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EFFECTS OF INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEM ON TIMBER, SOYBEAN, GRASS FORAGE AND CATTLE YIELDS

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ABSTRACT

A descriptive analysis of the second rotation cycle was carried out involving three production systems, one system under integrated crop-livestock (ICL) and two systems under integrated crop-livestock-forestry, ICLF14 (14x2m, 357 trees/ha) and ICLF22 (22x2m, 227 trees/ha), both with *Eucalyptus urograndis*, clone H13 trees. Grass forage used was *Brachiaria brizantha* cv. BRS Piatã through a period of three years for rearing of beef cattle followed by a soybean crop season, completing a rotation cycle of four years, in the Brazilian Cerrado. Results of this cycle are here presented, from 2013 to 2016, covering yields from, crop, forestry and, beef cattle. In the second cycle, it was observed that the influence of trees on the understory was accentuated, resulting in lower productivity from both crops and pasture, responding to density of trees, which, in contrast, increased their total timber production accordingly. Reductions in cattle yields were more pronounced during the dry season. At the end of this second cycle, thinning was carried out to remove 50% and 75% of the trees in ICLF22 and ICLF14, respectively, in order to increase light incidence and improve biomass production in the understory in the starting third rotation cycle.

Key words: animal production; forage production and quality; shading

INTRODUCTION

With the growing economic globalization and the consequent international markets opening, along with new demands over production processes, linked to sustainability, agriculture has been under pressure to reach levels of efficiency and competitiveness never seen before. Integrated systems have been developed in Brazil since the 1970s and have been adopted with greater intensity since 2010, due to the support from National Low Carbon Agriculture Plan (Plano ABC).

These production systems are a valuable option for sustainable intensification. They improve land use efficiency and farm profitability while reducing environmental impacts, especially related carbon sequestration and mitigating effects of greenhouse gases emissions. In research conducted in several regions of Brazil, integrated crop-livestock-forestry (ICLF) systems have shown excellent results (ALMEIDA et al., 2013). The impact of natural shade on cattle itself is favorable, as it improves thermal comfort and well-being in general. This leads to improvements on reproductive and productive performance (OLIVEIRA et al., 2014), however, for grass forage, shade can be either positive, with improvements in nutritional value, or negative, in case of shading at levels greater than 50%, which cause physiological, morphogenic and structural changes on plants that lead to decreased forage production (PACCIULLO et al., 2019).

In order to investigate details and develop strategies to recover degraded pastures and to adjust species, cultivars, tree densities, animal stocking rates and cultivation techniques in areas of the

Brazilian Cerrado under ICLF systems, a long-term experiment was implemented in 2008 in an area of 18 hectares, combining one year soybean cultivation followed by three years of grazing *Brachiaria brizantha* with *Eucaliptus urograndis* trees (227 and 357 trees/ha) for beef cattle production, in four-year rotation cycles. Below are shown results of the second rotation cycle, from 2013 to 2016.

MATERIAL AND METHODS

The experiment was conducted at the technological reference unit (URT) of Embrapa Beef Cattle, in Campo Grande, MS, Brazil (20°24′54.9″ S, 54°42′25.8″ W, altitude 530 m), in the biome Cerrado, belonging, according to the Köppen-Geiger climate classification, to the transition strip between Cfa and Aw tropical humid (KOTTEK et al., 2006). It has average annual precipitation of 1,560 mm and has hot and rainy summer with rather moderate cold but dry winter.

The experimental area consists of 3 treatments with 4 repetitions, having as forage component *Brachiaria brizantha* cv. BRS Piatã, a system under integrated crop-livestock (ICL, used as witness) and two systems under integrated crop-livestock-forestry, ICLF14 (14 x 2m with 357 trees/ha) and ICLF22 (22 x 2m with 227 trees/ha), both composed of *Eucalyptus urograndis*, clone H13.

Figure 1 illustrates how the experimental area was managed throughout the two rotation cycles. The farming practices adopted in the experimental area and the results of forage, crop and animal yields, from the first rotation cycle (2008 to 2012), are described in Pereira et al. (2014).

Year/ month		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	2008	Degraded pasture					1	1	1	1	1	2	2
1st cycle	2009	2-3	2-3	2-3	4-5	4-5	4-5	4-5	5	5	5	6	5
	2010	5	5	5-7	5-7	8	8	8	8	8	8	8	8
	2011	8	8	8	8	8	8	7-8	7-8	8	8	8	8
	2012	8	8	8	8	8	8	7-8	7-8	8	8	2	2
2nd cycle	2013	2	2	2	5	5	5	5	8	8	8	8	8
	2014	8	8	8	8	8	8	8	8	8	8	8	8
	2015	8	8	8	8	8	8	9	9	9	9	8	8
	2016	8	8	8	8	8	8	8	9	9	9	8	8
	2017	8	8	8	8	8	9-10	9-10	9-10	9-10	9-10	2	2

Figure 1. Cultivation scheme at the integrated crop-livestock-forestry system experiment at Embrapa Beef Cattle in Campo Grande-MS, Brazil: (1) Clearing, tillage, liming and fertilizer application; (2) Soybean cultivation; (3) Planting and care of Eucalyptus over soybean; (4) Sorghum cultivation over Brachiaria; (5) Brachiaria establishment for grazing; (6) Haying of Brachiaria; (7) Pruning of Eucalyptus; (8) Grazing with cattle; (9) Deferred pasture; (10) First Eucalyptus cut. Adapted from Pereira et al. (2014).

The second rotation cycle (2013 to 2016) started with the planting of soybeans in the 2012/2013 season. After soy harvest (March 2013), Piatã grass was sown and further managed under continuous grazing using variable stocking rate (put and take method), keeping sward height at least 20 cm, for the three years grazing. Nellore heifers were used, in the rearing phase. These were annually replaced by animals of the same category. Animals were weighed at intervals of approximately 30 days, when forage sampling was also carried out. The trees on the ICLF systems were measured twice annually, in the months of February/March and July/August. Annual maintenance fertilizer application was carried out, with 50 to 75 kg/ha of nitrogen, in the form of urea, and 200 to 300 kg/ha of the formula 0-20-20 (NPK), in January (rainy season).

Evaluations and analysis of the productive components were carried out from November 2013 to July 2016, following the methodology adopted in the first rotation cycle (PEREIRA et al., 2014).

RESULTS AND DISCUSSIONS

In the second evaluation cycle, the average heights of eucalyptus trees in 2013 and 2016 were 24.43 and 28.98 m in ICLF14 and 22.24 and 28.25 m in ICLF22, respectively. Shading observed in ICLF14 was 41% in February 2013 and 76% in August 2016 and, in ICLF22, it went from 40% to 61%, respectively (SANTOS, 2018). As for the average annual timber increment, the system with the highest tree density, ICLF14, showed higher productivity than the ICLF22, with averages of 24.04 and 13.78 m^3/ha in 2013, and 39.93 and 17.19 m^3/ha in 2016.

In the 2012/2013 soybean season, the ICLF14 and ICLF22 systems did not differ from each other and presented an average productivity of 2,154 kg/ha, which represented 74% of the ICL productivity (2,915 kg/ha) (QUINTINO et al., 2013).

As for the forage component, the average height of the Piatã grass in the rainy season (October to April) was 62.33, 65.67 and 64.67 cm and, in the dry season (May to September), 43.70, 47.00 and 52.00 cm, for the ICLF14, ICLF22 and ICL systems, respectively. Emphasizing that, in the drought, height of pasture sward above the expected is due to the fact that entry of the animals in the systems started exactly at that time of the year (Table 1).

Table 1. Average productive traits of three integrated systems (ICL, ICLF22 and ICLF14) during two seasons of the year, from 2013 to 2016: pasture sward height, forage dry mass, forage crude protein content (CP), stocking rate (SR), average daily gain (ADG), live weight gain by area (LWG) and soybean yield (2012/2013 harvest).

System	Sward height (cm)	Forage (kg/ha)	CP (%)	SR (AU/ha)	ADG (kg/day)	LWG (kg/ha)	Soybean (kg/ha)
Rainy season (October to April)							
ICL	64.67	2,718	10.43	2.23	0.505	303	2,915
$ICLF_{22}$	65.67	1,897	12.73	1.89	0.437	234	2,270
$ICLF_{14}$	62.33	1,209	13.47	1.47	0.437	148	2,038
Dry season (May to September)							
ICL	52.00	2,268	6.65	1.89	0.243	99	X
$ICLF_{22}$	47.00	1,283	8.83	1.28	0.211	40	X
$ICLF_{14}$	43.70	633	9.00	0.79	0.180	18	X

The averages of forage mass (kg/ha) and stocking rate (SR: animal unit/ha or AU/ha) in systems with trees were lower than on the system under full sun, mainly in the ICLF14 system, with a higher tree density. Average forage mass and the respective SR in the ICLF14 system was 1,209 kg/ha and 1.47 AU/ha, in the rainy season, and 633 kg/ha and 0.79 AU/ha, in the dry season; for ICLF22 it was respectively 1,897 kg/ha and 1.89 AU/ha, and 1,283 kg/ha and 1.28 AU/ha, and for ICL it was 2,718 kg/ha and 2.23 AU/ha and 2,268 kg/ha and 1.89 AU/ha (Table 1).

Higher content of crude protein (CP, %) and *in vitro* organic matter digestibility (IVOMD, %) were found in the green forage mass of systems with trees: ICLF14 with 13.47% CP and 58.1% IVOMD (rainy season) and 9.0% CP and 49.53% IVOMD (dry season), ICLF22 with 12.73% CP and 57.4% IVOMD (rainy season) and 8.83% CP and 50.0% IVOMD (dry season). The system under full sun (ICL) presented CP and IVOMD contents of 10.43% and 50.4% in the rainy season and 6.65% and 47.13% in the dry season (Table 1).

The average daily live weight gain (ADG) for the three-year grazing period in the rainy season did not vary between the ICLF systems (average 0.437 kg/day) but it was greater for the ICL system (0.550 kg/day). In the dry period, the ICLF14 system had the lowest ADG (0.180 kg/day), whereas the ICLF22 system had an intermediate result (0.211 kg/day) and the ICL had the highest ADG (0.243 kg/day). The average annual animal live weight gain per area, in the second cycle (2013 to 2016), was 402 kg/ha under ICL, 274 kg/ha under ICLF22 and 166 kg/ha under ICLF14 (Table 1).

Soybeans yield in the ICL system was slightly higher than the average for the 2012/2013 harvest in the state of Mato Grosso do Sul, that was 2,880 kg/ha (CONAB, 2013) where the experimental area is installed. The ICLF systems have harvested 75 % of this value, even with a tree density ranging from 257 to 357 trees/ha.

During the second cycle, there was a greater intensity of shading in the understory of the systems with trees (GAMARRA et al., 2017). As reported by Barros et al. (2020), in the same experimental area, this implies that the lower availability of radiation in the understory reduced the productive potential of the forage, making necessary to remove the animals from July to October in two consecutive years of grazing (2015 and 2016). This period is characterized by a lower availability of forage (PEREIRA et al., 2021). Details on dynamics of soil moisture are discussed in Glatzle et al. (2021).

Higher levels of crude protein and IVOMD were found in the forage mass in the shaded systems, contributing to the ADG of the animals being similar in the systems over the years, except for the dry period of the third year, when the ICLF systems were with intense shading, presenting ADG smaller than the system in full sun (SANTOS, 2018). There was no difference for the rainy season of the last year of the second rotation cycle in regards to animal ADG.

When observing the animal production by area in the second rotation cycle, we see that the ICLF14 and ICLF22 systems produced 41% and 68% of what was produced in the ICL, respectively. However, this reduction was more accentuated in the dry period, with relative yields of 18% and 40% for ICLF14 and ICLF22 in relation to ICL, while in the rainy season they were 49% and 77%, respectively, as demonstrated by Pereira et al. (2021) and Glatzle et al. (2021). Always relating to the ICL system, when comparing animal production by area between the first (2009 to 2012) and the second cycle (2013 to 2016), we see a decrease from 89% to 61% in ICLF22 and from 85% to 31% in ICLF14, due to the increased shading imposed by tree growth (ALMEIDA et al., 2019). Between systems with trees, ICLF22 proved to be promising for animal production. Despite shading interfering in forage production, there is a compensation through better nutritional quality in terms of crude protein content and IVOMD, thus favoring animal performance, since reduction in animal gain weight was only observed in the last years of the second cycle, when the shading of the pasture was more intense.

Recommendations from literature indicate that the tree component must undergo thinning in order not to damage forage productivity, being the ideal time to perform thinning when the understory has about 50% shading (PORFÍRIO-DA-SILVA et al., 2009). Results here obtained suggest that thinning at the right time can determine significant gains in animal productivity in the system. Although shading intensity was above 50% in the sixth year of implementation of the system, thinning occurred only in the eighth year (non-expected in the original project). But it was carried out just before the new crop cycle began, resulting in higher light incidence on soybeans and harvesting older timber, with higher added value. Thus, in the period from June to October 2017, selective thinning was carried out. There as a removal of 75% of trees in the ICLF14 system and 50% in the ICLF22. Spatial arrangements were adjusted to 28 x 4m and 22 x 4m, with 89 and 113 trees/ha, respectively, initiating the third rotation cycle, with the purpose of increasing light incidence in the understory to obtain greater forage and animal yields in these systems, in addition to providing revenue with the diversification of products.

In an investment analysis carried out by Pereira et al. (2017), it was observed that all systems in the present study were viable under several scenarios evaluated, but always having the ICL as more profitable than the ICLFs. However, in scenarios with greater timber value and possibility of environmental services and certification rewards, such as Carbon Neutral Brazilian Beef®, livestock systems with the forestry component tend to be more valued (PEREIRA et al., 2019).

CONCLUSIONS

Although ICLF systems offer forage with better nutritional value, it is clear from the results of the second rotation cycle that under intense light restriction (shading above 50%) forage growth is negatively affected, decreasing animal production animal per unit of area. Thus, the challenge remains on testing new spatial tree arrangements, forage cultivars more tolerant to shading and management practices involving all components, put together in long-term studies for different biomes, in order to support decision making towards adoption of ICLF systems.

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