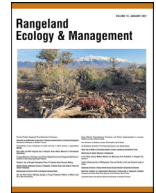




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Original Research

Determinants of Agropastoralist Households' Fodder Accessibility and Rangeland Conservation in Magu District, Tanzania[☆]Glory Rustis^{1,*}, Caroline Hambloch², Nedumaran Swamikannu³, Francis Moyo¹¹ Department of Sustainable Agriculture, Biodiversity and Ecosystem Management, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania² International Crops Research Institute for the Semi-Arid Tropics, Chitedze Agricultural Research Station, Lilongwe, Malawi³ Research Program on Markets, Institutions and Policies, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India

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ABSTRACT

The availability and accessibility of adequate and quality fodder is a huge challenge for pastoral and agropastoralist communities in Tanzania. Fodder scarcity, primarily driven by rangeland degradation, population growth, and climatic changes, limits livestock productivity and deepens rural poverty. This study assessed factors influencing agropastoralists' access to fodder and their willingness to conserve fodder sources in Magu District, Tanzania. A total of 210 agropastoralist households were surveyed in three wards covering six villages. The results show that access to fodder during the wet season is positively influenced by a household's income, land size, number of livestock, and physical capital. Dry season fodder accessibility is negatively influenced by households' land size, physical capital, and the number of livestock. Results also show that more than 60% of the agropastoral households accessed fodder sources formally (legally) in open areas, while 35% accessed fodder informally (illegally) in traditionally reserved highland areas, people's farms, and restricted urban areas. Conservation of rangelands and fodder sources is positively influenced by a head of households' level of education and income, and only 40% of households participated in conservation of rangelands and fodder sources. Improved land tenure, education, and income diversification can improve households' access to fodder and their willingness to conserve fodder sources.

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Introduction

Rangelands contribute immensely to livestock production, which is an important source of livelihoods and food security for rural communities around the globe (Chakeredza et al. 2007; Omollo et al. 2018). Rangelands comprise more than 60% of arid and semiarid areas in Africa and are dominated by pastoralist and agropastoralist communities (Bedunah and Angerer 2012; Fano Dargo and Osman 2015). In East Africa, the Lake Victoria Basin (LVB) rangelands contribute to 10–20% of the gross domestic product (GDP) in East African economies (URT 1997; Ernest et al. 2017). More than 36% of the livestock in Tanzania are found in the Lake Victoria zone, with predominantly smallholder agropastoralist communities (Ernest et al. 2017; Nkya et al. 2018). However, like in

most African rangelands, livestock productivity around LVB is low due to high dependency on unproductive natural pastures (IUCN 2019).

LVB rangelands are highly characterized by degradation due to uncontrolled grazing (Selemani et al. 2013), droughts, and increased abundance of invasive plant species (Manyeki et al. 2015), limiting the development of agropastoralist livelihoods in Tanzania (Hove et al. 2003; Rai 2018). However, a combination of innovative solutions in crop and livestock diversification and rangelands conservation have the potential to abate the agropastoral challenges (Nandi and Nedumaran 2021; Nandi et al. 2021). Crops diversification, for example, can provide alternative feed, and rangeland conservation strategies such as control of herd sizes and rotational grazing can reduce pressure on natural fodder, enhancing the availability and quality livestock feed (Peters et al. 2012; Zimmer et al. 2021). Evidence-based innovative fodder production technologies including oversowing of natural pasture with higher-yielding fodder species, promotion of fodder trees and legumes, effective use of crop residues, and forage conservation are readily available but less adopted by farmers (Wairore et al. 2015; Omollo et al. 2018). For example, Napier grass (*Pennisetum purpureum*),

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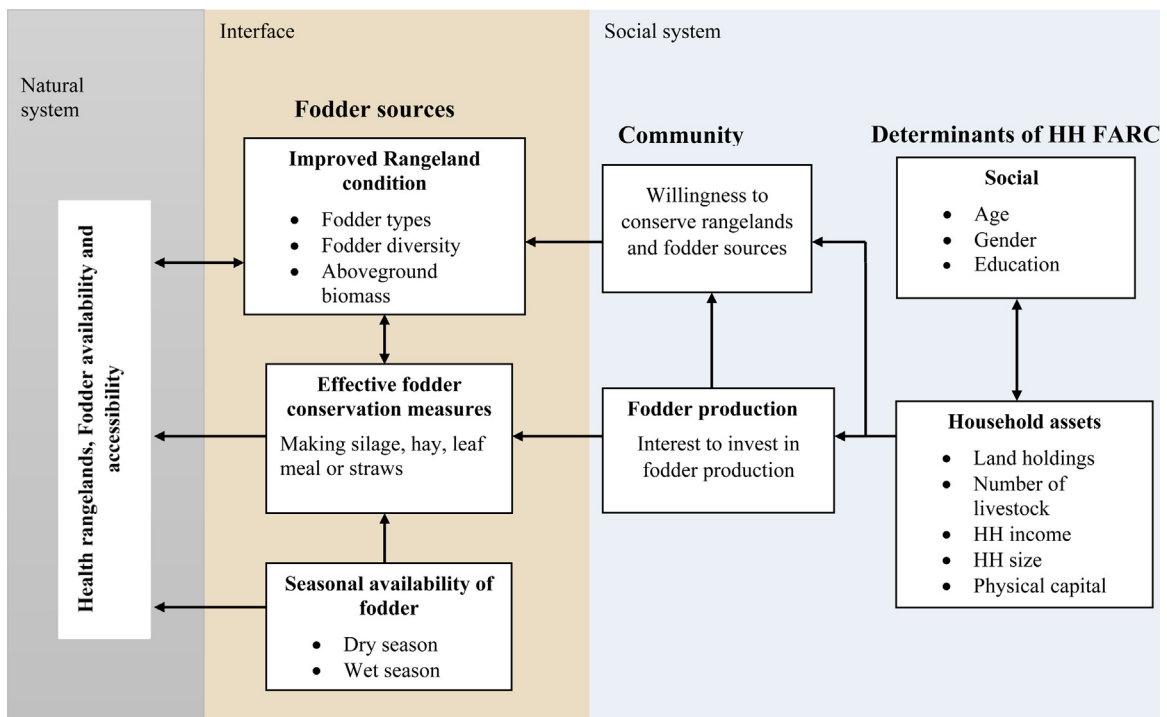


Figure 1. Conceptual framework modified from Niehof and Price (2001).

Table 1
Variables hypothesized to influence fodder accessibility and rangeland conservation.

Variables	Description	Expected influence	
		Accessibility	Conservation
Education	Education of the house head (No formal education = 0; Primary = 1; Secondary = 2; College = 3)	+	+
Gender	Gender of the house head (Male = 1; Female = 0)	±	+
Income	Household daily income (0.00–2.17 = 0; 2.61–4.34 = 1; 4.78–above = 2)	±	+
Landholding	Land owned by the household (Yes = 1; No = 0)	+	–
Land size	The size of land owned by household ([0.2–4 ha] = 0; [5–49] = 1; [50 above] = 2)	+	–
Livestock	Number of livestock owned by household (1–10) = 0; (11–40) = 1; (41 above) = 2	+	–
Native house head	The household head place of birth (Yes = 1; No = 0)	+	+

Note: 1 US\$ = 2 303.00 TZS

From Haile, F. 2019. The exchange rate: why it matters for structural transformation and growth in Ethiopia. Available at: <https://doi.org/10.1596/1813-9450-8868>. Accessed November 26, 2022.

Guatemala (*Tripsacum andersonii* J. R. Gray), buffel grass (*Cenchrus ciliaris*), and Rhodes grass (*Chloris gayana*) are among the high-yielding grass species and are highly promoted to improve fodder availability in tropics (Maleko 2020), yet they remain underused by agropastoral communities (Le Houerou 2000; Sanderson et al. 2007).

Studies on adoption of fodder production technologies, availability, and accessibility reveal that the head of households' gender, education level, membership in social groups, and access to extension services can influence households' participation in fodder conservation and production (Ernest et al. 2017; Maleko et al. 2018; Maleko 2020; Omollo et al. 2018; Mtengeti et al. 2008; Rai 2018). Yet African communities' traditional and cultural values are diverse and their livelihoods, strategies, and practices largely follow these traditions and cultural beliefs. Context specific empirical evidence is therefore needed to facilitate efforts to design interventions that accommodate local environment, culture, knowledge, and socioeconomic situations. This study assesses key determinants of households' access to fodder and rangeland conservation in Magu District, Tanzania. This study assumed that 1) a healthy rangeland, fodder availability, accessibility, and community willingness to conserve fodder sources would improve livestock production and agropastoral livelihood and 2) socioeconomic factors (age,

gender, education) and household assets (land holdings, number of livestock, households' income, households' size, physical capital) would facilitate the accessibility and conservation of rangelands by the household (Fig. 1). It also hypothesized that household assets (household income, number of livestock, landholdings) and socio-cultural settings (education, gender, and nativity of the household head) influence fodder accessibility and rangeland conservation in the study area (Table 1).

Methods

Study area

This study was conducted in Magu District, located in Mwanza Region, Tanzania. The livelihood strategies for residents here are mainly agropastoral activities. The District lies between latitude 20 10' and 20 50' south of the equator and between longitude 330 and 340 east (Fig. 2), with a tropical temperature ranging between 25°C and 30°C. The rainfall pattern is bimodal: October to December and March to May, and annual precipitation ranges between 700 mm and 1 000 mm. Temperatures and rainfall are strongly influenced by proximity to Lake Victoria and the equator (Ernest et al. 2017). The District borders Ukerewe District and Mara Region

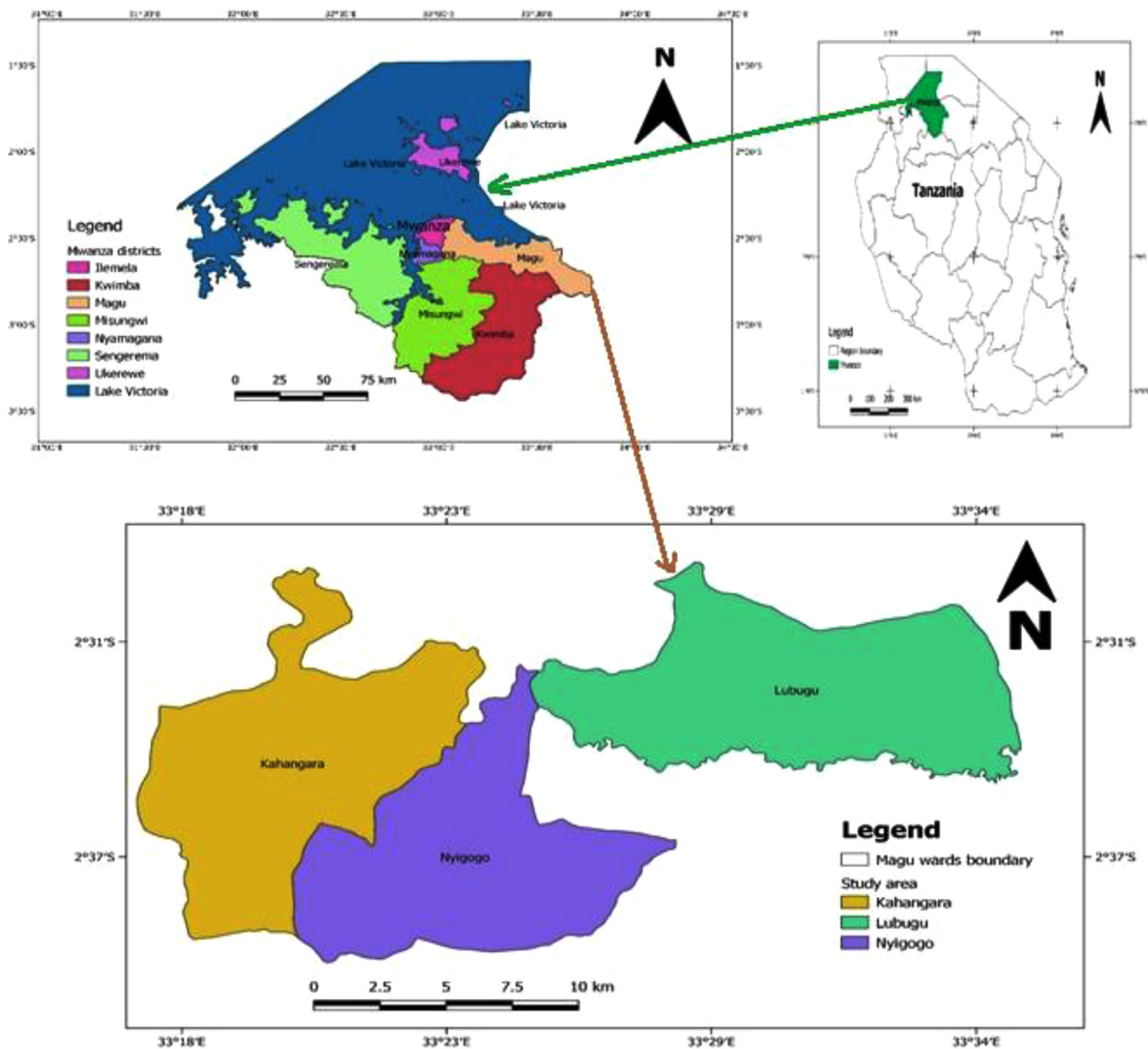


Figure 2. Map showing location of the study area.

to the North, Shinyanga region to the Southeast, Kwimba District to the South, and Mwanza District to the West. The Magu District has a total area of 4 800 km² with 1 725 km² area covered by Lake Victoria. Fifty percent (equivalent to 2 363 km²) of the land area is considered arable, 30% (equivalent to 1 440 km²) is pastoral land, and 3.4% (163.2 km²) is natural and planted forests (Otsyina and Magayane 2004). Our study focused on three wards, namely Kahangara, Nyigogo, and Lubugu, which were randomly selected.

Sampling design and data collection

This study used household surveys to collect data on factors influencing households' fodder accessibility and rangeland conservation. Interlocutors for the household's interviews were randomly selected from the list of a village register in each ward. A total of 210 agropastoral households were randomly selected for a household survey (70 households per ward in the study area) from 4 200 households' population, making a sampling intensity of 5% as proposed by Angelsen (2012). Closed-ended structured household questionnaires were used to capture information on households' socio-

economic characteristics including age, gender, marital status, level of income, occupation, educational level, number of livestock, land-holding, household size, physical capital (items in the household), house head place of birth, and land size. The survey also captured information on perception of households toward access to fodder sources and their participation in conservation of rangelands.

Fodder accessibility was assessed in two dimensions: accessibility during the dry season and accessibility during the wet season. Questionnaires were pretested in 15 households in Sukuma village, which was not part of the study villages but located in the same study wards. All interlocutors were asked for consent before interviews. Indigenous or local knowledge prevailing the study and physical observation were considered during data collection, which were important to consolidate the discussion of the findings. Two research assistants were hired and trained for 2 d to assist in households' data collection. The interview was conducted and lasted for 40 minutes to get more light on community perception toward the seasonal availability and accessibility of fodder. These study outcomes will be shared through organized formal meetings, written materials, workshops, and seminars basically from the

Table 2
Variables used for descriptive and inferential analyses.

Variables	Measurement
Response variables	
Fodder accessibility in dry season	Low amount = 0; Moderate amount = 1; High amount = 2
Fodder accessibility in wet season	Low amount = 0; Moderate amount = 1; High amount = 2
Rangeland conservation measures	Effective = 1; Less effective = 0
Explanatory variables	
Age	18–35 = 0; 36–60 = 1; 61 above = 2
Gender	Male = 1; Female = 0
Education level	No formal education = 0; Primary = 1; Secondary = 2; College = 3
Marital status	Widow/widower = 0; Not marriage = 1; Separated = 2; Marriage = 3
Household daily income	0.00–2.17 = 0; 2.61–4.34 = 1; 4.78–above = 2
Landholdings	Yes = 1; No = 0
Household land size	(0.2–4ha) = 0; (5–49) = 1; (50 above) = 2
Number of livestock	(1–10) = 0; (11–40) = 1; (41 above) = 2
Household size	Small (1–3) = 0; Medium (4–7) = 1; Large (8 above) = 2
Physical capital (number of items in the household)	Low (0–5) = 0; Moderate (6–15) = 1; High (15 <) = 2
Main income source	Agropastoralism = 2; Livestock keeping = 1; Others = 0
Native house head	Yes = 1; No = 0

researcher to the community members, decision makers, and experts.

Data analysis

Descriptive and inferential statistics were performed using R software version 3.6.0 (R. Team 2013). Logistic regression (binary and ordinal probit regression) was used to analyze factors influencing fodder accessibility and rangelands conservation. The variables used for descriptive and inferential analyses are presented in Table 2.

Specification of the model

The study deployed logistic regression analysis to analyze dependent variables having binary or dichotomous outcomes and ordinal probit regression analysis for the variables having more than two outcomes (Cleary and Angel 1984). A logit model was used because of the consistency of parameter estimation associated with the assumption that the error term in the equation has a logistic distribution (Masuku and Xaba 2013; Berger 2017). The model allows for predicting probabilities (the outcome variable) as a function of a set of socioeconomic factors (predictor variables) (Schreiber-Gregory and Bader 2018). The analysis was used to predict the (log odds/logit) positive or negative influence of the explanatory variables (age, gender, source of income, level of income, educational level, number of livestock, landholding, household size, house head place of birth, physical capital, and land size) on the accessibility of fodder to households and on the conservation of rangelands. Bergers' (2017) behavioral model was adopted to evaluate factors influencing fodder accessibility and rangeland conservation (Equation 1).

$$\text{Log odds ratio} = \alpha + \beta_1 \times X_i + \dots + \beta_n \times X_n + \varepsilon \quad (1)$$

where α is the intercept, β_1 is the regression coefficient of the first predictor, X_i is the first predictor, β_n is the regression coefficient of the last predictor, X_n is last predictor, and ε is the random error term.

The coefficient β shows the predicted change in the log(odds) for every one-unit increment of a given predictor (X). Equation 1 described the logit(P) as the natural log of the odds ratio as in Equation 2.

$$\text{Logit}(P) = \ln(\text{odds}) = \ln\left[\frac{P}{1-P}\right] \quad (2)$$

The model process

Three models were built to assess the impacts of the predictor or variables on three different response variables: Fodder accessibility in the wet season, fodder accessibility in the dry season, and rangeland conservation measures multicollinearity tests were used to ensure that the explanatory variables in the logit models were not linearly correlated. This was performed through the test of variance inflation factors (VIF) described by Daoud (2018). According to Akinwande et al. (2015), a suppressor variable should be allowed to be used in a regression model if the VIF is below 5. All candidate variables were tested for VIF, and all variables had VIF values below 5. Predictors (see Table 2) were used to build the models on household fodder accessibility and rangeland conservation. Model fit was assessed on the basis of the likelihood ratio, chi-square, and P value (Cleary and Angel 1984; Daoud 2018). A value with a high chi-square and a P value < 0.05 indicated a well-fit model. The *pseudo* R^2 of each model was calculated to determine the predictive power of the models (Berger 2017).

Results

Socioeconomic characteristics of households

The age of household heads ranged from 18 to older than 60 yr, but the majority (44%) were in the age group of 36 to 60 yr (Table 3). The average household size was six individuals, and the average landholding area was 5.7 ha (4.1 standard deviation) with a maximum of 20 ha and a minimum of 0.25 ha. Seven percent of the household heads were illiterate (unable to read and write), and only 3% had a tertiary education. Agropastoralism was reported by 78% of households as the main source of income, while 14% depended on pastoralism only, with an average of 25 livestock per household (18 standard deviation). Eight percent of the households depended on fishing, entrepreneurship, carpentry, or salary/wages as their main source of income.

Household fodder accessibility

The majority (65%) of households accessed fodder sources formally (legally) in open areas while 35% accessed fodder sources informally (illegally) in traditionally reserved highland areas, people's farms, and restricted urban areas (Fig. 3). During the dry season, 15% of the agropastoral households were likely to access a moderate amount of livestock fodder, while 85% of the households accessed a low amount of fodder. During wet seasons, 15% of the households accessed a high amount of fodder, while 79% of

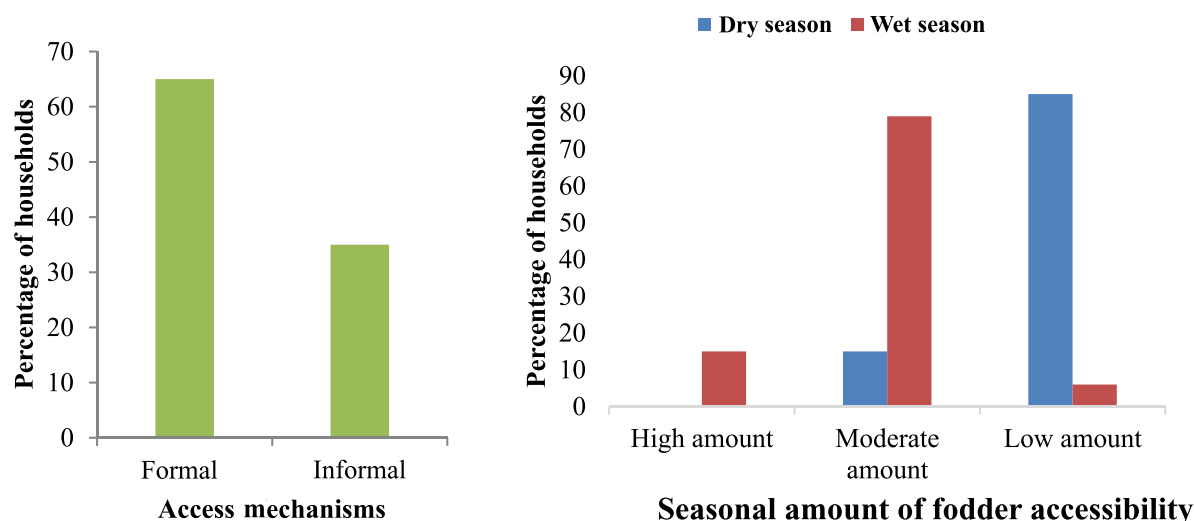


Figure 3. Percentage (%) of total surveyed households that responded to the mechanisms used to access fodder amount and the status of fodder accessibility during dry and wet seasons considering three measured factors (high amount, moderate amount, and low).

Table 3
Socioeconomic characteristics of households' heads in the study area.

Variable	Category	Responses	
		Frequency	Percentages (%)
Gender	Male	155	74
	Female	55	26
Age	18-35	58	27
	36-60	92	44
	> 61	60	29
Education level	Illiterate	15	7
	Primary	171	81
	Secondary	18	9
	College/University	6	3
Income source	Agropastoral	164	78
	Livestock keeping	29	14
	Others	17	8
Land holding size	(< 4 ha)	106	50
	(5-49 ha)	100	48
	(> 50 ha)	00	00
Household size	Small (1-3)	44	21
	Medium (4-7)	121	58
	Large (> 8)	45	21
Number of livestock	1-10	46	22
	11-40	123	59
	> 41	41	19

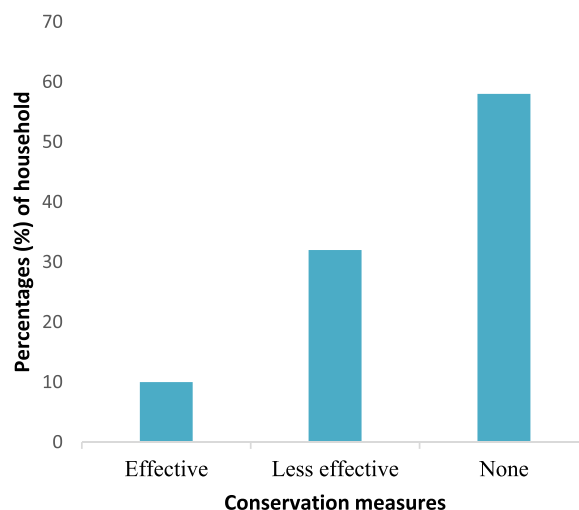


Figure 4. Percentage (%) of total surveyed households that responded to conservation measures which are taken by the community members to conserve the rangelands and fodder sources.

households accessed a moderate amount of fodder, and only 6% of households reported a very low amount of fodder (see Fig. 3).

Number of livestock, household land size, and income had significant positive influences ($P=0.009$, $P=0.004$, and $P=0.083$, respectively) on fodder accessibility during the wet season (Table 4). However, physical capital had a negative significant influence ($P=0.002$). During the dry season, households' land size, physical capital, and number of livestock ($P=0.000$, $P=0.027$, and $P=0.075$, respectively) had negative significant correlations with access to fodder (Table 4).

Rangelands conservation

Households' income, household land size, and education level had a positive significant relationship ($P=0.10$, $P=0.008$, $P=0.002$, respectively) with conservation of rangelands and fodder sources (see Table 4). About 40% of households were likely to conserve rangelands and fodder sources while 58% of the agropastoralist households were not taking any conservation measures (Fig. 4).

Households' heads with secondary and tertiary (college/university) education were more likely to conserve the rangelands and fodder sources than their counterparts. Also, there is a positive relationship between gender and rangelands conservation, with males being more associated with conservation of rangelands than females.

Discussion

Households' fodder accessibility

This study reveals that about 65% of agropastoralists' households in Magu District access fodder in open areas (road sides, playgrounds, uncultivated public lands, and field farms), while 35% access fodder from other sources including from traditionally reserved lands locally known as *Ngitiri* and restricted urban areas (see Fig. 3). Overdependence on naturally growing fodder is a major challenge facing sustainability of livestock production, leading to overgrazing and degradation of rangelands (Hove et al. 2003; Rai 2018; Maleko 2020). The problem is exacerbated by climatic changes and unpredictable rainfall patterns (onset, amount, avail-

Table 4
Marginal effect estimates of the influence of socioeconomic factors on fodder accessibility and rangeland conservation.

Variables concerning house head	Access in dry season	Access in wet season	Rangeland conservation
Age (36-60)	−0.055 (0.638)	−0.345 (0.221)	−0.000 (0.166)
Age (61 and older)	0.199 (0.767)	0.120 (0.207)	−0.008 (0.142)
Gender (male)	2.636 (2.596)	1.377 (0.184)	0.007 (0.053) ¹
Household size	0.097 (0.102)	0.027 (0.076)	0.059 (0.057)
Household daily income	1.075 (0.864)	0.067 (0.025) ¹	0.208 (0.399) ²
Education (college)	3.625 (2.258) ²	−0.459 (1.290)	3.625 (1.260) ²
Education (primary)	2.829 (2.035)	−0.179 (1.052)	1.239 (0.678)
Education (secondary)	2.374 (2.318)	−0.367 (1.326)	1.239 (0.068) ¹
Household land size	−0.316 (0.094) ³	0.089(0.047) ²	−0.070 (0.037) ²
Number of livestock	−0.023 (0.016) ²	0.225(0.048) ³	0.001 (0.010)
Source of income (agropastoralist)	0.154 (0.877)	0.435(0.034)	1.007 (0.015)
Source of income (livestock keeping)	−0.767 (0.871)	0.588(0.058)	−0.261 (0.031)
Landholdings	−0.003 (0.061)	−0.058(0.047)	−0.052 (0.037)
HH born in the village	0.476 (0.564)	0.287 (0.217)	0.151 (0.138)
Physical capital (low)	−2.448 (1.247) ²	−0.090 (0.219) ²	0.411 (0.881)
Physical capital (moderate)	−3.046 (1.220) ²	1.460 (0.221) ²	0.035 (0.846)
Mean variance inflation factors	4.23	3.25	4.52
Likelihood ratio (Chisq)	65.37 ³	109.35 ³	176.00 ²
Pseudo R-square	0.6784587	0.4335437	0.289003

Numbers in parentheses are standard errors.

¹ $P \leq 0.10$ (P is the alpha level).

² $P \leq 0.05$.

³ $P \leq 0.01$.

ability, and intensity), which limit fodder accessibility during dry periods (see Fig. 3) and force agropastoralists to graze in restricted areas including protected areas within the LVB. This finding aligns with studies by Sewando et al. (2016), Orr et al. (2020), and Msomba et al. (2021), who assert that climate change limits rangeland productivity, deepening rural poverty in developing countries (Ernest et al. 2017; Nandi and Nedumaran 2021).

Our results reveal that small landholdings and poor land tenure, which are related to rangeland fragmentation (Ernest et al. 2017; de Glanville et al. 2020; Nandi et al. 2021), force agropastoralists to graze on other people's farms, inciting land use conflicts and lower agricultural productivity due to destruction of soil (Quetier et al. 2005). Our data suggest that large landholdings and strong land tenure can enhance households' access to fodder and their willingness to produce fodder (Kariuki 2018; Omollo et al. 2018).

Fodder accessibility during dry and wet seasons

Fodder accessibility during the dry season was negatively influenced by households' land size, physical capital, and number of livestock. These findings suggest that households' assets negatively affect access to fodder in the dry season. These results did not support our hypotheses (see Table 1). Moreover, evidence from other studies suggests that agropastoralists can access fodder on open grassland and traditional reserved areas (Ngitiri) without considering the number of livestock, the size of the land owned, and wealth of a farmer (Selemani et al. 2013; Wairore et al. 2015; Yeneayehu et al. 2019; Sala et al. 2020). Ernest et al. (2017) also argue that access to fodder does not correlate to land size and number of livestock. Ernest showed that during the dry season, a large number of livestock moved from place to place searching for pasture, causing grazing pressure and degradation of rangelands (see also Tolera and Abebe 2007; Selemani et al. 2013; Barry and Huntsinger 2021). More research is needed to determine why our dry season results did not align with these other studies. On the other hand, our results revealed that household heads' education level had a positive significance influence on the accessibility of fodder during the dry season, which matched our hypotheses. Farmers who had higher education levels and the ones engag-

ing themselves in training associations were more likely to participate in the production of fodder crops than their counterparts. The study findings of Omollo et al. (2018) and Olila and Tambo (2014) assert that farmers' knowledge and awareness are key to ensuring the sustainability of livestock production in agropastoral communities.

Accessibility of fodder during the wet season was positively influenced by households' assets such as income, land size, physical capital, and number of livestock, supporting our hypotheses (see Table 1). Households with higher income may diversify fodder sources by purchasing from markets and neighboring farms and sourcing from their own farms. In contrast, households with low income depend mainly on open areas and free access to neighbors' farms. This study is in line with Maleko et al. (2018), Tolera and Abebe (2007), and Sala et al. (2020), who revealed that annual household income plays an important role in determining fodder availability and accessibility in harsh climatic conditions. Large land size, physical capital, and number of livestock likely influence fodder accessibility during the wet season because chunks of lands are used by farmers for cultivation of food crops, limiting access to grazing for poor households. Kamwenda (2002) and Selemani et al. (2013) also show that in semiarid areas in northwestern Tanzania, livestock pastures during the rainy season become limited for poor households, especially on the traditionally reserved (Ngitiri) areas, and therefore farmers can only access fodder in open lands and along road reserves.

Rangeland conservation by the households

The study indicates a positive significant relationship between household income and conservation of rangelands (see Table 4). Households with higher income were more likely to participate in fodder conservation compared with households characterized by low income, likely because the former had more options of accessing livestock feed than the latter. These results supported our hypotheses (see Table 1). Households with higher income sources therefore can afford to practice grazing in their private lands, leave their land fallow, or adopt enclosure systems that allow rangeland to naturally regenerate and regrow natural vegetation (Selemani et

al. 2013; Kariuki 2018). This echoes a study by Peters and Lascano (2003), which showed that households with high income can easily access fodder conservation technologies to diversify feed sources (for dry or winter seasons) in the form of hay, silage, leaf meal, or straws.

Household heads' education level had a significant influence on households' rangelands conservation measures, which matched our hypotheses (see Table 1). Adoption of newly introduced innovative farming practices Gessesse et al. (2016) and technologies (Yeneayehu et al. 2019) is highly influenced by education status. Educated individuals are likely to have better insight and reasoning ability to understand the benefits of adopting innovative farming solution than less educated individuals (Wairore et al. 2015; Moges and Taye 2017).

Households' gender showed a significant relationship with conservation of rangelands and fodder sources, whereas males were more associated with conservation of fodder sources than females (see Table 4). We expect that males were more likely to conserve rangelands and fodder sources because traditionally males have greater influence on households' participation in pastoral activities than females (Yeneayehu et al. 2019), and thus men have a greater chance to conserve fodder sources. Further, males are the main users of rangelands as they are believed to have the capacity to manage herds of livestock and travel long distances searching for pasture (Kamwenda 2002; Selemani et al. 2013).

Conclusion and management implications

This study aimed to assess factors influencing fodder accessibility and rangeland conservation by agropastoralists in LVB. The findings revealed that households' income, land size, number of livestock, and physical capital had enormous influence on accessibility of fodder during the dry and wet seasons. The study also showed that households' level of education and income positively shaped agropastoral communities' willingness to participate in the conservation of fodder sources and rangelands. The study suggests that efforts to improve agropastoral communities' livestock production should focus on enhancing land tenure, access to education, and diversification of households' income sources. The findings also stress the importance of adopting rangeland management strategies and policies that consider local socioeconomic characteristics and cultural issues to abate land use conflicts, overgrazing, soil erosion, and rangeland degradation.

Declaration of Competing Interest

None.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rama.2022.11.005.

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