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Range Use and Trophic Interactions by Agropastoral Herds in Southeastern Kenya

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ABSTRACT Habitat utilization patterns and feeding interaction of free ranging agropastoral herds were investigated in two cycles of four consecutive grazing periods, in a semiarid environment, southeastern Kenya. The bites count and herd locations per area methods were used. During the dry season, areas of concentrated drainage; river valleys, bottomlands and ephemeral drainage ways absorbed a greater feeding load, taking 57.1 to 60% of the grazing time by the animals. In contrast, areas of limited moisture concentration, the open sandy/clay plains, were mainly exploited in the wet season and accounted for 52.6 to 55.6% of the grazing time. The trophic interaction patterns indicated that goats and cattle had a seasonal mean diet overlap index of less than 0.5 for all forage classes. Sheep and cattle, and sheep and goats had a seasonal mean diet overlap index of greater than 0.5 on grass and forbs, and browse and forbs, respectively. This indicated that during periods of resource scarcity, sheep and cattle or sheep and goats could become competitive feeders for same feed resources. Grazing management strategies aimed at even distribution of grazing pressure and enhancing complementary trophic interactions could be central to sustainable livestock production in such environments.

INTRODUCTION

Agropastoralists, like pastoralists all over the world and especially in sub-Saharan Africa, are faced with problems of low livestock productivity. The main constraint to livestock productivity is inadequate natural supply of feeds both in quantity and quality. Low livestock productivity is further closely linked to increasing tendencies of degradation of land-based resources, particularly vegetation resources. Land degradation is caused by inappropriate land use practices, especially overgrazing and debilitating droughts. These problems are assumed to stem partly from the tragedy of the commons (Hardin, 1968), prevailing aridity (Ellis et al., 1993) and the cattle complex phenomenon. Approaches for addressing these problems in the past were centred on western models of rangeland management practices that emphasized determining grazing plans and stocking rates (Perrier, 1994). In Kenya, government policy interventions have focused on land privatization and appropriation to create grazing blocks and ranching schemes. However, evidence indicates that projects modelled on the ranch approach have often generated negative rates of return, and have favoured wealthier households (McCarthy and Swallow, 1999).

Livestock production problems at the agropastoral level are largely attributed to inadequate understanding of the ecology of semiarid environments, particularly the temporal and spatial variability of rangeland production, range utilization and trophic interaction patterns, and the role of mobility in sustaining livestock production in these environments (Ellis and Swift, 1988; Behnke and Scoones, 1993).

Utilization patterns depict the use of the landscape by the grazing animals. These are established once an animal has oriented itself in the landscape, and begins feeding along a grazing path based on spatial and species choice. At the landscape level, those physiognomic and thermal features that influence animal movement patterns characterize diet selection. Most herbivores are central place foragers, that is, they graze from a central point, usually a water point, from which they seek out the most efficient energy sources of forage. Once the animal sets into grazing from the central place, the subsequent distance covered by the animal is determined in part by digestive capacity, potential harvest rate of forage encountered, potential grazing velocity, and the level of satiety of the animal (Walker et al., 1989). Once satiated, the animal either returns to a thermal, water or strategic bedding site depending on the thresholds of these various needs. The interaction of thermal regulation and digestive capacity is responsible for the noticeable biospheres or rings of utilization, which diminish in area with the distance from the central place

Habitat utilization patterns are most pronounced at patch level. Patches are more homogeneous units of a habitat. They are delimited by the type of plant species present, their spatial arrangement, and structural configuration. Thus, a patch defines a spatial aggregation of bites over which instantaneous intake rate remains relatively constant (Illius and Hodgson, 1996). At the patch level, the animal's selection of a given plant community is largely related to those attributes that influence its ability to harvest nutrients. Senft et al. (1987) established that forage quantity and quality were closely related to the ratio of the time spent grazing in a given community relative to the area occupied by the community within the landscape. The abundance of seasonally preferred plant species also influences the patterns of plant community use (Senft et al., 1985). Plant communities that afford animals high harvest rates per unit of grazing time are preferred. The greater the density of high quality food species, the lower the grazing velocity, therefore the greater residence time and intake attained relative to other communities available to the animal (Senft et al., 1987). Thus, studies on grazing patterns and plant community preferences are important in defining the functional nature of landscapes with respect to grazing use.

Trophic interactions at the grazing level reflect how grazing animals utilize various food items. Grazing animals undergo ecological segregation to utilize different feed resources, to minimize competition and enhance reproductive fitness (Begon et al. 1990). Ecological separation is achieved by animals specializing on feeding discrete but different food items, or by selecting certain food items based on plant characteristics related to quantity or quality (Distel et al., 1995; Heitkoning and Owen-smith, 1998). An overlap in resource utilization is often with an increase in resource abundance (Gordon and Illius, 1989). Competitive interactions by animals on resources occur with overlap and resource scarcity (Voeten and Prins, 1999). Therefore, determining patch utilization patterns and trophic interactions offer opportunities to manipulate landscapes for improved animal use. This study aimed at characterizing seasonal range exploitation and grazing resource utilization patterns of free ranging agropastoral herds in a semiarid environment, southeastern Kenya.

MATERIALS AND METHODS

Study Area: The study was conducted in Kibwezi Division of Makueni District, southeastern Kenya. The district covers about 7,263 sq. km (RoK, 1994), and lies between 1.5^0-3^0S and 37^0-38.5^0E. It is bordered by Kitui District to the east, Taita District to the south, Kajiado District to the west and Machakos District to the north. The district receives an average annual rainfall of 500mm in the lowlands in the south and 1200mm in the highlands in the north. The rainfall is characterized by small total amounts, strong seasonal and bimodal distribution, with high temporal and spatial variability between seasons and years. Annual mean temperatures range between 19^0C to 26^0C (Jaetzold and Schmidt, 1983). The Kamba agropastoralists are the main ethnic inhabitants, and their mainstream economic activity is raising livestock and cultivating grains and pulses (Tiffen et al., 1994).

The district is classified into six agro-climatic zones (ACZ) (Sombroek and Braun, 1980). The dominant ones are ACZs IV and V where risks of crop failure are high. Based on agro-climatic zones, the district has three main soil types: AEZ UM2/LM2, covers areas with red clay on hills and lowlands, sand soils and black cotton soils; AEZ LM4/LM5, covers areas with red clay and black cotton soils; and AEZ UM3/LM3, covers areas with soils with high potential for cotton production (Jaetzold and Schmidt, 1983). The natural vegetation is the dry form of woodland and savanna, with several tree species, mainly: *Acacia (A)* species, *Commiphora africana*, *Adansonia digitata* and *Tamarindus indica*. Shrubs include *A. mellifera*, *A. Senegal*, and *Grewia* species. Perennial grasses include *Cenchrus ciliaris*, *Chloris roxburghiana*, *Panicum maximum*, *Eragrostis superba*, *Digitaria milanjiana* and *Enteropogon macrostachyus*. Kibwezi Division lies in the central part, in ACZ IV-V of the district. The study was conducted in zones ACZ IV and V of the division, described as low potential maize zone, and high potential livestock and millet zone; and very low potential maize zone and medium potential livestock and millet zone, respectively (Jaetzold and Schmidt, 1983; RoK, 1989).

Data Collection: Samples consisted of three livestock herds in the Kibwezi community. The three herds were selected as follows; one main transect (road/footpath) cutting through nine sub-locations of Kibwezi were taken. From the central place of each transect in the opposite direction, 2 to 3 agropastoral households were picked and identified at about every kilometer to give 5 to 6 households per transect. A total of 50 households were picked and arranged into a sampling frame. The first household from the sampling frame was randomly picked using the table of random numbers. The next two households were then picked at equal intervals from the first household on the sampling frame to provide the study herds.

Data on the grazing patterns of cattle, sheep and goats were collected through two wet and two dry seasons in sequence through daylong excursions across species and season. Three animals per species per herd balanced for weight and age were used to quantify food selection by the bite count method (Backer and Hobbs, 1982). Forage classes, plants and plant parts selected were recorded in 10-minute feeding observations for each animal species, alternately. A total of 432 feeding observations were conducted and evenly distributed across species and season. Forage classes were categorized as perennial grasses, annual grasses, forbs, and woody plants (browse). The grazed sites, based on soil and vegetation type, water bodies, and topographic features and intensity of use during the grazing period were also recorded. The intensity of use was estimated as the number of herd locations per unit area. Herd locations per unit area reflects the duration of time a herd spends in an area. Herd locations were recorded in Universal Transverse Mercator coordinates (UTM coordinates define two dimensional, horizontal positions) every 15 minutes using a hand-held global positioning system (GPS). The animals were dewormed at the beginning of the study.

Forages that comprised at least 3% of the total bites for each feeding observation were hand plucked, trying as much as possible, to simulate the plant parts and bite sizes selected by each livestock species (Baker and Hobbs, 1982). Botanical compositions of diets were determined on a dry weight basis by multiplying total bites by bite weight (averaged for 25 hand-plucked samples) following procedures of Baker and Hobbs (1982). Average total grazing time per animal species per day was determined during each sampling. Botanical compositions were calculated in grams (g) using equation 1.

$$g = \frac{BWT \times BC \times GT \times DM\% \times DOM\% \times 60}{20} \qquad (1)$$

Where BWT = bite weight (g), BC = number of bites, GT = grazing time per day (hrs), DM = dry matter (%), and DOM = digestible organic matter (%).

Diet diversity ($\bar{H}$) was calculated seasonally on a forage class basis for each livestock species and aggregate herd using the Shannon-wiener index (Shannon, 1948; Hurtubia, 1973). This index is given by equation 2.

$$\overline{H} = -\sum_{i=1}^{N_i} (p_i \log p_i) \qquad (2)$$

Where N_i = number of forage classes and

P_i = proportion of the i[th] forage class in a given diet.

Seasonal niche overlap among pairs of livestock species in diet selection was calculated using the modified Morisita index (Horn, 1966). The expression is given in equation 3.

$$\hat{C}_\lambda = \frac{2\sum_{i=1}^{si} x_i y_i}{\sum_{i=1}^{s} x_i^2 + \sum_{i=1}^{s} y_i^2} \qquad (3)$$

Where $\hat{C}_\lambda$ = modified Morisita index (overlap index).

The overlap index ranges from 0.0 for completely distinct diets to 1.0 for complete similarity.

S = total number of forage classes and

X_i and Y_i = proportion of the total diet of animal X and Y taken from the i[th] forage class

Data Analysis: The effects of livestock species and season on diet diversity were analyzed using a two-way analysis of variance, based on a completely randomized design. The least square difference (L.S.D) procedure was used to determine significant differences at the 0.05 level of probability (Steel and Torrie, 1980). Seasonal overlaps and intensity of use of different patches/sites was compared using the overlap index and descriptive statistics, respectively.

RESULTS

Grazing Patterns and Habitat Use: Table 1, presents average percent feeding time spent by animals in various microhabitats during the wet and dry seasons. In the dry season, areas of concentrated drainage that included river valleys, bottomlands and ephemeral drainage ways absorbed the feeding load, taking 57 to 60% of the

Table 1: Microhabitats and seasonal exploitation/feeding time of agropastoral herds

Microhabitat	*T1*		*T2*		*T3*		*T4*	
	No. of feeding station	*% feeding time*	*No. of feeding station*	*% feeding time*	*No. of feeding station*	*% feeding time*	*No. of feeding station*	*% feeding time*
Areas of concentrated drainage	12	60	12	57.1	4	22.2	5	26.3
Foothills/slopes	6	30	7	33.3	4	22.2	4	21.1
Sandy/clay plains	2	10	2	9.5	10	55.6	10	52.6
Total	20	100	21	100.0	18	100.0	19	100.0

Where T1 - mid dry (February and August), T2 - late dry (March and October), T3 - mid wet (April and November), T4 - late wet (May and December) season

feeding time. Foothills/slopes and the open sandy/clay plains followed with 30 to 33% and 9 to 10% of feeding time, respectively. The open sandy/clay plains were mainly exploited in the wet season, accounting for 52.6 to 55.6% of the feeding time. Exploitation of the foothills/slopes was intermediate, but taking more grazing load in the dry season than in the wet season. In the studied system, goats, sheep and cattle exploited a number of plant species ranging from 25-44, 25-35, and 18-29 in the dry to wet seasons, respectively.

Diet Diversity and Overlap of the Herd

Seasonal diet diversity by animal species and the aggregate herd are presented in Table 2. All the three animal species exhibited significantly ($p<0.05$) different diets during mid dry and mid wet seasons. The aggregate herd had significantly ($p<0.05$, lsd = 0.06) lower diet diversity in the mid wet season compared to mid and late dry seasons. Sheep and cattle showed a diet diversity trend rising from mid dry to late dry season, then declining to mid wet season before rising to late wet season. In contrast, goats exhibited a slight declining trend in diet diversity from mid dry to late wet season.

Seasonal diet overlaps between livestock species are shown in Figure 1. Goats and cattle exhibited lower diet similarity than either sheep and cattle or goat and sheep, except during the late dry season. During the dry season, cattle and goats had a high overlap index (0.9). Goats and cattle had the lowest seasonal mean diet overlap index over browse (0.38), grass (0.045), and forb (0.59) forage classes. Sheep and cattle, and sheep and goats had high seasonal mean diet overlap index with respect to grass (0.73) and forbs (0.63), and browse (0.53) and forbs (0.73), respectively (Figs. 2, 3 and 4). The highest overlap

Table 2: Seasonal diet diversity indices among the three key livestock species

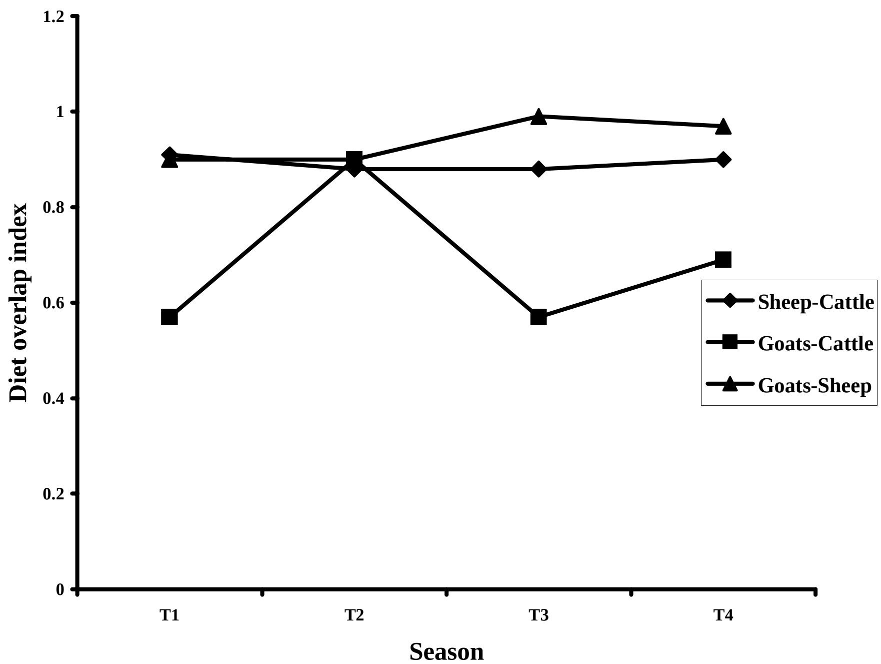
Animal species	*Time of grazing*			
	T1	*T2*	*T3*	*T4*
Sheep	0.42^a	0.45^a	0.36^a	0.42^a
Goats	0.29^b	0.28^b	0.26^b	0.26^b
Cattle	0.22^c	0.30^b	0.14^c	0.21^b
Aggregate herd	0.31	0.34	0.25	0.29

Column means followed by different letter superscripts are significantly different at $p<0.05$, lsd = 0.06

index for goats and cattle was realized in late dry season over browse forage class, a period when browse largely remains available relative to other feed resources. All pairs of animals showed an increasing dietary overlap with respect to forbs forage class from the mid to late dry season. This is usually a period of resource scarcity and thus available forbs that are consumed as supplementary feed by the animals receive greater grazing load.

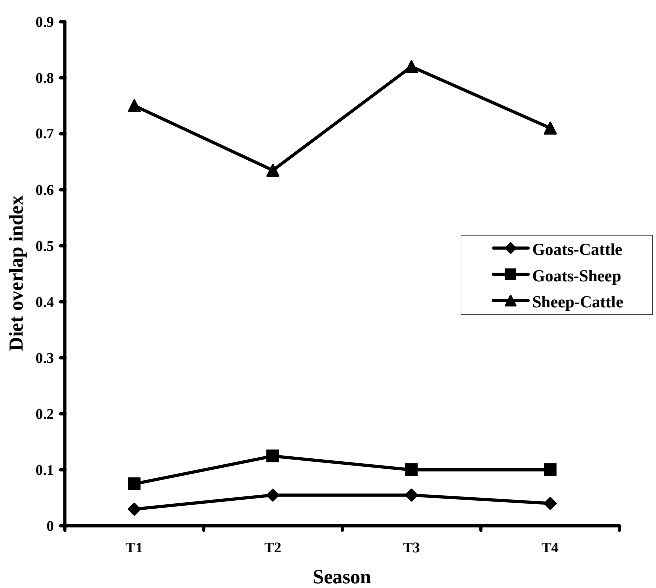
DISCUSSION

The agropastoral herds in the study area were grazed in different microhabitats. This followed a seasonal pattern of habitat use by the agropastoralists. The agropastoralists exploited microhabitats that were designated either as wet or dry season grazing areas. Areas of concentrated drainage: river valleys, bottomlands and ephemeral drainage ways, tend to concentrate moisture and allow for more forage production into the dry season. Thus, these areas are key production sites that were mainly used during the dry season. The open sandy/clay plains tend to have limited moisture concentration and were mainly exploited in the wet season. Exploitation of the foothills/slopes was intermediate, but taking more grazing load



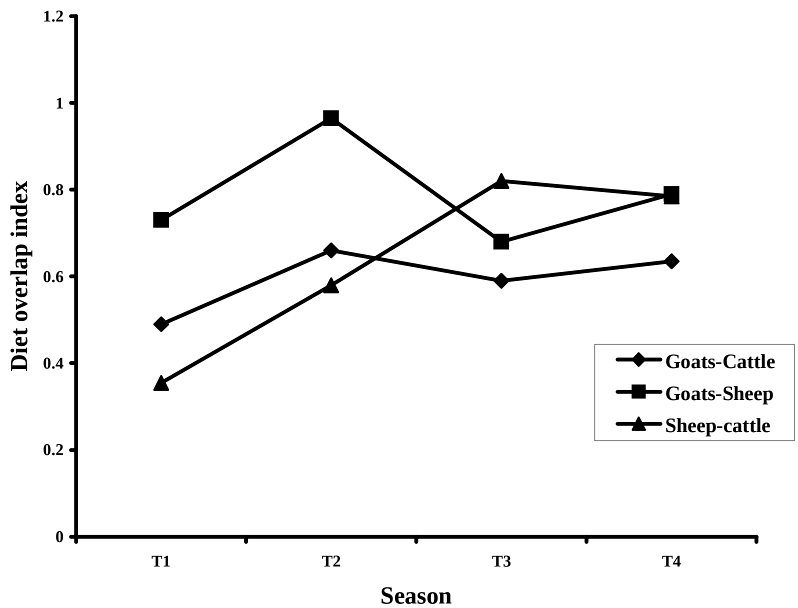
T1 - mid dry, T2 - late dry, T3 - mid wet, T4 - late wet

Fig. 1. Seasonal diet overlaps among livestock species



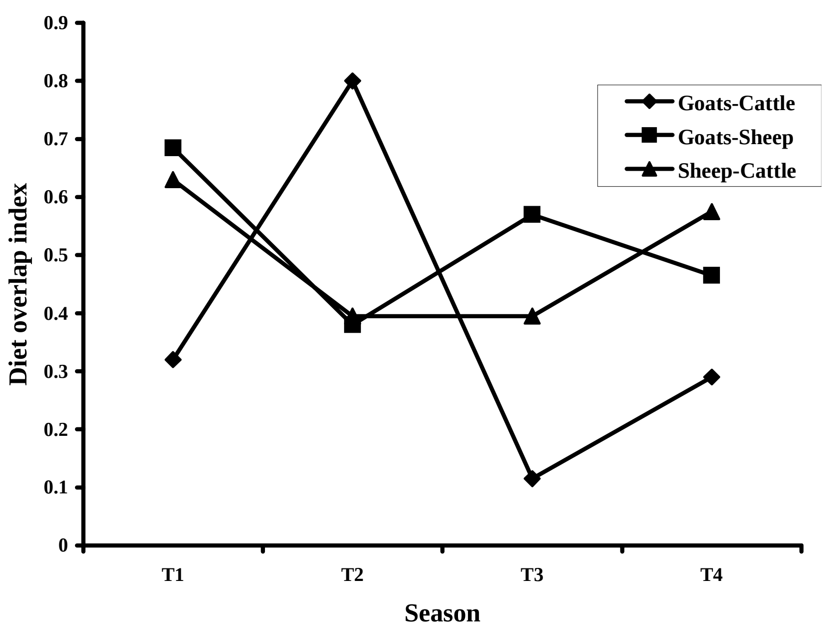
T1 - mid dry, T2 - late dry, T3 - mid wet, T4 - late wet

Fig. 2. Seasonal dietary overlap between pairs of livestock species for grass across seasons



T1 - mid dry, T2 - late dry, T3 - mid wet, T4 - late wet

Fig. 3. Seasonal dietary overlap between pairs of livestock species for forbs across seasons



T1 - mid dry, T2 - late dry, T3 - mid wet, T4 - late wet

Fig. 4. Seasonal dietary overlap between pairs of livestock species for browse across seasons

in the dry season than in the wet season. This resource use strategy ensured that the habitat was exploited in a manner that sustained livestock production throughout the year.

Trends in livestock diet diversity may be attributed to forage availability and selective grazing. The mid and late phases of dry season are usually periods of declining forage availability. This situation forces grazing animals to utilize any available forage to a large extent, resulting in an increase in diet diversity. As forage availability increases during the wet season, animals tend to shift their grazing habits to selective grazing that reduces diet diversity. Diet diversity begins to rise again during the late wet season into the dry period, as forage availability becomes the overriding factor. Goats that are largely selective feeders, generally maintained constant diet diversity across seasons. The observed trends in diet diversity across the animal species were probably reinforced by limited niche space and low plant diversity that are common in agropastoral settings. Kilonzo (2003), working in a similar environment, observed sheep diets to be more varied during the dry than the wet season. Otherwise, in areas of a wide niche space and high plant diversity, as in pure pastoral settings, grazing animals tend to have more varied diets during the wet and early dry periods than in mid or late dry periods (Coppock et al., 1986).

Observed seasonal diet overlaps between livestock species in the agropastoral system reveals that both sheep and cattle or goats and sheep exhibit high dietary overlaps across seasons. High dietary overlaps between livestock species suggest a strong interspecies competition. This form of interaction between animal species can have serious implications on both animal production and the grazing environment, particularly during periods of resource scarcity.

Resource scarcity forces animals to aggressively compete for available resources so as to enhance their reproductive fitness. In this respect, the competitive animal species gains while the less competitive animal species suffers productive losses and thus fitness. On the other hand, high overlaps during periods of resource scarcity can also exacerbate the grazing/browsing pressure on available feed resources. This leads to overshoots in grazing thresholds with severe consequences to the grazing environment in terms of resource damage and degradation. Therefore, seasonal shifts in grazing/browsing pressure must be factored-in in the grazing management so as to protect the environment. This calls for a management strategy that either controls the stocking rate or diversifies the resource base for the different livestock species.

In the studied system, the agropastoralists kept multispecies livestock that exploited a fairly wide array of plant resources. These plant species have different phenologies and occupy different microsites, creating a spatial heterogeneity in food resources that attain peak production at different times. This spatial heterogeneity in food resources affords livestock the opportunity to occupy patches yielding the highest gain and also ensures that energy extraction and intake are stabilized over time. That is, both seasonality in vegetation growth and heterogeneity in resource type act to promote stability in energy supply (McNaughton, 1977; Coughenour et al., 1985; Owen-smith, 1999). The agropastoralists grazed animals on transient forage resources early in the grazing cycle on the sandy/clay pains, followed by perennials dominated sites (areas of concentrated drainage). This indicated that resource extraction patterns by the agro-pastoralists closely followed the growth cycle of the plants.

CONCLUSIONS AND RECOMMENDATIONS

From the results of the current study, it follows that: areas of concentrated drainage and sandy-clay plains are key production sites in the agropastoral production system, absorbing the greatest grazing load during the dry season and wet season, respectively. These areas require management strategies that will uniformly distribute the grazing pressure and check the stocking levels to avoid overgrazing and physical damage to the resource base. This should partly include implementation of rotational grazing systems and close monitoring of range condition and trend. Plant species diversity in space and time offers a set of primary energy pathways that enhance livestock production in this variable environment. In this respect, any human activities that negatively affect diversity in grazing resources will undermine sustainable livestock production. Sustainable livestock production could be attained by maintaining resource diversity and practicing grazing management strategies that enhance feeding trophic interactions, particularly keeping complementary livestock species, in this case, goats and cattle.

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