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Review Article

Fodder Availability and Goat Foraging Behaviour in Rangeland of High Catchment Zone of Mandrare in Southern of Madagascar

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ABSTRACT

Forage resources have been assessed with goats in the High Catchment zone of Mandrare in Southern Madagascar. Floristic component, nutritive value of fodder species and goat foraging behaviour have been determined by sampling areas, monitoring, recording, calculating and analysing some parameters floristic index and foraging rhythms. Using one ram, two castrated goats and three ewes, foraging behaviours were examined by sequential recording during two periods (end of dry season and end of wet season). Using Principal Component Analysis, four pasturelands were identified with dominant browse species: *Acacia farnesiana*, *Poupartia caffra*, *Kigelianthe madagascariensis* and *Rhigozum madagascariense*. Their floristic aspect have been characterized a higher heterogeneity formation (1.04 ± 0.07) and Shannon – Weaver Index (0.18 to 0.95; $p < 0.05$) and lower pasture value have been recorded (19.14 ± 4.81 %; $p<0.05$). *Acacia farnesiana* rangeland has been dominated by shrubs with the highest pasture value and involved in better goat foraging behaviour. Most of the 43 identified species were available dominated by browses species with 12% spines species, a higher bite rate, best pasture and nutritive value have been mentioned in low lands. In fact, the relationships between phytosociology and nutritional parameters allow for improvement of range management and native rangeland restoration.

Keywords: browse, pasture value, foraging, goat, Madagascar.

INTRODUCTION

Pastureland represents an unstable ecological system which has been involved in biotic and biotic disturbance with direct dynamism. The relationships between the three components of plant, animal and environment determine the available production according to two function levels: primary (forage resource) and secondary production (animal production). Consequently, plant and animal are subject to forage resources available, both quantitative and qualitative, especially for ruminants (Toutain and Rasambainarivo, 1997). Primary production corresponds to biological structure of the vegetation such as total biomass and available resources. Vegetation resources are determined by canopy cover particularly for woody plants

species as mentioned by Ichowicz in Bellefontaine *et al*., (1997). The total biomass production depends on environmental parameters such as climatic factors, pedological structure and anthropological activities. The primary production is characterized by dry matter production which is determinate by agroclimatic conditions and especially fires action. The high temperature of fire decreases the forage availability (Granier *et al*., 1968). In side of secondary production, the exploitable biomass equivalent to browse forage quantity has been estimated by canopy structure and biomass accessibility by herbivores species. The exploitation rate varies between animal species such as a height of 1.2 metres equivalent to 25% of biomass accessible for small ruminants and below a height of 2 metres equivalent to 50% of biomass for large stock (Daget and Djellouli, 2002). Consequently, foraging behaviour is determined by biomass forage availability in pasturelands, (Meuret 1997; Delagarde *et al*., 2001) and environment and vegetation (Balent and Gibon, 1985; Bolibaker, 1989). Mentioned by Letouzey (1997), the floristic association between herbaceous and woody strata determines the rangeland type. Vegetation toposequential profiles are determined by the physiognomic structure and ecological conditions (Boudet *et al*., 1989). Most forage resources are exploited by herbivores in extensive management systems (Gilbert *et al*., 1968 and ILCA, 1975). In nutritional behaviour studies for Ruminants, many systemic and analytic methods have been considered in herbivores' digestive processes (Van Soest, 1982).

In Madagascar, two dominant vegetation types are identified as follow as 42,000,000 hectares characterized by low cover and 17,000,000 hectares by high cover and secondary vegetation. Grassland and rangeland ecosystems represent an important vegetation type covering 34,000,000 hectares such as 70 % of the vegetation of Madagascar. In southern region, vegetation profile is characterized by xerophyllous families such as Didieraceae and Euphorbiaceae (Cabanis, Cabanis, and Charbouls, 1969). These floristic structures come from some edaphic formation. The native rangelands consist of shrubs and tree species (Koechlin *et al*., 1974). In southern of Madagascar, livestock activities have an important place in the culture value of society and in economic activities for smallholders. The small ruminants number has been with 90 % of the national smallstock flock such as 900,000 heads of goats and 1,300,000 heads of sheep.

According to Jamenson and Hodgson (1979), two processes have been found such as an asymptotic relationship between fodder mass and intake (fodder density) and a quadratic relationship between plant height and intake rate (bites). The aim of this study was to describe the relationships between the phytosociological conditions and to assess goat foraging activities in Ebelo-South Ambosary. In sub arid zone, there is a need to determine the impact of Ruminant foraging behaviour on the vegetation and the managing of the degraded environment for pastureland rehabilitation and for sustainable development.

MATERIALS AND METHODS

Study Site

The region of Ebelo-South Amboasary is located 1,200 kilometers from the Capital at 24˚ 29' 0" South and 46˚ 2' 0" East. This agroecological zone is implied in an intervention zone for agriculture development by a program managed by International Fund for Agriculture Development (IFAD). In superficial area of 300 km², this agro-ecological zone is dominated by native faming system of livestock such as cattle, sheep and goats (PHBM, 2000). Situated between 105 and 350 m of altitude, the study site is surrounded with mountainous chain of Vohitsombe at 904 m. In point view of geomorphology, the cretaceous region contains two dominant geological types with volcanic massif of the Androy such as basaltic streams and rhyolitic streams. The

pedological formations are characterized by four edaphic categories such as complex lithosols and lower evolved soils from volcanic rocks; complex ferruginous soils; tropical ferruginous soils and low evolved soils and alluvial hydromorphic soils. In climatic aspect, the study area is involved in a dry and subarid zone with annual mean temperatures between 15.6˚C and 28.3°C and annual rainfall between 600 and 800 mm (Besairie, 1972; Benzarti and Habaied, 2001; Bergaoui and Alouni, 2001).

Vegetation Parameters

Characteristic vegetation has been assessed by superficial monitoring within quadrants of 400 m^2 size repeated in order to four or six places in function of pastureland type. Measuring the vegetation allows analysis of observed parameters such as vegetation cover, floristic density, species diversity, phenological state and abundance, dominance and species probability mentioned by Burel and Baudry (2000) and calculated parameters such as Shannon-Weaver index, diversity index and pasture value.

The Shannon-Weaver index (H) was determinate by a combination of the floristic and ecological structures as follows:

$$H = -\sum_{i=1}^{n} CS_i \log CS_i$$

The maximum diversity corresponds to the floristic richness with regard to total number of each plant species (S). The maximum diversity was calculated as:

$$H' = \log S$$

Among others, calculated parameters depend on specific quality index which is implied in specific abundance, bite rate and nutritive value. And the pastoral value was calculated as follows:

$$PV = \frac{1}{SI_{max}} \times \sum SC_i \times SI_i$$

With:

• SI_m: maximum specific index in the permanent phytomass;

• SI_i: specific quality index of plant i;

• SC_i : Specific Contribution of plant species i in rangeland pasture;

The specific quality index was calculated with the intake level throughout the palatability index (I_P) and the relative nutritive value of edible forage (I_e).

Foraging Behaviour Analysis

According to mix composition of herd, a local smallholder has been selected to ruminant foraging for choosing six adults goats as follows: one ram, two castrated goats and three ewes. During six successive days at two foraging periods (Period 1 during end of dry season and Period 2 during end of wet season), foraging behaviour have been observed during five minutes per animal every thirty minutes at the dominant foraging moment (from 08:30 to 11:00 and from 13:00 to 15:30). Goat foraging behaviour have been considered by pasture activities such as browsing, ruminating, moving or resting mentioned by Bourbouze (1981), Le Houérou (1980) and Meuret *et al*., (1985). During foraging, plant species intake and bite number were recorded and analyzed in native pastureland.

Analyzing Nutritional Value

During monitoring of goat foraging behaviour, intake fodder species were sampled for estimating the chemical composition. During sampling, leaf and pod in order to 1000 g fresh weight plants fodder were prepared with grinding after over drying at 60˚C during 72 hours and kept until process analysis. According to process analysis by AOAC (1980), all chemical analysis were based by gravimetric methods to determine nutritional contents such as dry matter by over drying process with 103 ± 1˚C during at least 4 hours; mineral matter content by incineration about 650˚C during at least 3 hours; total nitrogen by Kjeldhal method; the Weende crude fiber content and Van Soest fractions such as Neutral Detergent

Fiber by fibertec analysis and gross energy content by adiabatic calorimetry analysis.

Statistical Analysis

In pastureland types, two recorded data have been involved in statistic processing. Floristic parameters such as floristic composition, Shannon-Weaver index, maximum diversity and pasture value) and goat foraging behaviour such as foraging rhythms, bites rate and chemical composition data groups have been treated statistically using software statistical analysis (Statitcf, XLStat 6.0) The data have been subjected to analysis of variance (ANOVA) tests for estimating the significant difference between variables or individual data. Principal Component Analysis (PCA) has been used to classify the rangeland types according to floristic composition.

RESULTS AND DISCUSSIONS

Rangeland Types

In pastoral areas with different altitude, the rangeland vegetation have been compound by shrub species with 43 identified plants. The floristic composition has considered 12% of spinescent species which have adapted from physiological and climatic parameters. Using Principal Component Analysis (PCA) with biophysical and floristic parameters, four pastureland groups have been distinguished according to altitude, biophysic aspect parameters and dominance of browse species such as *Acacia farnesiana*, *Poupartia caffra*, *Kigelianthe madagascariensis* and *Rhigozum madagascariense* (table 1).

Table 1: Pastureland type in function of floristic composition

Pastureland group	Floristic composition
Acacia farnesiana	*Acacia farnesiana, Adina microcephala, Ficus coccifolia, Physenia sessiflora Antidesma madagascariensis, Mangifera indica, Secamone elliotti, Tamarindus indica, Salvadora angustifolia, Leucaena leucocephala, Mimosa delicatula, Panicum maximum, Hyparrhenia rufa, Terminalia boivini.*
Poupartia caffra and *Kigelianthe madagascariensis*	*Poupartia caffra, Kigelianthe madagascariensis, Ziziphus mauritiana, Secamone elliotti, Gonocrypta grevei, Albizzia boivini, Grewia lavanalensis, Grewia romboïdea, Azina tetracantha, Alluaudia procera, Didiera grandidieri, Flacourtia indica, Cedrelopsis grevei.*
Poupartia caffra and *Tamarindus indica*	*Poupartia caffra, Tamarindus indica, Adina microcephala, Ziziphus spina christa, Maerua nuda, Apoxylon madagascariensis, Poivrea coccinea, Tridax procumbans, Opuntia ficus indica, Albizzia polyphylla.*
Rhigozum madagascariensis.	*Rhigozum madagascariensis, Ziziphus mauritiana, Kigelianthe madagascariensis,Grewei romboîdae, Asparagus shumanianus, Opuntia ficus indica, Mangifera indica, Acacia delicatula, Grewia grevei, Thilachium pouponii, Gymnosporia divaricata, Cedrelopsis grevei, Ziziphus mauritiana, Alluaudia procera, Diospyros tropophylla, Terminalia boivini.*

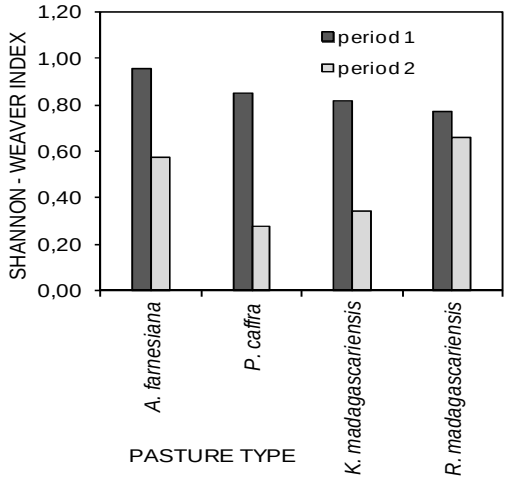

Figure 1: Shannon - Weaver diversity index variations in four pasture types

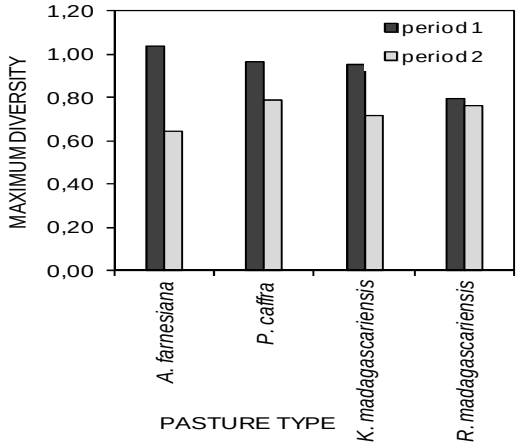

Figure 2: Maximum diversity of pastureland type in two periods

In these pastureland, floristic density has been involved in high significant different with 329±127 plants per hectare ($p<0.05$). The rangeland environment has a high floristic richness. Floristic variation depends on altitude and favourable edaphic conditions for improved physiological adaptation according to Cabanis *et al*., (1969); Koechlin *et al*., (1974) and Le Houérou (1980). Compared with results found by Akpo *et al*., (2002), floristic composition and pasture value have been lower than herbaceous vegetation in lying fallows such as 97 herbaceous species distributed in 35 Grass families represented by Poaceae with 27 per cent and Fabaceae with 27 percent.

Shannon - Weaver Index

In the four pastureland types, the relationship between altitude and floristic diversity results in high plant density and heterogeneity at lower altitudes. Following the environmental conditions, Shannon – Weaver Index has been implied in significant different with 0.18 to 0.95 ($p<0.05$). Humidity parameter increases the variation in Shannon – Weaver Index during the end of wet season (Period 1, see Figure 1).

As mentioned, the browse pasture shows a lower value of heterogeneity using the Shannon – Weaver index compared to the results (2.80 to 3.48) found by Rakotoarimanana (2002) in the savannah pasture zone in the South West of Madagascar, where the local conditions are more favourable (humidity and soils in particular). Our results indicate the poorer quality of the browse vegetation.

Maximum Diversity

Biophysic and altitude parameters have determinate the floristic diversity during wet season (Figure 2). During the dry season, plants species availability had decreased. Seasonal variations have influenced the physiological and botanical aspect in vegetation groups. A significant difference has been found in rangelands types. Acacia *farnesiana* rangeland type has been involved in a high diversity level with 1.04 ± 0.07 ($p < 0.05$).

During wet season, rangeland environmental conditions have been involved in floristic and specific development especially the annual plants. In fact, this better floristic diversity has been mentioned by Cabanis *et al*., (1969); Koechlin *et al*., (1974) and Le Houérou (1980). The rangeland ecosystems have better pastoral value during the leafing stage and where there are high quality fodder species. During end of dry season, maximum diversity value is lower than savanna formations with poor cover (Rakotoarimanana, 2002 and Puttick *et al*., 2011).

Pastoral Value

Pedological and environment parameters have determinate the pasture value. In low altitude, pastureland group have been characterized by high pasture value (24.7 %; rsd = 5.6). The floristic and agronomic parameters have been favored by better characteristics soil, high humidity and more accumulation of organic matter. Among others, the slums pastureland have a high pasture value (24.7 %; rsd = 5.6) which decreases in 12.6 % (rsd = 5.1) during the end of the rainy season. During dry season, pasture value decreases without significant variation in *p<0.05* (figure 3).

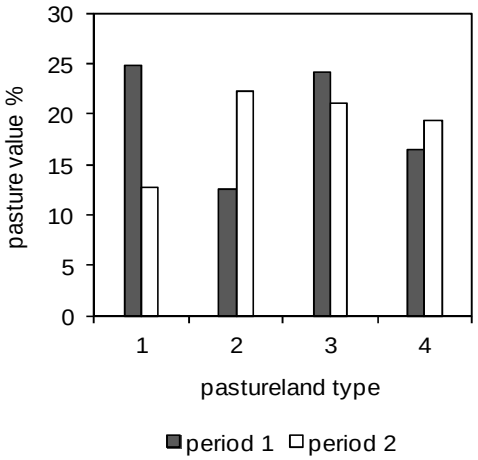

Figure 3: Variations of pastoral value in four rangelands (1: *Acacia farnesiana*, 2: *Poupartia caffra*, 3: *Kigelianthe madagascariensis* and 4: *Rhigozum madagascariense*).

During vegetation leafing stage, the ecosystems pastured have presented better pastoral value for Ruminants herds. The specific dominance increases the pastoral value and the fodder species quality (Rippstein, 1989). And with regard to savanna formations, the browse formation value is lower. It's due to the pastureland coverage rate and the botanical composition (Rakotoarimanana, 2002). During two periods, the pastoral areas have a lower floristic diversity (between 0.76 to 1.04 and 0.65 to 0.72) than diversity in Morocco by Aafi (2000; 3.46 with 17 identified species). In consequence, the floristic diversity is influenced by the season (Wilson, 1978). Biology, structure and physiological adaptation of the plants are determined by the climatic environment (Cabanis *et al*., 1969). The climate stress determines the floristic component with a decrease in species number between *Acacia farnesiana* and *Rhigozum madagascariensis* rangeland types. Among others, the relationships between herbaceous and woody plants have influenced the herbaceous development and herbivores foraging behaviour. Shrub forages have been more selected than herbaceous species resulting a negative impact on the woody species (Akpo, 1998).

Pasture value have been different between vegetation types according to Akpo *et al*., (2002). Floristic samplings have mentioned variability in specific diversity of fodder species from different categories between 32 percent and 28 percent. In consequence, pasture value have been lower in rangeland than herbaceous vegetation. Among others, relationships between pasture value and animal body score have been found. In fact, the foraging herbivores are stimulated by quantity and quality of biomass resources.

Foraging Behaviour and Bite Rate

Foraging rhythms have been implied in no significant variation with 546±12 minutes.day^{-1} and resting duration 87±7 minutes.day^{-1}. On the contrary, rumination and walking duration have been in significant difference ($p<0.05$) respectively with 15±7 minutes.day^{-1} and 22±6 minutes.day^{-1}. Using abundance resources and biomass accessibility, the determination of intake was described by the relationship between bite rate and pastoral value found during recording period in 12 rangeland types grouped in 4 vegetation types (Figure 4).

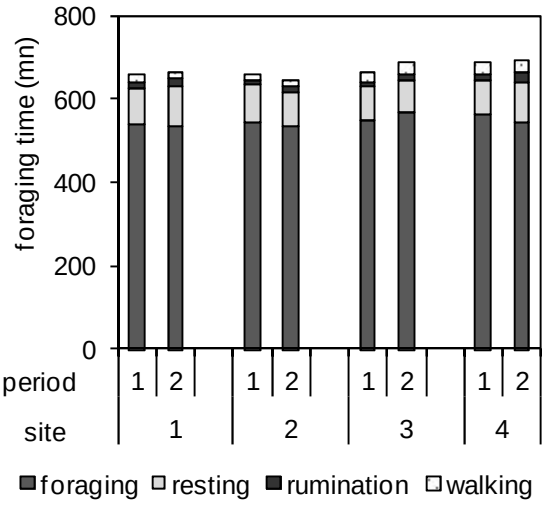

Figure 4: Goat foraging behaviour in four rangeland group during two periods

The forage biomass indicates important plant species in ten different phenological stages (foliage, flowering, fruit period). The fodder species were classified into five groups. Smallstock (goat and sheep) consume edible foliage more than the other phenological stages of the fodder plants mentioned by Rinehart (2008). In fact, ingestive rythms was recorded by some variation ($p<0.05$) according to availability of vegetation and to herd management in pastoral area. Walking less significantly improves the bite rate for small ruminants ($p < 0.05$). All vegetation types were characterized by high floristic compounds: vegetation type in *Acacia farnesiana*-dominated rangeland was heavily browsed with 2476 to 3292 daily bites.

Bites Rate

Acacia farnesiana range presents a best foraging and persistent daily bites (7-8 bites.mn^{-1}, $P<0.05$, figure 5) with high availability of forages species. In this way,

these relationships between phytosociology and nutritional parameters are studied for range management and to improve rangeland floristic with autochthons species.

Apart from floristic succession, the fodder accessibility is determined by the vegetation structure. In functional rangeland, bite rate value was lower with 1 to 9 bites per minute than rates found in grassland by Dicko – Touré (1980) with 57 bites per minute and by Bocquier *et al*., (1987) versus 50 to 75 bites per minute. Browsing and intake are determined by the plant height, which is different between grasses and browse species. Structural vegetation such as canopy cover and floristic density have influenced with important factors for ruminants during selecting forage species (Wilson, 1978). Foraging behaviour has been affected by the floristic density and distances between shrub and browse species. Herbivores must cover greater distances to find edible biomass in woodlands with poorer. This decreases the bites per minute number as found by Wilson and Harrington (1980) and Van Soest (1982).

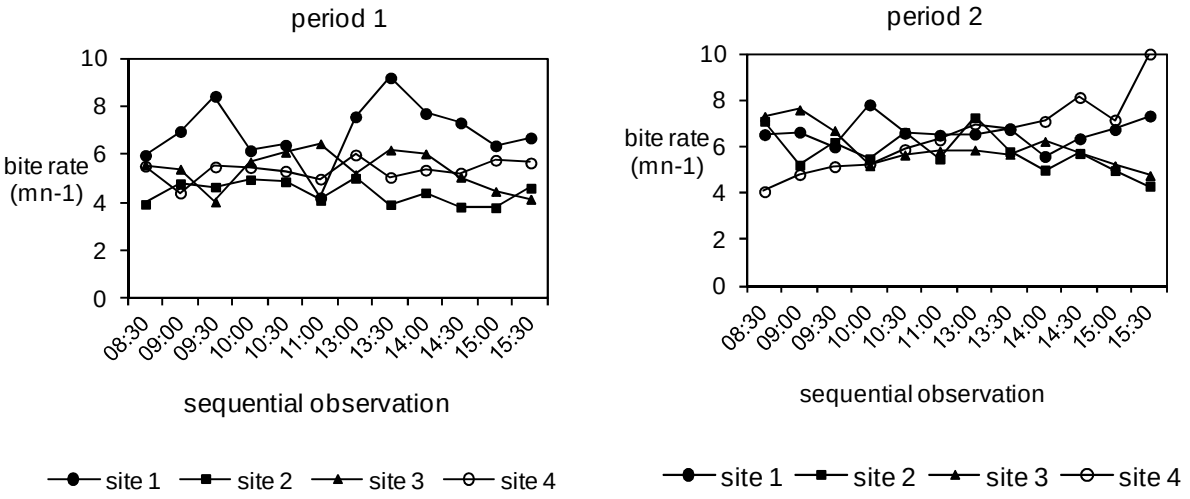

Figure 5: Sequential observation per site (1: *Acacia farnesiana*, 2: *Poupartia caffra*, 3: *Kigelianthe madagascariensis* and 4: *Rhigozum madagascariense)*.

In rangeland, Legumes species influenced the intake rate and have improved the ruminant behaviour (Weldemariam, 2015). In sub arid rangeland, pastoral vegetation has been dominated by browse species. Annual climatic variation have involved in fodder availability and in animal performance with natural forage supplementation (Kassa and Mekasha, 2014). In interactions between rangeland type and phenology, bite rate was better during the period of maximum biomass resource. Daily bite rate increased during the wet season and the beginning of dry season. A decrease in the average intake speed has been observed in the less accessible pastoral areas such as *Poupartia caffra* and *Kigelianthe madagascariensis* rangeland types but the ruminants increased their time spent on foraging activities. Intake rate decreases if width leaf and fibre content increase (Meuret, 1997). Mentionned by Ntuthuko *et al*., 2014, phenological stages did not appear to affect the fodder intake. Among others, the anti-quality factors improve selected and refused forage and decrease palatability (Devaux, 1973; Meuret, 1997). In fact, secondary substances are anti-quality molecules, synthesised and favoured by climatic conditions such as arid and subarid environments (Wilson, 1978). The preference ratio decreases with increasing numbers of unpalatable species in browse plant containing substances such as alkaloids, mimosin and tannins as mentioned by Bruneton (1999).

Nutritive Value

In all rangelands, the leaves and twigs have a high nutritive value with: variable Dry Matter (DM) content 14 to 66%;

variable Crude Protein between 82 and 227 g DM kg^{-1}; Crude Fibre 144 to 488 g DM kg^{-1} and gross energy between 3367 and 4998 kcal DM kg^{-1}. The sampled fodders were classified in 5 nutritional groups in function of gross energy.

Characteristic foliage have improved nutritive value and have been involved in better nutritional content than natural hay found by Kassa and Mekasha (2014) with 8.0% crude protein (CP) content, 73.1% Neutral detergent fiber (NDF) content and 43.6% acid detergent fiber (ADF) content. Chemical composition of fodder species presented significant difference in nutrional content such as 14–66% Dry Matter (DM); Crude Protein: 82–227 g DM kg^{-1}; Crude Fibre: 144–488 g DM kg^{-1} and gross energy: 3367–4998 kcal DM kg^{-1}. According to Houérou (1980) and Graffam et *al*. (1998), dry matter content in forage tree leaves is relatively variable. The relationship between biophysical structure and nutritive value contributes to improved dry matter intake and a decreased bite rate. The browse species have better nutritive value than shrub species as the result for gross energy, crude protein and crude fibre (table 1). According to ecological conditions and soil organic matter content, Dry Matter content was relatively variable in mass leaves of fodder trees mentioned (Houérou, 1980; Graffam *et al*.; 1998 and Delagarde *et al*., 2001). The photosynthetic activities were influenced by bio availability of the nutritional elements for plants species. The relationship between area leaf, section trunk and hydric regime influence the plants metabolic activities and nutritional production especially in the tropical pastureland (Fournier, 1995). With vegetation type and variation in climate, the ligneous forages contain high wall cell contents. In particular, the hydric limitation and the ecological conditions determine the fibre content which is characterized by lignifications acceleration (Kone *et al*., 1989). The sun radiation allows the accumulation of the leaf reserves especially energy. Compared to the results found by Skerman, Skerman and Cameron (1988) and Skerman (1990), the gross energy content of sampled fodder plants were higher than others tropical forages. And, the vegetation types and forage species have been involved in variable minerals content. In fact, the biophysic factors such as pedological and soil fertility have influenced the relationships between metabolic activities of plant and soils (Le Houérou, 1980).

Table 2: Chemical composition of fodder species group

Group	n		DM	MM	MA	CB	NDF	EB
			p. 100	g / Kg DM	g / Kg DM	g / Kg DM	g / Kg DM	Kcal. / Kg DM
1	14	Average	54±10	70±16	175±40	376±72	548±95	4464±323
		CV (p. 100)	18	22	23	19	17	7
2	7	Average	42±17	52±18	124±33	203±40	424±66	4439±259
		CV (p. 100)	42	35	27	20	15	6
3	14	Average	49±14	85±21	171±33	289±55	471±89	4335±298
		CV (p. 100)	28	25	20	19	19	7
4	8	Average	36±10	94±24	149±55	219±78	376±63	4102±255
		CV (p. 100)	29	25	37	36	17	6
5	7	Average	35±15	162±46	157±45	209±47	388±79	3617±348
		CV (p. 100)	42	29	28	23	20	10

DM Dry Matter ; MM Mineral Matter ; TN Total Nitrogen; CF Crude Fibre; NDF Neutral Detergent Fibre; GE gross Energy; CV Coefficient of Variation

CONCLUSIONS

In pastoralism, more investigation methods can be used in relationships between herbivores Ruminants such as goats and plants. The diachronic method in analytical and systematic approaches was used to clarify the interactions floristic parameters and foraging behaviour in pastoral areas during short - time. The intake activity allowed observation of the nuances in rangeland quality and quantity. In rangeland type characterized by high

pastoral value, goats tend to decrease the intake rate and walking rhythms. In lower altitude areas, high forage availability corresponds to a high bite rate. And, a level of satisfaction in foraging is implied in improved rangeland conditions. Among others, fodder shrubs species have better nutritional value for small stock in sub arid zone. In fact, this work provides important factors to help manage the forage resources with an aim for better utilisation of natural pastureland and restoration of the rangelands with the more selected indigenous forage species for sustainable development.

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