

Adaptive foraging strategy and dietary selection of goats in the Malagasy southwestern xerophytic thickets.

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Abstract

Xerophytic thickets are key grazing areas supporting goat herds and local livelihoods in southwestern Madagascar. This study assessed forage consumption and dietary preferences of goats to evaluate ecological–livestock interactions in these fragile ecosystems. Research was conducted in Toliara II district at two contrasting sites—a coastal zone (Soalara-Sud—SS) and a limestone plateau (Andranohinaly—AND)—during the rainy season (March 2024) and dry seasons (July and September 2024). Methods combined forage accessibility plots, continuous bite monitoring, and near-infrared reflectance spectroscopy (NIRS) for chemical composition. Goat diets showed high species richness (163 species) but were dominated by fewer than ten core species per season. Plateau herds maintained mixed herbaceous–woody diets, while coastal herds favored shrubs and trees. Two species were strongly selected: *Heteropogon contortus* (AND) and *Solanum bumeliifolium* (SS). Nutritional quality was strongly influenced by plant species, season, and functional group (herbaceous vs. shrubs/trees) ($p < 0.001$), while geographical location had little effect ($p > 0.05$). The most affected parameters were dry matter digestibility, ash, neutral detergent fiber, crude protein, and fat, while metabolizable energy and acid detergent fiber were moderately influenced. Forage selectivity was the main structuring factor of the feeding behavior, with goats demonstrating adaptive strategies to seasonal constraints. Results highlight (i) strong seasonal plasticity in diets despite limited site differences, (ii) nutritional trade-offs shaped by digestibility–fiber–energy optimization, and (iii) the ecological role of key shrubs as nutritional buffers. These findings underscore the need for integrated ecological–nutritional–spatiotemporal approaches for the sustainable management of xerophytic grazing systems.

Key words: xerophytic thickets, southwestern Madagascar, goats, feeding behavior, NIRS, RGCCA.

INTRODUCTION

The xerophytic thickets (XT) of southwestern Madagascar are a unique terrestrial ecosystem, characterized by high endemism in flora and fauna (Burgess et al. 2004). Vegetation is mainly dominated by Didieraceae and Euphorbiaceae species (Cornet and Guillaumet 1976), thriving under an arid tropical climate with a short rainy season. These XT provide vital ecosystem services, supporting both food security and livestock forage in extensive production systems (Randriamalala and Hervé 2022). The sustainable management of XT faces growing environmental and anthropogenic pressures, posing a significant challenge of the reconciliation of ecological integrity and livelihoods of local populations (Rigden et al. 2024). In addition, rapid population growth (INSTAT 2020), combined with the loss of vegetation cover due to agricultural expansion and deforestation for charcoal production, has intensified this pressure (Raoliarivelo et al. 2010; Rabeniala et al. 2013; Brinckmann et al. 2014; Randriamalala and Randriamalala 2016). In semi-arid ecosystems, goats are sometimes associated with vegetation decline due to grazing (Säumel et al. 2011; Bermejo et al. 2012; Montez-Sánchez et al. 2021). Their selective feeding places considerable stress on certain shrubs, particularly during periods of scarcity (Wilson et al. 1976), though they exert relatively little influence on the broader composition of plant species in the grazed landscape (Hester et al. 2006).

Sustainable management of XT requires understanding interactions among plant communities, herbivores, and environmental factors. Despite extensive research on plant–herbivore interactions, the dietary selectivity of herbivores and its implications for plant biodiversity remain poorly documented. Previous research has mostly focused on large ruminants and fewer for goats (Feldt et al. 2017), as in the area, livestock farming practices vary according to the cultural and economic value attributed to different animal species. In the region, zebu cattle are culturally and economically prioritized (Hänke and Barkmann 2017),

receiving preferential fodder allocation during scarcity. In contrast, goats' browsing behavior, higher reproductive rates, broader diet, and resilience make them highly exploitable and adaptable to XT conditions, while providing social and economic security for local communities (Feldt et al. 2016). Hence with a specific and possibly more versatile feeding behavior knowing goats' favorite species in the XT of Southwestern Madagascar could unlock the key to a more sustainable management of those vegetation and reduce other forms of anthropogenic pressure.

To our knowledge, this leaves a critical gap in our understanding of the feeding preferences of small ruminants—particularly goats—and their role in the management of this fragile ecosystem. In this context, the present study aims to evaluate goat feeding preferences by examining the complex interactions among forage nutritional quality, forage accessibility, and feeding behavior. Specifically, the study investigates: (i) the composition and quantity of forage consumed by goats according to site, season, and plant functional groups; (ii) the nutritional profile of ingested forage relative to spatial, temporal, and plant functional characteristics; and (iii) how xerophytic conditions, forage quality, and resource accessibility shape goat foraging patterns. The findings of this study will support the development and refinement of goat husbandry practices in the region by providing essential insights into feeding preferences and their effects on vegetation structure.

METHODS

Study sites

The study was carried out in southwestern Madagascar, specifically in the District of Toliara II, encompassing two municipalities: Soalara Sud (23°35'00" S, 43°43'00" E) and Andranohinaly (23°16'60" S,

43°58'60" E). These sites were selected for their contrasting edaphic gradients: one site lies on a limestone plateau with a rocky substrate (Andranohinaly), while the other one (Soalara sud) is in a coastal zone characterized by two areas, a reddish sandy and a calcareous soils. Andranohinaly is dominated by herbaceous and shrubby layers, frequently affected by bush-fires, whereas Soalara Sud is composed of low, degraded thickets heavily impacted by charcoal production (Randriamalala et al. 2017). The region is marked by semi aridity, with a prolonged dry season extending from April to October. The rainy season typically lasts around five months, and the average annual rainfall is approximately 400 mm (Guyot 2002).

Small ruminant husbandry in these regions of Madagascar follows an extensive management system. According to our field surveys, the main distinction between the two study sites lies in herd management practices. On the plateau, animals graze under herder supervision, whereas on the coast, they roam freely after the enclosure is opened and instinctively return on their own. Additionally, animals are known to undertake nocturnal excursions during full moon nights, particularly in the rainy season (local assistant, goatherd).

Data collect

Experimental design

The study of animal–plant interactions was conducted in both sites, Andranohinaly and Soalara sud (in the reddish sandy soil), over three distinct periods of time: Rainy Season (RS, March 2024), Early Dry Season (EDS, July 2024) and Late Dry Season (LDS, September 2024). Goats from both study sites were observed while grazing during each period, and the plant species consumed were systematically recorded. Concurrently, the availability of forage accessible for grazing was assessed at each site every season.

Additionally, samples of the consumed plant species were collected and analyzed with NIRS to evaluate their nutritional composition.

Measurement of accessible forage

Given the diversity of plant categories present in the vegetation—herbaceous species (grasses, forbs, and legumes), shrubs, and trees—an embedded quadrat sampling method was applied (Chebli et al. 2017). A destructive sampling approach was also used to quantify the biomass of accessible forage at each site per season. A total of forty subplots of 1 x 1 m² were randomly delineated within 10 x 40 m in goat grazing areas. Edible and accessible vegetation for goats—generally up to 1.50 m in height, or higher in the case of *Solanum bumeliifolium*, plant that goats cut the stem to consume the leaves on the top—was harvested, dried and weighed. Biomass of the accessible forage (Biom_access), relative frequency (Fqce_rel) and relative abundance (Abce_rel) were calculated.

Measurement of Forage Intake

A combination of direct visual observation and the Continuous Bite Monitoring method (Bonnet et al. 2015; Chebli et al. 2020) was employed to obtain forage intake data of grazing. Three adults female goats were monitored at each site, during active grazing periods, and the forage species consumed were recorded during the primary feeding times of the day (Bourbouze 1981). Observations were carried out over three consecutive days per season and per site (Feldt et al. 2017). Prior to data collection, a habituation phase to the presence of observers was conducted (Meuret and Provenza 2015). The counting of the number of bites per species *i* (NB_i) with the number of minutes spent on that species allowed to calculate the Bite Rate (BR). The consumed forage mass was calculated from this bite rate by measuring the bite mass (BM) using the

hand-plucking method on a daily basis, which replicates the foraging behavior of grazing animals (Halls 1954; Randrianariveloseheno et al. 2015; Chebli et al. 2020). For this purpose, 100 bites from the consumed plant species were collected (Bonnet et al. 2011). Several variables were calculated from the bite samplings, including the intake rate (IR), daily intake (DI), diet composition (DC), and diet selectivity (Si) of the goats.

The estimation of the average daily intake (DI) was calculated based on the average intake per minute (IR, g DM min⁻¹) derived from the sampling:

$$IR = BR \times BM \quad [1]$$

IR was then multiplied by the grazing time *t* (time spent in minute per day of the research of forage), following the formula adapted by Hodgson (1990) :

$$DI = IR \times t \quad [2]$$

The proportion of species *i* in the diet (%), where Diet Composition (DC_{*i*}) represents the dry biomass proportion of species *i* in the diet (El Aïch et al. 2007; Manousidis et al. 2016; Chebli et al. 2022):

$$DC_i = (BR_i \times BM_i) / \sum_{i=1}^n (BR \times BM) \quad [3]$$

The index of Ivlev was used and was represented by values between -1 and +1. A value approaching +1 indicates higher selectivity for the species, while a value approaching -1 indicates strong avoidance (Manousidis et al. 2016; Chebli et al. 2022):

$$Si = (DC_i - p_i) / (DC_i + p_i) \quad [4]$$

Where, *p_i* represents the percentage of species *i* in the grazed vegetation.

To make a better view to the analysis, plant species that individually contributed more than 20% to the diet, based on the percentage of bites taken of most consumed species and collectively accounted for over 50% of total intake, were considered.

Analysis of forage quality

Dry samples were oven-dried at 60°C for 72 h, ground to 1 mm, and analyzed by near-infrared spectroscopy (NIRS) using a Labspec 4 Std-Res spectrometer. Chemical composition, digestibility (Fanchone et al. 2009; Chebli et al. 2022), and metabolizable energy were determined with IndicoPro (v6.5) and prediction models from the Animal Nutrition Chemistry Laboratory, Ampandrianomby, Antananarivo, Madagascar.

They allow the characterization of the content in crude fiber content and parietal components such as Neutral Detergent Fiber (NDF), and Acid Detergent Fiber (ADF), as well as the digestibility of the dry matter (DMD). Other components considered included ash content (ASH), crude protein (CP), and fat content (FAT). Metabolizable energy (ME) was calculated from the percentage of Neutral Detergent Fiber (NDF) and crude protein (CP) for each species using the formula developed by the Noziere et al. (2018):

$$ME = 12.5 - 0.075 \times NDF + 0.12 \times CP \text{ [5]}$$

Where, ME : metabolizable energy (MJ kg⁻¹ DM).

Statistical Analyses

The effects of each factor on forage accessibility were assessed using permutation tests (lmPerm package), permuting factor levels while preserving experimental group structure. Normality was checked with the

Shapiro-Wilk test. A linear model analyzed Site–Season interaction effects on intake parameters and estimated daily intake, while generalized linear mixed models examined the main effects of site, season, and plant group on nutritional components. Analyses were conducted in R (v4.4.3).

Multivariate relationships among ecological factors, forage nutritional quality, accessibility, and goat feeding behavior were explored using Regularized Generalized Canonical Correlation Analysis (RGCCA; Tenenhaus and Tenenhaus 2011, 2014) via the RGCCA R package. Four blocks were defined: ecological factors (Site, Season, Plant_group), nutritional quality (ADF, ASH, NDF, DMD, CP, FAT, ME), forage accessibility (Biom_access, Fqce_rel, Abce_rel), and feeding behavior (BR, BM, DCi, Si). The Si variable was exponentially transformed (Si_exp) due to negative selectivity values. Categorical ecological variables were handled using full disjunction, while other blocks contained continuous data. The intake block served as the response. Cross-validation determined the regularization parameter τ , and a 10,000-iteration permutation test assessed group differences and model robustness. Canonical weights indicated each variable's contribution to the principal axes, with positive values have a constructive influence on the corresponding axis, whereas those with negative values exert a negative influence. The most influential variables were key in explaining feeding behavior. Cos^2 scores of individuals identified the most selected and consumed species and their associated nutritional quality.

RESULTS

Grazing accessible forage

Seasonal effects on forage accessibility were statistically significant ($p < 0.001$), with substantially higher values observed during the EDS and the RS compared to the LDS, but less pronounced for sites ($p < 0.01$).

Herbaceous plants showed greater accessibility compared to woody plants particularly in the plateau site ($p < 0.01$) (Fig. 1).

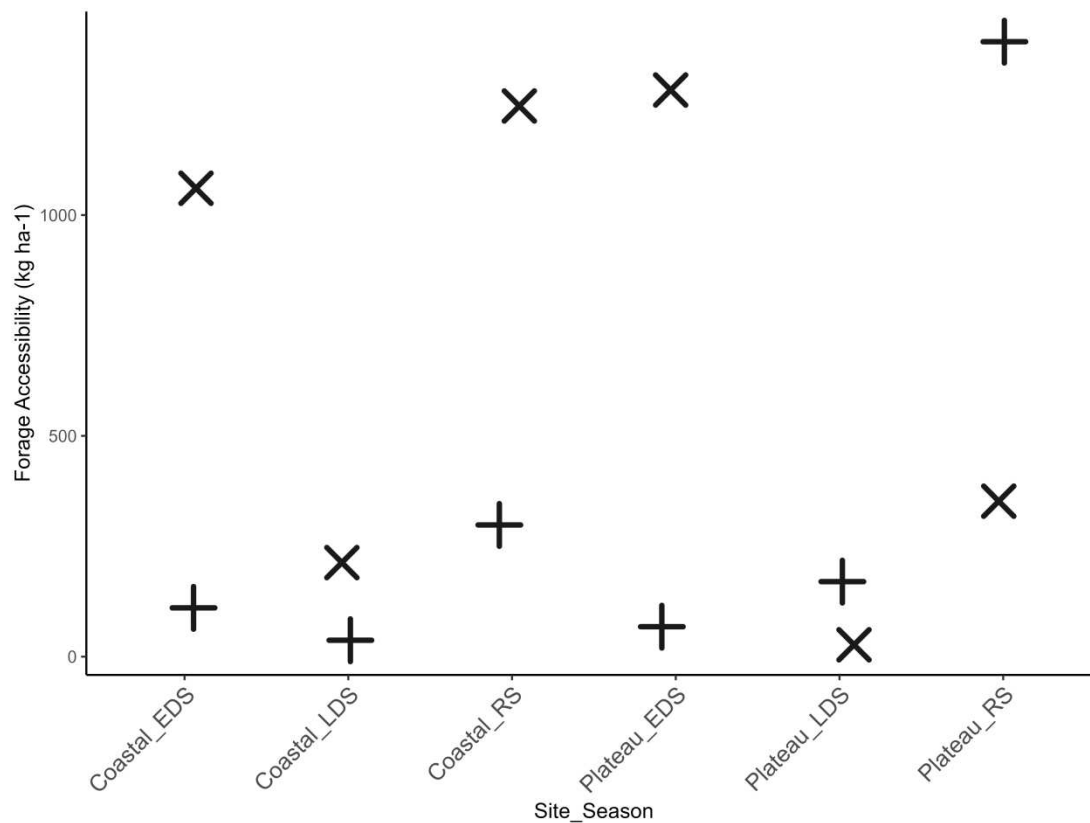


Fig.1 Forage accessibility according to sites and seasons

Forage Intake

Dietary analysis revealed a substantial diversity of plant species in goat diets, encompassing approximately 163 species across all seasons, belonging to 39 families, with 99 species recorded on the plateau site and 88 on the coastal site, with 24 common species. However, the diet was dominated by a limited number of species, with fewer than ten species representing the core dietary components. At Andranohinaly, the goats consumed herbaceous and shrub_tree species in nearly equal proportions across all seasons. In contrast, at

Soalara sud, shrub_tree species consistently dominated the diet, representing over 70% of the total forage intake throughout all seasons.

Season, plant species consumed, and the interaction Site_Season had significant effects on ingestion parameters ($p < 0.01$). In contrast, the site effect was significant for all variables except for diet composition ($p > 0.05$). Additionally, categorizing plant species by growth form (herbaceous vs. woody, including shrubs and trees) significantly influenced all ingestion parameters, except the selectivity index ($p > 0.05$). The selectivity index was -0.9 for almost all species, except in the dry season with *Heteropogon contortus* on the plateau and the fruits of *Solanum bumeliifolium* on the coastal, which showed that they were the most selected plants at a level of 1 (Table A1).

In addition, both Site and Season had statistically significant effects on daily intake variation, and the interaction between them was also highly pronounced ($p < 0.001$) (Table 1).

Table 1. Estimated of mean daily intake per site and season with their standard error

Site	Season	Estimated Daily intake (g DM)	Standard error
Plateau	LDS	1431.667	371.667
	EDS	1404.333	252.000
	RS	1706.000	160.767
Coastal	LDS	557.333	103.900
	EDS	2551.333	532.000
	RS	744.000	304.333
<i>P_value</i>			
Site		< 0.05	
Season		< 0.001	
Site × Season		< 0.001	

RS : Rainy Season, EDS : Early Dry Season, LDS : Late Dry Season.

Forage quality

The analysis revealed that species exerted a strong effect on all nutritional parameters ($p < 0.001$) (Table 2).

Seasonal variation was a major determinant of forage quality ($p < 0.001$), although its influence on fat was only marginal ($p < 0.1$). Plant group accounted for variation in ME, ADF, ASH, and NDF ($p < 0.001$), but showed no effect on digestibility, protein, or fat. The site–season interaction was a key driver of digestibility and ME ($p < 0.001$), while contributing less to other variables. The season–plant group interaction played a central role in digestibility, ADF, ASH, and NDF ($p < 0.001$), but had no effect on fat. The three-way interaction was particularly important for digestibility and ASH ($p < 0.001$), moderate for most other traits, and negligible for fat.

Table 2. Average proportion and standard deviations of nutritional components in goat forages from xerophytic shrubland in southwestern Madagascar.

Site	Season	Plant_group	DMD	ME	ADF	ASH	NDF	CP	FAT
Plateau	RS	herb	54,547 ±9,689	9,934± 1,151	35,342 ±2,205	10,783 ±2,693	55,919 ±8,831	13,566 ±4,517	3,363±1,6 86
		shbs_tr	66,865 ±6,872	11,657 ± 0,654	34,036 ±2,065	10,597 ±1,931	43,842 ±4,604	20,373 ±3,372	3,371± 1,489
	EDS	herb	52,722 ±14,16 2	10,022 ±1,675	34,720 ±4,872	9,937± 3,047	55,421 ±12,09 8	13,987 ±6,612	3,064±0,7 71
		shbs_tr	64,605 ±11,13 8	11,674 ±1,217	33,310 ±6,066	8,812± 4,475	44,417 ±8,498	20,875 ±5,110	2,509±1,1 06
	LDS	herb	50,779 ±11,11 9	9,689± 1,362	33,880 ±4,268	10,265 ±4,015	59,282 ±9,669	13,627 ±5,595	6,883±1,2 36

		shbs_tr	60,566 ±9,915	11,060 ±1,000	33,868 ±6,025	9,041± 3,274	47,204 ±9,001	17,501 ±4,569	7,127±2,2 64
Coastal	RS	herb	62,301 ±11,329	10,635 ±1,206	33,750 ±3,341	11,569 ±3,067	50,041 ±9,179	15,733 ±4,624	4,273±2,6 20
		shbs_tr	67,766 ±8,971	11,609 ±0,650	31,720 ±4,655	12,141 ±2,215	44,003 ±6,529	20,074 ±1,915	3,425±1,2 64
	EDS	herb	48,835 ±8,544	9,912± 0,940	35,059 ±5,750	8,696± 2,406	56,794 ±6,126	13,931 ±5,207	3,262±1,1 91
		shbs_tr	58,574 ±12,919	11,011 ±1,095	35,418 ±6,533	9,605± 3,555	49,410 ±9,047	18,475 ±4,289	4,226±1,6 71
	LDS	herb	40,541 ±13,524	9,240± 0,899	40,299 ±5,724	6,321± 3,964	60,399 ±8,388	10,583 ±3,636	6,499±1,8 84
		shbs_tr	59,170 ±12,661	10,628 ±1,171	34,475 ±3,986	10,465 ±3,260	52,559 ±9,132	17,252 ±5,583	10,263±2, 855

P_value

Site	< 0.05	ns	ns	< 0.05	ns	ns	ns
Season	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Plant_group	< 0.001	< 0.001	ns	.	< 0.001	< 0.001	< 0.001
Site×Season	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01
Site×Plant_group	ns	< 0.05	.	< 0.01	< 0.05	.	< 0.001

Season×Plant_group	< 0.001	ns	< 0.001	< 0.001	ns	< 0.01	< 0.001
Site×Season×Plant_group	< 0.001	.	< 0.001	< 0.001	ns	< 0.001	< 0.001

Plant_group: plant functional group, herb : herbaceous, shbs_tr : shrubs_tree, ADF:acid detergent fiber, NDF:neutral detergent fiber, DMD:digestibility of dry matter, ME:metabolizable energy, FAT:fat content, CP:protein content, ASH:ash content, RS:Rainy season, EDS:Early dry season, LDS: Late dry season, ns: not significant.

Specifically, the plateau site supports a broader diversity of herbaceous species with moderate fiber and protein levels, whereas the coastal area, especially during the dry season, offers species with markedly higher protein and fat contents (Table A2). Shrubs and trees species exhibited higher DMD, particularly during the dry season. The ME levels were highest in certain coastal herbaceous species, such as the Convolvulaceae named as “Lailelamotro” and *Sesuvium portulacastrum*. Protein content varied widely, reaching elevated levels in species such as *Heliotropium* sp. (species. singular), *Paederia grandidieri*. and fruits of *Solanum bumeliifolium* Dunal (“Hazonosy”). NDF was higher in herbaceous species, especially *Heteropogon contortus*. Lignin content remained high in some species, such as *Heliotropium* sp. (species, singular), potentially reducing digestibility. Notably, FAT was pronounced at the coastal site, particularly in *Solanum bumeliifolium* and its fruits, during the dry season.

Relationship between goat consumption and environmental factors

Intake variables, nutritional quality, and grazing-accessible forage contributed most substantially, accounting for 61.4%, 71.9%, and 76.1% of the explained variance, respectively. In contrast, the ecological factor block was the least represented in the model, explaining only 25.6% variance (Fig 2).

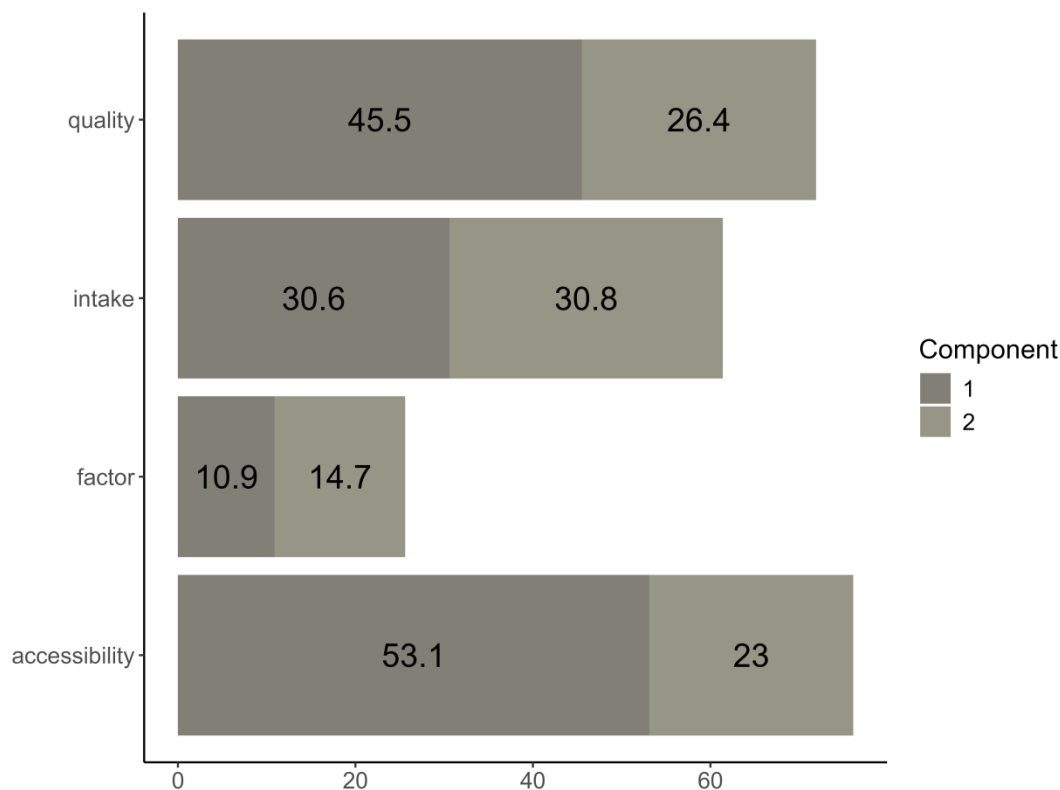


Fig.2 Corrected average of explained variance for each block

The 10000 iterations test of the model by RGCCA revealed highly significant results ($p < 0.001$). Furthermore, the dietary selection (Si_exp) is primarily influenced by the effects of other variable blocks, highlighting dietary selection as a central factor structuring the data, which was negatively loaded (Fig 3). In this study, most variables contributed significantly to the variation in feeding behavior of goats. The strongest positive influence was observed for the accessibility block, which represents accessible forage, measured as the relative frequency of accessible forage species. The block of nutritional quality variables,

including FAT, ME, and DMD, also had positive effects on forage selectivity, whereas NDF had a negative influence. The other variables exerting a more moderate effect on goat feeding behavior showed limited variation along the main axes and contributed less significantly to the data structure.

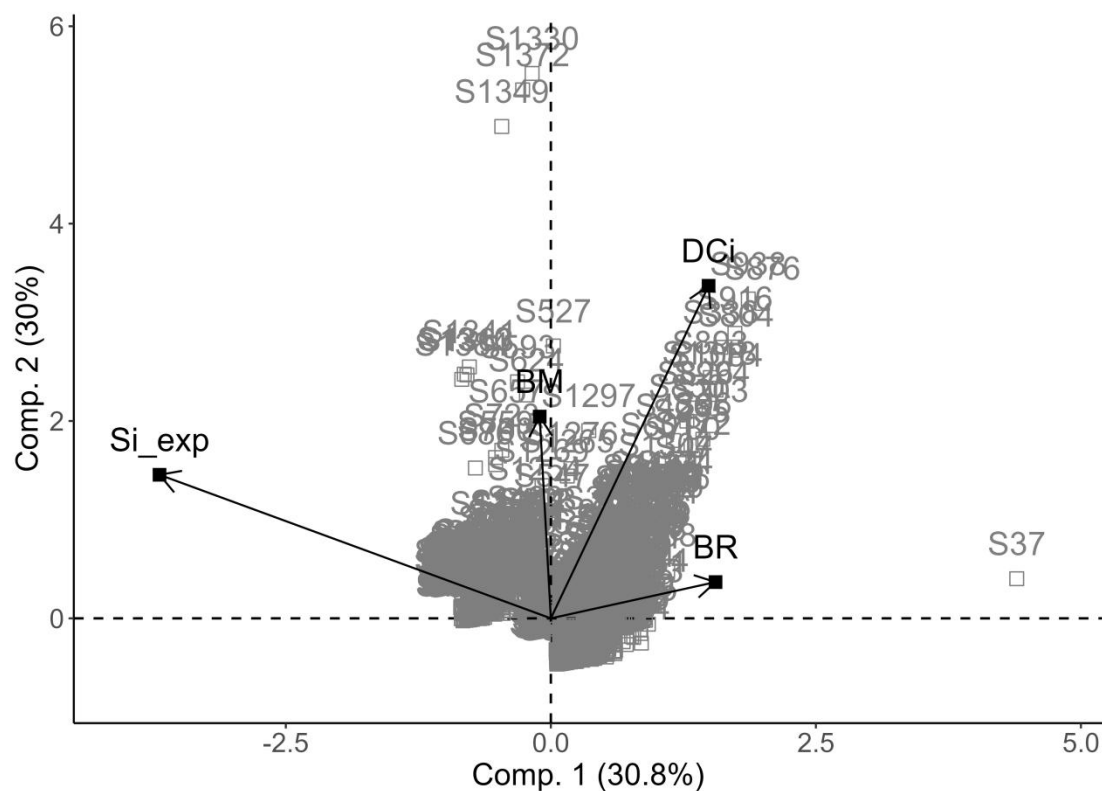


Fig.3 Biplot of the intake block

Generally, goat forage selectivity varied across seasons and plant groups. Herbaceous plants were associated with a decrease in the selectivity index (Si) in the dry season, whereas shrub and tree species showed stronger selection preferences during the rainy and early dry seasons. Similarly, herbaceous plants were not selected based on their type or functional group; rather, their consumption was primarily driven by their high relative frequency in the grazing area ($p < 0.001$). When these species were frequent in the pasture, goat forage selectivity tended to decrease. Moreover, goat dietary selectivity varied according to

the nutritional characteristics of the consumed species. Increases in DMD, ME, and FAT were generally associated with reduced selectivity, whereas NDF showed the opposite effect.

Discussion

Grazing-accessible forage, intake parameters, quality of intake forages within the feeding behavior of goats

The results indicate that both forage accessibility and quality are key determinants of goat feeding behavior, which interact closely with local ecological constraints and seasonal variability. Soil structural differences, particularly sandy and calcareous substrates with low water retention, explain the contrasting vegetation between the plateau, which is characterized by low savanna-like thickets, and the coastal zone, which is dominated by degraded thickets with strong xerophytic adaptations (Gaspard et al. 2018). However, XT recover slowly after slash-and-burn, with structural attributes such as height and basal area improving over time, while floristic diversity and herbaceous cover remain limited (Randriarimalala and Randriamalala 2016; Randriarimalala et al. 2019). The XT at AND probably represent a degraded form of those in SS, due to anthropogenic pressures including slash-and-burn agriculture and charcoal production. It is known that even after abandonment, recolonization by woody species is slow and often hindered by repeated disturbances (Bond et al. 2005; Rakotoarimanana and Grouzis. 2006; Oliveras and Malhi 2016).

Despite consuming a wide array of species, goats focus on fewer than ten key species, with a seasonal shift from herbaceous plants in the rainy season to a greater reliance on shrubs and trees in the dry season (Papachristou et al. 2005; Feldt et al. 2017), which aligns with typical ruminant adaptations in semi-arid regions (Chebli et al. 2022; Ferreira et al. 2024) but opposed the study of Randriamalala et al. (2022) in

Soalara sud, with no significant effect of the season. Bite rates are modulated by vegetation composition, increasing in areas with easily accessible forage and decreasing in shrub-dominated areas (Chebli et al. 2022). In the late dry season, goats increasingly exploit alternative resources, such as fruits and woody leaves, a strategy previously reported by Animut et al. (2005). Species such as *Heteropogon contortus*, *Solanum bumeliifolium*, and *Cenchrus ciliaris* are central to the diet throughout the year (Feldt et al. 2017; Villalobos et al. 2025). Maximum intake varied by site, peaking on the plateau during the RS and in the coastal at EDS. The unexpected reduction in coastal intake during the rains may reflect increased nocturnal grazing, as reported by local herders.

Forage quality closely follows the seasonal patterns. Dry-season water stress increases lignification, reducing digestibility and increasing fiber content (Yayneshtet et al. 2009), whereas the rainy season promotes protein-rich vegetative growth (Ammar et al. 2004). This drives spatial and temporal variation in diets: on the plateau, protein-rich shrubs such as *Paederia grandidieri* provide nutritional compensation during dry periods, whereas coastal goats rely on halophytic species and the energy-rich fruits of *Solanum bumeliifolium*. Shrubs also contribute essential minerals, as suggested by their higher ash content, although soil contamination may inflate the values of some herbaceous plants (Birnin-Yauri et al. 2011). Improved forage quality during the rainy season allows goats to meet their nutritional requirements more efficiently (Cellier et al. 2021). However, human-induced fires (slash-and-burn and bush-fire) represent a major disturbance, reducing soil organic matter and porosity, limiting water retention, and compromising post-fire regrowth quality (Kitzberger et al. 2005; Murphy et al. 2018).

According to the RGCCA, while spatial accessibility indirectly influences intake, nutritional quality variables are the primary drivers of feeding behavior. Species frequency predicts consumption levels, but

digestibility and fiber content dictate selectivity (Baumont et al. 2000); goats preferentially consume digestible, energy-rich species when available (Cellier et al. 2021), whereas high fiber content induces more selective feeding, as seen for *Heteropogon contortus*, *Panicum pseudowoeltzkowii*, and *Cenchrus ciliaris*. Some species, including *Paederia grevei* and the locally known “Entinenty”, are consistently consumed with low selectivity, suggesting their role as preferred fallback resources. Others, such as *Heliotropium* sp., *Combretum grandidieri*, and *Solanum bumeliifolium*, are consumed even during the dry season, regardless of nutritional quality or accessibility, implying additional factors, such as taste, medicinal properties, or tannin content, that warrant further investigation. Moreover, a better understanding of dietary selectivity in extensive livestock systems will improve knowledge of local feeding strategies (Zampaligre and Schlecht 2017). Goats adaptively shift their diet from selective browsing on shrubs during wet periods to more opportunistic grazing on herbaceous plants during the dry season, thereby maintaining their intake despite fluctuations in forage availability and quality.

Methodology limit

In this study, only the organic fraction was analyzed using near-infrared reflectance spectroscopy (NIRS). Similarly, tannins, which play a major role in goat forage selectivity, were not quantified because of the lack of laboratories in Madagascar capable of measuring their concentrations. However, tannins are known to influence forage digestibility (Frutos et al. 2004) and feeding selectivity (Malechek and Provenza. 1981), and could offer deeper insights into the dietary preferences of goats in their grazing environments. Despite these limitations, near-infrared spectrometry remains a rapid technique for assessing forage quality (Barotin et al. 2021).

The relationships between variables were interpreted cautiously due to statistical regularization. Parameters were adjusted following the recommendations of Tenenhaus and Tenenhaus (2014) for multi-group data analysis to optimize data representation and minimize noise, while preserving block correlations to capture key drivers of goat feeding behavior.

Impaction for goat breeding and xerophytic ecosystem in the southwestern Madagascar

To conclude, this study explores the links between forage quality, accessibility, and goat feeding behavior in the xerophytic shrubland of southwestern Madagascar. The methods, though improvable, revealed seasonal variations, differences among plant functional groups, and site representativeness. RGCCA highlighted complex parameter relationships, confirming the role of nutritional quality in dietary selectivity. Some species, both nutritious and accessible year-round, emerged as promising forage sources. The findings also show goats' adaptive strategies, particularly reliance on shrubs during scarcity. The results emphasize conserving key shrubs, managing rangeland not only for forage quality but especially for accessibility, and fostering shrub regeneration and heterogeneity. They also call for considering factors such as herd management, physiological state, and genetics. Restoring xerophytic thickets and prioritizing high-value species appear crucial for goat productivity and ecosystem resilience in arid regions.

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Statements and declarations

Competing Interests

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Contributions

1. **Mbolatiana Fiononantsoa Ranaivoharivelo** : Conceptualization - Investigation - Data curation - Methodology - Formal analysis - Software - Writing Original draft - Visualization.
2. **Jérôme Bindelle** : Conceptualization. Visualization - Writing - Reviewing and Editing. Supervision.
3. **Isabelle Herisoa Hantanirina** : Writing - Reviewing and Editing - Supervision.
4. **Josoa Ramarolanonana Randriamalala** : Writing - Reviewing and Editing.
5. **Arsène Jules Mbolatianarizao Randrianariveloseheno** : Conceptualization - Reviewing.
6. **Nicolas Jungblut** : Investigation - Data curation.
7. **Simon Leclerq** : Investigation - Data curation.
8. **Olivia Lovanirina Rakotondrasoa** : Project administration - Funding acquisition.

Data available

Data are not publicly available as they remain the property of the project, but can be obtained from the corresponding author for legitimate research purposes upon reasonable request.

Ethics approval

The use of animals was authorized by the ethics committee of Liège University (protocol 2116, 27/05/2019).

Conflict of interest

The authors declare that they have no conflict of interest.

Figure captions

Fig.1 Forage accessibility in both sites seasonally and between plant functional group.

Coastal_EDS: Coastal Early dry season

Coastal_LDS: Coastal Late dry season

Coastal_RS: Rainy season

Plateau_EDS: Plateau Early dry season

Plateau_LDS: Plateau Late dry season

Plateau_RS: Plateau Rainy season

+: herbaceous

×: shrubs_trees

Fig.2 Corrected average of explained variance

Comp. 1: Component 1

Comp. 2: Component 2

Fig.3 Biplot of the intake block.

Comp. 1: Component 1

Comp. 2: Component 2

Si_exp: Exponential of the selectivity

BM: Bite mass

DCi: Diet composition of the species i

NB: Number of bites

S: species

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [TableA1.xlsx](#)
- [TableA2.xlsx](#)
- [TableA3.xlsx](#)