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Economic Results of Forage Species Choice in Crop–Livestock Integrated Systems

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Abstract: Crop–livestock integrated production systems (CLISs) combine cash-crop production and forage production in succession. There are plenty of options of forage cultivars with differences in production aspects and seeds cost, and there is little information on how the choice of forage cultivar can affect the results of a CLIS. We hypothesized that different forage cultivars can have important economic impacts on production systems. Thus, we evaluated the two-year economic results of using three forage species in a CLIS: (1) *Urochloa ruziziensis*; (2) *Megathyrsus maximus* cv. BRS Zuri e; and (3) *Megathyrsus maximus* cv. BRS Tamani. The system was evaluated during 2018 and 2019 with no-tillage soybean (*Glycine max*) cultivation from November to March and grazing of cattle from May to August. The seed costs were, on average, USD 25.27 ha^{-1} for Ruziziensis grass, USD 39.97 ha^{-1} for Zuri guinea grass, and USD 64.13 ha^{-1} for Tamani guinea grass. Animal production varied from 96.4 to 147.5 kg of live weight per hectare per year and mean two-year soybean yields varied from 3849 to 4217 kg per hectare, both without differences between forage cultivars. However, the lowest values for animal and soybean yields were obtained with Ruziziensis grass, and the highest were obtained with Zuri grass. Thus, Zuri guinea grass presented a net income (NI) of USD 1039.87 ha^{-1} with an annual return on equity (ROE) equal to 11.19%, while Ruziziensis grass obtained an NI equal to USD 612.65 ha^{-1} with an ROE of 6.47%, demonstrating the economic impact of forage resource choice in CLISs. Therefore, the choice of forage cultivars adequate for the conditions of an individual farm can correspond to an increase of 69.7% in net income, which highlights the importance of continuing efforts to develop new cultivars and the simultaneous evaluation of these cultivars in different production scenarios in order to better recommend forage genetic resources for particular production environments.

Keywords: cattle; production systems; cost; income; return on equity

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1. Introduction

One of the biggest challenges in agriculture in the 21st century is boosting primary production (grains and forage biomass) with less prohibitive fixed costs and environmental preservation. Therefore, it is necessary to develop cultivation strategies that will allow the use of available abiotic resources in more sustainable ways. Crop–livestock integrated systems can increase land-use efficiency in a more rational way, since, when a strategic combination of different functional groups of plants is selected, it is possible to maximize production with the same resources [1,2].

Crop–livestock integrated systems (CLISs) are sustainable food production systems with no-till cultivation of cash crops and forage species in consortium, rotation, and/or succession. CLISs can increase food production per hectare, which increases the economic return and at the same time decreases the pressure for deforestation for food production systems [3,4]. Crop diversity improves soil physical, chemical, and biological parameters [5]. Simultaneously, multiple sources of income enable better cash flow and decrease risk [6,7]. CLISs with soybean–pasture succession yield grains in regular harvest seasons and good quality forage during the dry season of the year (harvest off-season) and are associated with high biomass input and good soil coverage following good no-tillage practices [8–11].

In CLISs, Dias et al. [12] found that the strategic diversification of different plant genera and species throughout the year promoted greater nutrient cycling when compared to a conventional system, thus contributing to production sustainability [13]. In a crop rotation system, over a period of 12 years, Rigon et al. [14] verified that the consortium of *Urochloa ruziziensis* with sorghum (*Sorghum bicolor*) generated a high-quality post-harvest residue, increasing phosphorus recycled by soybean *(Glycine max)*.

Muniz et al. [1] verified the effects of the cultivation of two grasses (*Urochloa brizantha* cv. 'BRS Paiaguás' and *Megathyrsus maximus* cv. 'BRS Tamani') intercropped with corn and showed that the intercropping systems provided greater soil coverage and nutrient cycling in relation to maize in monoculture; thus, intercropping favors greater soybean productivity. The authors showed that grass exhibited a greater fraction of carbon and nitrogen, slowing the straw decomposition process and providing an increase in organic matter and nutrients in the upper layers of soil.

Carvalho et al. [6], evaluating livestock production in agriculture systems over 9 years, showed increments in yield of 3,4%, 4,7%, 10,4%, and 10,8% in soybean, common beans, rice, and corn, respectively. Over 9 years of experiments, these authors showed that a traditional soybean system (exclusive soybean production) yielded 2.940 kg ha^{-1}, on average, while the CLIS (soybean and beef cattle production) yielded 4.860 kg ha^{-1}, converting beef into soybean equivalent.

Economic analyses of CLISs have great importance in guiding the decisions of farmers and for the definition of research priorities. Most CLIS studies evaluate only productivity parameters combined with soil properties and animal production aspects, and there is a lack of economic evaluation of whole systems [15]. Livestock rearing in a CLIS can be an opportunity for diversification and income [5], but it can also represent a significant increase in the cost of infrastructure (water tanks, fences, and corrals) and equity due the animal value, increasing the financial risk of the business [7]. The use of economic-based decision-making processes can enhance economic sustainability by economy of scope, due to a lower cost for the same product and lower risk due to product variety [16].

The cost of seeds and forage production potential differ according to forage cultivars, and it is not clear how the choice of forage cultivars can affect the economic results of production systems. There are more than 30 cultivars of forage species commercially available in Brazil nowadays. Most of these cultivars are from two genera: *Urochloa* spp. and *Megathyrsus maximus*. *Urochloa ruziziensis* is the main species used in CLISs due to the low seed cost, higher glyphosate sensitivity, fast growth with high biomass production, and soil coverage [17–19]. Cultivars of *Megathyrsus maximus* are, in general, associated with higher seed costs and higher forage/biomass production [20]. *Megathyrsus maximus* cv. BRS Tamani have a small size (20 to 60 cm in sward height), with high leaf-to-stem proportions, high nutritional value, and resistance to pasture leafhoppers [19,21]. *Megathyrsus maximus* cv. BRS Zuri, meanwhile, have a tall size (60 to 100 cm in sward height), fast growth, higher biomass production, high nutritional value, and resistance to spittlebugs in pastures [22]. However, these species are not widely used in CLISs due to the higher glyphosate doses required for desiccation and possible impairments to soybean no-till sowing in subsequent seasons due to the elevated amounts of biomass coupled with tussocks in the field. Thus, we hypothesize that the choice of cultivars that are adequate for environmental and farm conditions can enhance the economic results of CLISs, which could justify more research for improved decision-making processes regarding CLISs.

The aim of this study was to evaluate the production and economic consequences of choosing different forage cultivars in a CLIS. Therefore, the main points evaluated were:

(I) animal production; (II) residual biomass and canopy structure; (III) soybean yield; and (IV) the economic results of the CLIS.

2. Materials and Methods

The experiment was conducted on Encanto Farm (privately owned), located in Montes Claros de Goiás, GO, Brazil (15°43′54.69″ S and 51°37′13.09″ O). The farm is in Brazilian savanna with an AW climate, according to the Köppen climate classification (Köppen and Geiger [23]). Normally, there is no precipitation from May to September in this region.

The crop–livestock integrated system (CLIS) used here consisted of soybean cultivation during the summer (November to March) and pasture during the winter, with a grazing period from May to August. Three different forages were used in this production system during a two-year trial: (1) *Urochloa ruziziensis* (Syn. *Brachiaria ruziziensis*); (2) *Megathyrsus maximus* cv. BRS Zuri (Syn. *Panicum maximum* cv. BRS Zuri); and (3) *Megathyrsus maximus* cv. BRS Tamani (Syn. *Panicum maximum* cv. BRS Tamani), called hereafter Ruziziensis grass, Zuri guinea grass, and Tamani guinea grass, respectively. The experimental area (Figure 1) was 44.43 ha, divided into three paddocks for each of the grasses (15.26 ha for Ruziziensis grass, 16.67 ha for Zuri guinea grass, and 12.5 ha for Tamani guinea grass).

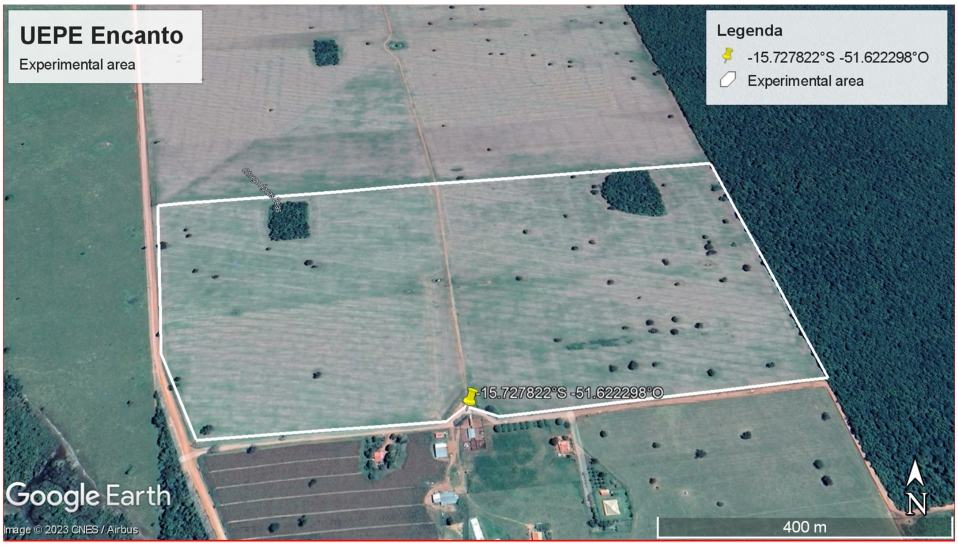

Figure 1. Experimental field on Encanto Farm in Montes Claros de Goiás, Goiás State, Brazil.

2.1. Animal and Forage Production

Soybean no-till sowing was performed in November of each year using the cultivar BMX Bônus. The plant protection management was the same for all the treatments and followed the agronomical recommendations. Soybean harvest was performed in March. The following production components were determined: grain yield (kg ha^{-1}), stands (plants m^{-2}), and yield per plant (g plant^{-1}). Manual sampling was performed at five points for each repetition, with sampling of two meters of two soybean rows (50 cm between rows). For soybean yield, all plants sampled in these two rows were threshed, the grains were weighed, and the moisture contents were measured. Then, grain yield was calculated by adjusting to 13% of moisture. To determine stands, the numbers of plants in the two 2-m rows were counted. At the side of the sampling point, five random plants were sampled, and later the numbers of pods and grains were manually measured to obtain data on production per plant.

Pasture was overseeded on soybean crops at R5.5 stage using 4 kg ha^{-1} of pure viable seeds of Ruziziensis grass, Tamani grass, and Zuri grass. Therefore, during the period between the grass seeding and the soybean harvest, an intercropping system was established. Grazing began when the pasture had reached the recommended sward height for grazing (30 cm, 65 cm, and 80 cm, respectively) [24–26].

The livestock phase involved setting up an electric fence, water tanks, and troughs (30 cm per animal) for supplementation. Heifers at 20 months of age and with an average weight of 290 kg were used. The numbers of animals used in 2018 and 2019 were, respectively, 28 and 46 for Ruziziensis grass, 46 and 42 for Tamani guinea grass, and 21 and 39 for Zuri guinea grass. The animals were weighed at the beginning and at the end of the experiment, and intermediated weighing sessions were carried out at each 28 days of grazing. The animals (testers) remained in the same paddocks during the whole experimental period, using a continuous stocking grazing system.

Forage dry mass was measured every 28 days [27,28]. The forage evaluation was performed, cutting 1 m^2 at five random points in each paddock. The cutting was performed with a pruner (STIHL® HS 45) at 10 cm above ground level. The forage available was harvested, weighed, and placed in a dry oven (55 °C) for 72 h, then weighed again, determining the available forage mass in kg of dry matter per hectare. The stocking rate was adjusted in each paddock based on live weight and forage dry matter mass every 28 days.

The animals received increasing supplementation planning during the 2018 grazing period, starting with 0.3% of live weight (LW), then 0.5% of LW and 1.5% of LW. During the 2019 grazing period, animals received mineral supplementation ad libitum (mean consumption of 80 g per animal per day). In the 2018 grazing period, heifers started grazing on May 2 for Zuri guinea grass and Tamani guinea grass and on June 5 for Ruziziensis grass. Grazing ended on July 04 for Zuri guinea grass and on August 30 for 'BRS Tamani' and Ruziziensis grass. Therefore, the numbers of grazing days in 2018 were 63, 120, and 86 for 'BRS Zuri', 'BRS Tamani', and Ruziziensis grass, respectively. In the 2019 grazing period, heifers started grazing on May 6 for all three grasses, and grazing ended on July 29 for Zuri and Ruziziensis grass and on September 04 for Tamani guinea grass. Therefore, Tamani guinea grass had 121 grazing days and the other grasses had 84 grazing days.

Stocking rate was defined in animal units (AU = 450 kg LW) per hectare. The average live weight gain per day (LWG) was calculated as the difference between initial and final live weights divided by the number of days between weighings. The paddock live weight gain was obtained from the LWG multiplied by the number of animals in the paddock at that period.

Fattening score was determined by visual appraisal at each weighing, following similar procedures to those described in Ayres et al. [29]. Heifers with adequate fattening scores (higher than 4 on a 1–5 scale) were sent to a commercial slaughterhouse, where carcass weights were recorded. Animals were commercialized in five rounds in 2018 and in four rounds in 2019.

2.2. Economic Analyses

Economic analyses were split into crop and livestock phases. Total cost (TC) consisted of the sum of livestock costs and soybean crop costs. The direct costs of the operation, considering all mechanized procedures (from pasture sowing, crop seeding, management, and harvest), animal purchases, and infrastructure purchases and installations, were evaluated. In the crop phase, all supplies expended were recorded. As the management during crop phase was equal to all forage cover crops, the soybean costs were the same for all treatments.

Operational costs, livestock supplements, crop cultivation inputs (such as fertilizers, pesticides, and seeds), animal values, and land values were measured. Labor expended with livestock management was determined by the average income per hour of cowboys in the region (USD 1.50 h^{-1}). The number of hours expended in each year was recorded and divided by the number of animals in the experiment, resulting in a cost of USD 0.10 $head^{-1}$ day^{-1} (2018) and USD 0.038 $head^{-1}$ day^{-1} (2019). The supplementation strategy used in 2018 resulted in more hours expended than in 2019.

Animal supplements offered in 2018 totaled 449.02 kg ha^{-1}, 455.41 kg ha^{-1}, and 509.02 kg ha^{-1}, for 'BRS Tamani', 'BRS Zuri', and Ruziziensis grass, respectively. In 2019, the mineral supplements offered totaled 33.94 kg ha^{-1} for Tamani guinea grass, 66.71 kg ha^{-1} for Zuri-grass, and 72.87 kg ha^{-1} for Ruziziensis grass. The supplementation used represented the main strategies used by farmers in CLISs in Central Brazil.

Pasture seed costs were determined by the total seed weights expended and the real prices paid out by the farmer. 'BRS Zuri', 'BRS Tamani', and Ruziziensis grass seed costs were USD 10.13, 17.23, and 7.87 per kg of pure viable seeds (PVS) in 2018 and USD 9.85, 14.83, and 4.77 kg^{-1} in 2019, respectively.

Animal purchase costs were USD 382.12 and USD 383.18 per heifer in 2018 and 2019. The mean selling prices were USD 2.25 and USD 2.43 kg^{-1} per kilogram of carcass in 2018 and 2019, respectively. The cost of FUNDEPEC-GO (livestock development fund) was USD 1.12 animal^{-1}, and other taxes (FUNRURAL and animal transit passes) for commercialization were added to the total livestock phase costs.

Total gross income (GI) was calculated on the basis of income from soybean commercialization (the amount produced multiplied by the mean selling price obtained by the farmer) and livestock (the difference between the selling and buying prices for each animal). Total net income (NI) was determined by the difference between total gross income (GI) and total cost (TC).

The equity value consisted of land value and circulating capital (animals plus total cost). Land values were determined by a price survey in the region, obtaining an average land value of USD 2682.04 ha^{-1}.

The return on equity per month (ROEm) was calculated by taking the net income of each phase (NI) divided by the total equity multiplied by the number of months for each phase, with four months for the livestock phase and eight months for the soybean phase. Then, the ROE per year was calculated: ROEy = ((ROEm + 1)^12)$^{-1}$, where ROEm = return on equity per month and ROEy = return on equity per year.

The results were submitted to an analysis of variance considering the effects of the three forage species, and, if an effect was significant ($p < 0.05$), the means were compared by least significant differences (considered to be equal to twice the standard deviation). Analyses used the car [30] and emmeans [31] packages in R software v.4.1.0 [32].

3. Results

Livestock and Crop Yields

There was no difference in mean forage availability in 2018 between the forage species. In 2019, Zuri grass had more forage availability compared to the other species (Figure 2). Regarding the two-year averages, Zuri grass presented higher forage availability.

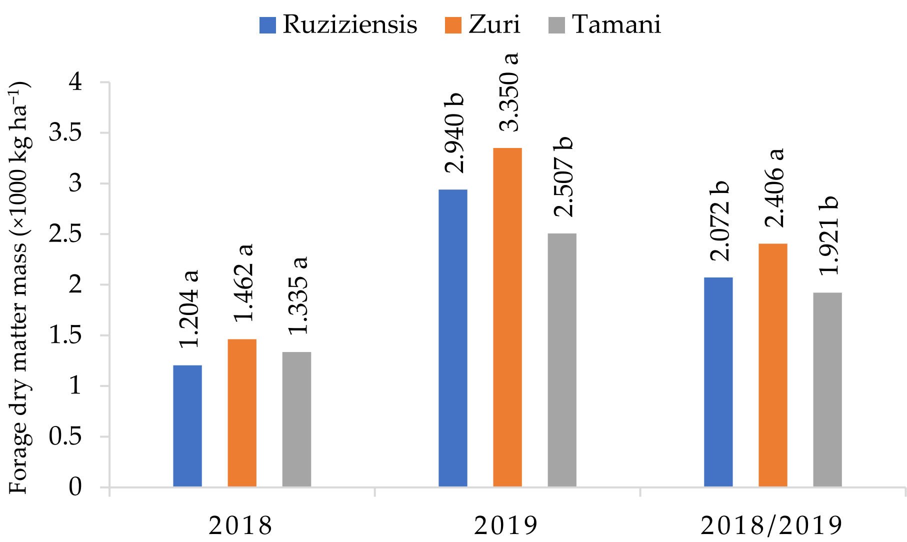

Figure 2. Mean forage dry matter mass availability during the grazing phase of the crop–livestock integrated system using different forage species: *Urochloa ruziziensis*, *Megathyrsus maximus* cv. BRS Zuri, and *Megathyrsus maximus* cv. BRS Tamani. Different letters in the same year means statistical differences between forage species.

In 2018, Tamani guinea grass had a lower stocking rate than the other species (Table 1). In 2019, there was no difference in animal grazing parameters. On average, Zuri grass had a higher stocking rate compared to Tamani guinea grass, while Ruziziensis grass was positioned in an intermediate position, not differing from either (Table 1).

Table 1. Livestock production in the crop–livestock integrated system over two years (2018 and 2019) using three forage species for winter grazing: *Urochloa ruziziensis*, *Megathyrsus maximus* cv. BRS Zuri, and *Megathyrsus maximus* cv. BRS Tamani.

Pasture	MLW (kg)	SR (kg ha^{-1})	SR (AU ha^{-1})	LWG (kg dia^{-1})	LWGH (kg ha^{-1})
			2018		
Ruziziensis	358.4 a	578.2 a	1.28 ab	0.701 a	96.70 b
BRS Zuri	326.8 a	943.6 a	2.10 a	0.975 a	180.65 a
BRS Tamani	356.2 a	444.3 b	0.99 b	0.793 a	133.92 a
			2019		
Ruziziensis	320.0 a	694.0 a	1.54 a	0.532 a	96.07 a
BRS Zuri	330.8 a	881.8 a	1.96 a	0.422 a	114.44 a
BRS Tamani	326.4 a	522.8 a	1.16 a	0.544 a	100.56 a
			Mean		
Ruziziensis	339.0 a	636.1 ab	1.41 ab	0.616 a	96.4 a
BRS Zuri	329.0 a	912.7 a	2.03 a	0.699 a	147.5 a
BRS Tamani	341.0 a	483.6 b	1.07 b	0.668 a	117.2 a
SD	16.52	200.50	0.45	0.203	32.85

Means followed by different letters in the column represent differences higher than two times the standard deviation of the variable. MLW: mean live weight; SR: stocking rate; LWG: live weight gain per day; LWGH: live weight gain per hectare; SD: standard deviation.

There was no effect of the forage species as cover crop on soybean yield (Table 2). Regarding plant stands, Ruziziensis grass showed higher numbers than the other species, but this did not affect soybean yield.

Table 2. Soybean yield and production components in the crop–livestock integrated system over two years (2018 and 2019) using three different forage species as cover crops: *Urochloa ruziziensis*, *Megathyrsus maximus* cv. BRS Zuri, and *Megathyrsus maximus* cv. BRS Tamani.

Year	Pasture	Grain Yield (kg ha^{-1})	Stand (Plants m^{-2})	Plant Yield (g planta^{-1})
2018	Ruziziensis	3.795 a	14.9 a	12.8 a
	BRS Zuri	3.796 a	12.9 b	14.7 a
	BRS Tamani	3.461 a	12.2 b	14.3 a
2019	Ruziziensis	3.904 a	10.5 a	17.0 a
	BRS Zuri	4.637 a	10.4 a	20.9 a
	BRS Tamani	4.660 a	9.8 a	18.3 a
Mean	Ruziziensis	3.849 a	12.2 a	14.9 a
	BRS Zuri	4.216 a	11.6 ab	17.8 a
	BRS Tamani	4.060 a	11.0 b	16.3 a
p-Value	Forage	ns	0.0013 **	ns
	Year	ns	ns	ns
	Forage × Year	ns	ns	ns

Means followed by different letters in the same column differ significantly ($p < 0.05$) according to Tukey testing. ns: not significant ($p > 0.05$); **: means significant effect with $p < 0.01$. Forage × Year: means the interaction effect between forage species and year in the model.

Economic Analyses

Tamani grass had the highest seed cost (USD 64.13 ha^{-1}), followed by Zuri guinea grass (USD 39.97 ha^{-1}) and Ruziziensis grass, which had the lowest (USD 25.27 ha^{-1}). Therefore, the adoption of Megathyrsus maximus represented increments of 58.7% (Zuri guinea grass) and 154.4% (Tamani guinea grass) in seed investment relative to Ruziziensis grass (the main forage cultivar used in CLISs). Seed expenditure represented 25% to 43% of the cost of the livestock phase, considering the average of the two years (Figure 3). Labor represented only 5 to 7% of the total cost of the livestock phase, while animal supplementation represented 52% to 69% of the cost of the livestock phase (Figure 3).

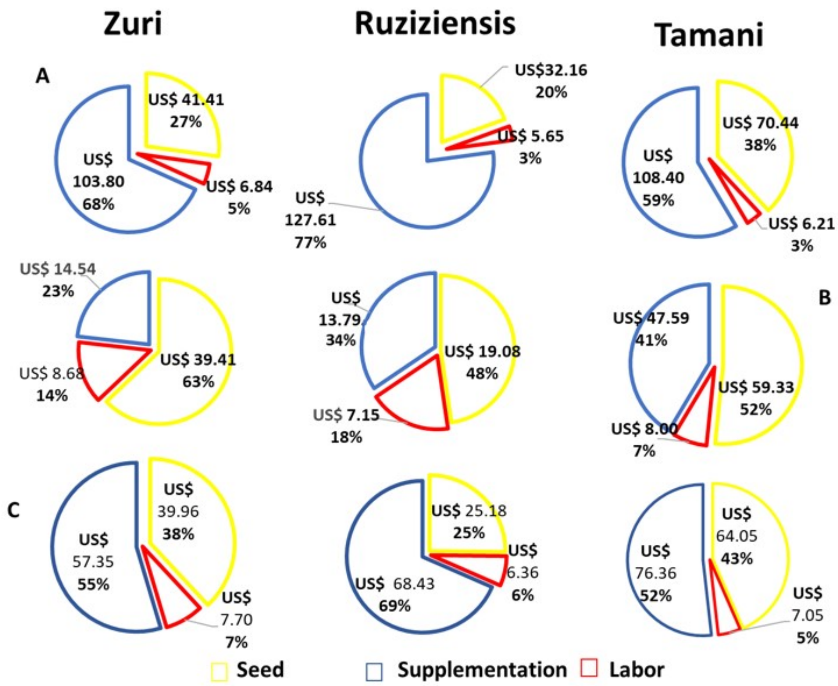

Figure 3. Cost composition (USD per hectare) of the livestock phase for 2018 (**A**), 2019 (**B**), and the two-year average (**C**).

There were no statistical differences in soybean production costs and production due to the different forage species used previously in the two-year evaluation (Table 2). Return on equity (yearly basis) for the soybean phase varied from 11.69% with Ruziziensis grass in the system to 17.77% with Zuri guinea grass in the system. In 2018, Ruziziensis grass presented a negative net income in the livestock phase, while Zuri guinea grass presented a 13.66% return on equity on a yearly basis (Table 3). In 2019, Tamani grass presented an ROE per year equal to 10.16%, while those of the other species were lower than 7% (6.99% for Ruziziensis grass and 6.5% for Zuri guinea grass). On average, return on equity (yearly basis) varied from 3.08% for Ruziziensis grass to 8.57% for Tamani guinea grass to 10.08% for Zuri grass during the livestock phase (Table 3).

Table 3. Economic results of livestock production using three forage species in a crop–livestock integrated system over two years (2018 and 2019).

Pasture	Carcass Cost (USD kg^{-1})	Total Cost (USD ha^{-1})	Net Income (USD ha^{-1})	Herd Value (USD ha^{-1})	Equity (USD ha^{1})	ROEm * (%)	ROEy (%)
2018							
Ruziziensis	50.21	150.74 b	−11.12 b	1120.43	4007.38	−0.07 b	−0.83 b
BRS Zuri	24.71	312.61 a	163.83 a	944.33	3818.20	1.07 a	13.66 a
BRS Tamani	40.56	275.81 ab	94.75 a	1295.48	4201.65	0.56 a	6.98 a

Table 3. *Cont.*

Pasture	Carcass Cost (USD kg^{-1})	Total Cost (USD ha^{-1})	Net Income (USD ha^{-1})	Herd Value (USD ha^{-1})	Equity (USD ha^{1})	ROEm * (%)	ROEy (%)
				2019			
Ruziziensis	12.51	119.89	79.84	853.74	3532.78	0.56	6.99
BRS Zuri	16.42	141.29	78.65	1033.26	3734.88	0.53	6.50
BRS Tamani	34.28	225.14	110.22	649.87	3403.78	0.81	10.16
				Mean			
Ruziziensis	31.06	135.07	35.09	984.95	3766.27	0.25	3.08
BRS Zuri	20.50	225.57	120.56	989.51	3775.87	0.80	10.08
BRS Tamani	37.37	250.07	102.60	967.50	3796.31	0.69	8.57
SD	14.18	76.67	56.29	211.74	241.87	0.38	4.81

* Return on equity (ROE) calculated considering 4 months for the livestock phase in one year of production for the crop–livestock integrated system. SD: standard deviation. Equity: sum of total cost, herd value, and land value (USD 2725.10 ha^{-1}).

Overall, the net income and return on equity were positive for all treatments (Table 4). Zuri guinea grass had an 11.19% ROEy, while Tamani grass and Ruziziensis grass had ROEy values of 9.51% and 6.47%, respectively.

Table 4. Economic results of the production system during the two years of soybean and livestock production using three different forage cultivars.

Forage	TC (USD ha^{-1})	GI (USD ha^{-1})	NI (USD ha^{-1})	Equity (USD)	ROEm (%)	ROEy (%)
Ruziziensis	2189.53	2802.90	612.65	4871.58	0.52	6.47
BRS Zuri	2199.04	3238.90	1039.87	4881.08	0.89	11.19
BRS Tamani	2283.62	3188.83	905.22	4965.66	0.76	9.51

TC: total cost; GI: total gross income; NI: net income; Equity: sum of total cost, herd value, and land value (considered equal to USD 2725.10 ha^{-1}); ROEm and ROEy: return on equity per month and per year, respectively.

4. Discussion

Zuri guinea grass had higher mean forage availability during the grazing period compared to the other species, 13.9% and 20.2% higher than Ruziziensis grass and Tamani guinea grass, respectively. This cultivar is known for its fast growth and high efficiency of use of available abiotic resources [33]. The higher forage availability allowed a higher stocking rate (2.03 AU ha^{-1}), which was 30.54% more than that of Ruziziensis grass (1.41 AU ha^{-1}). Otherwise, Tamani guinea grass had longer grazed periods in both years, which demonstrated the difference between tall-size and small-size types of *Megathyrsus maximus*.

Both *Megathyrsus maximus* cultivars (BRS Tamani and BRS Zuri) had higher live weight gains per hectare (LWGH) than *Urochloa ruziziensis* in the first year. In the second year, the differences between forage species narrowed, but the order was the same: Zuri guinea grass, Tamani guinea grass, Ruziziensis grass. At the end, on average, the Zuri guinea grass system produced 147.5 kg of LWGH, while Ruziziensis grass yielded 96.4 kg, which represents a 53% increment in animal weight produced per area. Similar results were observed by Dias et al. [12], which reinforces the need to explore these forage genetic resources in crop–livestock integrated systems.

There was no difference in soybean yield over the two years (Table 2), which reinforces that, with good management practices, cultivars of *Megathyrsus maximus* can be utilized in crop–livestock integrated systems without losses to main crops [34,35].

Supplement cost represented an important part of livestock cost, especially in the first year, when a strategy of protein-energetic supplementation was used. Santos et al. [36] also observed that supplement costs represented the highest proportions of livestock costs in crop–livestock integrated systems.

In general, *Megathyrsus* had higher seed costs than *Urochloa*, which can partially justify the intense use of *Urochloa ruziziensis* in crop–livestock systems in Brazil, as the use of Zuri guinea grass and Tamani guinea grass represented increments of 58.7% and 154.4% in investment in seeds, respectively. Thus, if a farmer does not expect important yield differences between forage cultivars, it is justified to choose the low-cost option. This shows the importance of studies verifying the productive and economic aspects of choices of forage genetic resources. Some previous studies have shown the higher forage/biomass production of *Megathyrsus* in crop–livestock integrated systems [35].

Investments for animal purchase represented 26% of the total equity of the system. The resource requirements for animals present one of the main challenges for livestock production in integrated systems. Compared to traditional livestock systems, the stocking rate is three to four times higher; consequently, the investment in animals per hectare is proportionally higher. At the same time, the livestock phase of the system was not always profitable and demonstrated huge variation in the three treatments over the two years. Ruziziensis grass in the first year had a negative net income, for example. Thus, the introduction of animals in production systems is an opportunity for increasing and diversifying income; however, this represents an increase in financial risk due to the increase in capital applied even more nowadays with increased price volatility of this commodity [37,38]. Poffenbarger [39] observed that CLISs had higher costs (higher investments) compared to conventional systems in the US between 2008 and 2015. These authors also concluded that they were associated with higher animal acquisition and labor costs. However, these authors showed better economic results for CLISs compared to conventional systems in the long term.

The return on equity for the whole system over the two years equaled 6.5%, 9.6%, and 11.2% for Ruziziensis grass, Tamani guinea grass, and Zuri guinea grass, respectively. Therefore, a simple choice of forage genetic resources can be responsible for a 69.7% increment in net income. This result is a consequence of the higher animal and soybean yields with moderate seed costs. Other studies have shown that Zuri guinea grass is a very fast biomass producer, with good animal performance and stocking rates in high-fertility soils [40–42].

5. Conclusions

Crop–livestock integrated systems can enable good economic results despite the elevated investments in animals they require. The choice of the forage genetic resources to be used is very important and can have an important impact on economic results: in the present study, the simple choice of forage genetic resources was responsible for a 69.7% increment in net income. Therefore, the evaluation of the production potentials of different forage species is essential to support the decision-making processes of farmers. Moreover, it is important to select species to be used in crop rotation systems with high biomass inputs coupled with no-till sowing to obtain sustainable production systems (environmentally and economically). For the region of this study, we highlight *Megathyrsus maximus* cv. 'BRS Zuri' as an important option for winter grazing as part of a crop–livestock integrated system with a crop rotation system.

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References

1. Muniz, M.P.; Costa, K.A.D.P.; Severiano, E.D.C.; Bilego, U.O.; Almeida, D.P.; Neto, A.E.F.; Vilela, L.; Lana, M.A.; Leandro, W.M.; Dias, M.B.D.C. Soybean yield in integrated crop livestock system in comparison to soybean maize succession system. *J. Agric. Sci.* **2021**, *159*, 188–198.
2. Amadori, C.; Dieckow, J.; Zanatta, J.A.; Moraes, A.; Zaman, M.; Bayer, C. Nitrous oxide and methane emissions from soil under integrated farming systems in southern Brazil. *Sci. Total Environ.* **2022**, *828*, 154–555. [CrossRef]
3. Ruviaro, C.F.; da Costa, J.S.; Florindo, T.J.; Rodrigues, W.; de Medeiros, G.I.B.; Vasconcelos, P.S. Economic and environmental feasibility of beef production in different feed management systems in the Pampa biome, southern Brazil. *Ecol. Indic.* **2016**, *60*, 930–939. [CrossRef]
4. Gléria, A.A.; Silva, R.M.; Santos, A.P.P.; Santos, K.J.G.; Paim, T.P. Produção de bovinos de corte em sistemas de Integração Lavoura e Pecuária. *Arch Zootec* **2017**, *66*, 141–150. [CrossRef]
5. Ambus, J.V.; Reichert, J.M.; Gubiani, P.I.; de Faccio Carvalho, P.C. Changes in composition and functional soil properties in long-term no-till integrated crop-livestock system. *Geoderma* **2018**, *330*, 232–243. [CrossRef]
6. Carvalho, P.C.D.F.; Peterson, C.A.; Nunes, P.A.D.A.; Martins, A.P.; de Souza Filho, W.; Bertolazi, V.T.; Anghinoni, I. Animal production and soil characteristics from integrated crop-livestock systems: Toward sustainable intensification. *J. Anim. Sci.* **2018**, *96*, 3513–3525. [CrossRef] [PubMed]
7. Rego, C.A.R.D.M.; Muniz, L.C.; Reis, V.R.R.; Cantanheide, I.S.D.L.; Costa, B.P.; Marques, E.D.O.; Oliveira, P.S.R.D. economic analysis of the implementation of different systemsde of crop-livestock-forestry integration in the municipality of Pindaré-Mirim, Maranhão. *Sodebras* **2018**, *13*, 146.
8. Alves, B.R.; Madari, B.E.; Boddey, R.M. Integrated crop-livestock-foresty sustems: Prospects for a sustainable agricultural intensification. *Nutr. Cycl. Agroecosyst.* **2017**, *108*, 1–4. [CrossRef]
9. Asai, M.; Moraine, M.; de Wit, J.; Hoshide, A.K.; Martin, G. Critical factors for crop-livestock integration beyond the farm level: A crossanalysis of worldwide case studies. *Land Use Policy* **2018**, *73*, 84–194. [CrossRef]
10. Schuster, M.Z.; Lustosa, S.B.C.; Pelissari, A.; Harrison, S.K.; Sulc, R.M.; Deiss, L.; Lang, C.R.; Carvalho, P.C.F.; Gazziero, D.L.P.; De Moraes, A. Optimizing forage allowance for productivity and weed management in integrated croplivestock systems. *Agron. Sustentar. Dev.* **2019**, *39*, 18. [CrossRef]
11. Nepstad, L.S.; Gerber, J.S.; Hill, J.D.; Dias, L.C.P.; Costa, M.H.; West, P.C. Pathways for recent Cerrado soybean expansion: Extending the soy morato-rium and implementing integrated crop livestock systems with soybeans. *Environ. Res. Lett.* **2019**, *14*, 029–044. [CrossRef]
12. Dias, M.B.C.; Costa, K.A.P.; Severiano, E.C.; Bilego, U.O.; Almeida, D.P.; Brand, S.C.; Vilela, L.; Furtini-Neto, A.E. Brachiaria and Panicum maximum in an integrated crop-livestock system and a second-crop maize system in succession with soybean. *J. Agric. Sci.* **2020**, *1*, 1–12. [CrossRef]
13. Costa, N.; Andreotti, M.; Crusciol, C.A.C.; Pariz, C.M.; Bossolani, J.W.; De Castilhos, A.M.; Nascimento, C.A.C.D.; Lima, C.G.D.R.; Bonini, C.D.S.B.; Kuramae, E. Can Palisade and Guinea Grass Sowing Time in Intercropping Systems Affect Soybean Yield and Soil Chemical Properties? *Front. Sustain. Food Syst.* **2020**, *4*, 81. [CrossRef]
14. Rigon, J.P.G.; Crusciol, C.A.C.; Calonego, J.C.; Pavinato, P.S.; Azevedo, A.C.; Rosolem, C.A. Intensive crop rotations and residue quality increase soil phosphorus lability under long-term no-till in tropical soils. *Soil Tillage Res.* **2022**, *223*, 105446. [CrossRef]
15. Soler, R.; Peri, P.L.; Bahamonde, H.; Gargaglione, V.; Ormaechea, S.; Herrera, A.H.; Jardon, L.S.; Lorenzo, C.; Pastur, G.M. Assessing Knowledge Production for Agrosilvopastoral Systems in South America. *Rangel. Ecol. Manag.* **2018**, *71*, 637–645. [CrossRef]
16. Martha Júnior, G.B.; Alves, E.; Contini, E. Dimensão econômica de sistemas de integração lavoura-pecuária. *Pesqui. Agropecuária Bras.* **2011**, *46*, 1117–1126. [CrossRef]
17. Carvalho, A.M.; De Souza, L.L.P.; Guimarães Junior, R.; Alves, P.C.A.; Vivaldi, L.J. Plantas de cobertura com potencial de uso para sistemas de integração lavoura-pecuária na região do Cerrado. *Pesq. Agropec. Bras.* **2011**, *46*, 1200–1205. [CrossRef]
18. Tegegn, A.; Kyalo, M.; Mutai, C.; Hanson, J.; Asefa, G.; Djikeng, A.; Ghimire, S. Genetic diversity and population structure of Brachiaria brizantha (A. Rich.) stapf accessions from Ethiopia. *Afr. J. Range Forage Sci.* **2019**, *36*, 129–133. [CrossRef]
19. Dias, M.B.D.C.; Costa, K.A.D.P.; Severiano, E.D.C.; Bilego, U.O.; Vilela, L.; de Souza, W.F.; de Oliveira, I.P.; da Silva, A.C.G. Cattle performance with Brachiaria and Panicum maximum forages in an integrated crop-livestock system. *Afr. J. Range Forage Sci.* **2021**, *39*, 230–242. [CrossRef]

20. Jank, L.; Barrios, S.C.; Do Valle, C.B.; Simeão, R.M.; Alves, G.F. The value of improved pastures to Brazilian beef production. *Crop Pasture Sci.* **2014**, *65*, 1132–1137. [CrossRef]
21. Tesk, C.R.M.; Cavalli, J.; Pina, D.S.; Pereira, D.H.; Pedreira, C.G.S.; Jank, L.; Sollenberger, L.E.; Pedreira, B.C. Herbage responses of Tamani and Quênia guinea grasses to grazing intensity. *Agron. J.* **2020**, *112*, 2081–2091. [CrossRef]
22. Lima, G.C.; Hungria, M.; Nogueira, M.A.; Filho, M.C.M.T.; Moreira, A.; Heinrichs, R.; Filho, C.V.S. Yield, yield components and nutrients uptake in zuri guinea grass inoculated with plant growth-promoting bacteria. *Int. J. Innov. Educ. Res.* **2020**, *8*, 103–124. [CrossRef]
23. Köppen, W. *Das Geographische System der Klimate*; Gebrüder Borntraeger: Berlin, Germany, 1936; pp. 1–44.
24. Dias Filho, M.B. Formação e manejo de pastagens. Comunicado Técnico 235, Embrapa Amazônia Oriental 2012. Available online: http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/937485 (accessed on 1 October 2022).
25. Costa, J.A.A.; Queiroz, H.P. *Régua de Manejo de Pastagens—Edição Revisada*; Embrapa: Campo Grande, Brazil, 2017; 7p.
26. Fidalski, J.; Tormena, C.A.; Alves, S.J. Intervalo hídrico ótimo de um latossolo vermelho distrófico, após o primeiro período de pastejo contínuo de Brachiaria ruziziensis, em sistema integração lavoura-pecuária. *R. Bras. Ci. Solo* **2013**, *37*, 775–783. [CrossRef]
27. Silva, D.J.; Queiroz, A.C. *Análise de Alimentos: Métodos Químicos e Biológicos*, 3rd ed.; UFV 235: Viçosa, Brazil, 2002.
28. Detmann, E.; Souza, M.A.D.; Valadares Filho, S.D.C.; Queiroz, A.C.D.; Berchielli, T.T.; Saliba, E.D.O.S.; Cabral, L.D.S.; Pina, D.D.S.; Ladeira, M.M.; Azevedo, J.A.G. Métodos para análise de alimentos. *Visconde Do Rio Branco Suprema* **2012**, *17*, 214.
29. Ayres, H.; Ferreira, R.M.; Torres-Júnior, J.R.D.S.; Demétrio, C.G.B.; de Lima, C.G.; Baruselli, P. Validation of body condition score as a predictor of subcutaneous fat in Nelore (*Bos indicus*) cows. *Livest. Sci.* **2009**, *123*, 175–179. [CrossRef]
30. Fox, J.; Weisberg, S. *An {R} Companion to Applied Regression, 3rd ed*; Sage: Thousand Oaks, CA, USA, 2019; Available online: https://socialsciences.mcmaster.ca/jfox/Books/Companion/ (accessed on 1 July 2022).
31. Length, R. _emmeans: Estimated Marginal Means, aka Least-Squares Means_. R package version 1.8.0. 2022. Available online: https://CRAN.R-project.org/package=emmeans (accessed on 1 July 2022).
32. R CORE TEAM. R: A Language and Environment for Statistical Computing; R Foundation for Statistical Computing, Vienna, Austria. 2020. Available online: https://www.R-project.org/ (accessed on 1 July 2022).
33. Silva, S.C.; Sbrissia, A.F.; Pereira, L.E.T. Ecophysiology of C4 forage grasses—Understanding plant growth for optimising their use and management. *Agriculture* **2015**, *5*, 598–625. [CrossRef]
34. Almeida, R.E.M.; Gomes, C.M.; Lago, B.C.; Oliveiras, S.M.; Pierozan Junior, C.; Faravin, J.L. Corn yield, forage production and quality affected by methods of intercropping corn and Panicum maximum. *Pesq. Agropec. Bras.* **2017**, *52*, 170–176. [CrossRef]
35. Momesso, L.; Crusciol, C.A.C.; Soratto, R.P.; Vyn, T.; Tanaka, K.S.; Costa, C.H.M.; Costa, J.F.N.; Cantarella, H. Impacts of nitrogen management on no–till maize production following forage cover crop. *Agron. J.* **2019**, *111*, 639–649. [CrossRef]
36. Santos, A.A.P.D.; Vidigal Filho, A.L.; Vidigal, L.L.D.V.; De Souza, V.L.; De Figuereido, A.M.B.; Piacentini, M.T.S. Análise da rentabilidade do sistema semi-intensivo de engorda de bovinos semiconfinamento. *Res. Soc. Dev.* **2022**, *11*, e10011427128. [CrossRef]
37. Hoag, D.L. *Applied Risk Management in Agriculture*; CRC Press: Boca Raton, FL, USA, 2010; pp. 419–424. ISBN 9781439809730.
38. Girdžiūtėa, L. Risks in agriculture and opportunities of their integrated evaluation. *Procedia Soc. Behav. Sci.* **2012**, *62*, 783–790. [CrossRef]
39. Poffenbarger, H.; Artz, G.; Dahlke, G.; Edwards, W.; Hanna, M.; Russell, J.; Sellers, H.; Liebman, M. An economic analysis of integrated crop-livestock systems in Lowa, U.S.A. *Agric. Syst.* **2017**, *157*, 51–69. [CrossRef]
40. Soares, K.A.R.S.C. *Avaliação Nutricional da Silagem de Capim-Zuri (Panicum maximum cv. BRS Zuri) Contendo Diferentes Aditivos. Sinop-MT: Dissertação (Mestrado)—2017*; Universidade Federal de Mato Grosso, Instituto de Ciências Agrárias e Ambientais, Programa 50 de Pós-Graduação em Zootecnia: Cuiabá, Brazil, 2017.
41. Braga, G.J.; Maciel, G.A.; Guimarães Junior, R.G.; Ramos, A.K.B.; Carvalho, M.A.; Fernades, F.D.; Fonseca, C.E.L.; JANK, L. Performance of young Nellore bulls on guinea grass pastures under rotational stocking in the Brazilian Cerrado. *Trop. Grassl. Forrajes Trop.* **2019**, *7*, 214–222. [CrossRef]
42. Silva, E.B.; Carneiro, M.S.D.S.; Furtado, R.N.; Lopes, M.N.; Braga, M.D.M. Chemical composition of Panicum maximum 'BRS Zuri' subjected to levels of salinity and irrigation depths. *Rev. Ciênc. Agron* **2020**, *51*, 1–10. [CrossRef]