# Forage Production and Grazing Behaviour of Beef Cattle in Agrosilvopastoral Systems in Brazil during the Dry Season

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# Forage production and grazing behaviour of beef cattle in agrosilvopastoral systems in Brazil during the dry season

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**Key words**: *Bos indicus*; chewing behaviour; grazing systems; canopy structure; tropical forage

**Abstract**
We aimed at evaluating the microclimate, canopy structure, and grazing behaviour of cattle on *Brachiaria* sp. pastures within continuous pasture (CON), integrated crop-livestock (ICL), and crop-livestock-forestry (ICLF) systems in Brazilian dry season. Forage accumulation was monthly assessed in four paddocks per system from May to August 2019. To characterize the microclimate, air temperature and relative humidity were measured every hour and temperature-humidity index calculated. Grazing behaviour of 12 Nellore heifers per system (mean bodyweight 355 standard deviation±32.6 kg) was recorded by chewing sensors on nine continuous days (1 d adaptation + 8 d measurement) of three 15-d periods. Four animals per system were evaluated per period (n=3 systems x 3 animals x 3 periods x 8 d). Data were analysed by mixed model using SAS v9.4. Statistical significances were tested at $P<0.05$. Across the whole dry season, heifers were exposed to 343 hours of moderate heat stress and 76 hours of severe heat stress in CON and ICL. Instead, 342 hours of moderate heat stress but no severe heat stress conditions were observed in ICLF. Forage accumulation rate was greater in CON than ICLF, with no differences between ICLF and ICL. There were no differences between the systems for proportions of green leaf and dead plant material, although dead material accounted for 73% of total forage biomass on dry matter basis. Pasture in ICL was taller and had greater stem proportion than CON and ICLF. Forage canopy structure likely reduced bite mass in CON and ICL. As a compensatory mechanism, heifers in CON and ICL increased their number of grazing bites and prolonged their daily grazing time (in CON) as compared to animals in ICLF. In summary, under conditions of Brazilian dry season, grazing behaviour of Nellore heifers seems to be more influenced by canopy structure than by microclimatic factors.

## Introduction
Low availability and nutritional quality of forage on pastures limit the performance of cattle in grazing systems in Brazil, in particular during the dry seasons. Furthermore, high ambient air temperatures and solar radiation may induce heat stress, even in adapted breeds such as Nellore cattle. The additional energy costs for thermoregulation coupled with the poor nutrition challenge the beef cattle production in Brazilian grazing systems, typically in the dry season. Planting trees on pastures can improve the microclimatic conditions by reducing the environmental heat load. In integrated crop-livestock-forestry systems (ICLF), the arboreal component reduces solar radiation that reaches the forage canopy. To compensate for light restriction and reduce the negative effects of shading on plant growth, tropical forage grasses increase their specific leaf area, leaf elongation rate, and leaf length (Paciullo et al., 2011). Moreover, several authors have reported an improvement in forage nutritive value under shading, particularly an increase in crude protein concentration. Such changes in morphological and nutritional composition over their canopy profile affect behaviour of grazing cattle (Mezzalira et al., 2014), as the animals try to maintain their forage intake to meet their nutritional needs. However, forage intake of grazing cattle decreases when grazing conditions severely limit bite mass due to inability to maintain intake rate and time spent on other activities besides grazing, such as, ruminating, social interaction, and ordinary maintenance activities. The forage canopy structure strongly influences the foraging decisions of grazing animals such as the daily grazing time and the number and diurnal distribution of grazing events (Mezzalira et al., 2014). Not only forage characteristics would influence grazing behaviour, but also microclimatic conditions in the Tropics due to their potential to control the thermal comfort zone for the animals under pasture. Having cattle exposed constantly to heat stress with low animal performance due to the low forage biomass and quality in the Brazilian dry season, ICLF systems would be an alternative to improve productivity indexes, if well-managed. Therefore, the present study aimed at evaluating the microclimate, forage canopy structure, and grazing behaviour of cattle on *Brachiaria* sp. pastures within continuous pasture (CON), integrated crop-livestock (ICL), and integrated crop-livestock-forestry (ICLF) systems. The corresponding hypotheses are that shading from the eucalyptus trees in ICLF would ameliorate the thermal conditions for heifers in comparison to ICL and CON, which in turn would prolong grazing time in ICLF compared to ICL and CON. On the other hand, shading reduces forage accumulation of tropical forage grasses, and thus lower forage accumulation is expected in ICLF than ICL and CON. Moreover, to adapt to

limited radiation incidence as in ICLF, forage grasses may develop mechanisms to increase their photosynthetic capacity such as a change in their canopy structure, which would in turn impact grazing behaviour of heifers. For instance, we expect that a taller canopy with more leaves in ICLF than ICL and CON likely increases bite mass of the animals in ICLF.

## Study Site and Methods

The experimental area was sited at Embrapa Beef Cattle, in Campo Grande – Mato Grosso do Sul, Brazil (54°37′W, 20°27′S, and 530 m above sea level). It is geographically situated at the Cerrado biome. Field data collection was carried out in three different grazing-based beef production systems in the dry season, from May to August 2019. The three systems evaluated were characterized as follows:

I. Common CON system was a continuous monoculture pasture of *Brachiaria decumbens* cv. Basilisk grazed at a constant stocking density of 1.7 animal unit/ha (1 animal unit, AU = 450 kg bodyweight, BW) *Bos taurus indicus* Nellore heifers;

II. An ICL system with a pasture of *Brachiaria brizantha* cv. BRS Piatã grazed at 2.0 AU/ha stocking density of *Bos taurus indicus* Nellore heifers over three consecutive years and rotated with 1 year of soybean (*Glycine max* cv. BRS 255RR) in a no-tillage system every four years, and;

III. An ICLF system with *Eucalyptus urograndis* trees (*Eucalyptus grandis x Eucalyptus urophylla*; H13 clone) planted in single rows arranged along a North-South axis at distances of 4 m within and 22 m between rows (i.e., 113 trees/ha). During the experimental period, the average tree height was 30 m. The crop component was also soybean (*Glycine max* cv. BRS 255RR) cultivated in the no-tillage system every four years in rotation, followed by three consecutive years of a *Brachiaria brizantha* cv. BRS Piatã pasture that was grazed at a 1.0 AU/ha stocking density of *Bos taurus indicus* Nellore heifers.

The total area covered 13 ha that were divided into eleven paddocks with four paddocks for CON (0.8 ha each), three paddocks for ICL (1.4 ha each), and four paddocks for ICLF (1.4 ha each). The CON system was implanted in 1993, but since its implantation in 1993, CON system had been managed extensively without any management, which had led to severe degradation of the pasture. Therefore, at the end of 2017, the system was renewed by soil preparation and applications of 2000 kg of lime/ha, 800 kg of gypsum/ha, 110 kg/ha of NPK 0-20-20 as source of phosphorus (P) and potassium (K), and 45 kg of nitrogen (N)/ha as urea. The ICL and ICLF systems was implanted in 2008, and the present study was conducted in the second year of the third rotation cycle. Nitrogen fertilizer was applied at a rate of 75 kg N/ha in ICL and ICLF in March 2019. A total of 36 Nellore heifers were randomly allocated into all the paddocks in November 2018. Ambient air temperature and relative air humidity were hourly measured by Tinytag Plus 20 (Gemini Data Loggers, UK Ltd) in paddocks of CON and ICLF, over the whole experimental period. The Temperature-Humidity-Index (THI) was calculated according to Yousef (1985). Forage mass was sampled every month from May to August. For this, metal frames of 1.0 m x 1.0 m were randomly located in three sampling points in CON, and five sampling points in ICL and ICLF. Within these frames, canopy height was measured with a graduate ruler and thereafter above-ground forage mass was harvested at the height of 4 cm from the ground by a brush cutter. Additionally, exclusion cages of the same dimensions were established in CON (n=3 per paddock) and in ICL and ICLF (n=5 per paddock) to measure the forage accumulation rate (FAR) by the paired cage-difference method. The forage inside the exclusion cages was harvested monthly and the cages were moved to a new sampling point. Comparable points outside the cages with similar characteristics as that inside the cages were harvested at the same time to simulate the forage growth on pastures. The difference between forage mass inside the cages and outside the cages from the previous harvest was calculated and divided by the number of days between two consecutive sampling to calculate the FAR (kg dry matter (DM)/ha and day). All forage samples were weighed immediately after harvest, and pooled, and a sub-sample of each paddock was taken dried in a forced-air oven at 65ºC until constant mass for DM analysis. Another sub-sample was taken for separation into green leaves, green stems, and dead plant material. During three periods of 15 days, grazing behaviour was recorded by chewing sensors (RumiWatch, Itin&Hoch GmbH, Switzerland) in four animals per system for eight continuous days (i.e., 3 periods x 4 animals per system). While in CON and ICLF, two paddocks with two animals each were assessed per period, one paddock with four animals per period was chosen in ICL. The data were then converted by the RumiWatch Converter (V.0.7.3.36) into 24-hours intervals, summarizing grazing (min/day) and ruminating time (min/day), numbers of grazing bites (bites/day), grazing events (n/day), and rumination chews (n/day). Every grazing bout is defined as an event with a minimum duration of 7 min, and the inter-bout interval with a minimum threshold of 7 min (Werner et al., 2018). Some data were deleted from the data set due to either equipment failure or outliers. Hence, total number of observations of animal behaviour was 234, after some data deleted (i.e., 3 systems x 4 animals x 3 periods x 8 d). Heifers were individually weighed at the beginning and end of the experiment, with 16 hours of fasting prior weighing. Their mean BW across the dry season, from May to August, was 355 kg (standard deviation 32.6 kg). All animal-related procedures were approved by the Ethics and Animal Use Commission of the Embrapa Beef Cattle under protocol nº 002/2018. The forage intake (kg dry matter intake (DMI)/animal and day) was estimated from the faecal excretion of individual animals as determined using the external faecal marker titanium dioxide ($TiO_2$), and the apparent total tract organic matter (OM) digestibility of the consumed diet. The latter was estimated from the faecal crude protein concentrations based on the curvilinear relationship developed by Lukas et al. (2005; using ai=a2 from Gumpenstein location data). The forage intake was divided by the number of grazing bites (apprehensions) per animal and day in order to calculate the bite mass (kg OM/bite). Data were analysed by mixed model. All statistical analyses were performed by SAS v9.4. For forage data, the model included system as fixed effect, whereas for grazing behaviour data, period and system were included as fixed effects, paddock and animal as random effects, and day as repeated measurement. Statistical significances were tested at $P<0.05$ and Least Squares means (LSmeans) compared using the Tukey test. Results are presented as LSmeans±standard error.

## Results

The average THI observed at 07:00, 09:00, 11:00, 13:00, 15:00, and 17:00 in CON and ICL were 62±10.0, 70±8.9, 74±8.5, 76±5.0, 74±10.9, and 70±4.3, respectively, whereas in ICLF the corresponding values were 62±8.5, 65±12.6, 71±8.7, 72±8.5, 71±8.7, and 69±5.0. According to Baêta and Souza (2010), THI values up to 70 are within thermal comfort of Zebu cattle breed in tropical conditions, whereas values from 71 to 78 indicate moderate, and from 79 to 83 severe heat stress conditions. From 09:00 to 17:00 of May to August, the heifers in CON and ICL were thus exposed to moderate heat stress conditions for 343 hours and severe heat stress conditions for 76 hours. Similar times of moderate heat stress conditions were found in ICLF (342 hours), but heifers were not exposed to severe heat stress conditions. Forage accumulation rate (kg DM/ha and day) was greater ($P$=0.040) in CON (55.8±8.59) than ICLF (19.3±8.59), and intermediate for ICL (33.0±9.92), which did not differ from CON ($P$=0.250) neither from ICLF ($P$=0.571). Canopy height (cm) was taller (P=0.040) in ICL (42±2.9) than CON (30±3.3), whereas no differences between ICLF (31±2.5) and ICL ($P$=0.064) and CON ($P$=0.935). There were no differences ($P$=0.193) between the systems for the proportion of green leaves (CON 14±3.5, ICL 15±4.0, and ICLF 23±3.5) and dead plant material ($P$=0.130, CON 73±5.1, ICL 56±5.9, and ICLF 59±5.1). However, differences ($P$=0.008) between the systems were found for proportion of green stems. The greatest ($P$<0.001) proportion of green stems was observed in ICL (27±2.4). The ICLF (18±2.1) and CON (14±2.1) did not differ between each other ($P$=0.351). Heifers in CON (658±14.9 min/day) spent longer ($P$=0.017) time grazing than the ones in ICL (600±14.5 min/day). Grazing time in ICLF (614±13.7 min/day) did not differ neither from CON ($P$=0.077) nor from ICL ($P$=0.786). However, the number of grazing bites (bites/day) was similar ($P$=0.312) in CON (27,635±1,496.7) and ICL (24,560±1,487.6), were both greater (P≤0.044) than in ICLF (19,618±1,406.8). Nevertheless, the number of grazing events (9±2.0 n/day) did not differ ($P$=0.699) between the systems. Moreover, the largest ($P$=0.01) bite mass (g OM/bite) was found in ICLF (0.3±0.06). The ICL (0.2±0.05) and CON (0.2±0.08) did not differ between each other ($P$=0.981). There were no differences between the systems for ruminating time (min/day, $P$=0.385) and the number of rumination chews (n/day, $P$=0.373). Heifers ruminated for 413±18.6 min/day in CON, 378±20.3 min/day in ICL, and 409±18.1 min/day in ICLF. The respective number of rumination chews (n/day) for CON, ICL, and ICLF were 23,333±1,417.0, 20,705±1,519.0, and 21,055±1,376.9. The longest ($P$=0.005) time spent with other activities was found in ICL (453±17.1).

## Discussion [Conclusions/Implications]

The lower FAR in ICLF compared to CON partially supports our hypothesis that under shading (our findings were 44% of the incident radiation), photosynthetic rates of tropical forage grasses diminish (Baldissera et al., 2016), although FAR in ICLF did not reduce compared to ICL. Moreover, several studies have shown that tropical grasses may develop tolerance to moderate shading through a series of adaptations, including structural, morphological, and chemical mechanisms. For instance, shading on forage grasses increases their canopy height by stem and leaf elongation and results in greater leaf proportions, as mechanisms to improve light capture by the plant (Baldissera et al., 2016). The lowest FAR in ICLF was rather restricted by water competition between forage and the eucalyptus. In ICLF the canopy height as well as green leaf and stem proportions were not greater than ICL and CON, likely due to a deficit in soil water availability and the grazing effect, since pasture structural and morphological parameters were taken outside of the cages. In this line, Santos et al. (2016), who also did not observe any effect of shading in an ICLF system on the canopy height, concluded that during water stress conditions, plants cannot compensate for the limited radiation by triggering mechanisms to increase photosynthetic capacity. Additionally, as a result of low forage allowance in ICLF, the removal of leaves by the heifers in this system would be expected to be more pronounced than in ICL and CON. The ICLF was expected to provide a lower THI and radiation incidence than ICL and CON, and accordingly, no periods of severe heat stress were observed in ICLF. Although the maximum and minimum air temperature in CON and ICL were 31 and 16 °C and in ICLF 29 and 18 °C, respectively, the dry season in Brazil occurs in the coldest months of the year, when the weather conditions are more favourable for the thermal comfort of the animals in comparison to summer. Therefore, similar times of moderate heat stress for Nellore heifers were found for all the systems, and then, in the dry season, grazing behaviour seems to be more influenced by canopy structure than by thermal conditions. Heifers spent longer time grazing in CON than ICL, and ICLF did not differ between the systems. Although the proportion of dead plant material did not differ statistically between systems, it was particularly high in CON, which could explain the longer grazing time of animals in this system than in ICL and the lower bite mass than in ICLF. Heifers in CON may have searched for forage (forage biomass in CON 1,901 kg DM/ha vs. 3,853 kg DM/ha in ICL) to compensate for a low bite mass and/or they more selectively grazed for green biomass in this system than in ICLF as the forage allowance in CON was even greater than in ICLF. Instead, the low bite mass in ICL despite its great forage biomass and allowance may be related to the greatest stem proportion in ICL. Stems present a vertical and horizontal barrier for the animals to apprehend leaves, interfering with bite formation and negatively affecting bite mass (Benvenutti et al., 2009). To avoid consuming stems, animals increase their number of manipulative mouth movements (Mezzalira et al., 2014). These results confirm our hypothesis that ICLF would promote a greater bite mass than CON and ICL. Additionally, the reduced bite mass in CON and ICL supports their greater grazing bites (see methodology, apprehension given in bites/day) than ICLF, as compensatory strategy of animals to maintain forage intake (Mezzalira et al., 2014). The fact that animals avoided through their grazing behaviour the consumption of dead plant material and stems in CON and ICL, respectively, might have contributed to the similar time spent for ruminating time and other activities to ICLF, because cattle require more chewing effort for stems (McLeod and Smith, 1989) and potentially also for dead plant material than for green leaves. The implications in forage availability during the Brazilian dry season still befall in ICLF due to light and water limitation. However, the low FAR in ICLF does not impair the grazing behaviour of cattle ensued from changes in the forage canopy. Moreover, the fact that the trees' presence prevents severe heat stress cannot be dismissed.

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