Use value of indigenous range grass species in pastoral northern Kenya

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Research

Abstract

Background: Land degradation is a major challenge facing the world today, with devastating effects particularly among communities inhabiting semi-arid rangelands who are more directly dependent on natural resources. Over the years, indigenous grasses have provided multiple economic, ecosystem and cultural benefits for many communities in Kenya. However, they have increasingly experienced declining abundance, diversity and productivity over the years, compromising their benefits. This study was conducted to assess use value and local knowledge of indigenous grasses among pastoral communities in Isiolo and Samburu Counties in northern Kenya.

Methods: Ethnobotanical data were computed and ranked based on four use indices: relative frequency of citation, relative importance index, cultural value index and cultural importance index. Four key use-categories of the grasses were identified including livestock forage, erosion control, thatching and making hay for sale.

Results: Top ranked grasses across these use-categories included *Pennisetum mezianum, Chrysopogon plumulosus, Heteropogon contortus* and *Sporobolus helvolus*. These are perennial grasses with multiple uses and are available in wet and dry sessions and in drought periods. While trend analysis revealed overall declining availability of indigenous grasses over recent decades, it strongly came out that the four above-mentioned most preferred species had highest declining availability as perceived by local communities.

Conclusions: These findings indicate need for enhanced actions for conserving indigenous grasses considering their multiple benefits and declining availability. Practical local knowledge, traditional structures and their pasture management models are great opportunities for creating responsive actions for rehabilitating degraded critical grazing areas while conserving key indigenous grasses.

Keywords: Biodiversity loss, community knowledge, drylands, ethnobotanical, indigenous grasses, Kenya

Background

Unprecedented land degradation and biodiversity loss have been on the rise in the recent years, making them major environmental challenges facing the world today. Land degradation has led to declining productivity of nearly one-quarter of the global land surface, impacted the wellbeing of nearly 3.2 billion people and cost approximately 10 percent annual global gross domestic product attributed to lost ecosystem services. The average abundance of native species in most major land-based habitats has fallen by about 20 percent and nearly 1 million species face extinction in the next few decades unless urgent measures are taken globally to reduce the pressure on nature (Graham 2019). The ecosystems and local communities, such as pastoralists, that heavily and directly depend on ecosystem services have increasingly become more vulnerable with weakening adaptive capacities. Unsustainable land-use practices including overgrazing, deforestation, poor farming practices, pollution, overgrazing, inappropriate irrigation, urbanization and commercial development and climate change and their interactions are among the major drivers of land degradation and biodiversity loss (Mganga *et al.* 2019, Pörtner *et al,* 2022). In Kenyan context, land degradation and biodiversity loss are causing depletion of vegetation cover and biodiversity loss with far reaching implications on productivity of land resources, livelihoods and economic progress. They have particularly compromised ecological functions and diversity of arid and semiarid lands (ASALs), including their role as carbon sink and socio-cultural values for the local communities (Bolo *et al.* 2019). Approximately 2 percent of Kenya's ASALs has completely been lost due to degradation, and about 40 percent of ASALs in Kenya is experiencing serious decline in abundance and productivity of natural resources, which have been substantially attributed to unsustainable grazing practices and deforestation that catalyze soil erosion (Mganga *et al.* 2019). The ASAL Counties in Kenya, including Isiolo and Samburu, have strongly expressed concerns over worsening loss of diversity and productivity of natural resources, attributing it to unsustainable land-use and land use change and extreme weather events (Isiolo CIDP 2018, Pas 2019, Samburu CIDP 2018). Indigenous grasses, while they have demonstrated strong adaptive capacities in semi-arid rangelands and their associated dynamics, are today among the most threatened vegetation in Kenya. Under diverse climatic and anthropogenic drivers, indigenous grasses have continued to experience significant decline in productivity with some facing risk of extinction (Kimiti *et al.* 2018). Loss of these grasses does not only affect their availability and access for livestock forage but also compromises their socio-cultural and ecological benefits in the country (Kaindi *et al.* 2019, Karuku 2018). The situation will potentially worsen in the coming decades considering climate projections which have strongly expressed that extreme weather events will increase contributing to further reduction in abundance and productivity of indigenous range grasses and their associated impacts on local communities and livelihoods (Pörtner *et al,* 2022).

Interventions to restore degraded lands and address already experienced and future impacts have become a matter of urgency. Indigenous grasses are among the most appropriate resources for restoring degraded rangelands for various reasons: they have higher success rates in reseeding degraded lands attributed to their high adaptive capacities, longer-term resistance to invasion and ability to catalyze re-establishment of several native forbs. These indicate their important role in restoration of the wider ecological systems (Cole *et al.* 2017). Among pastoral communities in Kenya, indigenous grass species have multiple economic, socio-cultural and ecological benefits. Despite these benefits, efforts to conserve and use these grasses in restoring degraded lands remain inadequate, particularly in pastoral setups in Kenya (Petzold *et al.* 2020). This is substantially attributed to weak understanding and use of community knowledge of economic, socio-cultural and ecological values of indigenous grasses and how such local knowledge can complement scientific evidence for enhancing actions for address land degradation challenges (Mukuna 2013).

Local and community knowledge can make practical contribution to socio-cultural and economic development (Ghorbani *et al.* 2013), and influence effectiveness and sustainability of interventions for addressing land degradation, climate change and building resilience of natural resources and livelihoods (Barker 2016, Hiwasaki *et al.* 2014). Tengö *et al.* (2017) emphasized that sustainable management of rangeland resources need integration of local knowledge and practices (Dika Godana 2016, Hill *et al.* 2020). This study was conducted to analyze use value, availability trends and community knowledge of indigenous grass species among pastoral communities in Isiolo and Samburu Counties, Kenya. The study was motivated by the need to recognize and integrate indigenous knowledge and its role in management of rangelands and therefore contributing to biodiversity and rangeland conservation and enhanced pastoral livelihoods. This is consistent with the Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC AR6) which recommends that more effective, inclusive and sustainable climate action that reduce current and future climate risks should integrate and be informed by cultural values, indigenous and local knowledge (I Pörtner *et al,* 2022).

Materials and Methods

The study area

Kenya has 47 Counties as sub-national governance structures that facilitate services delivery to the people. This study was conducted in Isiolo and Samburu Counties, in semi-arid rangelands of northern Kenya (Figure 1), which are among the Counties that are increasingly experiencing land degradation with indigenous grass species among most affected. This implies increasing loss of their economic, social-cultural and ecological benefits to the local communities, who are already encountering rise in livestock movement and associated pasture-based conflicts driven by degradation of pastures in recent years. In this relation, there have been growing interest in pasture conservation among local communities (Pas 2019). Isiolo County is located between 36° 50′ – 39° 50′E and 0° 05′S – 2°N, and Samburu between 36°15′ – 38°10′E and 0°30′ – 2°45′N. Isiolo and Samburu counties cover area of about 25,700km^2 and 21,022 km^2 respectively of which over 80% are non-arable and are dominantly used livestock grazing (GoK 2013 Samburu County CIDP 2018). The population in Isiolo County has grown from 143,294 to 268,002 while that of Samburu has grown from 223,947 to 310,327 people between the year 2009 and 2019, making them among counties with highest population rise in the country, thus increasing pressure on natural resource.

Isiolo and Samburu Counties experience tropical climatic conditions characterized by two rainy seasons; receive long rains from March to May, while the short rains are experienced from October to November (GoK 2013, GoK 2018a). Due to climate change and other drivers, they receive rainfalls in highly erratic and unpredictable patterns, which partly explains why crop cultivation is unsuitable and unreliable source of livelihood in these counties (GoK 2013, Kalele *et al.* 2021). This partly contributes to high levels of food insecurity and poverty in the two counties. Pastoral production is the main source of livelihood and major land use practice among communities in these counties. The increasing droughts, erratic rainfall, poor soils, change in land use practices, urbanization, resource-based conflicts among other factors present a set of challenges to pastoral systems and natural resource degradation in these counties. The declining productivity of rangelands contributes to the high poverty rates and overdependence on relief food in these counties (GoK 2016, KNBS 2019).

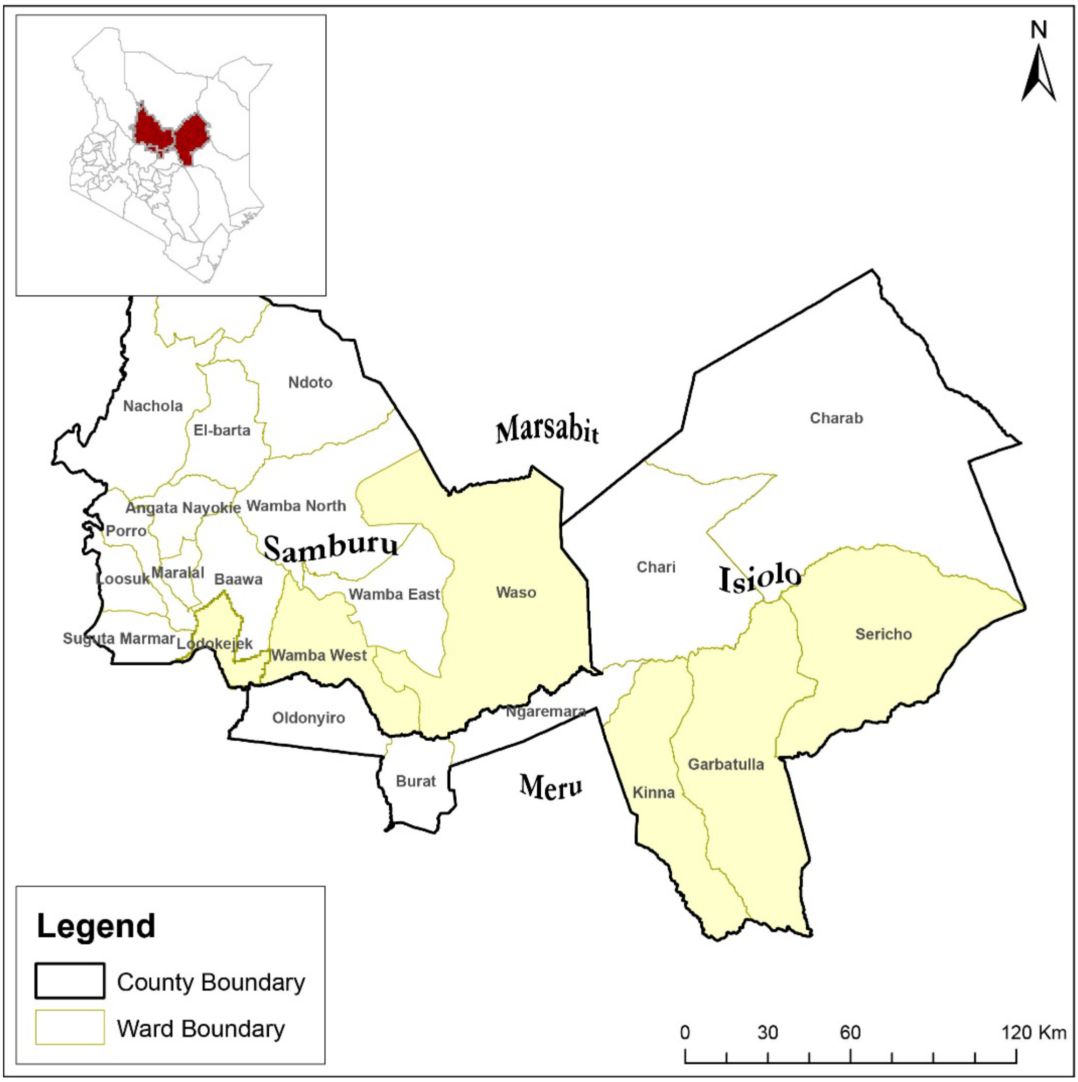

Figure 1. Map of Isiolo and Samburu Counties, Kenya. Source: Author, 2022

Sampling procedure

A total of six wards were purposively selected for the study, including Kina, Garbatulla and Oldonyiro in Isiolo County and Waso, Wamba West and Lodekejek in Samburu County. While degradation is widely spread across these two counties, the selected wards have comparatively high potentials for conservation of indigenous grass species and are also experiencing increasing livestock movements across the two counties which have compounding effect on degradation of indigenous grasses and the ecosystem (GoK 2018a, Pas 2019). Interviews were conducted with 306 pastoral households, distributed proportionally across the six wards to gather information on local knowledge of indigenous grass species and their cultural use values. The sample size was determined using equation (Eq.1) established by Kothari (2004):

$$n = \frac{Z^2(1-p)p}{e^2} \quad \textbf{\textit{Eq.1}}$$

where *n* is the sample size, *Z* is the preferred Z-value resulting in priority degree of confidence, *p* is approximate proportion of the population, and *e* is the permittable absolute error in estimating *p*. A p-value of 0.5 was adopted for this study because the population proportion is unknown due to mobility nature of pastoralists who are the target in the study. A 0.5 proportion size provides optimal and statistically satisfactory sample size particularly in such cases. Similar approaches have been used in various related studies, for instance Muricho *et al.* (2019). A 95% confidence level was used with Z value of 1.96 (two tailed) and allowable error of 0.056. These values were substituted into the formula to compute the sample size:

$$n = \frac{1.96^2(1-0.5)0.5}{0.056^2} \approx 306$$

This sample size was considered sufficient representative of the study population, indicating minimal variance in the data set.

Ethnobotanical data collection

The study adopted ethnobotanical research approaches to collect data on local names, nomenclature and uses of the preferred indigenous grass species. Data was collected through 12 key informant interviews (KIIs) and 12 focus group discussions (FGDs) and 306 individual interviews. The KII and FGD participants comprised of purposively selected community members with experience and good understanding of indigenous grasses, their local uses and importance. Some of the key participants in KIIs included Chiefs, Assistant Chiefs, County Livestock Officers, Grazing Management Leaders, Extension Officers and Chairpersons of Pasture Producer Groups. Half of the 12 FGDs were women and the other half men, with each group comprising 8–10 members. Free listing approach was used where FGD and KII participants were asked to spontaneously list all useful indigenous grass species that they knew and their specific uses. This was guided by the questions, *"Can you tell me the names of all the useful grass species that you know?"* and *"What do you use them for?"* After free listing of grass species, a pre-tested open ended question guide was used to further the discussions and obtain more data for the study. Grass species were identified by their vernacular and scientific names. Voucher specimens for the grass species identified as useful were collected and an experienced taxonomist helped in their detailed scientific characterization, similar to the approach adopted by Camou-Guerrero *et al.* (2008), Tardío & Pardo-de-Santayana (2008). Ethnobotanical information from KIIs and FGDs was used to classify grasses into four use categories: livestock forage, thatching, soil erosion control, and making hay for sale.

Determination of the most preferred grass species using Proportional Piling

Through the interactive proportional piling method, FGDs were asked to rank the identified grass species by their relative importance considering all the four use-categories. In this exercise, 200 stones were provided and assumed to represent 100% of important indigenous grass species in the study area. Circles were drawn on flip charts representing each grass species and participants were given the 200 stones to allocate into the circles in piles according to the relative importance of each species with the most important species receiving the highest number of stones. This method is more quantitative than simple ranking because it allows great graduation of emphasis, facilitates problem analysis, enhancing participation and decision making. Stones allocated to each species were counted and FGD notified of the outcomes. The outcomes were then discussed by probing participants to enable understanding what informed the stones allocation and therefore the outcomes. Through this method, the top ranking and common grass species were identified and subjected to individual interviews. Similar approaches have been adopted by other studies including Odongo *et al.* (2018), Yazan (2011) among others.

Data Analysis

Computation of use value indices

Use value indices in this study were computed on the basis of the primary structure of the ethnobotanical information, that is, interviewee *i* indicates use of species *s* in use category *u.* A user report (UR) is the outcome of combining the three variables (*i, s and u*). In a given survey that results in number of species (NS) ($s_1, s_2,...,s_{NS}$), with a total of use-categories (NC) ($u_1, u_2,..., u_{NC}$) and N interviewees ($i_1, i_2,..., i_N$), UR_{sui} is able to give the value of 1 when a combination exists or 0 when this combination is not mentioned. Total number of UR for each species is one of the most widely used methods in studying cultural value of plants. The total UR for each species is computed by summing the number of respondents that have reported use of a given species in a specific use-category and the sum of values for each use-category. The maximum value of UR for any ecotype is the total number of respondents multiplied by the total number of use categories (Whitney *et al.,* 2012). Equation 2 provides a mathematical expression for determination of UR:

$$URsui = \sum_{u=u1}^{uNC} * \sum_{i=i1}^{iN} URui \quad \textbf{Eq.2}$$

The UR for all interviewees (from i_1 to i_N) were summed for under each use-category for a given species (the number of interviewees who mentioned each use-category for that species). This was followed by adding up all UR of each use-category (from u_1 to u_{NC}). The total UR per species is the sum of all individual respondents using a given grass species for a specific category and the sum of all those categorical values. The maximum value of UR per species is the total number of respondents multiplied by the total number of use categories. The number of uses (NU) is the total number of UR categories mentioned for each species. The importance and use value of indigenous grasses was computed based on four use indices including: relative frequency of citation (RFC), relative importance index (RI), cultural value index (CV), and cultural importance index (CI).

Relative Frequency of Citation (RFC)

User report and other indices show multiplicity and diversity in use of the grass species among target population (Kaur & Vashistha 2018, Tardío & Pardo-de-Santayana 2008). RFC values signifies the spread of use and level knowledge of any given species among local communities. Therefore, the higher the value the wider the use and knowledge about the species among the study population (Faruque *et al.* 2018). RFC index was calculated by dividing the number of interviewees mentioning use of the species, also known as frequency of citation (FC), by the total number of survey participants (N). This index ranges from 0, when no interviewee refers to the species as useful, to 1 in the event that all the interviewees indicate the use of the species. It is important to note that index does not consider *u* (use-category). It is computed using the formula as presented in equation 3:

$$RFCs = \frac{\mathrm{FCs}}{\mathrm{N}} \quad \textbf{Eq.3}$$

Relative importance index (RI)

The RI index accounts and considers the use-categories and was computed using equation 4:

$$RIs = \frac{RFCs(max) + RNUs(max)}{2} \quad \textbf{Eq.4}$$

Where $RFCs_{(max)}$ is the relative frequency of citation over the maximum FC value in all the survey species, that is, the maximum number of informants citing any species as useful under in the user category under consideration. It was thus determined by dividing FCs by the maximum FC value in all the survey species; $RNUs_{(max)}$ is the relative number of use-categories over the maximum FC value in all the survey species and calculated by dividing the number of uses of the species by the maximum FC value in all the survey species.

Cultural value index (CV)

The CV, developed by Reyes-García *et al.*, (2006) was determined using the formula expressed in equation 5:

$$CV_s = \mathrm{NUs}/_{\mathrm{NC}} * \mathrm{FCs}/_{\mathrm{N}} * \sum_{u=u1}^{uNC} \sum_{i=i1}^{iN} URui /_{\mathrm{N}} \quad \textbf{Eq.5}$$

The first factor in the equation is the relationship between the total number of use-categories considered in the study (NU_s/NC) and the number of different uses reported for the species. The second factor (FCs/N) is the RFC of the species. The third factor ($\sum_{u=u1}^{uNC} \sum_{i=i1}^{iN} URui / N$) is the summation of all UR for the species, that is, sum of number of participants who mentioned each use of the species, divided by N.

Cultural importance index (CI)
Equation 6 provides the formula used to determine the CI index:

$$CI_s = \sum_{u=u1}^{uNC} \sum_{i=i1}^{iN} URui / N \quad \textbf{Eq.6}$$

This index, which is also the third factor of the CV index, expresses sum of proportion of interviewees who mention each species use. It reflects cultural significance, awareness and knowledge about each grass species in the community. The CI also elucidates number of sample population that mentioned any given grass species making it an important index for identifying species with high agreement among study participants (Abbasi *et al.* 2013). This additive index considers the distribution of each species' use as well as its versatility (the diversity and spread of its use).

The results of the four indices (RI, RFC, CV and CI) were compared to show how different grass species rank on each index and their three primary values measured in the study (frequency of citation, number of use reports and number of uses for each species). Frequency of citation mainly indicates the spread of knowledge of useful plants, whereas numbers of use-reports (other indices) indicate the multiplicity of use. Grass species with the highest value was regarded as highly preferred while those with low values less preferred.

Results

Community knowledge of indigenous grass species and their uses

Most (54.6%) of the interviewed household representatives were males, while the remaining (45.4%) were females. The average age of the participants was 52 years, with the youngest and oldest being 30 and 83 years old respectively. The survey data from the communities reflected rich local knowledge and understanding of the local landscapes and associated variability regarding when and where various indigenous grass species are available and drivers of their changing trends in availability across years. A list of 24 most common indigenous grass species was generated from the survey (Table 1).

Table 1. List of the 24 most common indigenous grass species identified by study communities

Scientific name	Borana name	Samburu name
Aristida adscensionis L.	***Bila***	***Ntalangwani***
Brachiaria leersoides (Hochst.) Stapf	***Ensili***	***Lanana***
Cenchrus ciliaris L.	***Matguthes***	***Logusgus/Larau***
Chrysopogon plumulosus Hochst.	***Alal***	***Lkawa***
Cyperus sp L.	***Shantu***	***Lorian***
Dactyloctenium aegyptiaca Willd.	***Alata***	***Lamurwai***
Dactyloctenium scindicum Boiss.	***Kuraa***	-
Digitaria velutina (Forssk.) P.Beauv.	***Ilmagor***	-
Enteropogon macrostachyus (Hochst. ex A.Rich.) Munro ex Benth.	***Gedi***	***Lperesi***
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	***Serich***	***Lopii***
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	***Chira***	-
Latipes senegalensis Kunth	***Ilmogori***	***Loonoro***
Microchloa kunthii Desv.	***Salaqo***	***Sapai***
Oropetium capensis Stapf	***Robanjires***	***Lkuroti***
Panicum maximum Jacq.	***Finical***	-
Pennisetum mezianum Leeke	***Ogonicho***	***Lgurme***
Sorghum purpureo-setaceous L.	***Bododi***	***Nterian***
Sporobolus fimbriatus (Nees ex Trin.) Nees	***Robanjires***	-
Sporobolus helvolus (Trin.) T.Durand & Schinz	***Hitho***	***Ntapukai***
Sporobolus marginatus Hochst. ex A.Rich.	***Kunda***	-
Sporobolus marginatus Hochst. ex A.Rich.	***Kunda***	-
Tetrapogon spatheceous (Hochst. ex Steud.) Hack.	***Dalat***	***Lmejarai***
Tetrapogon tenellus (J.Koenig ex Roxb.) Chiov.	***Dalata***	-
Themeda triandra Forssk.	***Gedi***	-

Source: FGDs; N=12

Table 2 presents ten most preferred indigenous grasses that were identified and ranked through proportional piling by FGD participants. Most of these grasses have a range of complementary benefits to the communities. Study participants expressed clear understanding of seasonal change and availability of different grass species, that is, species that are available and utilized in wet and dry seasons as well as those conserved for use during drought periods as indicated in Table 3. They also expressed understanding of different niches within their wider landscapes where these different grasses grow such as swampy areas, on mountains and planes. This informs their management and utilization. The study characterized 10 top ranked priority grass species as identified and described by study participants (Table 3). Some grass species are only available in a very short period at the onset of rainy seasons. Such grass species are very critical as they provide feed for livestock given that they shoot sooner after rains.

Table 2. Ranking of indigenous range grasses using proportional piling by FGD participants

Indigenous Grass species	Average score	Percent (%)	Rank
Pennisetum mezianum Leeke	43.1	21.5	1
Chrysopogon plumulosus Hochst.	38.3	19.1	2
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	30.6	15.4	3
Sporobolus helvolus (Trin.) T.Durand & Schinz	24.9	12.5	4
Brachiaria leersoides (Hochst.) Stapf	18.4	9.2	5
Latipes senegalensis Kunth	14.7	7.3	6
Cenchrus ciliaris L.	12.3	6.1	7
Enteropogon macrostachyus (Hochst. ex A.Rich.) Munro ex Benth.	7.4	3.7	8
Sorghum purpureo-setaceous L.	6.1	3.1	9
Aristida adscensionis L.	4.3	2.1	10

Source: FGD; N=12

Apart from livestock forage as the primary and most important use of grass species among pastoral communities in the study areas, different grass species were reported to be used for the purposes of rehabilitating degraded rangelands and controlling erosion, thatching houses and making hay for sale. Pastoral communities in study areas are increasingly adopting pasture production and conservation as a source of forage for their domestic uses or hay for sale. These 10 grass species have either been used or can potentially be used to make hay and contribute to control erosion except *B. leersoides, L. senegalensis* and *A. adscensionis*. These grass species are not used to make hay given their short and soft nature and that they only occur over very short periods, that is during and after rains. *P. mezianum* was identified by the study participants as a lead grass in giving livestock a lot of energy while *C. plumulosus* is highly palatable and highly preferred by livestock. *H. contortus* was characterized as the best and most suitable for thatching traditional huts, in addition to other benefits including being nutritious grass that is available in both wet and dry periods. This perennial grass is widely known as forage and typically used as material for thatching, weaving and erosion control. Hay making for sale is still very low in the study area especially in Samburu county and therefore most grasses were only identified to have the potential for that purpose.

Table 3. Description of top 10 grass species identified by the communities

Scientific name	Description
Aristida Adscensionis L.	- Annual grass that is as available during wet season grazing - It is useful in controlling erosion and making hay for sale
Brachiaria leersoides Hochst.) Stapf	- Highly nutritious annual grass. It is soft and highly rainfall dependent that only grows soon after rains. - It provides a critical wet season grazing for starving livestock at the onset of rains following droughts. It however does not last long after rains
Cenchrus ciliaris L.	- Perennial grass that is important as dry season grazing - It is useful in controlling erosion and making hay for sale
Chrysopogon plumulosus Hochst.	- A key perennial grass, available in both wet and dry seasons, and during drought - Has high biomass and highly palatable thus preferred by livestock - Important in controlling erosion, can be used to make hay and thatch.

Enteropogon macrostachyus (Hochst. ex A. Rich.) Munro ex Benth.	- Perennial grass that is important as dry season grazing - It is useful in controlling erosion, making hay and thatching
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	- Perennial grass that grows soon after rains and stays longer thus key grazing in wet and dry seasons. - It is highly nutritious and found in drought grazing reserves - It is the best for thatching huts and useful in controlling erosion
Latipes senegalensis Kunth	- Soft, short perennial grass mostly preferred by browsers especially goats - It is a highly valued wet season grazing
Pennisetum mezianum Leeke	- An important perennial grass that is found in wet and dry season grazing areas and drought grazing reserves. Reported to give a lot of energy to livestock - Important in controlling erosion and used to make hay and thatch
Sorghum purpureo-setaceous L.	- Annual grass, used as wet season grazing, and regarded as very good for livestock fattening - It is among the first grasses to grow at the onset of rainy season and disappears soon after rains
Sporobolus helvolus (Trin.) T. Durand & Schinz	- Perennial grass that grows in swamps and provides wet and dry season grazing. It is found in drought grazing reserve - Important in controlling erosion and can potentially be used to make hay and thatch.

Source: FGD; N=12

Use values of indigenous grass species among the Borana and Samburu pastoralists

Use-Reports (UR) and Percentage of Use Categories

Table 4 presents the four use categories for the grass species, number of UR and the percentage of each use category. Livestock forage was identified as the single most important use category of grasses among the sample population, accounting for nearly 80% of the UR. This is based on the fact that livestock keeping through pastoral system is the most important land use practice and source of livelihood in the study area, making pasture an important resource among pastoralist communities. Erosion control, thatching and hay for sale as other use categories accounted for 7.3%, 6.7% and 6.2% of UR respectively.

Table 4. Number of Use-Reports (UR) and Percentage of Use Categories.

Categories (Code)	**Number of UR**	**Percentage (%)**
Livestock forage	1386	79.8
Erosion control	127	7.3
Thatching	116	6.7
Hay for sale	107	6.2
Total	**1736**	**100**

Source: household surveys; N=306

Cultural importance index (CI) of the 10 top ranked grass species

Table 5 presents contribution of each use category to the total CI of the 10 most preferred grass species among pastoral communities in the study areas. *P. mezianum* was identified to be the most culturally significant species. Given its highest CI of 0.99, it was highlighted to be widely available spatially and temporally, making it a major forage in wet and dry seasons as well as during droughts ($CI_{Livestock\ forage}$ = 0.76). Its other uses such as erosion control, making hay for sale and as thatch were found to be relatively minimal among the respondents as reflected in the low CIs ($CI_{Erosion\ control}$ = 0.1; $CI_{Hay\ for\ sale}$ = 0.09 and $CI_{Thatching}$ = 0.04). The second most preferred grass species according to this index was *H. contortus* with a CI of 0.96. A part form being one of the most preferred grasses for grazing, it is also considered the best grass for thatching traditional huts, recording the highest CI for thatching ($CI_{Thatching}$ = 0.19). The other grass species that recorded high CI were *C. plumulosus* and *S. helvolus*, taking the third and fourth ranks respectively. While the other ranked grass species were considered important, they were reported not be widely available across the two counties, thus mentioned by fewer informants. They are largely available as short-lived wet season grazing and are limited in terms of their categories of use. *B. leersoides, L. senegalensis* and *A. adscensionis,* for instance, were mentioned under only one-use category, as livestock forage indicating narrower value and spread of use. Further, they are only wet season grasses and therefore reflect limited extent of availability for pastoral communities. With respect to CI, therefore, the study established that *P. mezianum, C. plumulosus, H. contortus* and *S. helvolus* are comparatively the most useful and widely available grass species among the pastoralist communities in the study areas. In addition, the communities were widely aware and knowledgeable about use of these species.

Table 5. Cultural Importance Index (CI) of the 10 Top ranked Grass Species in the Study area with the CI Component of Each Use-category

Species	Livestock forage	Hay for sale	Erosion Control	Thatching	Total CI
Pennisetum mezianum Leeke	0.76	0.09	0.10	0.04	0.99
Chrysopogon plumulosus Hochst.	0.69	0.03	0.09	0.05	0.86
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	0.62	0.07	0.08	0.19	0.96
Sporobolus helvolus (Trin.) T.Durand & Schinz	0.61	0.04	0.02	0.07	0.74
Brachiaria leersoides (Hochst.) Stapf	0.54	-	-	-	0.54
Latipes senegalensis Kunth	0.43	-	-	-	0.43
Cenchrus ciliaris L.	0.32	0.04	0.03	-	0.39
Enteropogon macrostachyus (Hochst. ex A.Rich.) Munro ex Benth.	0.21	0.02	0.06	0.02	0.31
Sorghum purpureo-setaceous L.	0.21	0.03	0.03	-	0.27
Aristida adscensionis L.	0.17	-	-	-	0.17

Source: household surveys; N=306

Comparison of Different Indices (CI, RFC, RI and CV)

Table 6 presents comparison of the four indices including CI, RFC, RI and CV based on the three primary values measured in this study including frequency of citations, number of use-reports and number of uses for each species. Understanding grass species with regards to the different indices is important as it allows comprehensive and multi-perspective knowledge of use and prioritization of grass species in efforts to enhance their conservation and use to rehabilitate degraded lands. Analysis of the four indices reflected widespread awareness about *P. mezianum* and its availability across the two counties, and therefore was ranked top. Being perennial, *P. mezianum* is available across wet and dry seasons, as well as during drought periods. It has multiple use across the four use categories considered in this study. Top prioritization and overall high ranking of the species implies need to give it major attention in conservation and rehabilitation of degraded lands. *C. plumulosus* was ranked second in terms of CI, RFC and RI but was placed third, after *H. contortus,* with regards to CV. While *C. plumulosus* and *H. contortus* were both considered useful across the four use categories, the latter was identified by most study sample as top grass for thatching of traditional huts. This explains why *H. contortus* ranked above *C. plumulosus* on the basis of CV.

The results show that the four most preferred grasses that includes *P. mezianum, C. plumulosus, H. contortus* and *S. helvolus* were all perennial grasses making them key forage in both wet and dry seasons, and more importantly found in drought grazing reserves. These grass species were also described by informants to have certain extra values. For instance, *P. mezianum* was indicated to give a lot of energy to livestock when consumed; *C. plumulosus* was reported to have high biomass and to be highly palatable thus preferred by livestock, while *H. contortus* was mentioned as the best grass for thatching traditional huts.

It was noted that the other six grasses ranked in this study were not mapped under all the four use categories apart from *E. macrostachyus.* They were largely annual grasses that are only available for grazing at the onset or during wet seasons. *B. leersoides*, *L. senegalensis* and *A. adscensionis* were reported to be only useful for grazing but were not identified as useful in other three use categories. *C. ciliaris* and *S. purpureo-setaceous* were also identified mainly as forage with fewer mentions for making hay for sale and erosion control use categories. They were reported to be low in spatial and temporal availability thus limited knowledge about them among the pastoralist communities, explaining their low ranking.

Relationship between number of use-categories for each species and frequency of citation

Figure 2 shows a scatter plot of the correlation between number of use-categories for each of the ten grass species and frequency of citation. The use-categories include livestock forage, hay for sale, erosion control and thatching. It depicts some level of dependence of frequency of citation on diversity of use. The relation between FC and NU implies that a grass species that is versatile is likely to be mentioned by more study sample, that is to say, the more versatile a species is, the higher probability that more members of the community are aware of it, its use and importance. While FC as an index does not directly factor diversity of use of the grass species, the diversity and multiplicity of use are explicitly reflected in the number of study participants that identified the grass as useful. Figure 2 emphasizes the versatility of *P. mezianum, C. plumulosus, H. contortus* and *S. helvolus* as most useful grass. They were mentioned in all the four user categories by the highest numbers of study sample. While *E. macrostachyus* was identified as useful across the four user categories, it was only mentioned by much fewer study population. *C. ciliaris* and *S. purpureo-setaceous* were mentioned as useful under three of the four user categories but with more study sample mentioning *C. ciliaris* than *S. purpureo-setaceous. B. leersoides, L. senegalensis* and *A. adscensionis* did not indicate any user multiplicity as they were only mentioned under livestock forage category.

Table 6. Most Useful Grass Species in the Study Area Ranked Using Four Quantitative Indices

Species	Primary Values			Indices				Ranking			
	FC	UR	NU	CI	RFC	RI	CV	CI	RFC	RI	CV
Pennisetum mezianum	281	304	4	0.99	0.93	1	0.94	1	1	1	1
Chrysopogon plumulosus	270	263	4	0.86	0.89	0.98	0.78	3	2	2	3
Heteropogon contortus	265	293	4	0.96	0.88	0.97	0.85	2	3	3	2
Sporobolus helvolus	259	227	4	0.74	0.86	0.96	0.64	4	4	4	4
Brachiaria leersoides	224	164	1	0.54	0.74	0.52	0.10	5	5	8	7
Latipes senegalensis	189	131	1	0.43	0.63	0.46	0.07	6	6	9	8
Cenchrus ciliaris	123	121	3	0.39	0.41	0.59	0.12	7	7	6	5
Enteropogon macrostachyus	105	97	4	0.31	0.35	0.69	0.11	8	8	5	6
Sorghum purpureo-setaceous	89	84	3	0.27	0.29	0.53	0.07	9	9	7	8
Aristida adscensionis	82	52	1	0.17	0.27	0.27	0.01	10	10	10	10

CI=cultural importance, RFC=relative frequency of citation, RI=relative importance, CV=cultural value, FC=frequency of citation, UR=number of use-reports, NU=number of uses. Source: household survey; N=306

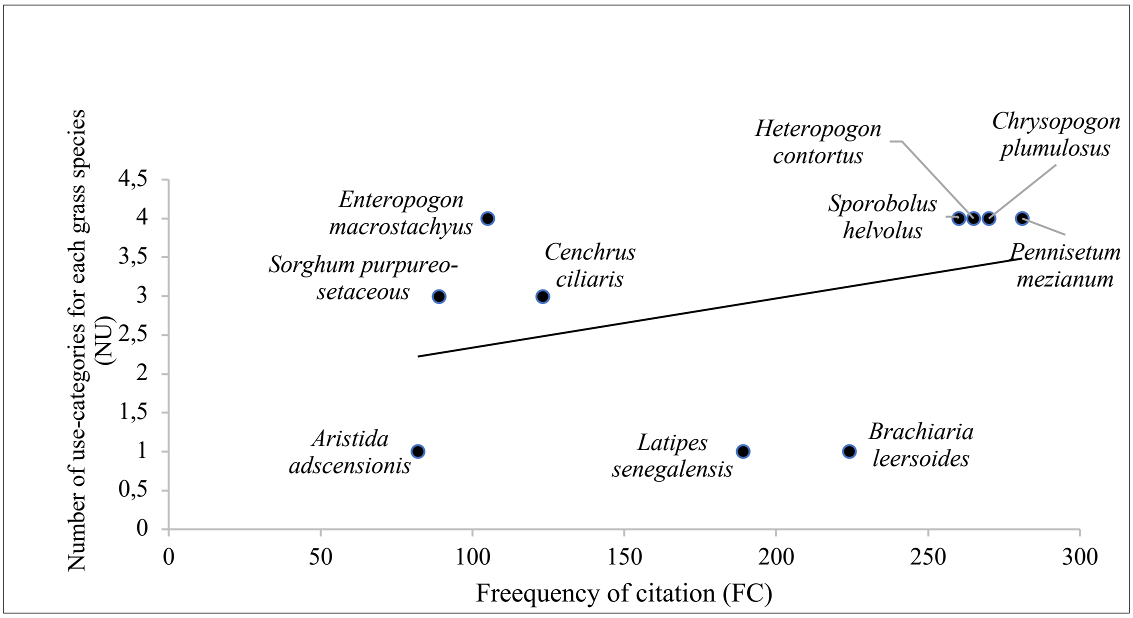

Figure 2. Relationship between number of use-categories for each species (NU) and frequency of citation. Source: household survey; N=306

Trends in availability of indigenous grass species as perceived by pastoralists in study area

The study also sorted to establish trends in availability of the ten grass species between 1990 and 2020 as perceived by study sample. As established in the study, the ten grass species indicated an overall declining trend in their availability over the 30-year period as perceived by community members who participated in the study. As indicated by study sample, the grasses have dropped in their availability for all use categories. Comparatively, these grass species were more abundantly available in 1990s, than in 2010s as perceived by the study sample, availability of these grass species has shrunk more adversely in the last decades. The trend was strongly attributed to a range of drivers including unsustainable grazing practices, which is the mains use of these grass species, violent resource-based conflicts with other communities, severe droughts all of which together catalyze degradation of these important indigenous grasses. The grasses including *P. mezianum, C. plumulosus, H. contortus* and *S. helvolus*, mapped as the key grasses across the four use categories, were also found to have recorded the highest decline in availability over the period, as indicated in figure 3. Factors identified by study participants as key drivers of the increasing degradation of indigenous grass species included unsustainable land use practices particularly overgrazing, conversion of grazing land into crop lands, increasing livestock population and subdivision of traditionally communal grazing lands as key anthropogenic factors. They were found to be exacerbated by increasing extreme weather events, particularly droughts which have become more frequent and severer, compromising the productivity of grass species.

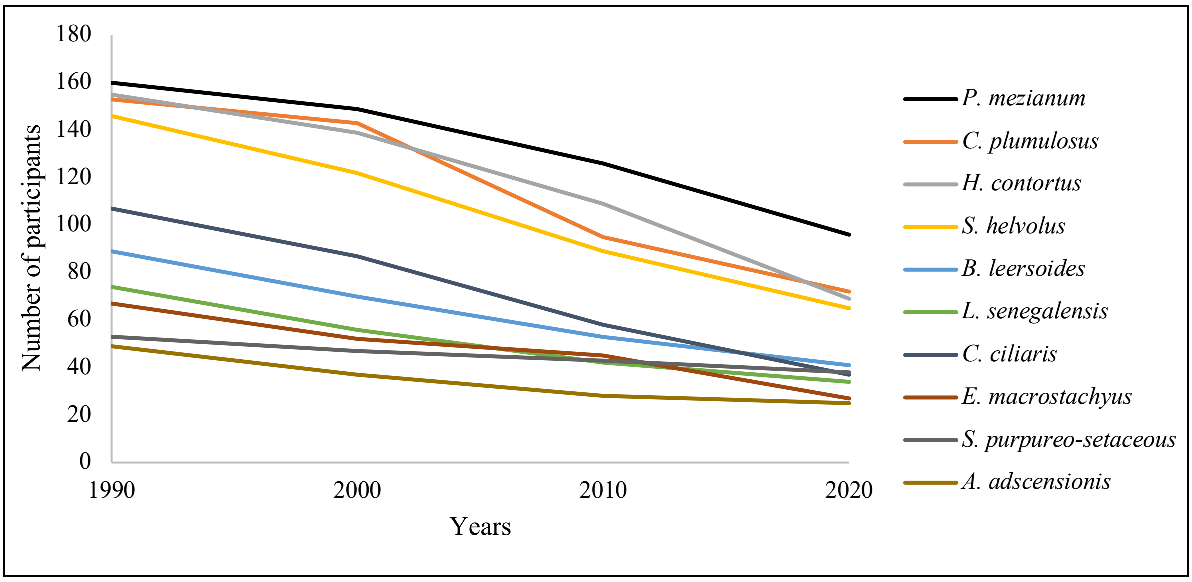

Figure 3. Trends in availability of indigenous grasses as perceived by pastoralists in the study areas.
Source: household survey; N=306

Discussion

Pastoralists' knowledge of indigenous grass species and their uses

The study participants demonstrated clear understanding and were able to characterize indigenous grasses in terms of when and where they are available within the wider landscape as well as their uses. This reflects their complementary importance in enabling community members to meet their diverse needs, in terms of livestock forage, controlling soil erosion, thatching and making hay for sale at different time of the year and season. Tyrrell *et al.* (2017) confirms community knowledge on uneven temporal and spatial distribution and availability of indigenous grasses in the rangelands, which are driven by diversities in biophysical and biochemical properties of the grass species. Heterogeneity of grazing resource characterized by change in availability provides the basis and why grazing management practices become critical among pastoral communities especially in this era where adverse impacts of climate change have and will continue to cause far-reaching adverse effects on pastoral systems particularly in ASALs of Kenya (GoK 2018b).

Some of these grasses including *B. leersoides; S. purpureo-setaceous, C. ciliaris*, *L. senegalensis* and *A. adscensionis* are largely soft, very nutritious and disappear soon after rainfall stops. Previous studies have established that wet seasons are characterized by greener, low biomass and high-quality grazing resources. This transforms into high biomass and low-quality forage as the season progresses into dry period (Tyrrell *et al.* 2017). Seven out of the ten key grass species considered in this study were found to be perennial. This could be attributed by the fact that perennial grasses are available most part of the year compared to annual grasses. They consistently have relatively higher biomass and height across all seasons making them critical dry season grazing bank (Tyrrell *et al.* 2017). They help maintain livestock in both wet and dry seasons and are major grass species in drought grazing reserves. This category of grasses also comprises those with capacity to withstand grazing pressure, long droughts, as well as those that grow in swampy or near water sources such as *S. helvolus* (Wasonga *et al.* 2016). Perennial grasses also have good self-seeding abilities. With good management practices, they therefore can easily and quickly establish, spread and grow to give good cover (Mganga *et al.* 2021). This knowledge of characteristics of local grasses is very important for pastoral communities in their grazing planning and management. It is documented that community-driven and local knowledge-based range management have reflections of interrelationships of human adaptation, natural resources conditions and variability, as well as land use change. Such knowledge has stayed practically relevant and effective in grazing management among pastoral communities given its continuous application and use (Oba 2012).

Use values of indigenous grass species in Isiolo and Samburu Counties

Indigenous grass species play multiple socio-cultural, economic and ecological roles across communities. While these roles are cross-cutting, it is important to understand the nature of use the grasses may differ from one community to another depending on their location, perceptions and cultures, that is to say, different communities may have different socio-cultural uses of same grass species (Kamau 2020). Over the decades, pastoral system of livestock production has remained a key land use practice and source of livelihood for most pastoral communities in Kenya, and across the world, with naturally growing pastures as key input in terms of forage. The potentials of pastoral systems towards realizing the United Nations Sustainable Development Goals (SDGs) are immense, and will substantially contribute to economic development, poverty reduction while enhancing environmental and climate resilience (Zinsstag *et al.* 2016). This points to the current and future importance natural pastures as primary source of livestock in pastoral systems, particularly in Kenya (Kirui *et al.* 2022). Despite the understanding of the role of grass as livestock forage, their availability has been declining over the years due to various drivers including land degradation, land use changes and progressive sedentarization of pastoralists coupled with extreme weather events resulting from climate change, particularly droughts. In response, there is growing action for grazing conservation and demand for pasture production to address the widening livestock feed gap (Rossi *et al.* 2019). Further, pasture production for sale is also fast expanding in Kenya, particularly in pastoral set-ups given increasing adverse effects of drought diminishing communal grazing lands, which have compromised productivity and availability of natural grazing lands. Community are also appreciating the need to diversify their sources of livelihood, thus some of them are engaged in commercial hay production for sale to other livestock keepers. Though the scale of production is still very low among local community members, commercial hay production has high potentials in Kenya. Recent studies have demonstrated convincing profitability of both hay and grass seeds among households in rangeland setups in Kenya (Omollo *et al.* 2017, Omollo *et al.* 2019).

In respect to addressing land degradation, there is strong evidence that indigenous grasses have played key roles in rehabilitating degraded rangeland among many communities across the globe with successful outcomes. In fact, reseeding with indigenous perennial grasses has been regarded as one of the most practical approaches for not only restoring and rehabilitating degraded rangelands but also enhancing vegetation cover and forage production in the drylands (Mganga *et al.* 2021). Many development partners, for instance, are working closely with County Government of Isiolo to promote pasture reseeding and conservation practices in efforts to not only enhance availability of feed resource in drought periods, but also to rehabilitate degraded rangelands (Mohamed Sala *et al.* 2020). Indigenous grasses such as *Cenchrus ciliaris, Enteropogon macrostachyus*, *Eragrostis superba* and *Panicum maximum* have been found to be very useful as vegetative barrier that help in conserving the soil and control erosion (Mandal *et al.* 2017). They improve grass cover and soil hydrological properties, which in turn help to slow down surface water runoff, enhance infiltration while stabilizes the soil to prevent erosion (ORASECOM 2014). There are several reasons justifying why indigenous grass species are strategically preferred for rehabilitating degraded rangelands: they exhibit comparatively higher adaptive capacities thus more drought tolerant, using diverse indigenous species enhances biodiversity and soil protection (ORASECOM 2014, Mganga *et al.* 2019). These are key indicators of successful rehabilitation. Other key consideration in the selection of grass species for rehabilitation is their seedling abilities and survivability as well as their ability to produce high biomass and nutritious forage for livestock (Kamau *et al.* 2020). This demonstrates that ability of a given grass species to provide multiple benefits is a key determining factor in their selection. Contrarily, using exotic grass species, may require more efforts and investments, such as more water and soil nutrients in order to survive and grow. They generally have higher water requirements, have relatively limited adaptive mechanisms and disturbs natural balance of the ecosystem, thus causing comparatively expensive economic and environmental costs (Shahin & Salem 2018).

Apart from economic and environmental benefits, indigenous grasses also have useful socio-cultural and therapeutic uses across communities (Shahin & Salem 2018). However, different grass species have been used differently by communities to undertake important rituals, for medicinal purposes and for thatching traditional huts (ORASECOM 2014). In this study, various grass species were identified to be potentially useful for hut thatching, with *H. Contortus* standing out as most suitable and used for thatching. Other studies have also demonstrated socio-cultural usefulness of various indigenous grasses across the world. For instance, *C. ciliaris* is an important traditional herb among Zulu community that is used to relieve pain and cure several diseases including menstrual irregularities, urinary tract infections, kidney pain and wounds. Secondly, *Cyperus rotundus*. is a perennial grass widely found in sandy and saline soils in Tunisia, Southern Africa among other parts of the world, is not only providing forage for livestock but is also consumed to remedy menstrual irregularities, treat worm infections and a key ingredient in making teeth-whitening powder (Shahin & Salem 2018).

Trends in availability of indigenous grass species as perceived by pastoralists in study area

Globally, the ASAL ecosystems experience disproportionate degradation problems, leading to loss of biodiversity, decrease in ecosystem goods and services and threatens economies and livelihoods of people who depend on them (Davies *et al.* 2021). Degradation of natural resource particularly indigenous grasses is a major challenge in managing ASALs in Kenya. As demonstrated by the study, indigenous grass species have over the last decades experienced declining availability and abundance. It is well understood from recent studies that rangelands, like other ecosystems, have been adversely affected by degradation and land use changes, leading to decline in their provision of various essential services. These are driven by interconnected factors such as rising population, overgrazing, invasive species, change in land use practices among others and exacerbated by increasing extreme weather events (Mbaabu *et al.* 2020, Mulinge *et al.* 2016). About half of global grassland ecosystems have been degraded of which about 5 percent are experiencing strong to extreme degradation. (Tiscornia *et al.* 2019). Degradation is expected to increase in the next decades in the context of climate projections, which have indicated that extreme weather events, particularly more severe droughts, will increase in ASAL ecosystems, exacerbating rapid vegetation changes, including woody plant encroachment and increase in exotic grass invasion. This will be driven by the fact that most prolific invasive species have characteristics that enable them to take advantage and use the climate driven changes including rising warming, wildfires and anthropogenic CO_2 emissions. Invasive species in ASAL ecosystems will continue to be colonial and expand their abundance in the coming years, with far reaching implications for indigenous species availability and composition in the ecosystem (Ravis *et al.* 2022).

Conclusion

Pastoral communities have not only practical knowledge of indigenous range grasses in their local landscapes in terms of their socio-economic and ecological importance, seasonal availability but also their declining abundance and availability and drivers of changing trends in recent decades. While livestock forage in the main use of indigenous range grasses among pastoralists, most preferred indigenous grasses are those that have multiple uses such as controlling erosion, house contraction and usability to make hay for sale. The most preferred grass species are also the most threated by degradation as manifested by their relatively higher declining trends in abundance and availability especially in recent years. The increasing loss of key and locally adapted ranges grasses imply losing their critical multiple social-economic and ecological values and benefits to the communities and wider rangeland ecosystems. Actions for conserving indigenous range grasses and sustainably manage rangeland ecosystems need to effectively understand and appreciate the role of local knowledge, build synergies with traditional institutions and integrate community-driven grazing management models in a manner that builds holistic and responsive actions.

Declarations

List of abbreviations: ASALs=arid and semiarid lands; IPCC AR6=Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change; SDGs=United Nations Sustainable Development Goals; KII=key informant interviews; FGD=focus group discussions; UR=user report; NS=number of species; NC=use-categories; NU=number of uses; RFC=relative frequency of citation; RI=relative importance index; CV=cultural value index and; CI=cultural importance index

Ethics approval and consent to participate: All study participants and informants were briefed about the objectives of the present study. All of them rendered an oral consent to share the information

Consent to publish: The final manuscript was read and approved for publication by all authors.

Availability of data and materials: The authors will provide the raw data on request without the names of informants/The final manuscript was read and approved for publication by all authors/ The data generated for this study are available upon request.

Competing interest and conflict of interest: The authors declare that they do not have any competing interests

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Author contributions: EOo conceived guided be OVW and ELC. Field work and manuscript writing was conducted by EOO, OVW and ELC read, corrected and approved the manuscript.

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