Discover Sustainability

Research

Indigenous knowledge of browse species and nutritional quality of dominant indigenous browse species in the Kavango West Region of Namibia

Rosa N. Hamukwaya[1] · Vonai Charamba[1] · Absalom Kahumba[1] · Maria N. T. Shipandeni[1] · Johnfisher Mupangwa[1]

Received: 4 August 2024 / Accepted: 4 November 2024
Published online: 27 December 2024

Abstract
Livestock production is crucial to the livelihoods of rural Namibians but highly constrained by feed shortages due to climate change and bush encroachment. The study investigated the grazing and feeding practices and indigenous knowledge of browsable and non-browsable species by interviewing 30 small-scale farmers in the Kavango West Region. It assessed the nutritive value for the three most commonly identified browsable species. The study observed that livestock relies on communal rangeland, roadside, and riverside grazing, with supplements from crop residues during the dry seasons. However, most farmers experience feed shortages mainly in the dry season, which results in decreased livestock productivity. Farmers are knowledgeable on browsable and non-browsable woody species in their locality, but most do not harvest pods, leaves and twigs to supplement their animals in the dry season, citing labour shortage, and they are not aware that the bush species resources can be harvested and be used during seasons when feed resources are scarce. The nutritive value analysis indicated that there is a need for strategic supplementation of the browsable species for them to be effectively utilised as livestock feed, thus farmers must be capacitated on when and how to utilise these species when herbaceous pasture grasses and legumes are senescent as well as how to harvest forage alongside rivers and roads for stall feeding to avoid accidents. Our findings will be important for policy formulation in trying to come up with better ways of mitigating the consequences of climate change.

Keywords Livestock production · Grazing challenges · Woody plants · Feed constraints · Browsable species nutritive value

1 Introduction

The Namibian meat and livestock industry forms the mainstay of the country's agricultural sector, contributing 63.6% to the agricultural gross domestic percentage (GDP;1990–2019 average) [1]. Livestock production supports 42% of the rural Namibian households [2]. In Kavango West Region (KWR), rural residents reap considerable benefits from cattle and goats. Both individual and regional herds are economically beneficial and should be encouraged [3]. In

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s43621-024-00636-1.

✉ Vonai Charamba, vcharamba@unam.na | [1]Department of Animal Production, Agribusiness & Economics, Faculty of Agriculture, Engineering and Natural Sciences, Neudamm Campus, University of Namibia, Private Bag 13301, Windhoek, Namibia.

addition, 63% of the rural households in the KWR rely on mixed farming, as the main source of income [4], with livestock production being more dominant over agricultural crop production [3]. Cattle are the region's most important livestock species, and their value is realised in providing draught power, manure, milk, and meat. According to the Namibia National Livestock Census Report of 2019, there were 120,778 cattle and 46,400 goats in KWR [5], sustaining 22.8% of the households [2] and all depend on rangeland grazing as the basic feed resource. Goats are kept primarily for meat production and sale, but are less numerous and constitute a smaller proportion of the ruminant livestock.

A major constraint to livestock production in tropical and sub-tropical regions is the scarcity and fluctuating quantity and quality of the year-round feed supply. Due to climate change and severe drought, smallholder farmers experience a shortage of fodder for their livestock, especially during the dry season [6, 7]. Animals have to survive on the rangeland which also has a low nutritional value for most of the year. The crude protein (CP) content of the rangeland vegetation ranges between 8 to 12% of dry matter at the beginning of the rainy season but drops down to 2–4% during the dry season [8] leading to prolonged periods of animal malnutrition. Browse species have considerable potential in agro-pastoral production systems, to supplement low-quality feeds. Moreover, the ability of most browse species to remain green for a longer period is attributed to deep root systems, which enable them to extract water and nutrients from deep in the soil profile and this contributes to the increased CP content of the foliage [9]. Ongoing climate change is expected to create harsher environmental conditions such as drought which is predicted to be more frequent and severe, [10–12], resulting in more devastating effects to smallholder farmers, especially in tropical and sub-tropical regions such as Namibia [11]. The fast depletion of natural resources, rising living standards, and ever-increasing population pressure have made diversification of present-day animal agriculture production extremely important, to meet the increasing demand for animal products.

Herbaceous plants and browsable woody plant species are the major feed source for livestock in the extensive communal arid and semiarid rangelands. Conventional supplemental feeds such as pearl millet, maize grains, and oilseed cakes are not produced adequately to meet the livestock requirements [13]. Woody plants, such as trees, shrubs and climbing plants, form the principal components of forests and many other ecosystems. Browse plant species are useful sources of cheap feed for ruminant animals in tropical and sub-tropical regions. In addition, as perennial plants, woody plant species are more resilient and able to withstand onslaughts of drought and their bounty remains permanent throughout the years, making them an alternative feed source in droughts and drier seasons when herbaceous species are senescence.

About 70% of the Kavango East and West regions' total population resides along the Kavango River terrace [14], on about 5% of the region's land area and the livestock population follows the same density pattern. River terraces are generally rich in vegetation some of which are browsable by livestock. Despite the wider use of observed indigenous browse species, little has been documented about their potential nutritive value. However, Behnke [3] reported that there is limited local knowledge of browse feed resources in the Kavango regions, and those with some knowledge make limited use of it. Therefore, the objective of the study was to identify potential browse resources, and determine the nutrient composition and in vitro digestibility of dominant indigenous browse species livestock feed on in the KWR of Namibia. The findings are intended to guide policy on how best to assist these communities in meeting their livestock feed requirements without competition with humans.

2 Materials and methods

2.1 Study area

The study was carried out in Mpungu and Tondoro constituencies of the KWR of Namibia (Fig. 1) which have a high livestock population in the region. The climate of the region is a transition between a subtropical steppe and a subtropical (sub) humid climate [15]. The annual rainfall ranges between 500 and 550 mm (19,721.6 inches), which falls between October/November to April [16] with the highest rainfall experienced between January and March [17]. The temperature ranges from 6 ºC in winter to > 37 ºC in summer [17]. KWR is characterised by woodlands and sandy soils and extensive systems of seif dunes, orientated in an east–west direction, clearly distinguished by dune amplitude and the depth of sand mantle to underlying calcrete [15]. These dunes are associated with a deep sand mantle, gradually losing their distinctive morphology towards their east side. Most constituencies in KWR are comprised of arenosol soils with stripped patches of calcicols dune valleys [18]. The soils are poor in nutrients and are primarily suited for grazing although they

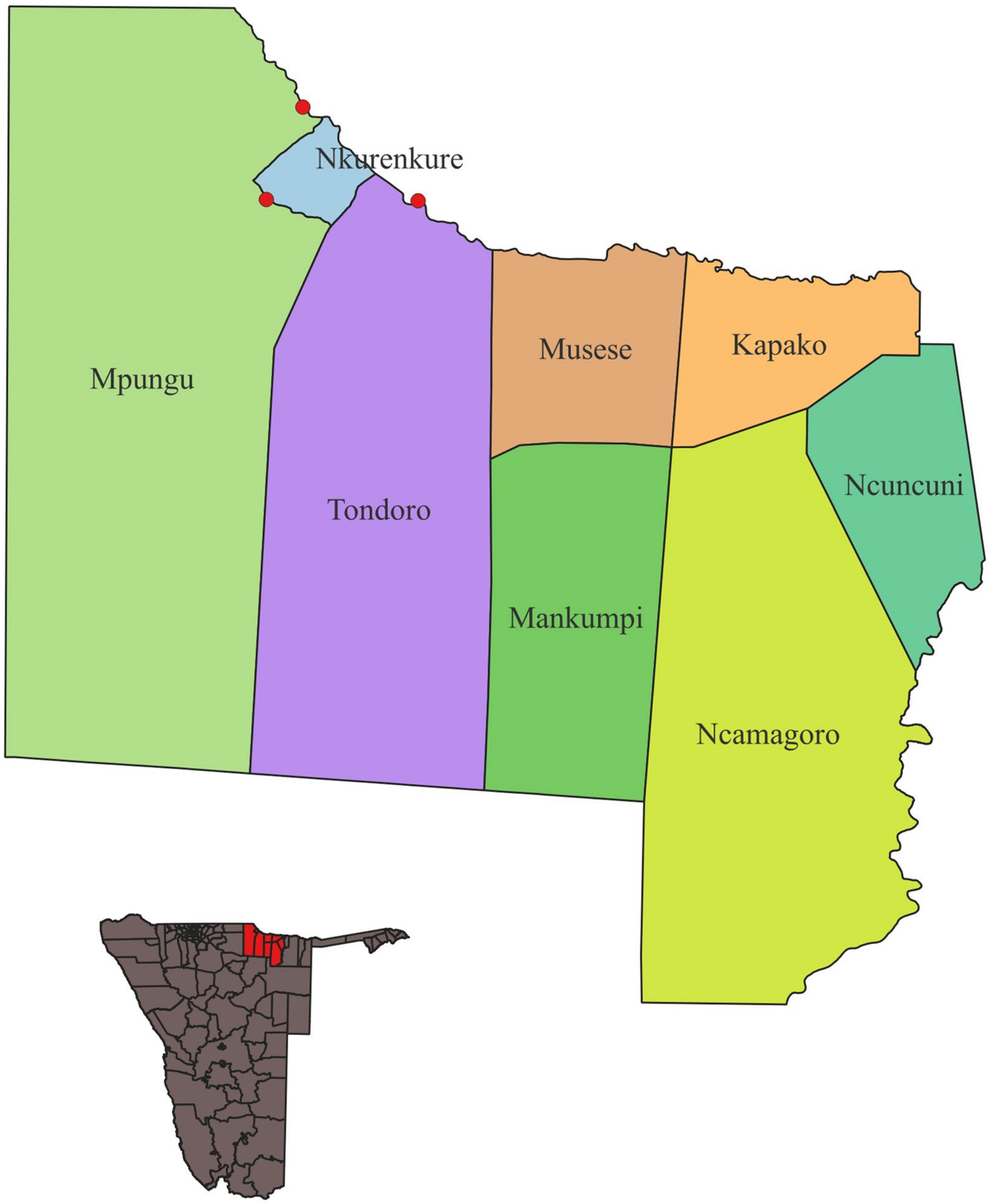

Fig. 1 Kavango West Region of Namibia indicating Karayi, Sitopogo and Kankundi villages marked in red

can be used for dryland farming. Thus, livelihoods are based mainly on livestock production, dryland cropping and use of forestry production [19]. KWR belong to the tree and shrub Savanna Biome, with the vegetation comprised of dry medium and tall woodland Savanna with featureless plains [16]. Dominant vegetation types are Zambezi teak (*Baikiaea plurijuga), Terminalia spp*, *Combretum spp*, *Burkea africana*, *Pterocarpus angolensis*, *Lonchocarpus spp,* Pose wood (*Guibourtia coleosperma)* and Manketti *(Schinziophyton routenenii)* [16, 19–21]. Large patches of dense bush are evident with flamethorn (*Senegalia Ataxacantha*) and wild lavender (*Croton gratissimus*) being common.[16]

2.2 Site selection

Approximately 60% of households in KWR rely on farming as their main source of income and 28% have livestock production as their main agricultural activity [2, 22]. The study selected Mpungu and Tondoro constituencies for the current study because they have the highest number of livestock farming households as reported by NSA [2]. The stock densities range from 5 to 10 cattle per square kilometre (0.05 – 0.1 cattle per ha) inland and as high as 20–100 cattle per square kilometre (0.21 cattle per ha) alongside the Kavango River [23]. The study selected three villages (Kankudi, Karayi and Sitopogo) in the two constituencies based on the population density of the ruminants within the region and advice from the local Department of Veterinary Service of the Ministry of Agriculture, Water and Land Reform. A household was used as a sampling unit, with ten (10) livestock farming households selected per village based on the livestock they owned, which amounted to a total of 30 households and 16.4% of the 182 livestock farming households in the three sampled villages for the survey. The sample size was considered adequate since the data collected were mainly qualitative. The communal farmers raise mixed livestock species mainly of indigenous cattle and goat breeds. In addition, the farmers grew crops such as pearl millet, cowpeas and pumpkins at a subsistence level.

The insert map shows the location of the Kavango West Region within Namibia.

2.3 Data collection

2.3.1 Survey data collection and species identification

Semi-structured questionnaires were administered through face-to-face interviews to collect primary data on socio-demographic characteristics (age, sex, marital status, level of education, household size, labour, type and the number of livestock owned), the feeding resources available to their livestock during the wet and dry seasons, the size and type of ownership for the grazing land available for their livestock and whether they harvest bush based feed resources to feed their livestock during the feed scarce seasons, if they provide supplementary feeding, and if they encounter any feed challenges. Respondents were asked to rank feed resources according to their importance in feed provision to their livestock where 1 was the rank for the major feed resources and 5 for the least contributing feed resources as well as ranking the worst 5 feed constraints (selecting from a pool of 12), where 1 is the constraint with the worst effects and 5 being the constraint with the least effects. Data on farmers' indigenous knowledge of the different browsable plant species (i.e., trees, shrubs, bushes, and herbs) browsed and not browsed by livestock in the area were also collected. The study targeted household members who were responsible for caring of livestock. The questionnaire was pre-tested with 10 households in another village, which was not part nor sampled for the study, to ensure that the questions were answered easily and collected the data they were supposed to and were understood by all interviewees in the same manner before the final data collection questionnaire was revised for data collection. The interviews were conducted in July 2022, and done in local languages (Rukwangari and Nyemba). Communal farmers were asked to name browsable plant species in their local language. The enumerators sought consent from the respondents and local leadership for conducting interviews and no information linking responses to the interviewee was collected. The field data collectors took photos of the species identified and collected some samples for verification. The botanical and scientific names of the browsable plants utilised by animals as mentioned by the respondents were identified using Le Roux and Müller's Field Guide to the Trees and Shrubs of Namibia [24] and The Tree Atlas of Namibia [25] books for guidance and to confirm the species.

2.4 Sample collection and preparation

The three main species browsed by livestock in the KWR were identified based on the frequency of being mentioned and their nutritive value was determined. Sample of ± 400 g were randomly harvested from different plant fractions (whole plant, i.e. leaves & stems/twigs, leaves, twigs/stems < 2.5 cm stem diameter), and pods (if any) of the identified main browsable species using a hand shear/secateur in sufficient quantities (± 1.5 kg fresh weight) from all sides of each plant species. The harvested material was placed in separate brown paper bags. The samples were dried under shade to a constant weight. The dried samples were milled through a 2 mm screen and then further milled through a 1 mm screen. The milled samples were stored in clean, clearly labelled, airtight plastic containers pending laboratory analysis.

2.5 Laboratory analysis

The dry matter (DM) content of bush species samples was determined by drying the samples in a forced draught oven at 100 °C for 24 h[26]. Ash was determined by incineration in a muffle furnace at 550 °C for 6 h [26]. The crude protein (CP) method no. 978.04 [27] was used to determine the total nitrogen content and CP was estimated by multiplying the percentage of N content by a factor of 6.25. Ether extract (EE) was determined using the AOAC method 920.39 [26]. Ash-free neutral detergent fibre (NDFom) and ash-free acid detergent fibre (ADFom) were determined following the procedures of [28] with NDFom assayed without use of an alpha-amylase, but with sodium sulfite. The concentration of calcium (Ca) was analysed using the inductively coupled plasma-atomic emission spectrometry (ICPAES) (icap 6000 series) methods [29], while the phosphorus (P) content was determined using UV–vis-spectrophotometry [27].

2.5.1 In vitro digestibility

The dry matter in vitro digestibility was determined using the Daisy II incubator (ANKOM Technology Corp, USA). Nylon bags (40 um pore size) containing 0.5 g of milled browse samples were heated-sealed and incubated at 39 °C for 48 h in ruminal fluid combined with buffer solution (1:4, v/v) in a Daisy II incubator. After incubation, the jars were drained, and the bags were rinsed thoroughly with tape water and dried in an oven for 24 h at 60 °C. The dried bags and contents were weighed. The digestibility was calculated from the amount of browse placed in the bag and the residues remaining in the bag after 48 h digestion.

2.6 Statistical analysis

The data were analysed using descriptive statistics to summarise the proportions for each response category (the number of respondents who identified a browsable species and the proportion of respondents who mentioned a particular feed challenge). The Chi-square goodness of fit was used to test if the proportions in response categories differed significantly while the Z-test for proportions was used for pairwise comparison to detect if proportions differed significantly. The results for the rank survey questions were analysed by computing the weighted average:

$$\frac{x_1w_1 + x_2w_2 + x_3w_3 + \cdots + x_nw_n}{Total\ number\ of\ responses}$$

where.

w is the weight of the rank position.

x is the response count for that choice.

Each respondent's preferred choice was ranked number 1 and allocated the largest weight tallying with the number of choices and the least preferred choice a weight of 1. In cases where the required number of choices was less than the number of choices available, the choices that were not selected by the respondent were given a weight of 0. The responses were then given overall ranks according to the weighted scores. The means and standard deviations for the nutritive values of the three main species identified by the respondents were computed and the nutritive values for the three species were compared using one-way analysis of variance (ANOVA).

3 Results

3.1 Socio-demographic description of the respondents

Among the respondents, 76.7% (a significantly higher proportion) were male, while 23.3% were female (Table 1). About 43% of respondents were > 64 and 16.7% were < 45 years old. A significantly higher proportion of respondents were legally married (56.7%), which increases the likelihood of co-ownership. Most respondents had a secondary education up to secondary level (56.7%, $p < 0.05$), while 10% of respondents never attended school. Most household heads had education levels from primary to tertiary level, while 26.7% of household heads never attended school. Of the 30 households included in the interview, 53.3% (significantly higher proportion) had < 10 household members, 23.3% had 11–15 household members, 16.7% had 16–20 household members and 6.7% had > 20 household members. About one-third (33.2%) of households had > 5 household members contributing to family labour, while the remaining 66.7% had 15 household members contributing to family labour.

Cattle were the dominant livestock with a significantly higher proportion of households owning > 20 cattle (46.6%), while 26.7% of the households owned 11–20 cattle and 26.7% of households owned 10 or fewer cattle (Table 2). Goats were also significantly dominant with 60% of households owning 1–10 goats, 30% owned owning 11–20 goats and 10%

Table 1 Socio-demographic characteristics of households (n = 30) included in the interviews within the Kavango West Region of Namibia

Characteristic	Sub-characteristic	Percentage (%)	P-value
Age (respondents)	35–44	16.7	
	45–54	20.0	
	55–65	20.0	
	64 +	43.3	0.14
Gender (respondents)	Male	76.7	
	Female	23.3	0.003
Education (respondents)	None	10.0	
	Primary	33.3	
	Secondary	56.7	
	Tertiary	0.0	0.000
Education (HHH*)	None	26.7	
	Primary	46.7	
	Secondary	20.0	
	Tertiary	6.7	
Marital status (HHH*)	Single	43.3	
	Married	56.7	0.47
Household size	1–5	3.3	
	6–10	50.0	
	10 +	46.7	0.002
Household members able to contribute to family labor	1–5	66.7	
	6–10	23.3	
	10 +	9.9	0.0004

*HHH = Household Head

of households owning > 20 goats. Among the households, 46.7% owned donkeys while 16.7% owned other livestock, mainly pigs, with most farmers owning less than ten animals.

3.2 Feed resources, grazing practices and constraints of livestock feed resources

Rangeland grazing was ranked as the most contributing feed resource for livestock, crop residues were ranked second, woody browse species with leaves, twigs and pods were ranked third and purchased feed was ranked fourth. Table 3 shows the responses of the respondents when asked about grazing characteristics, availability of grazing and sustainable feeding methods. Grazing practices appear to be within the bylaws which gives farmers 100% access to rangelands. The existing grazing resources consisted of only the communal grazing land for all the respondents (100%), while roadside grazing land was utilised by 96.7% of the respondents and riverside grazing land was used by 73.3% of the respondents. Despite the availability of these grazing resources, most respondents (83.3%) indicated that the grazing land was not enough for their livestock.

Feeding access was reported to be free and accessible to all respondents and there was no feeding priority. All respondents identified communal grazing and feeding at homesteads as the most common livestock feeding places (Table 4). All respondents alluded that browsing and free grazing were the two main ways of livestock feeding used for their goats and cattle and only 6.7% indicated stall feeding.

Table 2 Livestock herd compositions (% of respondents, n = 30) owned by households included in the interviews in the Kavango West Region of Namibia

Size of herd	Cattle	Goats	Donkeys	Others
1–10	26.7	60.0	46.7	16.7
11–20	26.7	30.0	0.0	0.0
20 +	46.6	10.0	0.0	0.0
Significance level	**	***	***	***

***, **, * are 0.01, 0.05 and 0.1 significant levels, respectively

Table 3 Grazing characteristics, availability of grazing and sustainable feeding methods

Characteristic	Description	Percentage (%)
Types of grazing land*	Communal grazing land	100.0
	Roadside grazing land	96.7
	Riverside grazing	73.3
Feed resources available/used*	Crop residues	100.0
	Tree leaves, twigs and pods	100.0
	Supplements	36.7
Adequacy of grazing land	Yes	16.7
	No	83.3
Ways of feeding*	Free grazing	100.0
	Stall feeding	6.7
	Browsing	100.0
Free feeding access	Yes	100.0
	No	0.0
Feeding place*	At homestead	100.0
	Arable land	3.3
	Communal grazing	100.0
	Cattle post	3.3
Experience feed shortage	Yes	100
	No	0.0

*This is a multiple responses question where respondents can select more than one options

The study revealed several challenges with livestock grazing (Table 5). The respondents reported inadequate rainfall as the top challenge, resulting in feed shortages, while land degradation, low biomass yields, livestock population pressure, and shortage of grazing land were classified as severe feed constraints. Other constraints to livestock production reported were low feed quality and variability across seasons and land use conflict. In addition, households did not have the knowhow to improve livestock feeding.

The main challenges encountered by farmers on the available grazing land were overgrazing which was identified by 100% of the respondents as the challenge while predators were the second challenge as stated by 66.7% of the respondents and 50% of the respondents stated community conflicts as the third main challenge in the area (Table 5). The main predator was the Nile crocodile (*Crocodylus niloticus*) which attacks livestock when grazing along rivers or drinking water from rivers. Land use conflicts led to livestock mortalities and roadside accidents occurred when livestock grazed along roads. Respondents noted that the shortage of feed reduced livestock productivity through weight loss, reduced milk production, reduced growth, and increased mortality, morbidity, and aborted foetuses. Community conflicts included fencing of common land, farmers grazing their livestock in communal areas where they do not belong, and farmers who leave their livestock to graze without a herder, which can destroy other farmers' crops.

Most respondents (86.7%) did not secure feed for their livestock (Table 6). However, 6.7% of households harvest crop residues and 6.7% move their livestock to places with better pastures (i.e., pastoralism). In addition, 6.7% of households harvest tree leaves, twigs and pods for feeding their livestock in the dry season. The respondents that did not harvest pods

Table 4 The ranking of the constraints that contribute to feed shortages

Constraints	Rank
Shortage of rainfall	1
Livestock population pressure	2
Shortage of grazing land	3
Land degradation and biomass yields	4
Low quality and variability of feed across seasons	5
Land use conflict	6
Lack of knowhow on improved feeding	7
Poor access to feed markets	8

Table 5 Grazing land problems and consequences of feed shortage

Characteristic	Description	Percentage (%)
Grazing land problems*	Overgrazing	100
	Predators	66.7
	Land use conflict	50
	Road accidents	20
	Weed plant invasion	3.3
	Erosion, bare soil and gullies	3.3
Consequences of feed shortage*	Weight loss	100
	Weak animals	93.3
	Reduced growth	80
	Increased mortality	76.7
	Abortion	76.7
	Milk yield reduction	33.3
	Increased calving/kidding/lambing interval	23.3

*This is a multiple responses question where respondents can select more than one options

indicated that pods fall on the ground on their own (73.3%). Respondents indicated they are challenged by a shortage of labour (70%), old age (13.3%), scarcity of trees to harvest the pods from (10%) as well as the bulkiness of materials (6.7%).

3.2.1 Woody plant species utilized by cattle and goats

Browse plant species and the fraction used as livestock feed (Table 7). About 90% of respondents identified camel thorn (*Vachellia erioloba*) as the most browsed plant species, followed by *Strychnos cocculoides* (80%), *Diplorhynchus condylocarpon* (73%), *Combretum collinum* (67%) and *Baphia massaiensis* (67%). Other species such as *Philenoptera nelsii*, *Boscia albitrunca, Terminalia sericea, Baphia massaiensis, and Dichrostachys cinerea* were also identified as plant species livestock feed on. The respondents indicated that livestock do not feed on woody plant species such as *Salacia luebbertii, Combretum imberbe, Ziziphus mucronate, Clerodendrum uncinatum, Baikiaea plurijuga, Burkea africana, and Pterocarpus angolensis* (Table S1). However, some respondents indicated some browse species, namely *Clerodendrum uncinatum*, *Baikiaea plurijuga*, *Strychnos pungens* and *Guibourtia coleosperma* could be consumed by livestock, while some respondents considered them nonedible.

3.3 Nutritive value of the three main browsable species identified by the respondents

The chemical composition and in vitro DM digestibility of the main browse species in KWR (Table 8). From the ANOVA results, there was no significant difference in the dry matter content across the species for both leaf and whole plant

Table 6 Supplementation of feed and feed shortage

Characteristic	Description	Percentage (%)
Methods to secure enough feed*	Do nothing	86.7
	Harvest crop residues	6.7
	Move livestock to better grazing land	6.7
	Harvest tree leaves, twigs, pods	6.7
Reasons why the household does not harvest pods*	Pods fall from the trees	73.3
	No labor	70.0
	Old age	13.3
	Scarcity of trees	10.0
	Bulkiness of material	6.7
	Lack of knowledge	6.7

*This is a multiple responses question where respondents can select more than one option

Table 7 Browse plant species and the fraction used as livestock feed in the study area

Scientific name	Common names	Local names	Fraction livestock feed on	% of respondents (n = 30)
Vachellia erioloba	Camelthorn	Musu	Leaves and pods	90
Vachellia tortilis	Umbrella thorn	Ekonda	Leaves	3
Annona stenophylla	Dwarf custard apple	Maroro	Leaves and pods	7
Boscia albitrunca	The Shepherds' tree	Munkudi	Leaves	17
Baphia massaiensis	Sand camwood	Mbunze	Leaves	67
Baikiaea plurijuga	Rhodesian teak/ Zambesi redwood	Uhahe	Leaves	30
Bauhinia petersiana	White bauhinia	Muhusi	Leaves	37
Combretum collinum	Weeping bushwillow/ bicoloured bushwillow	Mupupu	Leaves and pods	67
Clerodendrum uncinatum	Cats claw	Itwampuku	Leaves	7
Dichrostachys cinerea	Sickle bush	Mwege	Leaves and pods	27
Diospyros chamaethamnus	Sand apple	Makwevo	Leaves and pods	15
Diplorhynchus condylocarpon	Horn pod tree	Murere	Leaves	73
Guibourtia coleosperma	Rhodesian mahogany/Pose wood	Usivi	Leaves and pods	27
Philenoptera nelsii	Kalahari appleleaf	Mupanda	Leaves and pods	63
Schinziophyton rautanenii	Mongongo / Manketti tree	Ugongo	Leaves and pods	17
Strychnos cocculoides	Monkey orange	Uguni	Leaves and pods	80
Strychnos pungens	Spineleaved monkey orange	Matu	Leaves and pods	10
Terminalia sericea	Silver terminalia	Mugoro	Leaves and pods	57
Vangueria esculenta	Edible wild medlar	Nombu	Leaves	7

fractions (P > 0.05) although there was a tendency (P = 0.07) of high DM in the leaf fraction of *G. coleosperma*. However, all the other nutrients (CP, ash, ADF, NDF, OM) differ significantly across the three species for both the leaf and whole plant fractions (P < 0.05). *Strychnos cocculoides* was found to contain the highest ash content for both leaf and whole plant fractions at 5.9% and 5.3%, respectively, followed by *P. nelsii* which recorded ash content of 4.7% in leaves and 4.9% in whole plant. *Guibourtia colesperma* had the lowest ash content of 3.2% in leaves and 2.9% in whole plants. *Guibourtia colesperma* had the highest OM content for both leaves and whole plant with 90.9% in both followed by *P. nelsii* with 88.7% in leaves and 88.4% in whole plant while *S. cocculoides* recorded the lowest OM content of 87.5% in leaves and 88.1% in whole plant. *Guibourtia colesperma* contained the highest CP content in both leaves and whole plant with 9.5% and 11.5%, respectively. *Philenoptera nelsii* had the second highest CP in leaves with 5.7% while *S. cocculoides* had the second highest % CP in whole plant with 6.7%, which was similar to the CP content of *P. nelsii* whole fraction (6.1%). The

Table 8 Chemical composition and in vitro digestibility of the three most common browse species

Plant fraction	Species	% DM	% Ash	% OM	% Fat	% CP	% NDF	% ADF	% Ca	% P	% in vitro
Leaf	*S. cocculoides*	93.43	5.9^{a}	87.5^{c}	1.1^{b}	4.5^{c}	33.9^{b}	25.7^{c}	0.29^{b}	0.09^{b}	69.0^{a}
	P. nelsii	93.40	4.7^{b}	88.7^{b}	0.6^{c}	5.7^{b}	48.7^{a}	42.3^{a}	0.28^{b}	0.02^{c}	60.0^{b}
	G. coleosperma	94.14	3.2^{c}	90.9^{a}	1.8^{a}	9.5^{a}	35.2^{b}	30.3^{b}	1.42^{a}	0.21^{a}	67.5^{a}
	SEM	0.11	0.06	0.07	0.04	0.03	0.22	0.18	0.01	2.75	0.50
	P-value	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Whole plant	*S. cocculoides*	93.43	5.3^{a}	88.1^{b}	1.9^{b}	6.7^{b}	45.2^{b}	36.2^{b}	1.24^{b}	0.15^{b}	63.0^{a}
	P. nelsii	93.38	4.9^{a}	88.4^{b}	0.7^{c}	6.1^{b}	47.4^{a}	40.0^{a}	0.75^{c}	0.06^{c}	56.0^{b}
	G. coleosperma	93.84	2.9^{b}	90.9^{a}	2.5^{a}	11.5^{a}	36.1^{c}	32.3^{c}	2.00^{a}	0.34^{a}	63.5^{a}
	SEM	0.23	0.08	0.20	0.06	0.15	0.19	0.11	0.06	0.50	0.76
	P-value	0.47	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.03

^{abc} Means in the same column with different superscripts are significantly different (P < 0.05). NDF (Neutral Detergent Fibre), ADF (Acid Detergent Fibre), DM (Dry matter), OM (Organic matter), Ca (Calcium) and P (Phosphorus) fat content was highest in *G. colesperma* for both leaf (1.8%) and whole plant (2.5%) fractions followed by *S. cocculoides* with 1.1% fat content in leaf and 1.9% in whole plant fraction. *Philenoptera nelsii* recorded the lowest fat content with 0.6% in leaves and 0.7% in whole plant fraction. *Philenoptera nelsii* contained the highest NDF content for both leaves and whole plant, 48.7% in leaves and 47.4% in whole plant while *S. cocculoides* recorded the second highest NDF content in whole plant at 45.2%, *G. colesperma* was third highest in whole plant with 36.1%. *Guibourtia colesperma* leaves were second highest NDF content of 35.2% which was comparable to the NDF content of *S. cocculoides* of 33.9%. *Philenoptera nelsii* contained the highest ADF content for both leaves (42.3%) and whole plant (40.0%) followed by *S. cocculoides* in whole plant (36.2%) with *G. colesperma* recording the lowest in whole plant (32.3%) and second highest in leaves with 30.3%. *Strychnos cocculoides* leaves were found to have had the lowest ADF content of 25.7%.

The highest calcium levels were recorded in *G. colesperma* for both leaves and whole plant with 1.4% and 2. 0%, respectively followed by *S. cocculoides* with 1.2% in whole plant. *Philenoptera nelsii* had the least calcium content of 0.8% in whole plant, but the calcium content of *S. cocculoides* and *P. nelsii* were similar (0.3%). *Guibourtia colesperma* contained the highest potassium levels for both leaf (0.2%) and whole plant (0.3%) fractions, followed by *S. cocculoides* with 0.09% in leaves and 0.15% in whole plant. *Philenoptera nelsii* had the lowest potassium of the three species with 0.02% in leaves and 0.06% in whole plant.

There were significant differences between the in vitro DM digestibility of the three plant species for both plant fractions ($P < 0.05$). *Strychnos cocculoides* and *G. Colesperma* had the highest in vitro DM digestibility of leaves (69.0% and 67.5%, respectively) while *P. nelsii* had the lowest (60.0%). For the whole plant fraction, G. *Colesperma and S. cocculoides* had the highest in vitro DM digestibility (63.5% and 63.0%, respectively) while *P. nelsii* had the lowest value of 56.0%.

4 Discussion

Namibia is one of the countries in Sub-Saharan Africa where livestock farming is of paramount importance [30]. Although livestock production sustains many communal farmers in rural areas of Namibia, it is highly constrained by the lack of feed resources due to the consequences of the ever-increasing rural population, and environmental degradation, which is exacerbated by climate change [31] and an increase in drought prevalence and bush encroachment [32]. Our study assessed the feed resources, constraints and browsed plant species used in feeding livestock in the KWR.

4.1 Feed resources and feed constraints in Kavango West Constituency

The livestock statistics reported in our study support earlier observations by Mendelsohn [4] and Behnke [3], who also reported that cattle are the most important livestock species in the Kavango regions with goats being less numerous, and rarely exceeding 30 heads. Our results show that livestock mainly rely on rangeland grazing and all households have access to free communal grazing land as part of the Kavango Region land (46.4%) used for communal grazing [4]. Crop residues are secondary to rangeland grazing, ahead of tree leaves, twigs and pods, and purchased feed because the study respondents practice mixed farming and pearl millet is grown on about 95% of all cultivated land in the Kavango Region [4]. Roadside and riverbed grazing is common because homesteads are mainly along the Kavango River terraces where browsable species are abundant [20]. However, these areas pose risks including road accidents and crocodile attacks. Aust [33] observed that Nile crocodiles kill livestock annually in Northeastern Namibia. It has been estimated that 0.29 to 7.8 cattle per kilometre of river frontage per year are attacked, and cattle are the most frequently attacked species (74%82%) [33]. This could be because cattle spend time grazing on emergent floodplain vegetation which exposes them to crocodile attacks. Attacks on small stocks and calves are underreported due to a relatively limited data on such incidence [33]. Thomas [34] reported the rate of crocodile attacks on livestock in the Okavango delta is increasing linearly. Purchased feed such as concentrates are less utilised by Kavango West communal residents because these are low income households living in extreme poverty as the Kavango Region is considered one of the poorest regions in Namibia [14, 35].

The study observed the livestock pressure on rangeland resources as a challenge, which concurs with Behnke [3] who observed uncultivated grazing land is in short supply in the Kavango Region. The land conflicts we observed concur with other studies that observed conflicts emanating from illegal fencing, use of land without the consent of the community and community leadership, as well as fencing beyond the 50 ha that the Communal Land Reform Act (CLRA) allow under the customary land rights [36, 37]. The CLRA of 2003 prohibits fencing of communal lands. We observed that although farmers are aware of browsable plant species, most respondents do not harvest their leaves, twigs, or pods to feed their animals during dry seasons when feed is scarce mainly because pods fall from the trees and shortage of labour. However, few respondents indicated old age, scarcity of browsable trees and bulkiness of their materials as the reasons why they do not harvest leaves and pods from woody plant species to feed their animals during the dry seasons when herbaceous species are scarce. Although respondents are knowledgeable about the browsable species that their livestock feed on, some do not harvest because they are not aware that the leaves, twigs and pods of these browse species can be harvested for use as feed when feed resources are scarce. Strohbach [20] reported no clear signs of woody plant species harvesting, adding that the Okavango Valley vegetation is an important resource for ecosystem functioning.

4.2 Indigenous knowledge of browsable species

The majority of the respondents in the study were males and this could be attributed to the majority of households headed by males and also male household members are mostly responsible for animal welfare and aware of feeding and grazing patterns as well as the plant species livestock feed on. The findings of this study agree with Marius [38], who reported 76.7% male and 27% female respondents and Mendelsohn [39] who reported 78% males and 22% females. In addition, the literate elderly respondents who participated in the survey were more likely to be knowledgeable about livestock farming and woody browse species consumed by livestock.

The study indicated that communal farmers have a wide knowledge base on the species consumed and not consumed by their livestock. Some of the browsable woody plant species identified by the communal farmers such as *Vachellia erioloba, Vachelia tortilis* and *Combretum collinum* have also been identified by other researchers [19–21]. This demonstrates that the respondents have indigenous knowledge about the browsable species that can be utilised as animal feed in their community.

4.3 Nutritive value of the main browsable plant species

Dry matter (DM) represents nutrients contained in a feed sample other than water and is an indicator of nutrients available to the animal in a ration [40]. Livestock need to consume a certain amount of dry matter per day (kg/day) to maintain health and production. The overall DM content of the species is high, an indication that the nutritive value available for livestock is high, hence the species can be utilised as feed resources. The DM of *G. colesperma* leaves tended to be higher than DM in *S. cocculoides* and *P. nelsii*. *Strychnos cocculoides* had a higher ash content in leaves and whole plant fraction compared to other browse species, an indicator of high inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a particular feed. *Guibourtia colesperma* has a high organic matter compared to *S. cocculoides,* and *P. nelsii* species. Crude protein is considered the most important nutrient component. However, nitrogen and its various substances are of more concern in ruminant nutrition than proteins and amino acids, which are synthesized by both domestic and wild ruminants. The amount of nitrogen compounds present in trees and shrubs varies with the environmental factors, the kind of tissue, the age or stage of development, and the season of growth. The pods and the meristematic tissues of the fodder shrubs contain higher percentages of crude protein than leaves or other parts. In a similar study, the tips of the pods contain higher protein levels than other sections [41]. *Guibourtia Colesperma* was found to have the highest CP in both plant fractions than *S. cocculoides,* and *P. nelsii* species. The high CP content of *Guibourtia Colesperma* indicate that it as a can be given to livestock during the dry season as a protein supplement for lowquality forages. However, the CP content of the leaves of *S. cocculoides* and *P. nelsii* were below the minimum protein requirement (6.08.0%) for rumen microorganisms' activities [42]. Kasale [10] study shows a higher CP content of 13.49% in *Guibourtia Coleosperma*.

The NDF and ADF are more useful measures of feeding value and should be used to evaluate forages and formulate rations because they affect intake, digestibility and animal performance. Since *P. nelsii* had the highest NDF and ADF content, they can be useful high roughage feed during the dry season for ruminants, especially if fed to animals with browse which have low fibre but high in protein content. According to van Soest [43], *P. nelsii* has the highest amount of NDF among other woody species, due to differences in the cell wall structure of woody species [44], hence species variability. The NDF contents of the browse species in this study are below the critical level (60–65%) that limits appetite, intake and digestibility in ruminants [45]. Moreover, in exception of *P. nelsii*, the ADF value of browse species was less than the threshold value of 40% which are believed to have high quality feed [46]. Crude fats are known to supply more energy (2.25 times more) than carbohydrates due to their high fat and oil contents. *Guibourtia colesperma* and *Strychnos cocculoides* are an important source of energy for animals during the dry season when they rely more on dry grass (hay) which is very low in soluble sugars. Ruminants are not dependent upon fat in shrubs since fat is synthesized in the rumen from carbohydrates and proteins. However, range animals seem to benefit from grazing on shrubs such as *G. colesperma*, which contains good fat levels. Kasale [10] found a crude fat content of 2.3% in *G. colesperma* which is comparable to the content reported in the whole plant (2.5%) in this study.

The digestibility of a feed is defined as the proportion that is not excreted in the faeces and it is assumed to be absorbed by the animal body. *Philenoptera nelsii* recorded a lower in vitro DM digestibility than *G. colesperma* and *S. cocculoides* in both leaves and whole plant, which could be attributed to differences in fibre fraction [45], hence the high NDF and ADF content. In this study, browse species were above the digestibility value (< 55%) and regarded as low-quality forage [47], however, there is still a need of strategic supplementation for the efficient utilization of these species.

4.4 Proposed technical interventions

Given the feed challenges highlighted by the respondents, the communal livestock farmers in KWR should be encouraged to utilise the identified browsable woody species as supplementary feed for their livestock when natural forages are scarce. Farmers should be encouraged to implement selective harvesting techniques to ensure that the browsable woody plant species are used sustainably and do not negatively impact the ecosystem, and eventually help prevent the overuse and degradation of rangelands. Harvesting guidelines should be developed for harvesting these species, including the best harvesting time to ensure optimal use of nutrients, and how much can be removed without compromising the overall health of the degeneration of the plants and rangelands. To this effect, community engagements and knowledge sharing sessions through training programmes and workshops should be undertaken to educate the smallholder farmers on how to utilise these species as livestock feed efficiently. These should include training on how to identify, harvest, process though chipping and milling, and formulate feed through workshops to demonstrate the practical applications of using these species as supplementary feed. The interventions should be introduced through the participatory approach where the local farmers are involved in the development and implementation of feeding strategies and management practices to ensure that they are practical and culturally acceptable. Long-term plans for livestock feed based on managing the grazing areas and supplantation of herbaceous natural forage with woody browsable species can help build community resilience and sustainability.

Because of the dangers of crocodile attacks on livestock and humans, the Revised National Policy on Human Wildlife Conflict Management [48] recommends the construction of wire fences where high incidences of crocodile attacks occur and in protected areas to be utilised for livestock to drink water safely. The fencing would need to be adjusted during high floods and droughts to ensure the safety of livestock from crocodile attacks during high tides and to enable the livestock to access water during droughts. In addition, the policy recommends the development of alternative water resources to allow livestock to drink water safely away from the Kavango River. The sudy suggests livestock monitoring to ensure these policies are implemented and minimize the risk of crocodile attacks.

Since commercial feed and supplements are not affordable to many communal farmers in Kavango West, initiatives could help them combat the shortage of feed resources during the dry seasons by making woody species available. The nutritional value of forage is dependent on several factors namely, species, phenology, stage of maturity, and the season of growth [49]. This implies the need for policies to train and educate farmers on the appropriate time to harvest leaves and pods of browse plant species and how to harvest and formulate feed to supplement their livestock feed in dry seasons. Harvesting of bush species for feeding animals can curb bush encroachment [19]. Farmers also need assistance with utilising bush species and crop residues in feed formulation to enhance their nutritional value. As livestock farmers rely mainly on communal grazing land which is common to all farmers, some interventions such as fencing grazing land, and paddocking are not feasible because unauthorised fencing of communal lands is prohibited [19]. However, it could be useful for farmers to be advised and informed on how to make supplementary feed from browsable plant species as well as the best time to harvest herbaceous plant species in abundance during the wet seasons (summer) and scarce in the dry season (winter) due to senescence [32]. Pioneering results on the use of bush feed by farmers and feeding trial studies in Namibia have demonstrated that if bush materials are properly mixed with other ingredients and formulated correctly, the resultant bush-based feed can support livestock growth under drought conditions [50]. We recommend research to assess the nutritional composition of these browsable species in the wet and dry seasons to determine seasonal variation in nutrients and advise farmers accordingly. Since low quality and quantity of forage during the dry season are a major concern for livestock farmers in KWR, and farmers are aware of the species that their livestock feed on and do not feed on, farmers need to learn about harvesting and conservation of these species when they are nutritious to supplement their livestock in the dry season. In addition, this could help with problems related to bush encroachment.

5 Conclusions

Most farmers in the Kavango West region have free access to rangeland resources (i.e., natural grazing and browsable woody species) for their livestock and supplement their livestock with crop residues. However, feed shortage is still a constraint of livestock production in KWR resulting mainly in the loss of livestock body weight, weakness, reduced growth, abortion and mortality. Lack of rainfall, livestock population pressure, shortage of grazing land, land degradation and biomass yield are the main factors causing feed shortages in Kavango West. Overgrazing, predators, and land use conflicts are the main grazing problems encountered in the area. The browse plants most commonly used in feeding animals in the region were *Vachellia erioloba, Strychnos cocculoides, Diplorhynchus condylocarpon, Combretum collinum, Baphia massaiensis, Philenoptera nelsii, and Terminalia sericea*. The nutritional values of the main browse species vary. *Guibourtia coleosperma* had a higher CP content compared to other species, while *P. nelsii* had higher NDF and ADF, hence lower in vitro DM digestibility compared to other species. Although farmers are aware of browse species available in their area, most farmers do not harvest leaves, twigs, and pods from these browsable woody plant species to secure feed for their livestock mainly because pods fall from the tree, labour shortage and old age.

Integrating indigenous knowledge, with nutritive value data on dominant browsable species in the KWR can enhance livestock management and sustainability. By validating traditional practices, developing targeted feeding strategies and engaging local communities, the use of natural resources to improve livestock productivity can be optimised. Sustainable management practices and continuous monitoring can further support effective adoptive livestock productivity in the arid environments of Namibia. Livestock farmers can be encouraged to harvest leaves and pods when they are nutritious and preserve them for use as feed resources in their dry season instead of waiting for the dry season for the livestock to search for the bush leaves and pods. It is recommended that farmers consider harvesting fodder from the riverbeds and stall-feed their livestock especially calves and small stock to minimise the dangers of riverside grazing. Further studies are recommended to evaluate the seasonal variation, anti-nutritional factors of the browse plant species, and feeding trials to assess the performance of animals when fed the browse species. Moreover, other browse species, which have not been analysed in this study should be evaluated to determine their nutritional values in the future.

Acknowledgements The authors acknowledge the support of the University of Aberystwyth and the University of Namibia collaborative research project funded by the Global Challenges Research Fund.

Author contributions 1. RH: Research, Data collection, Methodology, Resources, Experiment administration, Writing – original draft preparation. 2. VC: Guidance, Methodology, Data Analysis, Coaching, Writing. 3: AK: Guidance, Coaching, Writing, Review and Editing.4. MNTS: Writing, review and editing. 5. JM: Sourcing of funding, Writing, review and editing.

Data availability The data is available from the corresponding author on request

Declarations

Ethics approval and consent to participate The research, which poses a minimum risk to participants, was conducted in compliance with the University of Namibia (UNAM) Research Ethics Policy, Regulations and Guidelines which recognises the United Nations Declaration on the Rights of Indigenous Peoples (2007). The manuscript is based on research undertaken by an undergraduate student, RNH, and the research proposal was assessed for scientific merit and ethical compliance by the supervisors/lecturers of students at the departmental level. The department committee approved the proposal, following UNAM research ethics guidelines as it is a minimum-risk study that does not include human tissue, children and other vulnerable groups. The research participants volunteered and consented to participate by signing informed consent forms and were treated respectfully. Moreover, they were free to withdraw at any time during the interview and their data was handled confidentially. The University of Namibia does not require formal ethical clearance for undergraduate research projects posing minimum risks to participants, they only require that the proposals be assessed by supervisors and lecturers at department level.

Consent for publication All authors have agreed to submit the manuscript to the Journal of Discover Agriculture.

Competing interests The authors have no competing interests to declare relevant to this article's content.

References

1. Meat Board of Namibia. 2019–2020 annual report. Windhoek, Namibia: Agripublishers; 2020. https://nammic.com.na/wp-content/uploads/Library/Operations/Public%20Relations/Annual%20Reports/Annual%20Report%202019-2020.pdf. Accessed 13 Jul 2023.
2. Namibia Statistics Agency (NSA). Namibia 2011 Population and Housing Census. Kavango West Region Tables Based on 4th Delimitation. Windhoek, Namibia: Namibia Statistics Agency; 2011 https://cms.my.na/assets/documents/p19dptss1r1kk3u15j041eq11m9ji.pdf. Accessed 22 Mar 2023.
3. Behnke RH. Kavango grazing systems study: final report. Windhoek, Namibia: NOLIDEP; 1998. http://the-eis.com/elibrary/sites/default/files/downloads/literature/Kavango%20Grazing%20System%20Study-%20Final%20Report_%20RH%20Behnke.pdf. Accessed 1 Dec 2022.
4. Mendelsohn J. Land use in Kavango: past, present and future. OKACOM, Maun. 2009 https://www.raison.com.na/sites/default/files/Land%20use%20in%20Kavango%20past%2C%20present%20and%20future.pdf. Accessed 14 Aug 2023.
5. Meat Board of Namibia. 2020–2021 annual report. Windhoek, Namibia: Agripublishers; 2021. https://nammic.com.na/wp-content/uploads/Library/Operations/Public%20Relations/Annual%20Reports/Annual%20Report%202020-2021.pdf. Accessed 13 Jul 2023.
6. Joubert D, Rothauge A, Smit G. A conceptual model of vegetation dynamics in the semiarid Highland savanna of Namibia, with particular reference to bush thickening by Acacia mellifera. J Arid Environ. 2008;72(12):2201–10.
7. Olafadehan O, Okunade S. Fodder value of three browse forage species for growing goats. J Saudi Soc Agric Sci. 2018;17(1):43–50.
8. Amaning-Kwarteng K. Sustainable dry-season feeding of ruminants in Ghana: the use of crop residues and leguminous shrubs as feed stuffs. The complementarity of feed resources for animal production in Africa. 1992; 149–50.
9. Le Houérou H. Chemical composition and nutritive value of browse in tropical West Africa. Browse in Africa. 1980; 261–89.
10. Kasale F. Determination of nutritive values of browsable plants utilised by cattle during the dry season in Sibbinda constituency of Zambezi Region-Namibia. [Windhoek, Namibia]: University of Namibia; 2013. https://repository.unam.edu.na/bitstream/11070/775/1/kasale2013.pdf. Accessed 20 Dec 2022.
11. Morton JF. The impact of climate change on smallholder and subsistence agriculture. Proc Natl Acad Sci. 2007;104(50):19680–5.
12. Routhage A. Namibia Integrated Landscape Approach for enhancing Livelihoods and Environmental Governance to eradicate poverty (NILALEG) , Annex V Key Strategies & Proposed Interventions [Internet]. Windhoek, Namibia: NILALEG; 2019. Report No.: 5640. https://www.meft.gov.na/files/files/Annex%20V%205640%20Strategies%20to%20promote%20sustainable%20rangeland.pdf. Accessed 31 Jan 2024.
13. Abule E, Snyman H, Smit G. Comparisons of pastoralists perceptions about rangeland resource utilisation in the Middle Awash valley of Ethiopia. J Environ Manage. 2005;75(1):21–35.
14. Thiem M, Jones BT. Scraping the Pot: Chapter 9 - Kavango Region. WIndhoek, Namibia: Legal Aid Center and Desert Research Foundation; 2013. (Scraping the Pot). https://www.lac.org.na/projects/lead/Pdf/scraping_two_chap9.pdf.
15. Koppen W. Das geographische System de Klimate. Handbuch der klimatologie. 1936; https://koeppen-geiger.vu-wien.ac.at/pdf/Koppen_1936.pdf.
16. Nkurenkuru Town Council. Environmental Assessment Scoping Report for: Permanent Closure and Rezoning of Erf 682, Nkurenkuru Extension 1 from "Public Open Space" to "Business" in Nkurenkuru Kavango West Region. Windhoek, Namibia; 2024.
17. Kahorere E, Mutota C, Nathile V, Disho SN. Environmental Managemnt Plan—Nkurenkuru designated disposal site. Windhoek, Namibia: Nkurenkure town council; 2020. http://the-eis.com/elibrary/sites/default/files/downloads/literature/1820_EMP_Construction%20and%20Operations%20of%20the%20Nkurenkuru%20Designated%20Disposal%20Site.pdf. Accessed 7 Mar 2022.
18. MLR. Integrated Regional Land Use Plan (IRLUP) for the Kavango West Region, Baseline Report. Windhoek, Namibia, SPC, AHT, GEOCARTA & SAIEA: Ministry of Lands and Resettlement; 2014. Report No.: Volume 1.
19. NILALEG. Profile of the Nkulivere Focal Landscape. WIndhoek, Namibia: Namibia nature conservation; 2021. https://www.meft.gov.na/files/files/NILALEG%20Project_Nkulivere%20Profile(2).pdf. Accessed 3 Mar 2023.
20. Strohbach BJ. Vegetation of the Okavango river valley in Kavango West, Namibia. Biodiv Ecol. 2013;5:321–39.
21. Marius LN, Osafo EL, Mpofu ID, van der Merwe P, Boys J, Attoh-Kotoku V. Indigenous knowledge and identification of local woody plant species as potential feeds for goats in the communal farming areas of Namibia. Livest Res Rural Dev. 2017;29(10):1.
22. NSA. Kavango West Region Profile. Census of Business Establishment 2019–2021. Windhoek, Namibia: Namibia Statistics Agency; 2021. https://nsa.org.na/publications/. Accessed 2 Mar 2024.
23. MLR. Rapid Survey of Farms in Kavango. Windhoek, Namibia, SPC, AHT, GEOCARTA & SAIEA: Ministry of Lands and Resettlement; 2013.
24. Le Roux PJ, Müller M, Curtis B, Mannheimer C. Le Roux. https://pza.sanbi.org/references/mannheimer-c-curtis-b-2009-le-roux-and-muller%E2%80%99s-field-guide-trees-shrubs-namibia. Accessed 21 Dec 2022.
25. Curtis B, Mannheimer C. Tree atlas of Namibia. National botanical research institute, ministry of environment and tourism; 2005. https://www.treeatlas.biodiversity.org.na/. Accessed 21 Dec 2022.
26. AOAC. Official methods of analysis, association of analytical chemists. 15th ed., Washington D. C. Washington D C USA. 2000.
27. AOAC. Official methods of analysis. 18th ed. Gaithersburg: Association of Official Analytical Chemists; 2005.
28. Mertens DR, Allen M, Carmany J, Clegg J, Davidowicz A, Drouches M, et al. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: Collaborative study. J AOAC Int. 2002;85(6):1217–40.
29. AOAC 2007. Official methods of analysis of AOAC International. Association of Official Analysis Chemists International. 2007.
30. Nangolo M, Alweendo N. Agriculture in Namibia: an overview: democracy report. IPPR; 2020. https://ippr.org.na/publication/agriculture-in-namibia-an-overview/. Accessed 2 Apr 2023.
31. Inman EN, Hobbs RJ, Tsvuura Z. No safety net in the face of climate change: the case of pastoralists in Kunene Region, Namibia. PLoS ONE. 2020;15(9): e0238982.
32. Coppock DL, Crowley L, Durham SL, Groves D, Jamison JC, Karlan D, et al. Community-based rangeland management in Namibia improves resource governance but not environmental and economic outcomes. Commun Earth Environ. 2022;3(1):32.

33. Aust PW. The ecology, conservation and management of Nile crocodiles Crocodylus niloticus in a human dominated landscape. [London]: division of biology, imperial college London; 2009. https://d1wqtxts1xzle7.cloudfront.net/87868539/Crocodiles_20in_20NE_20Namibia_20Patrick_20Aust_20Thesis_202009-libre.pdf?. Accessed 22 Dec 2022.
34. Thomas GD. Human-crocodile conflict (Nile crocodile: Crocodylus niloticus) in the Okavango Delta, Botswana. [Stellenbosch]: Stellenbosch University; 2006. https://scholar.sun.ac.za/items/49f0c0ee-2074-418f-8951-d4b2b4b9d7b2. Accessed 3 Mar 2024.
35. MLR. Land Use Planning Framework for The Kavango region of Namibia within the Okavango river basin, Windhoek. Windhoek, Namibia: ministry of lands and resettlement, Republic of Namibia; 2010. http://the-eis.com/elibrary/sites/default/files/downloads/literature/Kavango%20land-use%20planning%20framework.pdf. Accessed 1 Mar 2022.
36. Hebinck P. Land and grazing disputes and overlapping authorities in Namibia. J Legal Pluralism Unofficial Law. 2021;53(3):356–66.
37. Muduva TK. Grazing rights in communal areas of a post-independent namibia: a case study of a grazing dispute in western Kavango region. University of the Western Cape; 2014. https://www.lac.org.na/projects/lead/Pdf/Muduva_MPhil_2014.pdf. Accessed 2 Mar 2024.
38. Marius LN. Evaluation of local feed resources, their response on intake, growth, milk yield and composition and product properties of Namibian indigenous goats. Kwame Nkurumah University; 2016. https://ir.knust.edu.gh/items/96893f0e-b1f2-45d6-9ed2-74bd1a63fe63. Accessed 13 Dec 2023.
39. Mendelsohn J. Rapid Survey of Farms in Kavango. Windhoek, Namibia: Ministry of Lands and Resettlement; 2013. https://www.raison.com.na/sites/default/files/Rapid%20survey%20of%20farms%20in%20Kavango.pdf. Accessed 3 Jul 2023.
40. Saha UK, Sonon LS, Hancock DW, Hill NS, Stewart L, Heusner GL, et al. Common terms used in animal feeding and nutrition. University of Georgia; 2010. https://esploro.libs.uga.edu/esploro/outputs/report/Common-terms-used-in-animal-feeding/9949316317402959. Accessed 31 Dec 2023.
41. Aldous C. A winter study of mule deer in Nevada. J Wildl Manag. 1945;9(2):145–51.
42. National Research Council, Committee on Animal Nutrition, Subcommittee on Dairy Cattle Nutrition. Nutrient requirements of dairy cattle: 2001. National Academies Press; 2001.
43. Soest PJ. Nutritional ecology of the ruminant. London: Cornell University Press; 1994.
44. Marius LN, Shipandeni MN, Rodríguez-Campos LA, Osafo EL, Mpofu ID, Ansah T, et al. Seasonal variation in chemical composition and in-vitro gas production of woody plant species of semi-arid condition of Namibia. Agrofor Syst. 2021;95(6):1191–204.
45. van Van Soest P, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci. 1991;74(10):3583–97.
46. Kellems RO, Church DC. Livestock feeds and feeding. Prentice Hall; 1998. https://books.google.com.na/books?id=18kpAQAAMAAJ
47. Leng RA. Factors affecting the utilization of 'poor-quality' forages by ruminants particularly under tropical conditions. Nutr Res Rev. 1990;3(1):277–303.
48. MET. Revised national policy on human wildlife conflict management 2018–2027. Windhoek: Ministry of Environment and Tourism, Directorate of Wildlife and National Parks, Republic of Namibia; 2018.
49. Norton B. Differences between species in forage quality. Slough: CommonWealth Agricultural Beareau; 1982. https://doi.org/10.5555/19820731201.
50. Mupangwa J, Lutaaya E, Shipandeni MNT, Kahumba A, Charamba V, Shiningavamwe KL. Utilising encroacher bush in animal feeding. In: Mupangwa J, editor. Towards sustainable food production in Africa: best management practices and technologies. Cham: Springer; 2023. p. 239–65.