Evaluating Rangeland's Grazing Capacity for Livestock and Wild Herbivores Using the Delta Diet Tool and GIS Technology

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Abstract. Rangelands are dynamic and complex systems requiring appropriate adaptive decision-making to calculate grazing capacity integrating livestock and herbivore wildlife. This work describes the development and application of an integrated framework using the microhistological analysis (DeltaDiet tool) to identify key forage used by different herbivores from the same area associated with GIS technology to mapping landscape containing forage productivity and quality information. This study was conducted in a management unit, representative of the Nhecolândia sub-region landscape, Pantanal. During the dry period, representative fecal samples were collected from cows, capybaras and deer grazing in the same management unit for diet analysis, using the DeltaDiet tool. A field survey was conducted to assess key forage composition and utilization degree of the pastures. Landscape units and satellite image maps were made in order to define the main pastures categories. An algorithm was used to evaluate grazing capacity for livestock and wildlife integrating all the diet and pastures information as well as information available from the literature. It was then possible to define grazing capacity for each pasture categories and quality of diet selected by different herbivores.

Keywords: Extensive grazing system, fecal microhistology, rangeland, herbivore diet.

Introduction

Marginal areas with restrictions to agriculture can be adequate for extensive cattle production. This is the case for the Brazilian Pantanal, the world's largest marshy floodplains. To ensure sustainable production in this type of habitat, it is necessary optimize forage resource use in accordance to environmental limitations. In general, management areas are large and stock densities are very low and fixed throughout the year. However, the Pantanal is a complex mosaic of landscape units with different pastures types which are used by herbivores at different degrees which makes the estimation of grazing capacity (GC) a complex task. Livestock is reared together with wildlife. Wildlife usually has lower metabolic biomass than grazing cattle in the same area. Therefore the major determinant of the natural pasture GC of the Pantanal is the use made by cattle. According to Santos *et al*. (2011), this estimate for the Pantanal should be flexible and spatially variable. It should depend on the landscapes units and be temporally variable due to variation in climatic conditions. It should also take into consideration the preferred foraging habitat of the different species considered. Currently, there is no well-established method to determine the carrying capacity for common use of forage resources (wild and domestic herbivores) in the Pantanal. Holechek (1988) used the concept of key specie and key area to estimate stocking rate. This work describes the development and application of an integrated framework using the DeltaDiet tool to identify key forage used by different herbivores in the same area and their respective key areas associated with GIS technology to map landscapes containing forage productivity and quality information in order to estimate grazing capacity.

Methods

Study area

This study was conducted in Nhumirim ranch, located in the Nhecolândia sub-region, Pantanal, MS, Brazil (19°04'S, 56 36'E; elevation 98m). The ranch includes landscapes representative of the sub-region characterized by rain-floodplain system and presence of a mosaic of physiognomic groups: wetland, open grassland, savanna shrubland, savanna woodland and semi-deciduous forest. The ranch is divided into management units ranging from 80 to 250 ha, with extensive livestock production with continuous stocking.

Field sampling and diet analysis

Forty six Nellore cows, 12 capybaras and four deer were also present in the study area. Representative fecal samples for each species were collected and micro-histological slides were made to determine diet botanical composition and identify key forages. The Deltadiet, a tool based on the Description Language for Taxonomy (DELTA) system (Dallwitz and Paine, 1986) was developed to include taxonomic data of plant leaf anatomy descriptors (Desbiez *et al*. 2010) and used to

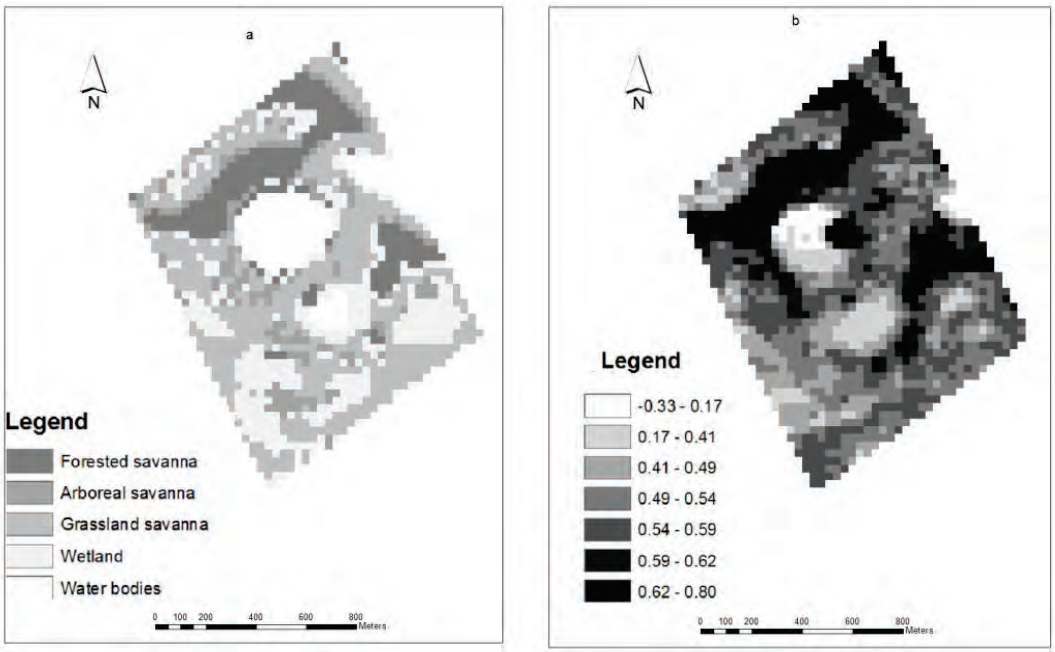

Figure 1. (a) landscapes units map; (b) Pastures categories in according NDVI ranges (-0.33-0.17=water bodies; 0.17-0.41=wetland with intensive use; 0.41-0.49 = open grassland with intensive use; 0.49-0.54 = open grassland with moderate use; 0.54-0.59 = open grassland or roughages with casual use; 0.59-0.62= arboreal savanna with casual use).

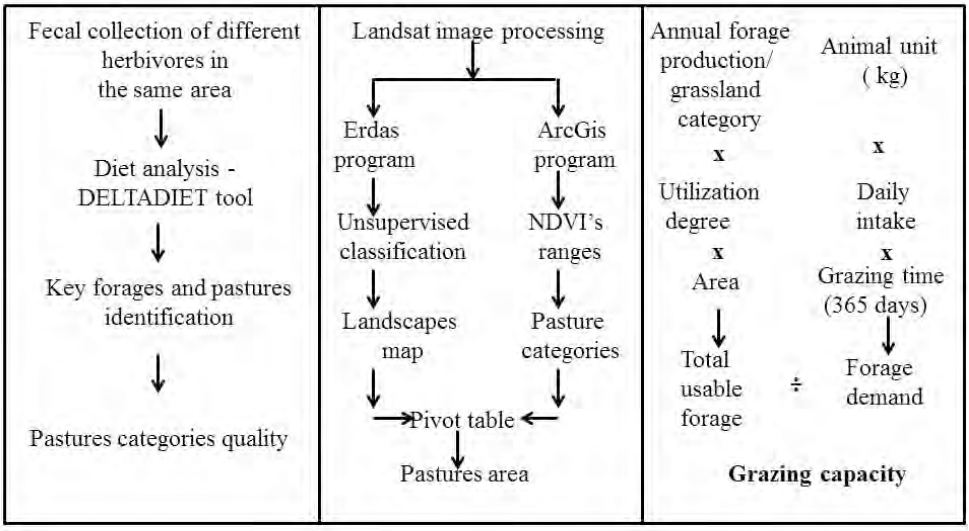

Figure 2. Schematic representation of the grazing capacity model for extensive rangeland.

guide reading (identification) of fragments of plants found on slides. Forages with greater proportion in the diet (over 2%) were identified as key forage. Key forage species composition was evaluated from transects on pastures by point method. Field survey was performed throughout study area to define pasture utilization degree (PUD) as: degraded = 100%, intense use = 75%, moderate use = 50%, casual use = 10% and no grazing = 0%. Key forages, grazing areas, as well as obtaining 30 point data aiming to establish the respective ranges of Normalized Difference Vegetation Index (NDVI) values for each pasture category also were evaluated.

Images processing

A Landsat 5-Thematic Mapper (TM) satellite image from 1997 was acquired from INPE, the Brazilian space agency. The image was chosen preferentially from the late dry season to avoid clouds and to obtain better visualization to estimate vegetation units. Data preparation and image processing were carried out utilizing ERDAS (2010) software package. All images were rectified to UTM zone 21, WGS 84. Unsupervised classification was then used to map the vegetation units in ERDAS into five vegetation types: (1) forested savanna; (2) arboreal savanna; (3) grassland savanna; (4) wetland; and (5) water bodies with accuracy assessment of 91% (Fig. 1a). The NDVI as a measure of photo-synthetic activity otherwise greenness was calculated using ARCGIS 9.3 (ESRI, 2008) as described by Grant and Carter (2011). Seven ranges of NDVI and respective pasture class were defined (Fig. 1b). These two maps were overlaid and then created a pivot table to determine

pastures categories in each vegetation unit and respective area (ha).

Grazing capacity estimate

An algorithm was used to evaluate the grazing capacity based on Holechek (1988) and Santos *et al*. (2008) integrating all information (Fig. 2). The calculation of the total usable forage is a product of the annual forage production, utilization degree and area. The average annual forage production was based in the key pasture according to Santos *et al*. (2008). The calculation of the forage demand was determined as the product of the body weight (measured as animal unit), grazing time (365 days) and intake. For livestock, an animal unit (AU) in the Pantanal was defined as a dry cow of 350 kg (Santos *et al*. 2008), for capybara 40 kg, and for deer 30 kg. Then, also it is possible to estimate the animal unit equivalent (AUE) in relation to livestock for capybara that has 40 kg (0.11 AUE) and deer 30 kg (0.09 AUE). Intake was estimated as the percent of body weight of each animal. For cattle 2% was considered while for the wild herbivores 4% was considered (Stuth and Sheffield, 1986).

The utilization degree (UD) used was defined as pasture utilization degree (PUD) (Table 1). PUD was considered in the calculation when the key forages identified in the diet corresponded to key forage of the pastures. Where the diet key species consisted of secondary species, or little key species, the UD was considered casual (10%). When the diet key species represented an intermediate amount of pasture key forage, the UD represented the average of PUD. The division of total usable forage and forage demand result in the grazing capacity (AU/ha or UAE/ha). Quality (crude protein-CP) of each pasture was calculated based on the key forage composition following $N_i = \sum a_{ij} x_j$ where N_i is the CP dietary composition, a_{ij} is the ith CP forage species content and $x_j$is the forage species dry weight composition. The CP content was based on average values in the same study area and dry weight by proportion of key species on pastures considering forage annual production defined by Santos (2008).

Results

The proposed approach to model grazing capacity (Fig. 2) allowed estimating the extensive rangeland grazing capacity using a single field survey during the dry period (Table 1). Considering that NDVI is an indicator of greenness, the values are influenced by diverse factors such as flooding level that are extremely dynamic in the region, making it of limited use in regression models. In this study NDVI's values ranges associated with rapid field survey provide a reliable estimate of grazing distribution based on the additional knowledge of the utilization degree of the pastures as well as of the identification of key species of different herbivores that graze the same area. Annual grazing capacity for cattle of the total area was 44.9 AU that represent around 3 ha per AU. This value is very similar to the adopted in the Pantanal, which are about 3.6 ha per AU. Grazing capacity for capybara and deer were 90.3 AU (9.9 AUE) and 152.2 AU (13.7 AUE), respectively, values lower to

Table 1 – Selected average crude protein and grazing capacity estimates for five main categories of pastures.

Main categories of pastures	Pasture utilization degree (%)[1]	Key Forages Identified in the diet[2]	Average Crude protein selected (%)[3]			Annual forage production (kg) [1]	Area (ha)	Grazing capacity (AU /ha)[4]
			L	C	D			
Casual use (arboreal savannah)	10	*Axonopus purpusii (L), Mesosetum chaseae (L), Sebastiana hispida (D), Byrsonima cydoniifolia (D)*	6.6	-	9.8	3000	6.7	0.8, 0, 4.6
Casual use (open grassland-roughages)	10	*A.purpusii (L), M. chaseae (L), S. hispida (D), B. cydoniifolia(D)*	6.6	-	8.8	6000	28.7	6.7, 0, 39.3
Moderate use (savannah grassland)	50	*A. purpusii (L, D), M. chaseae (L)*	7.0	-	7.0	3000	30.6	18.0, 0, 52.4
Intense use (savannah grassland)	75	*A. purpusii (L,C , D), Panicum laxum (L, C), Cynodon dactylon (L.C)*	7.0	9.5	7.0	2000	17.4	10.2, 44.7, 19.9
Intense use (wetland)	75	*Hymenachne amplexicaulis (L, C, D), P. laxum (L, C, D), E. minima (L, C) Aeschynomene fluminensis (D), Melochia simplex (D), Ludwigia* spp. (D)	12.0	12.0	12.6	3000	10.5	9.2, 45.6, 36
Total pasture								44.9, 90.3, 152.2

[1]Utilization degree is the proportion of year's forage production that is utilized by a group of species; [2]Key specie which makes up over 2% of overall diet of the animals studied, livestock (L), Capybara (C) and deer (D). Pasture key specie in bold; [3]Average crude protein selected considering the proportion of the key species in each pasture; [4]Animal unit (AU) represents 350 kg/ha, 40 kg/ha and 30 kg/ha for livestock, capybara, and deer, respectively.

the observed in the natural population densities, showing that there are surplus of native forage in the Pantanal region, allowing the cattle raising if an appropriate grazing capacity would be set up. These results also indicate that capybara and deer are more selective grazers than livestock. Capybaras have a restricted grazing area close to water bodies.

Conclusion

This approach allows the annual estimate of the livestock-wildlife grazing capacity for extensive rangeland on continuous grazing with the aid of satellite images, DeltaDiet tool and a single field inventory made during dry period. However, caution is necessary and common sense must prevail in the decision making due to dynamic nature of the ecosystem.

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