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Theme 2. Grassland production and utilization
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Mechanics of combining divergent herbivores in cultivated pastures

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Introduction

Sustainable intensification of cultivated pastures is needed in ruminant production if we are to feed a growing world population expected to exceed 9 billion by 2050. Planting pastures of diverse, and therefore more productive and resilient, plant species has been proposed and researched. Despite illustrative examples from wild grasslands (Hofmann, 1989) and rangelands (Glimp, 1988), very little research and even less application of multiple herbivore species (MHS) in cultivated pastures has followed. We review the specific mechanics of divergent domesticated ruminants and theorize how these could best be combined to sustainably intensify meat, milk and fiber production from cultivated pastures around the world.

Materials and Methods

We reviewed historical research looking at the mechanics available to us for intensifying plant utilization in cultivated pasture production through consciously designed MHS. The literature on this topic comes primarily from natural ecosystems, some from rangelands but very little from cultivated grasslands. We divided our efforts broadly into grazers versus browsers and concentrate versus bulk feeders. These categories, despite their popular historical use, are rarely absolute because herbivore species differ in the degree of mechanics rather than absolutes. In the conclusions we propose how these ranges in herbivory mechanics may be useful in intensifying animal production in cultivated pasture without additional land or inputs.

Results and Discussion

Grazers versus browsers: Large grazers are often categorized as bulk and roughage eaters. Compared to most ungulate browsers, they usually have larger rumen, omasum, and abomasum compartments leading them to have slow passage and low fermentation rate. As a result, grazers have the capacity to digest feed with high proportion of cell wall (Hofmann, 1989). Using wider, less agile mouths, these ruminants usually ingest grasses more than dicots simply because the first are often found in uniform swards that provide easy harvest and rumen fill. For bulk grazers, herbage height and bulk density (herbage mass per unit canopy volume) are the most important sward determinants of rate of intake within a patch. Bite is the smallest scale and is defined by a sequence of herbage prehension, jaw and tongue movements, and severance by head movement. Efficiency of grazing depends on incisor arcade breadth, on the force the animal can exert when biting, and in cattle, on the degree of tongue protrusion (Prache *et al*., 1998) which defines bite area and, depending on the herbage height and bulk density, will determine grazing efficiency for bulk grazers.

In contrast to grazers, browsers preferentially select dicotyledonous herbage with high nutrient concentrations. Goats are the most common browsing species among domestic livestock, and their foraging characteristics provide insights into highly selective foraging which is required for use of woody herbage for ruminant production. Compared to other domestic ruminants and wild herbivores which prefer grasses, goat diets are more variable and more often overlap with grazers when herbage quantity is limiting (Garcia *et al*., 2012). Animal species, available herbage, and livestock management were among factors affecting diet overlap. These factors are potential management considerations for MHS stocking approaches. Even greater benefits can accrue from providing appropriate combinations of grasses, herbaceous legumes, and other plants, including browse species, based on nutrient requirements of target species. Condensed tannins of many browse species limit protein availability, particularly on low-quality diets, with protein limitations sometimes restricting animal performance despite adequate herbage crude protein levels. Thus in addition to inherent herbivore

mechanisms partitioning available herbage resources, effective use of resources and herbivore productivity can be manipulated in MHS cultivated pastures by stocking approaches and effective selection of plant species components. An almost global pattern of stocking browsing livestock, particularly goats, on marginal lands only after deterioration under other uses including cropping and grazing (Garcia *et al*., 2012) indicates that appropriate MHS stocking before substantial deterioration may provide a sustainable option.

Concentrate versus bulk selectors: Variable herbivore species body mass leads to different energy and other nutrient requirement, ingestive, and digestive capacities. These characteristics at least partially explain differences in foraging behaviour among grazing and browsing ruminant species (Prache *et al*., 1998). Concentrate selecting ruminants tend to have smaller body sizes, smaller muzzles, longer tongues, more mobile lips, faster rate of passage, and larger reticulum and salivary gland size for their body weight, than bulk grazers (Hofmann, 1989). Mobile prehensile organs and small body size allow for agility to access browse and forbs in brushy and rocky landscapes and specific selection of young, high nutritive value plants and plant parts. The concentrate selector's diet is therefore more diverse and more likely to contain browse and forbs containing secondary compounds (*e.g*. tannins) which saliva helps to buffer. Dietary selection of specific plant species may overlap among concentrate selectors and other herbivore types depending on the type and quantity of forage available, growing season, and other biotic and abiotic conditions.

Conclusion

Future efforts to harness diverse mechanics: Harnessing differences between grazers and browsers or selective versus bulk feeders is one means of sustainably intensifying production through MHS in cultivated pastures. Rather than removing over-story canopies or applying herbicides and fertilizers in an effort to favor grasses, including MHS mixtures specifically designed for those pastures may produce more with less. Naturally occurring ecosystems indicate the types of pasture plants (and therefore herbivores) that may be most sustainable. Grassland ecosystems should sustain primarily herbaceous species, while pastures in humid woodlands and semi-arid shrub-lands will be more sustainable when woody plant components are included than when composed of only herbaceous species. In turn, animal species and their ratios need to reflect vegetation rather than vice-versa as most commonly done today. Where grass is a minor component, over-grazing and under-browsing leads to pasture destabilization (Silva *et al*., 1999; Table 1). There is danger, however, in over-simplifying diversity in herbivory mechanics when maximizing MHS production. Increasing herbivore diversity is no substitute for sound management principles such as soil health, compatible plant mixtures, adequate herbage allowance, short-duration herbivory, and periodic pasture rest. The goal of MHS is to maintain pasture health over time through sustainable intensification that feeds a growing population on less land.

Table 1: Total herbage dry matter (kg THDM/ha) and grass percentage of herbage in modified Brazilian Caatinga as a result of variable sheep grazing management.

Management	1992		1994	
	THDM/ha	% Grass	THDM/ha	% Grass
HHF	3169	23.0	4934	0
LHF	2331	33.0	4249	0
Mean	2750	28.0	4592	0
HH	2038	13.0	3371	0
LH	2091	16.0	3786	0
Mean	2065	14.5	3579	0

HHF: high herbage allowance with fertilizer; LHF: low herbage allowance with fertilizer; HH: high herbage allowance without fertilizer; LH: low herbage allowance without fertilizer. Adapted from Silva *et al*. (1999).

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