Research Article

Rotational Grazing of Native Pasturelands in the Pantanal: an effective conservation tool

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Abstract

Deforestation and conversion of native habitats to exotic pasture and crops, plus inefficient agricultural and cattle management practices, are placing great pressures on natural resources in the Pantanal and Cerrado. To prevent further deforestation and protect biodiversity, areas already developed for farming and ranching need to be managed more efficiently and profitably, so that economic incentives for additional deforestation are minimized. To that end, the Wildlife Conservation Society (WCS) has been working with rural community partners to promote best-management practices that optimize profitability and efficient use of developed lands, while minimizing pressures on natural resources. To improve pasture conditions and reduce cattle impacts, we evaluated the use of rotational grazing as a management tool by monitoring native pasture and cattle within continuous and rotational grazing areas on a southern Pantanal ranch. Monthly comparisons of the grazing systems showed that forage dry mass in the rotational area was greater compared to that of continuously grazed areas. After 17 months, mean cattle weights were 15% heavier and pregnancy rates 22% higher for the herd using the rotational system. Based on forage allowance estimates, the potential stocking rates of the rotational system were 2 to 6 times higher than rates typical of continuously grazed areas in the Pantanal. Results support the use of rotational grazing in native pasture areas of the Pantanal.

Key words: rotational grazing, native pasture, forage allowance, cattle management, conservation, Pantanal

Resumo

Práticas agropecuárias sem critérios técnicos, tais como o desmatamento e a conversão de habitats naturais em pastagens exóticas, associada com o manejo inadequado, são responsáveis pela pressão negativa sobre os recursos naturais do Pantanal e Cerrado. Para evitar desmatamentos e proteger a biodiversidade, propriedades agropecuárias podem ser manejadas de forma mais eficiente e rentável, para não haver necessidade de novos desmatamentos. Com essa finalidade, a WCS trabalha com a comunidade rural promovendo melhores práticas para otimizar a utilização dos recursos naturais e a rentabilidade das propriedades. Como forma de melhorar o estado de conservação das pastagens e reduzir os impactos do gado, foi avaliada em uma fazenda do Pantanal sul a prática de pastejo rotacionado em pastagem nativa. São apresentados resultados do monitoramento de pastagens e produtividade de gado em pastejo contínuo e em pastejo rotacionado. Medições mensais dos dois sistemas de pastejo mostraram que a massa seca da forragem no sistema rotacionado foi maior quando comparada com o sistema de pastejo contínuo. Após 17 meses, o peso médio e a taxa de prenhez do rebanho utilizando o sistema rotacionado foram 15% e 22% maior, respectivamente. Baseado em estimativas da oferta de forragem, a lotação potencial do sistema rotacionado foi 2 até 6 vezes maior que as taxas típicas das áreas de pastejo contínua. Os resultados foram favoráveis ao uso do pastejo rotacionado em pastagens nativas do Pantanal.

Palavras chave: pastejo rotacionado, pasto nativo, oferta de forragem, manejo de gado, conservação, Pantanal

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Introduction

On the alluvial plain of the Pantanal and bordering highlands of the Cerrado in central-western Brazil, cattle ranching and agriculture are the principal economic activities [1,2]. A variety of crops like soy, sugar cane, and corn are grown on the Cerrado highlands, and cattle are raised mostly on planted exotic (i.e., non-native) pastures [2]. In the annually flooded Pantanal, activities are largely restricted to raising cattle, both on naturally open native savannas, and in cleared areas that have been converted to exotic grasses [1]. On Pantanal ranches, grazing management units for cattle are typically large (>500 ha) and used continuously for lengthy periods of time, e.g., year round or during seasonal periods of five to seven months [1]. For the historically very large properties of the Pantanal, which had a range of native pasture types and low cattle densities, the continuous grazing system was economically and environmentally sustainable. Due to divisions among heirs and a variety of economic factors, present-day properties are smaller and require higher cattle densities to be economically viable. Continuous grazing on these smaller, high-cattle-density properties is consistently associated with uneven use of available pasture [3]. This can potentially affect the resilience of grazing lands and compromise the health and performance of livestock, as well as the environmental integrity of a rancher's property.

Cattle that are grazing for extended periods within large enclosures rapidly consume favored forage species, denuding and degrading some areas, while allowing overgrowth and encroachment of less palatable forage species in others [3]. Overgrazing and related soil damage create conditions that promote the growth of invasive species, and consequently reduce pasture area [1,3]. Undergrazing of less-favored forage species creates areas with tall unpalatable grasses, which the landowner may burn in an attempt to regenerate young palatable leaves [1,3]. In worse-case scenarios, highly degraded native pasture and adjacent vegetation areas like forests and wetlands are cut, burned, drained, plowed under, and planted with exotic grasses. Although intended for pasture recuperation, these practices also destroy native vegetation formations that are comprised of a variety of high-quality forage species and have important conservation values [1,3-4].

In the Pantanal and Cerrado, deforestation, habitat fragmentation, and conversion of native habitats to exotic pasture and croplands have caused incalculable losses of natural resources and ecosystem services, as well as declines of charismatic wildlife species like jaguar, peccaries, and giant river otters [2,5]. To prevent further deforestation and protect the extraordinary biodiversity of the Pantanal and Cerrado, the areas already developed for farming and ranching need to be managed more efficiently and profitably, so that economic incentives for additional deforestation are minimized. To that end, the Wildlife Conservation Society (WCS) has been working with a range of rural community groups to promote best-management practices that optimize profitability and efficient use of developed lands, while minimizing pressures on natural resources. The goal is to prevent additional deforestation and eliminate the harmful impacts of poorly managed farms and ranches in the Pantanal basin and Cerrado highlands, maintaining ecosystem services, biodiversity, and populations of key wildlife species.

To reduce pasture degradation on Pantanal ranches and maintain the traditional practice of using native forage species, we have been investigating a range of management techniques developed for more efficient use of native pasturelands [1,3,6]. One of the management tools being evaluated is rotational grazing, a widely recommended technique that has rarely been tested or practiced in the Pantanal [6-10]. The objectives were to maximize livestock productivity and economic gain from use of native pasture, while minimizing the areal needs and impacts of grazing cattle. In a rotational grazing system, livestock are moved frequently among small pasture enclosures using a schedule designed to optimize forage quality, quantity, and livestock nutritional gain [7-10]. Exclusion of the cattle from enclosures between grazing periods promotes pasture recuperation [7-10]. Compared to continuous grazing systems, a properly managed rotational system can improve pasture and livestock health, reduce cattle-related impacts like overgrazing, erosion, and degraded water quality, and consequently improve the long-term profitability and sustainability of a cattle operation [7-10]. Here we compare results of native pasture and cattle monitoring between continuous and rotational grazing areas on a ranch in the Aquidauana subregion of the southern Pantanal.

An important objective of the study was to determine whether stocking rates of native pasture areas in the Pantanal could be increased where rotational grazing was practiced. If affirmed, ranchers would be able to increase cattle productivity without increasing the area used for grazing, thereby reducing incentives for deforestation and implantation of exotic pastures. To determine stocking rates, we estimated forage allowance, which is a measure of forage availability in relation to animal use (live weight) of a grazing area, i.e., kg of forage (dry mass) per 100 kg of animal live weight (the ratio expressed as a percent) per day [11]. Higher percent values of forage allowance indicate greater pasture availability in relation to the total quantity of cattle. Depending on climate, soil type, seasonal conditions, and forage species, there is an ideal range of forage allowance that optimizes forage and cattle productivity. For example, Moojen and Maraschin [12], studying native pasture in southern Brazil, concluded that cattle productivity was maximized with a forage allowance of approximately 12% per day. At allowance levels above the optimal range, pasture species become less palatable for grazers and a layer of senescent organic material forms on the soil, shading out and impeding new-growth. At these forage allowance levels, grazing pressure is too low, and cattle densities (i.e., stocking rates) should be increased. Below the optimal range, the nutritional value and biomass of the pasture are not sufficient to support the cattle, i.e., the pasture is being overgrazed and stocking rates should be reduced. Based on forage allowance trends, we present estimates of optimal stocking rates for a native pasture rotational system in the Pantanal.

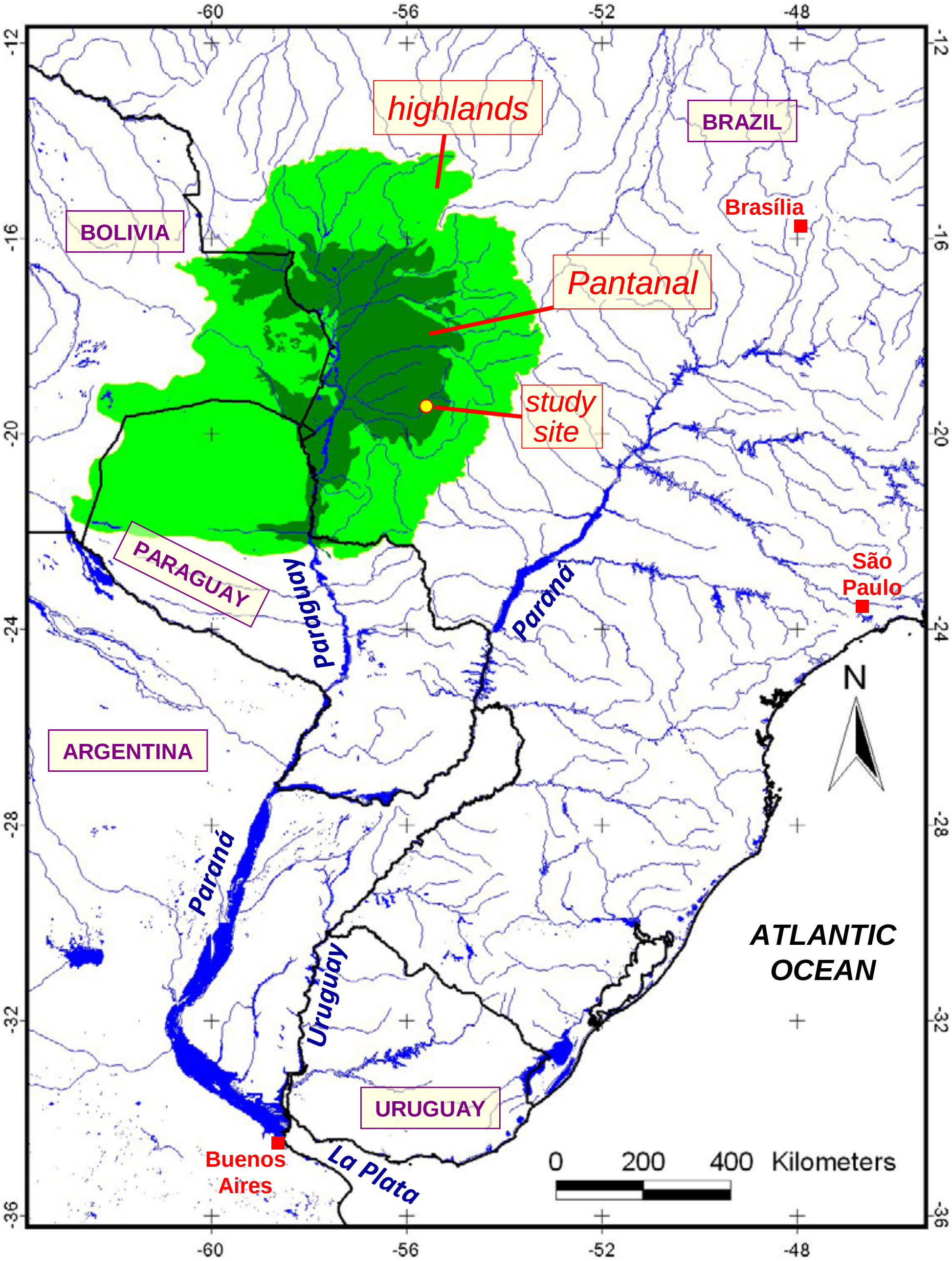

Fig. 1. Map highlighting the upper basin of the Paraguay River in central South America. Within the basin, highland regions (light green) and the alluvial plain of the Pantanal (dark green) are shown. The study site location in the Aquidauana subregion of the southern Pantanal is indicated by a yellow dot. Rivers and river names are shown in blue, international borders in black, country names in purple, and major cities in red.

Methods

Study site

We conducted the study in the Aquidauana subregion of the southern Pantanal (Fig. 1) on a traditionally managed 5,700 hectare (ha) cattle ranch (S 19°32'41", W 55°33'46"). Like other regions in the Pantanal, vegetation consists of a heterogeneous mixture of savanna, forest, and aquatic formations, which are strongly influenced by annual and multi-annual flood patterns, and comprise species characteristic of adjoining biomes, i.e., the Cerrado, Atlantic forest, Amazon, and Chaco [13-14]. Annual rainfall from 1998 through 2009 averaged 1,414 ± 196 mm (95% confidence interval) at the study site, and air temperatures from 2006 through 2009 averaged 28°C (D.P. Eaton, and Fazenda Campo Lourdes, unpublished data). Rainfall was highly seasonal with 82% falling between the months of November and May. Air temperatures during the hotter wet season, December through April, and the cooler dry season, July though September, averaged 30°C and 26°C, respectively.

Grazing systems

Prior to establishment of a rotational system on the ranch, continuous (year-round, or seasonal) grazing of native pasture areas within enclosures of 750 to 1,600 ha had been practiced for at least 20 years. Within one of the continuously grazed enclosures, we designed a rotational system that was constructed between September and November 2007. The system, which covers a total area of approximately 500 ha, consists of five divisions, or paddocks, enclosed by solar-powered electric fences. Using GPS surveys at the site and GIS analysis of vegetation cover (ArcView GIS 3.2, Environmental Systems Research Institute, Inc.), we set up the divisions so that each paddock would contain approximately 60 ha of native pasture and a variable coverage of other habitat types (i.e., forest formations and aquatic environments).

For grazing-system comparisons, we monitored key variables related to pasture and cattle productivity (described below) in the rotational system and in two adjacent areas (without divisions) that were grazed continuously. The latter included an area of 626 ha that made up the rest of the large enclosure where the rotational system was established, and a second area of 1,317 ha located along the eastern border of the rotational system. Prior to initiation of monitoring activities, the three study areas, i.e., the rotational system and the two continuously-grazed enclosures, had nearly identical grazing histories (see stocking rates below), the same types of vegetation cover, and very similar pasture conditions in terms of forage composition and availability (see results).

For rotational grazing, we used a five-week cycle that consisted of moving cattle between paddocks every seven to eight days. Therefore, during the study period, January 2008 through May 2009, each paddock was exposed to one week of grazing followed by four weeks without grazing. In mid-December 2007, we launched the rotational system by excluding cattle from the paddocks for an initial four-week rest period from grazing. Consistent with practices in the Pantanal, the continuously grazed areas did not have a grazing rest period. In mid-January 2008; we introduced cattle (described below) into the rotational system at a stocking rate of 0.43 AU (animal units).ha^{-1} and began monitoring pasture and cattle productivity variables. We set the stocking rate at twice the average rate recommended for continuous grazing areas in the Pantanal, i.e. 0.22 AU.ha^{-1} [1], to test the response of the rotational system under conditions of above-average grazing pressure. During the study period, the stocking rates of the continuously grazed areas remained at levels used by the landowner before initiation of the rotational system, i.e. 0.36 AU.ha^{-1} in the 626 ha pasture and 0.38 AU.ha^{-1} in the 1,317 ha pasture.

Forage dry mass

During the study period, native pasture in both the rotational and continuous grazing areas was dominated (> 98%) by four grasses, *Paspalum plicatulum* (felpudo, 38.3%), *Axonopus purpusii* (capim-mimoso, 36.9%), *Setaria parviflora* (rabo-de-raposa, 16.4%), and *Eragrostis articulate* (barba-de-bode, 6.8%). We determined the combined forage dry mass of these four species using standard methods accepted by the Natural Resource Conservation Service (NRCS) and Bureau of Land Management (BLM) [15]. Just before cattle were moved into a rotational system enclosure (pre-grazing), we sampled five one-meter squared plots by throwing a 1 m^2 plastic frame in five randomly chosen areas of pasture. We clipped the herbaceous vegetation within the plots at a height representative of cattle grazing, collected the material, and during the following days dried the samples at 60°C until a constant weight was obtained. Because cattle were moved weekly, this method produced twenty replicate samples of pasture each month that were averaged for monthly dry mass estimates (kg.ha^{-1}). In the continuous grazing areas, where cattle movements were not managed, we used the same methods once per month to obtain dry mass estimates.

To compare forage dry mass between the two grazing systems, we used a repeated-measures factorial ANOVA with grazing system as the main factor and monthly sampling period as the repeated measure ($\alpha = 0.05$) [16]. To meet assumptions of normality and variance homogeneity, we added 1 to forage dry mass values and applied a natural-log transformation. Because the interaction between grazing system and sampling period was significant (see results), we conducted four post-tests to compare forage dry mass between the grazing systems within specific monthly sampling periods, i.e., during peak wet- and dry-season months (March and August, respectively) and during wet-to-dry and dry-to-wet season transitional months (May and October, respectively). We used a Bonferroni-adjusted significance level of $\alpha' = 0.0125$ for the four post-test comparisons. We ran the ANOVA, post-tests, and *t*-tests (described below) with SYSTAT, 7.0 [17].

Cattle

Cattle of the Nelore variety (*Bos primigenius indicus*) were raised at the ranch. In May 2007, we ear-tagged a majority of the cattle (approximately 2,100), so that each animal would have an individual identification number that could be associated with records of age, weight, vaccinations, pregnancy, and health status, etc.. Using the database constructed from this information and the results of weighings and uterine palpitations for pregnancy status in early January 2008, we randomly chose two groups of 220 cows that were in the pool of 2- to 3-year-old, non-pregnant animals. One of the groups was released into the rotational system in mid-January 2008, and the other remained in the continuously grazed areas. We compared the initial weights of the two groups with a *t*-test ($\alpha = 0.05$). Both groups remained in their respective grazing areas throughout the study period.

Bulls were also chosen at random from the pool of available animals at the ranch and allocated to the rotational and continuous grazing systems at a bull-to-cow ratio of 1:25. Individual bulls were maintained throughout the study period in either the rotational or the continuous grazing areas to minimize problems associated with adapting to novel grazing management. Based on recommendations for the Pantanal [1], mineral salts were provided to cattle in the rotational and continuous grazing areas throughout the study period.

After initiation of the rotational system, we weighed and checked the pregnancy status of cows from the rotational and continuous grazing areas during periods when they were rounded up for routine vaccinations and other treatments, i.e., May 2008, September 2008, and May 2009. For the May 2009 data set, we compared cattle weights between the rotational and continuous grazing systems with t-tests ($\alpha = 0.05$). We compared animals in the same age range (i.e., 3.5 to 4.5 years in May 2009) and analyzed pregnant and non-pregnant cows separately. We also compared the proportion of pregnant cows between the two grazing systems with a binomial test ($\alpha = 0.05$) [16], again, using animals in the same age range (i.e., 3.5 to 4.5 years).

Forage allowance

For the rotational grazing system, we calculated monthly forage allowance, i.e., kg of pre-grazing forage dry mass per 100 kg of animal live weight (the ratio expressed as a percent) per day, using methods described by Santos *et al.* [11]. For the calculations, we used the total area of native pasture in the rotational system (i.e., 297 ha), adjusted the number of cattle from 220 to 170 to account for the presence of younger animals that graze less, assumed that 50% of forage dry mass was suitable for consumption by cattle, and (based on our cattle monitoring) used an average cow weight of 300 kg. We used the forage allowance estimates to calculate optimal stocking rates for the rotational system during wet- and dry-season months, assuming that optimal forage allowance for native pasture in the Pantanal would be similar to that of southern Brazil, i.e., 12% per day [12].

Results

Because of shared grazing histories and types of vegetation cover, initial pasture conditions in terms of forage composition and dry mass were the same in the three adjoining study areas, i.e., the rotational system and the two continuous-grazing areas. In November 2007, one month before launching the rotational system, forage biomass averaged 933 ± 307 kg/ha (95% confidence interval) in the three study areas. Fig. 2 compares forage dry mass between the grazing systems from January 2008, one month after the rotational system was launched, through December 2008. A repeated-measures ANOVA showed significant effects of grazing system, sampling period, and the interaction of grazing system and sampling period (grazing system: $F = 184.30$, df = 1, 13, $P < 0.0001$; sampling period: $F = 17.85$, df = 6, 78, $P < 0.0001$; grazing system by sampling period: $F = 4.78$, df = 6, 78, $P = 0.0003$). The significant interaction indicated that the magnitude of the grazing system effect varied with sampling period. Bonferroni-adjusted post-tests comparing the grazing systems within four key sampling periods, i.e., peak wet- and dry-season months (March and August, respectively), and wet-to-dry and dry-to-wet transitional months (May and October, respectively) showed that forage dry mass was significantly greater in the rotational system throughout the year (March: $t = 13.96$, df = 13, $P < 0.0001$; August: $t = 4.22$, df = 13, $P = 0.0010$; May: $t = 10.21$, df = 13, $P < 0.0001$; October: $t = 5.85$, df = 13, $P = 0.0001$) (Fig. 2). Differences were especially large during the wet season, but continued through the dry season as well (Fig. 2). Fig. 3 shows the obvious difference in forage availability between the rotational and continuous grazing areas during the dry season of 2008.

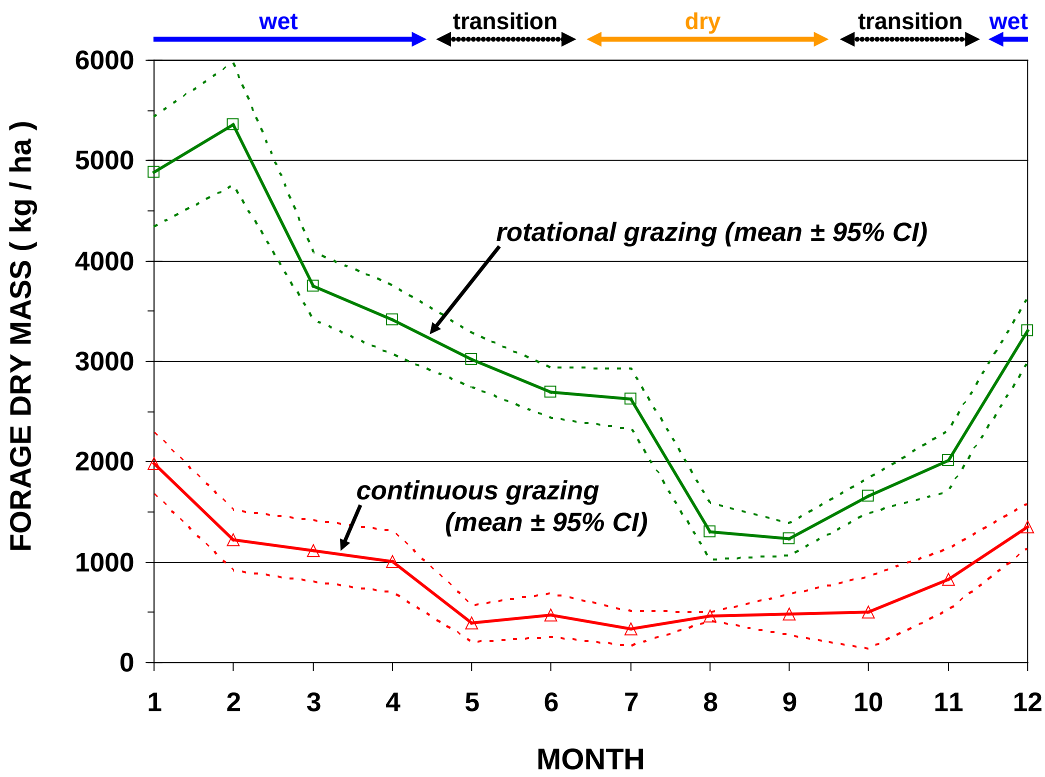

Fig 2. Monthly forage dry mass (kg.ha^{-1}), means ± 95% confidence intervals (CI), compared between continuous grazing areas (626 ha, 0.36 AU.ha^{-1} and 1,317 ha, 0.38 AU.ha^{-1}) and a rotational grazing system (497 ha, 0.43 AU.ha^{-1}) on a cattle ranch in the Aquidauana subregion of the southern Pantanal. Arrows above the graph indicate wet, dry, and transitional seasons.

Cattle weights from January 2008 were not significantly different between the two groups of 2- to 3-year-old, non-pregnant animals that were placed in the rotational system and continuous-grazing areas, respectively (overall mean weight, 277 ± 7.5 kg [95% confidence interval]; t = 0.9244, n = 210, P = 0.36). Seventeen months after the rotational system was launched, in May 2009, we again compared cattle weights between the continuous and rotational grazing systems. Consistent with results obtained in May 2008 [18], average weights were significantly greater for the herd using the rotational grazing system (pregnant, t = 7.296, df = 319, P < 0.001; non-pregnant, t = 4.248, df = 94, P < 0.001) (Fig. 4a). Combining weights from pregnant and non-pregnant cows, cattle in the rotational system were 46 kg (15%) heavier than those in the continuous grazing areas. Also during May 2009, we determined the pregnancy status of 211 cows from the rotational grazing system and 567 cows from the continuous grazing areas. In the rotational system, 93% of the cows were pregnant, while only 71% were pregnant in the continuous grazing areas (Fig. 4b). A binomial test showed that this difference was statistically significant (Z = 6.33, P << 0.001).

Seasonal patterns of forage allowance and weight gain by cattle from the rotational grazing system during 2008 are presented in Fig. 5. Results showed that forage allowance during wet season months, January through April, was above optimal levels (i.e. > 12% per day). Based on our estimates of pasture availability, a conservative (based on minimum forage allowance) stocking rate of 1.5 $AU.ha^{-1}$ could be used during wet season months in the rotational system. During the most extreme dry season months, August through September, forage allowance was well above the level that would indicate overgrazing (Fig. 5). In addition, the cattle continued to gain weight during dry season months (Fig. 5). Our estimates of forage allowance indicate that a stocking rate of 0.5 $AU.ha^{-1}$ would be optimal in the rotational system during dry season months.

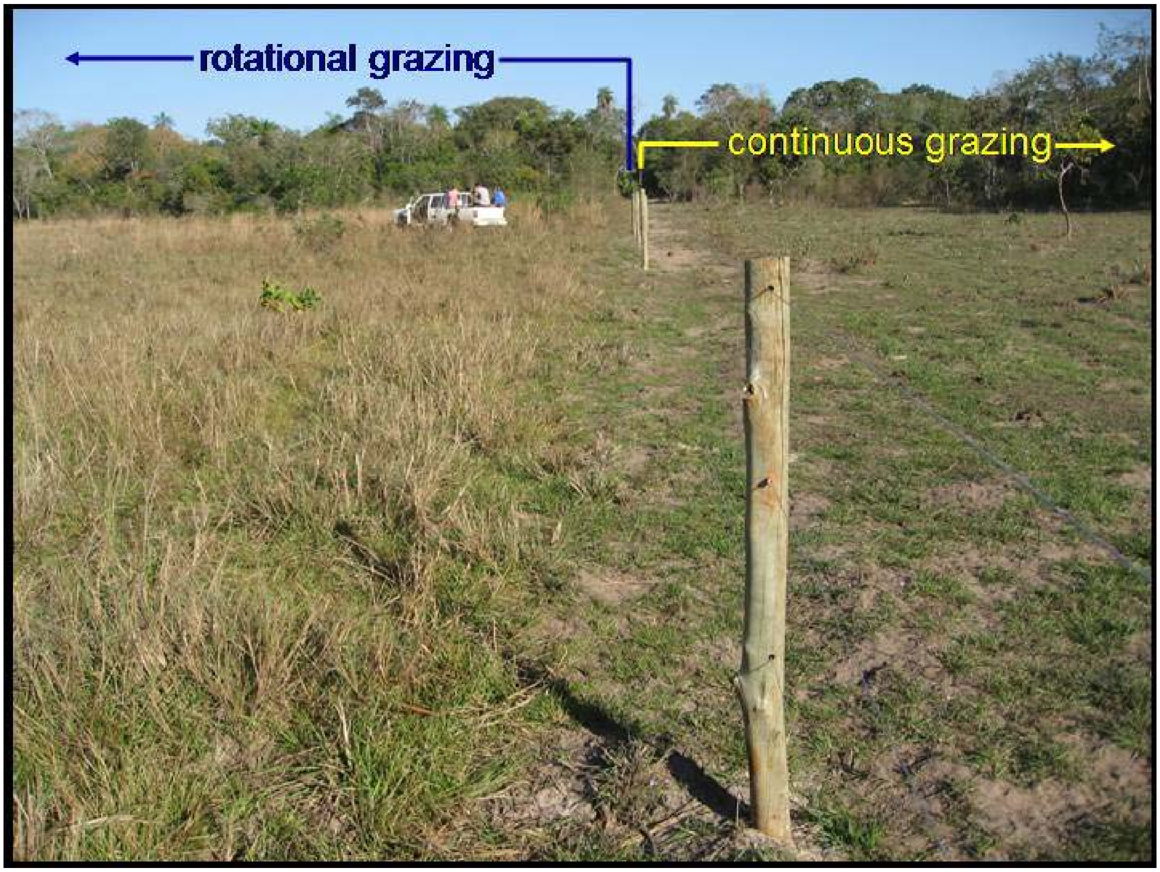

Fig. 3. Comparison of dry season forage availability in rotational and continuous grazing areas, July 2008, on a cattle ranch in the Aquidauana subregion of the southern Pantanal.

Discussion

In comparison to continuous grazing, the traditional and most widely used grazing practice in the Pantanal, rotational grazing improved native pasture conditions and cattle productivity. Annual rainfall levels during both experimental years, i.e., 1,138 mm in 2008 and 1,171 mm in 2009 (D.P. Eaton and Fazenda Campo Lourdes, unpublished data), were significantly less than the 10-year average at the partner ranch, i.e., 1,414 ± 196 mm (95% confidence interval), so the two grazing systems were tested under climatic conditions that were less favorable, on average, for both forage or cattle growth. Nevertheless, forage dry mass and cattle weights were significantly greater in the rotational system, even during the peak of the dry season (Figs. 2 - 4). For cattle in the Pantanal, dry season months (July through September) are typically associated with reduced weight gain and increased mortality [1], so additional forage from a rotational grazing system would be expected to have large benefits on herd health and productivity.

During a two-year study in the Nhecolândia subregion of the Pantanal, Crispim *et al*. [4] documented the seasonality of forage dry mass and species composition in a continuously grazed area of native pasture. The types of pasture formations the study monitored and the drier-than-average climatic conditions it reported were similar to this study [4]. The stocking rate used, however, was lower, i.e., 0.30 $AU.ha^{-1}$ used by Crispim *et al*. [4] vs. 0.36 - 0.38 $AU.ha^{-1}$ used in the continuous grazing areas of this study. Crispim *et al.* [4] recorded much higher quantities of forage dry mass compared to the continuously grazed areas of this study. The latter showed obvious signs of overgrazing and pasture degradation, e.g., the prevalence of bare soil patches (Fig. 3).

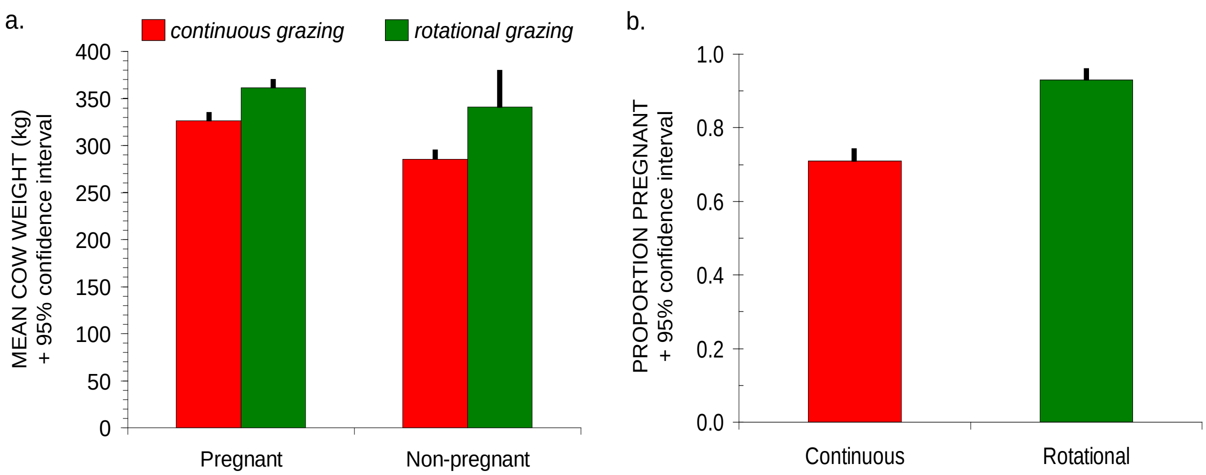

Fig. 4 a. Cattle weights (means + 95% confidence intervals), and b. the proportions of pregnant cows (+ 95% confidence intervals) compared between herds using continuous (red bars) and rotational (green bars) grazing systems on a cattle ranch in the southern Pantanal. Cow weights are separated by pregnancy status, i.e. pregnant or non-pregnant.

Compared to the rotational system of this study, which had an even higher stocking rate (i.e., 0.43 $AU.ha^{-1}$), Crispim *et al.* [4] documented a very similar seasonal range of forage dry mass. This similarity of forage availability under differing grazing pressures could be explained by increased forage productivity in the rotational system, a positive outcome that is frequently reported from studies of rotational grazing systems [7,9-10]. An alternative, but not mutually exclusive, hypothesis is that both the rotational system from this study and the pasture area monitored by Crispim *et al*. [4] were undergrazed, allowing forage species to reach similar growth maxima. Based on forage allowance estimates (discussed below), we suggest that undergrazing, in combination with increased forage production in the rotational system, was responsible for the similarities in forage availability during the wet season, while similarities during the dry season were due primarily to the latter, i.e., greater forage productivity associated with the rotational grazing system.

The improved reproductive success and greater weight gain of the animals demonstrated the potential financial benefits of establishing rotational systems in native pasture areas of the Pantanal. Based on beef cattle and calf prices for the Pantanal in May 2009, the potential economic gain from the heavier cows and additional calves in the rotational system was approximately $68 (R$136 reais) per adult animal. Numerous studies investigating a variety of livestock have reported increased savings and profits related to the use of rotational systems [7,9-10].

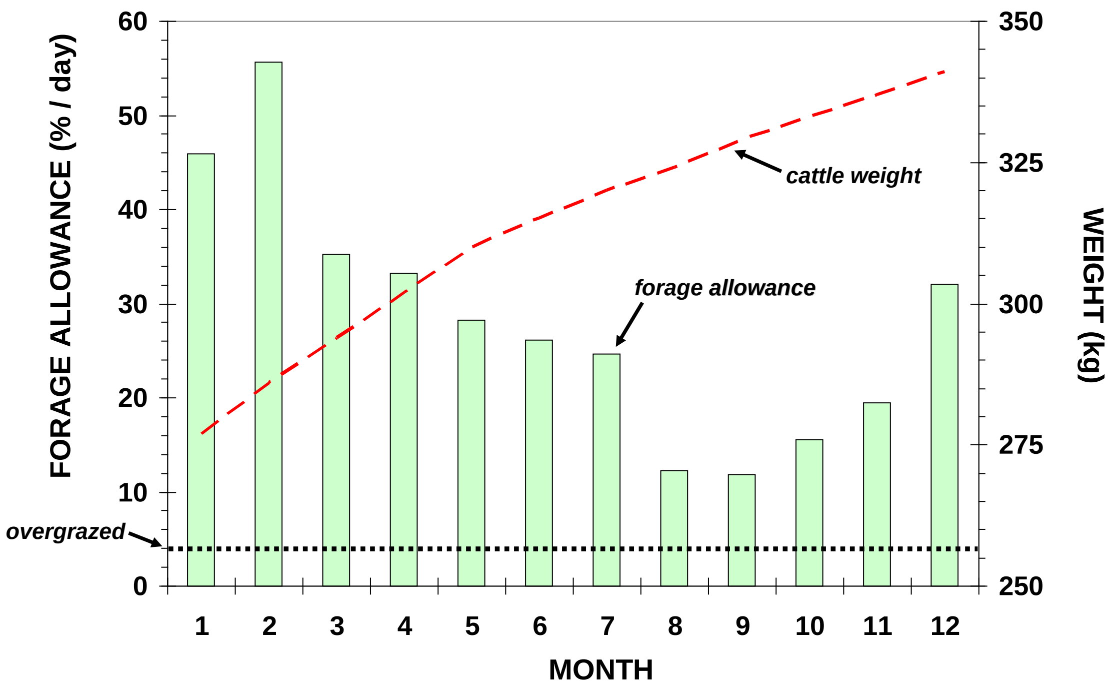

Fig. 5. Seasonal trends of forage allowance (% per day, light green bars), a measure of pasture availability in relation to the quantity of cattle using an area, and cattle weight gain (kg) (red dashed line) in a pasture rotational system of a ranch in the southern Pantanal. The black dotted line shows the forage allowance level that typically indicates overgrazing.

Based on forage allowance levels from the rotational system, the optimal stocking rates reported here for both wet and dry seasons were well above rates recommended for continuously grazed native pasture in the Pantanal [1]. This emphasizes another widely reported advantage of establishing a rotational grazing system, i.e., that more cattle per unit area can be supported [7,9-10]. In fact, the wet season stocking rate for the rotational system fell within the range of values reported for exotic pasture in the region, e.g., 0.80 $AU.ha^{-1}$ for continuously grazed areas with *Brachiaria* spp. in the Pantanal [1] and 2.42 $AU.ha^{-1}$ for a medium-intensity rotational system in the Cerrado [8]. The dry season stocking rate for the native pasture rotational system, however, fell below the range for exotic pastures.

The high forage allowance levels observed in the rotational system during the wet season indicated that stocking rates should be increased substantially to take advantage of pasture abundance and avoid problems associated with undergrazing, like the accumulation of less palatable forage and dead leaves [7,9-10]. The latter process provides fuel for naturally caused and human-set fires that may penetrate adjacent habitats that are less resilient to fire damage, e.g., forests and humid, low-lying vegetation formations that border aquatic environments [3,7]. Allowing fires to enter these habitats is counterproductive for the cattle operation and harmful for local flora and fauna [3,7]. The low-lying vegetation formations bordering aquatic environments provide some of the most nutritious forage for cattle and native grazers [3], and a large proportion of native mammals and birds are dependent on forest resources [19]. During the dry season, we calculated that the optimal stocking rate for the rotational system, which was more than double the recommended rate for continuously grazed native pasture in the Pantanal, should be approximately one third of the wet season rate. To reduce the stocking rate and avoid overgrazing during the dry season, a portion of the animals that used the rotational system in the wet season could be sold, and additional grazing areas that are only available during the dry season, i.e., those exposed after flood waters recede, could be used [1].

Implications for conservation

For landowners in the Pantanal, the potential financial gain from increased cattle productivity should be an important incentive for experimenting with and adopting rotational grazing in native pasture areas. The environmental benefits of rotational grazing, which are important for long-term sustainability of cattle operations, as well as regional conservation, are well documented in other regions [7,9-10]. Soil erosion and compaction are reduced, and soil moisture content is increased, because use of the grazing area is more even. Water quality is improved for cattle and wildlife, either because artificial water sources are provided for cattle, or natural water sources are allowed to recuperate from cattle impacts during grazing rest periods. Nutrient enrichment of water bodies, and possibly livestock-wildlife disease transmission, is reduced [20], because the distribution of cow manure and urine is more even and largely restricted to pasture areas [7,9-10]. These benefits in combination increase and improve habitat for the flora and fauna of native pasturelands [10], and should reduce cattle impacts in adjacent, non-grazing habitats [7]. With respect to the latter benefit for ranches in the Pantanal, we are currently evaluating whether the reduced grazing area requirements and improved pasture conditions of the rotational system diminish cattle use and impacts in adjacent forest and aquatic habitats.

In addition to the advantages of the rotational system, there are long-term benefits associated with using native, rather than introduced exotic pastures [3]. Native pasture is naturally renewable and adapted to the seasonal flood regime and extremes of regional climate [3]. It also provides a diversity of forage plants, each with a unique range of nutritional components [3-4]. In contrast, exotic pasture has a usable life span and in the Pantanal is associated with additional costs for deforestation, periodic clearing of secondary vegetation, replanting, and drainage of flood-prone lands. In addition, the nutritional range of an exotic monoculture is more restricted than the temporally and spatially diverse forage available in native pasture areas [3-4,21]. From a sustainability and conservation perspective, native pastures in the

Pantanal are composed of a biodiverse flora and fauna deserving of preservation, and the use of these natural grazing areas avoids the environmental consequences associated with deforestation and introduction of exotic grasses.

Native pasturelands in the Pantanal are spatially and temporally heterogeneous, so applying results from this and other studies from single locations will require careful analysis of local conditions [1,3]. By expanding studies that relate native pasture availability and quality with cattle productivity to other regions of the Pantanal, we hope to contribute to a regional database that presents optimal forage allowance levels for a variety of native pasturelands. This, in turn, will allow managers to set optimal stocking rates for particular pasture types, grazing systems, seasons, soil types, etc., creating an extremely valuable tool that will promote the efficient use of native pasture areas in the Pantanal and reduce pressures on forests and other environments. These studies should also be extended and expanded to highland Cerrado regions, where optimizing the use of existing exotic pasture areas should improve the sustainability of cattle operations and discourage additional deforestation [7].

Results from this study show that proper management of native pasturelands in the Pantanal will improve cattle productivity and simultaneously reduce pressures on natural resources, i.e., by improving pasture conditions and consequently reducing the area needed for grazing. Despite opposition by Embrapa-Pantanal (Brazilian Enterprise for Agricultural Research) and regional conservation organizations to deforestation, uncontrolled burning, and widespread indiscriminate replacement of native vegetation by exotic grasses [1,3,7,21], these harmful and unsustainable practices continue in the Pantanal and Cerrado. This study presents an economically and environmentally sustainable alternative for regional landowners that maximizes the production potential of native vegetation formations, while maintaining ecosystem services and biodiversity.

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