International Journal for Innovation Education and Research

ISSN: 2411-2933

Animal production and economic viability of integrated crop livestock systems

Gustavo Antunes Trivelin;Cristiana Andrighetto;Gustavo Pavan Mateus;Patrícia Aparecida da Luz;Elaine Mendonça Bernardes;Gelci Carlos Lupatini;Helena Sampaio Aranha;Erikelly Aline Ribeiro Santana;Aline Sampaio Aranha;Bianca Midori Souza Sekiya;Juliana Mara de Freitas Santos;Humberto de Jesus Eufrade-Junior

Abstract

Integrated crop-livestock system appears as strategy to reduce pasture recovery costs and diversify farmer's income with the sale of the wood of eucalyptus trees. The objective of this work was to evaluate the animal performance and economic viability of systems without shade availability (ICL: Integrated Crop-Livestock) and with two tree densities (ICLF-1L: Integrated Crop-Livestock-Forest, 196 trees ha-1; ICLF-3L: Integrated Crop-Livestock-Forest, 448 trees ha-1). Sixty castrated Nellore cattle were used to evaluate performance during rearing and finishing. For economic analysis, the cash receipts, cash outflow, cash flow, net cash flow and internal rate of return (IRR) were evaluated between December 2012 and June 2016. The performance of the animals was lower in ICLF-3L system ($P<0.05$) due to the higher density of trees, and consequently, greater shading of the pasture. In ICL and ICLF-1L systems, the revenue from soybean and corn fully paid for the costs of implementing the systems, and ICLF-1L still covered the cost of forest deployment. In ICLF-3L, the costs were almost completely covered. The reduction in the productive indices also reduced the revenue from the slaughter of cattle in ICLF-3L, with the highest revenue in ICL and ICLF-1L, respectively. In addition, the IRR in ICL and ICLF-1L was higher. ICLFs contribute to the amortization of the recovery costs of the pastures and the implantation of eucalyptus. The ICL and ICLF-1L is more economically viable than ICFL-3L until the fourth year of implementation.

Keyword: Nellore; net cash flow; productivity; sustainable system

Published Date: 8/1/2020 **Page.530-540** **Vol 8 No 08 2020**

DOI: https://doi.org/10.31686/ijier.vol8.iss8.2559

Animal production and economic viability of integrated crop livestock systems

Gustavo Antunes Trivelin
São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena-SP 17900-000, Brazil, gustavotrivelin@hotmail.com

Cristiana Andrighetto (Corresponding author)
São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena-SP 17900-000, Brazil. e-mail: cristiana.andrighetto@unesp.br. Fone 55 18 3821-8153

Gustavo Pavan Mateus
Agência Paulista de Tecnologia dos Agronegócios – Andradina-SP 16900-970, Brazil. E-mail: gpmateus@apta.sp.gov.br

Patrícia Aparecida da Luz
São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena-SP 17900-000, Brazil. e-mail: patricia.luz@unesp.br

Elaine Mendonça Bernardes
São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena-SP 17900-000, Brazil. e-mail:elaine.mendonca-bernardes@unesp.br

Gelci Carlos Lupatini
São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena-SP 17900-000, Brazil. e-mail: gelci.lupatini@unesp.br

Helena Sampaio Aranha
São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena-SP 17900-000, Brazil. e-mail: helena-aranha@live.com

Erikelly Aline Ribeiro Santana
São Paulo State University (Unesp), School of Veterinary Medicine and Animal Science, Botucatu-SP, 18618-000, Brazil. E-mail: erikellysantana@hotmail.com

Aline Sampaio Aranha
São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena-SP 17900-000, Brazil. e-mail: alinearanhassa@gmail.com

Bianca Midori Souza Sekiya

São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena 17900-000, Brazil e-mail: bia_souza_sekiya@hotmail.com

Juliana Mara de Freitas Santos

São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena 17900-000, Brazil e-mail: julianazootec@yahoo.com.br

Humberto de Jesus Eufrade-Junior

São Paulo State University (Unesp), School of Agriculture, Botucatu-SP, 18610-034, Brazil. E-mail: hdjejunior@gmail.com

Abstract

Integrated crop-livestock-forest system appears as strategy to reduce pasture recovery costs and diversify farmer's income with the sale of the wood of eucalyptus trees. The objective of this work was to evaluate the animal performance and economic viability of systems without shade availability (ICL: Integrated Crop-Livestock) and with two tree densities (ICLF-1L: Integrated Crop-Livestock-Forest, 196 trees ha-1; ICLF-3L: Integrated Crop-Livestock-Forest, 448 trees ha-1). Sixty castrated Nellore cattle were used to evaluate performance during rearing and finishing. For economic analysis, the cash receipts, cash outflow, cash flow, net cash flow and internal rate of return (IRR) were evaluated between December 2012 and June 2016. The performance of the animals was lower in ICLF-3L system (P<0.05) due to the higher density of trees, and consequently, greater shading of the pasture. In ICL and ICLF-1L systems, the revenue from soybean and corn fully paid for the costs of implementing the systems, and ICLF-1L still covered the cost of forest deployment. In ICLF-3L, the costs were almost completely covered. The reduction in the productive indices also reduced the revenue from the slaughter of cattle in ICLF-3L, with the highest revenue in ICL and ICLF-1L, respectively. In addition, the IRR in ICL and ICLF-1L was higher. ICLFs contribute to the amortization of the recovery costs of the pastures and the implantation of eucalyptus. The ICL and ICLF-1L is more economically viable than ICFL-3L until the fourth year of implementation.

Keywords: Nellore; net cash flow; productivity; sustainable system

1. Introduction

Integrated crop-livestock systems provide economic and social benefits (Müller et al., 2011), such as increased productivity, diversification of farmers' income, increased profitability and can be used from livelihood agricultural production to large farms, contributing to increased food production and reduction of hunger and poverty, which affect, currently, one billion individuals worldwide (FAO, 2016; 2017).

In Brazil, another aggravating factor are degraded pastures (those with a low forage yield per area), this has negative implications for livestock sustainability, in addition to the greater costs of establishing the pasture and fertilization. Therefore, in order to have a more positive economic return, it is very important that these pastures are used in the most efficient way possible (Balbino et al. 2011).

In this regard, the combination of integrated crop-livestock systems may be one of the best alternatives for reduce the investments needed to form and recover pastures, once the grains produced as part of the system amortized the cost of pasture renewal (Yokohama et al., 1999), making systems of low production more economically and ecologically sustainable (Bernardi et al. 2009). However, data on systems that involve trees, as well as on the assessment of the effects of its different densities on the economic variables, are insufficient. Furthermore, there is a possibility of guaranteeing economic return from the sale of the wood.

Despite the importance of the economic dimension for decision-making, most articles on crop-livestock integration are mainly related to agronomic aspects; that is, little information has been made available that focuses on the economic aspect (Vilela et al. 2012; Moraes et al. 2014). The same is true for the crop-livestock-forest integration systems, with number of published works lower than those of the crop-livestock integration systems (Moraes et al. 2014).

Therefore, based on the assumption that the economic evaluation of integrated crop-livestock systems will contribute to a better understanding of the system and bring important information to the rural producer and to the scientific community, the objective of this work was to evaluate the animal production and economic viability of the crop-livestock integration system and crop-livestock-forest integration systems with 196 trees ha^{-1} and 448 trees ha^{-1}.

2. Materials and methods

The experiment was carried out in accordance with the established ethical principles for animal tests (Protocol No. 26/2014 - ECAU).

2.1 Area characteristics

The experiment was carried out at the Agência Paulista de Tecnologia dos Agronegócios (APTA), located in Andradina (20° 53' 38" south latitude, 51° 23' 1" west longitude, and an altitude of 400 m), west of São Paulo state. In the first half of 2012, the experiment was designed, with the choice of treatments and the division of paddocks (Table 1). In the second half of 2012, soil sampling, soil analysis, liming, plastering, fertilization and the marking of treatments to start planting eucalyptus occurred.

Table 1. Paddock and experimental area treatments.

Paddock	Area (ha)	Production system
A	1.88	ICL
B	1.95	ICL
C	1.81	ICL
D	2.04	ICL
E	2.75	ICLF-3L
F	2,03	ICLF-1L
G	2.12	ICLF-1L

H	1.97	ICLF-3L
I	2.33	ICLF-1L
J	2.13	ICLF-3L
K	2.39	ICLF-1L
L	2.31	ICLF-3L
Total	**25.71**	

ICL: Integration Crop-Livestock; ICLF-1L: Integration Crop-Livestock-Forest, with eucalyptus trees planted in single lines, the distance between each eucalyptus range being 17 m to 21 m and the distance between plants of 2 m, with a density of 196 trees.ha^{-1}; ICLF-3L: Integration Crop-Livestock-Forest, with eucalyptus trees planted in triple lines, the distance between the eucalyptus ranges being 17 m to 21 m, the distance between plants of 2 m and the distance between eucalyptus lines of 3 m, with a density of 448 trees.ha^{-1}.

In July 2012, the soil type was conditioned based on chemical analyses (0–20 cm layer), which revealed the following attributes: pH ($CaCl_2$) 4.8; M.O. 16 g dm^{-3}; P (resin) 3 mg dm^{-3}; K+, Ca^{2}+, Mg^{2}+ and H+Al 1.9, 7, 5 and 20 mmolc dm^{-3}, respectively; S-SO_4^{2-} 1 mg dm^{-3} and V% (base saturation) of 42%. The clay, silt and sand contents were 107, 113 and 780 g kg^{-1}, respectively. Dolomitic limestone (PRNT 80%) was applied at a rate of 1200 kg ha^{-1} and incorporated into the soil for a saturation increase of 70% bases. Agricultural gypsum was applied totaling of 600 kg ha^{-1} to supply the sulfur required by soybean and corn crops, as recommended by Bulletin 100 for the state of São Paulo (van Raij et al., 1997). Terracing, plowing and leveling were performed to prepare the soil.

2.2 Tree planting

Trees were introduced from November 2012 to March 2013 through the manual planting of the seedlings, following the level variations present in the area (Porfírio da Silva et al. 2010). The eucalyptus clone used was the I-224 of *Eucalyptus urograndis*, for cellulose production, which is the prevailing market of region. For fertilization, 350 kg ha^{-1} of the 04-30-16 (Nitrogen-Phosphorous-Potassium) formula was used, resulting of 210 g per seedling (8.4 g N, 63 g P_2O_5, 33.6 g of K_2O) for each planting pit. During the top dressing phase, carried out in February 2013, 37 kg ha^{-1} of nitrogen, 3 kg ha^{-1} of zinc and 2 kg ha^{-1} of boron were used, applying 50 g of urea (23 g N), 9 g of zinc sulfate (1.8 g Zn) and 12 g borogan (1.2 g B) in the form of a crown under each eucalyptus seedling. In January 2014, another top dressing was carried out with 123 kg ha^{-1} of N and using 160 g of urea (73.6 g N) in the form of a crown under each seedling.

Weed control and selective irrigation was applied to newly planted trees as needed. Due to the high temperatures and the water deficit (summer) occurred tree replanting in beginning 2013.

In each treatment, the area occupied by eucalyptus was calculated according to the number of trees in each paddock (experimental plot). Area used was 4 m² (2 × 2) per tree in the ICLF-1L treatment (single eucalyptus lines with 196 trees ha^{-1}) and 16 m² (8 × 2) for every three seedlings in the ICLF-3L treatment (triple eucalyptus lines with 448 trees ha^{-1}). The mean area covered by eucalyptus trees was 8% for ICLF-1L and 28% for ICLF-3L. This area was used for the calculation of planting and maintenance costs and to obtain crop and livestock productivity data.

2.3. Seeding and the production of soybeans

The seeding of soybeans (cultivar BMX Power) was performed in December 2012 in all systems, totaling 400,000 seeds per ha. Soybeans were fertilized with 12 kg ha^{-1} N, 90 kg ha-1 P_2O_5 and 48 kg ha-1 K_2O. The top dressing was carried out 40 days after planting, with 200 kg ha^{-1} of the formulat 00-20-20.

The weed control in the post-emergence phase was carried out on January 24, 2013, applying herbicide based on glyphosate (Zapp QI 620) in the amount of 1,240 g i.a. ha^{-1}. During the application, cobalt-molybdenum-based fertilizer (COMO Platinum) was used for the tank mix in the amount of 150 ml ha^{-1} of the commercial product. The soybean haverst was carried out in May 2013, yielding 35 bags with 60 kg ha^{-1}. Weed control followed, using glyphosate-based herbicid (Roundup WG®) at dose of 1440 g a.i ha^{-1} and a total applied volume of 250 l ha^{-1}, by means of a tractor sprayer, using fan-type nozzles with a spacing of 0.50 m. The price of one soybean sack was taken from AgriAnual (2014). The trees were in the area when the soy was planted, therefore for the tree treatments were discounted the area occupied by eucalyptus.

2.4 Corn and pasture planting and harvesting

In December 2013, the grass was sown, using *Urochloa brizantha* (Syn. *Brachiaria brizantha*) cv. Marandu, in the amount of 8.0 kg ha^{-1} of pure and viable seeds, with a spacing of 0.20 m between rows using the no-tillage seeder model SAM 200 (Semeato Ltda., Passo Fundo, RS), driven by a tractor model TL 75 4×4.

After the grass was planted, the maize was sown, with hybrid BG 7049 (Biogene), and seeds were treated with thiametoxan insecticide (Cruiser 350) at a rate of 300 ml/100 kg of seeds. The spacing between the lines was 0.80 m, aiming to reach population density of 62,500 plants per hectare, while the fertilization of seedlings corresponded to 24.8 kg ha^{-1} of N, 86.8 kg ha^{-1} of P_2O_5 and 49.6 kg ha^{-1} of K_2O. Twenty days after the emergence of maize sprouts, a top dressing was performed, using 92 kg ha^{-1} of nitrogen.

Corn was harvested in March 2014 at the silage point, the price paid by the producer was used to calculate the crop's gross revenue. A total of 79 data points was collected on the prices of silages harvested throughout Brazil under conditions similar to those of the experiment. From this data, the average price of this product was obtained.

Maize production for silage, which was used in this work, had been previously evaluated by Domingues et al. (2017), the natural matter of ICL was 19,5 t ha-1 and 17,8 t ha^{-1} of natural matter was obtained in the ICLF-1L and ICLF-3L. The treatments with contained the arboreal component, the area occupied by eucalyptus was discounted (8% for ICLF -1L and 28% for ICLF 3L).

2.5 Animal production

In September 2014, 128 animals were introduced to the area for grazing (without a division of paddocks) for 11 days, and then 167 animals were introduced for 7 days. Land use during this period was considered to be a lease (which brought additional revenue). For this value, the average price of the lease in the region was used, provided by the Institute of Agricultural Economics in 2014 (the monthly payment was US$8.56). In addition, to facilitate calculations, the monthly lease of US$8.56 was divided by 30.4 (the average number of days in a month) to find the exact value of the daily payment, which amounted to

US$0.28/ head/day.

The corn was harvested in April 2014. The area remained untouched until the introduction of the animals. Between December 8, 2014 and January 9, 2015, the forage was standardized by means of mechanical weeding at a height of 15 cm, followed by nitrogen fertilization of 40 kg ha^{-1} of N in the form of urea. In January 2015, the Nellore steers were introduced in the area to begin the experiment.

The adopted grazing method was continuous stocking with a variable stocking rate, using the put and take technique (Mott and Lucas, 1952). In each paddock, five animal testers and a variable number of regulators were used, according to the need to adjust the stocking rate to maintain the handling goal, with a mean grass height of 30 cm; this height is within the range (20 to 40 cm) that is considered to be the ideal pasture condition (Silva 2004).

In January 2015, the rearing phase started, followed by the termination of the animals. The animals started the experiment with a mean live weight of 235.43±25.46 kg and mean age of 16±2.81 months; they were slaughtered with a mean live weight of 453.68±29.69 kg and at a mean age of 34±2.81 months. The animals received supplementation during the rainy season (January to April 2015 and November 2015 to April 2016) and dry seasons (April to November 2015), consuming 0.1% of live weight. From April to July 2016, the animals were supplemented with 0.7% concentrate of live weight (17% crude protein and 82% total digestible nutrients).

Weights were recorded every 28 days, after a fast of 16 hours. The average daily gain was obtained by the difference between the final and initial weights, divided by the number of days in the period. The live weight gain by area was calculated by multiplying the mean of the average daily gain by the average number of animals per hectare and the number of grazing days. The grazing stocking rate was also calculated during the evaluated period as the number of animals, or animal units (1 AU = 450 kg PV), divided by the grazed area. Finally, the kilograms of carcass produced per hectare was calculated as: live weight gain x carcass yield, in which the carcass yields were 57.89%, 57.97% and 57.94% for ICL, ICLF-1L and ICLF-3L, respectively, evaluated for Luz et al. (2019) with the same animals of this work.

2.6 Economic evaluation

For the economic analysis, the net cash flow of each system per period was required, so that the time factor could also be taken into account. Cash flow shows the sources and uses of cash by period and by system. The net cash flow corresponds to the balance between the sources (cash receipts) and uses (cash outflow), according Boehje and Eideman (1984). For the purposes of evaluating the systems in question, the annual cash flows of each system were analyzed. Each system was interpreted as a project, starting from the purchase of the land and ending with the sale thereof. In the present study, the possible valuation of the land was not included in the land price at the end of the period and will be subject to future analysis.

From each net cash flow, the internal rate of return (IRR) was calculated for each system, according to Noronha (1987). The IRR method of analysis takes into account the time factor and depends exclusively on the cash flow of the analyzed project (in this study, of each particular system):

$$\sum_{t=0}^{N} \pi_t (1-\rho^*)^{-t} = 0$$

Whereby: π_t = net annual cash flow; ρ^* = internal rate of return (IRR) and t = time (in years).

All revenues and expenses that occurred in the integration systems were calculated at the time when they occurred, including estimates of the future production of wood, making possible, later the analysis of the results. The clone used in the experiment was I224, with a profile suitable for cellulose exploration. It is estimated that the wood is usually ready to be harvested in 7 years, which in our case will only occur in 2020. As the period of this study does not coincide with the maturity time of the eucalyptus to be harvested, the sale of the current available volume of wood according to the area was simulated. For the conversion of the values from real (Brazilian currency) to dollar, the average value of the dollar obtained by the Central Bank of Brazil between 2007 and 2017 was used.

2.7. Statistical analysis

For the evaluations of the animal production indices, a complete block design with three treatments and four replications was used. In each repeated treatment (paddock), five animals were used, totaling 20 animals per treatment and 60 animals for the whole experiment.

Performance data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC, USA, 2010). We used the UNIVARIATE NORMAL procedure, and the normality of the data was confirmed using the Shapiro–Wilk test ($W \geq 0.90$). The paddock was considered the experimental unit for all studied variables and the Tukey were performed to compare averages. The effects were considered statistically significant at $P<0.05$.

3. Results and Discussion

With respect to animal performance, there was no significant difference between treatments in terms of average daily gain (ADG). On the other hand, there were differences between the treatments for the live weight gain by area (LWG; $P=0.02$), stocking rate in kg and in animal units (SR; $P=0.001$ in both), and kilograms of carcass produced per hectare (KCP; $P=0.02$; Table 2).

Table 2. Performance of Nellore cattle evaluated during the rearing and finishing phases in Integrated Crop-Livestock (ICL), Integrated Crop-Livestock-Forest, densities of 196 tree.ha^{-1} (ICLF-1L) and Integrated Crop-Livestock-Forest, densities of 448 tree.ha^{-1} (ICLF-3L).

Variables	ICL	ICLF-1L	ICLF-3L	SE	*p-value*
ADG (g)	0.48	0.46	0.47	0.012	0.974
LWG kg.ha-^{1}	690 a	619 ab	572 b	14.629	0.026
SR kg.ha-^{1}	1028 a	983 a	808 b	18.602	0.001
SR UA.ha-^{1}	2.28 a	2.18 a	1.79 b	0.041	0.001
KCP ha-^{1}	399.45 a	358.80 ab	331.35 b	8.466	0.026

ADG: Average daily gain; LWG: Living weight gain per area; SR: Stocking rate; KCP: kilograms of carcass produced per hectare. UA = Animal unit = 450 kg of live weight.

Different letters in the same line differ from each other by Tukey test ($P<0.05$).

The trees present in the pastures were proven to be efficient for helping the animals to lose heat and regulate their body temperature (Garcia et al. 2011). However, in this study, the microclimate provided by the trees at their different densities was not a determining factor to increasing the weight gain of the animals. This can be explained by the high adaptability of zebu animals to tropical climates. As these animals have a greater number of sweat glands and a larger surface area, they are better adapted to these types of climate than European animals (Müller, 1989). A similar effect was found by Ferro et al. (2016), who evaluated the performance of Nellore cattle confined and submitted to different levels of artificial shading. As a result, the authors did not find differences in the ADG between treatments. Although higher heat tolerance was observed in adapted animals, the use of shading has still been recommended to guarantee better quality-of-life conditions for animals (Ferro et al. 2016).

The SR (both in kg and AU) was lower in the ICLF-3L treatment, compared to the ICL and ICLF-1L treatments (P=0.001). This occurred due to the reduction of net pasture area given by the higher density of eucalyptus and also the greater shading of the pasture. Studies indicate a decrease in the productivity of forage species when they are submitted to shade (Martuscello et al. 2009; Gobbi et al. 2009). Shading caused by trees reduces photosynthesis and carbon fixation by the plant, thus reducing the dry matter production (Castro et al. 1999). Moreover, trees compete for water and nutrients, which reduces forage production, influencing the stocking rate and, consequently, the live weight gain per area (LWG; P=0.02).

The KCP in ILC was higher than ILCF-3L (P=0.02) and ICLF-1L did not differ from both treatments. Martha Júnior et al. (2006) observed that o KCP, in ICL systems, the amplitude of weight gain in the first year of pasture varied between 135 and 600 kg of carcass per hectare per year. Considering the KCP (Table 1) in the 16 months of the experiment the gain of carcass per hectare was 399,45kg; 358,80kg and 331,35kg respectively for ILC, ICLF-1L and ICLF-3L, these data are within the standards established by Martha Júnior et al. (2006).

Tables 3, 4 and 5 show the cash flow of the ICL, ICLF-1L and ICLF-3L treatments, respectively. The introduction of the animals into the system was delayed due to a problem in the construction of the fences for the division of the paddocks and, consequently, of the treatments. During this period (November to December of 2014), the pasture was high and it was necessary to introduce the animals in the area to reduce the forage mass. A total of 128 Nellore cows, weighing approximately 450 kg each, were placed in the grazing area for 11 days, and subsequently, 166 Nellore cows grazed for 7 days, resulting in 1,408 and 1,162 animals grazing daily, respectively. In order to estimate the revenue corresponding to this period, the price of the pasture lease was taken into account. There were 2,570 animals daily, and at a value of US$0.28/day (given the monthly value of US$8.56), this provided US$719.60 of revenue, which was divided equally between all treatments.

The average production of the soybean crop was 35 bags of 60 kg per hectare. Using the price of US$22.40 per bag, which was relevant for the period, the average revenue was US$784.20, U$720,26 and U$569,11 per hectare of planted soybean, for ICL, ICLF-1L and ICLF-3L, respectively.

The maize silage resulting in a revenue of US$1,461.50, US$1,240.69 and U$ 980,33 respectively for ICL, ICLF-1L and ICLF-3L per hectare. The income obtained from corn silage was lower in the ICLF-3 L (U$980,33), which has larger number of trees that occupy more space in the area.

In relation to cash flow, the largest investment for all the evaluated systems was the fences and the purchase of animals. Table 3 shows that the sum of expenses (cash outflows) for the implementation and maintenance of the system (soil preparation, soybean, corn and pasture) until 2014, before the entry of the animals in the systems; these were US$1,781.02 for the ICL system and revenue from soybean and maize was US$2,245.70. In systems with trees (Tables 4 and 5), taking into account the implementation and maintenance (soil preparation, soybean, corn, pasture and trees) until 2014, before the entry of the animals in the systems, the cost was US$1,889.71 for the ICLF-1L and US$1,955.14 for the ICLF-3L systems, while the revenue from the harvest of soybeans and maize was US$1,960.95 and US$1,549,44 for ICLF-1L and ICLF-3L, respectively.

When subtracting the costs for the implantation of the crop, pasture and eucalyptus (ICLF-1L and ICLF-3L) from the values of cash inflow (revenues from the sale of corn silage and soybeans), the results were US$ 464.68, US$ 71,24 and -US$ 405,70 for the ICL, ICLF-1L and ICLF-3L, respectively. In the ICL and ICLF-1L systems, the income from soybean and corn, fully paid for the implementation of the systems, while ICLF-1L still covered expenses related to the planting of the forest. In ICLF-3L, the accompanying expenses were almost completely covered, accounting for the planting of the forest.

These results confirm the findings of Bernardi et al. (2009), who stated that crop in integrated production systems has been used to amortize pasture recovery investments. These results also corroborate with Alvarenga and Noce (2005), who found that the amortization of some of the costs incurred due to the renewal of pasture is possible by producing crops, thus encouraging producers to use this technology to recover their degraded areas and increase depleted production values.

The wood production of the evaluated systems was estimated using the forest inventory. The obtained volume of wood was 16.68 m^3 ha^{-1} in the ICLF-1L treatment and 38.85 m^3 ha^{-1} in the ICLF-3L treatment. As the wood production of the experiment focused on wood pulp production, the average amount paid for the wood used for this purpose in the region was US$19.43 per m^3. The eucalyptus crop, when considered for its wood production in the fourth evaluated year, presents a higher revenue in the ICLF-3L system (US$760,91) compared to ICLF-1L (US$330,14), due to the higher density of trees (Tables 4 and 5). With the introduction of trees, it would be possible to obtain a source of revenue over a longer period of time.

The ICLF-1L has a lower tree density, with trees occupying a smaller area in the system and influencing livestock values, such as the stocking rate, weight gain per area and kilograms of carcass produced per hectare, to a lesser extent than in ICLF-3L (Table 2). The reduction in the production indexes also decreased the revenue from the slaughter of the cattle in the ICLF-3L system (US$2,945.10), with ICL and ICLF-1L revenues close to US$3,704.48 and US$3,469.17, respectively, thus contributing to a higher net cash flow in the system with a lower density of trees (ICLF-1L; US$10,334.92) compared to the ICLF-3L (US$10,258.47) and ICL (US$10,184.08) systems.

Therefore, the IRR, which was also higher in ICL (1,89%) and ICLF-1L treatment (1,81%) than ICLF-3L (1,1%); this means that the adoption of this system should be favored, since the return was greater. The ICLF- 3L showed less IRR, because it has a larger number of trees than the other systems, which decreased the income with soybean and silage, providing less IRR. It should be noted that this treatment will have a better financial return in the long term, when the trees are cut

In all evaluated ICL systems, there was a cash flow deficit until the third year after tree planting. In fact, these years usually correspond to a period of investment in forest formation. From the fourth year, with the sale of cattle, the cash flow started to show a surplus. Trees will be cut 6 or 7 years after being planted. Greater revenue is expected with the production of wood as trees grow and with the continuation of the productive cycles of livestock. In this regard, it is advisable to seek the ideal balance between the cultures of the system so that all the integrated components are able to produce the highest possible profitability.

Table 3. Cash flow per hectare of Integrated Crop-Livestock (ICL).

IRR = Internal Rate of Return.

YEAR	2012	2013	2014	2015	2016
			US$		
CASH RECEIPTS		784.20	1,493.00		10,559.83
Harvest Soybeans		784.20			
Corn Silage			1,461.50		
Slaughter cattle					3,704.48
Sale of land					6,855.35
Lease			31.50		
CASH OUTFLOW	7,569.50	727.44	3,274.70	232.19	375.75
Buy Land	6,855.4				
Fences			1,421.40		
Drinking troughs and tube			120.78		
Soil preparation	322.42				
Planting and maintenance Soybean	391.68	199.06			
Planting and maintenance Corn		426.99	250.07		
Planting and maintenance Pasture		101.39	89.41		
Buy Animals			1,365.60		
Feeding animals			27.44	232.19	375.75
CASH FLOW					
Accumulated Cash Flow	- 7,569.50	- 7,512.74	- 9,294.44	- 9,526.63	657.45
Net cash flow	- 7,569.50	56.76	- 1,781.70	- 232.19	10,184.08
IRR					1.89%

Table 4. Cash flow per hectare of Integrated Crop-Livestock-Forest, densities of 196 tree.ha^{-1} (ICLF-1L).

YEAR	2012	2013	2014	2015	2016
			US$		
CASH RECEIPTS		720.26	1,267.96		10,654.66
Harvest Soybeans		720.26			
Corn Silage			1,240,69		
Slaughter cattle					3,469.17
Sale of land					6,855.35
Lease			27.27		
Cutting of trees					330.14
CASH OUTFLOW	7,593.45	800.92	3,080.71	210.30	319.74
Buy Land	6,855.35				
Fences			1,230.18		
Drinking troughs and tube			104.52		
Soil preparation	322.42				
Planting and maintenance Trees	55.91	132.80	38.90		
Planting and maintenance Soybean	359.77	182.83			
Planting and maintenance Corn		392.17	229.68		
Planting and maintenance Pasture		93.12	82.11		
Buy Animals			1,370.48		
Feeding animals			24.84	210.30	319.74
CASH FLOW					
Accumulated Cash Flow	- 7,593.45	- 7,674.11	- 9,486.86	- 9,697.16	637.76
Net cash flow	- 7,593.45	- 80.66	- 1,812,76	- 210.30	10,334.92
IRR					1.81%

IRR = Internal Rate of Return.

Table 5. Cash flow per hectare of Integrated Crop-Livestock-Forest, densities of 448 tree.ha^{-1} (ICLF-3L).

YEAR	2012	2013	2014	2015	2016
			US$		
CASH RECEIPTS		569.11	1,006,71		10,561.36
Harvest Soybeans		569.11			
Corn Silage			980,33		
Slaughter cattle					2,945.10
Sale of land					6,855.35
Lease			26.38		
Cutting of trees					760,91
CASH OUTFLOW	7,603.07	862.94	2,801.04	185.39	302.89
Buy Land	6,855.35				
Fences			1,190.42		
Drinking troughs and tube			101.15		
Soil preparation	322.42				
Planting and maintenance Trees	141.04	335.03	98.14		
Planting and maintenance Soybean	284.26	144.46			
Planting and maintenance Corn		309.87	181.46		
Planting and maintenance Pasture		73.58	64.88		
Buy Animals			1,141.01		
Feeding animals			23.98	185.39	302.89
CASH FLOW					
Accumulated Cash Flow	- 7,603.07	- 7,896.90	- 9,691.23	- 9,876.62	381.85
Net cash flow	- 7,603.07	- 293.83	- 1,794.33	- 185.39	10,258.47
IRR					1.1%

IRR = Internal Rate of Return.

It is important to reiterate that the area in which the systems were deployed was degraded and was unproductive before introduction of the systems. In addition to helping to recover the investment spent on pasture recovery, the integrated systems still improved the animal production indexes and promoted the appreciation of the land, increasing its attractiveness and market value. This valuation was not incorporated into the calculations. Data focused on the recovery of pastures and, possibly, the valuation of areas, should be the subject of future analyses.

5. Conclusion

Livestock productivity is similar in ICL and ICLF-1L systems until the fourth year after implementation. In the ICLF-3L, the area occupied by eucalyptus reduces the available area, decreasing livestock production, but due to the larger number of trees in this system, it is supposed higher wood production can economically compensate this difference when the trees are ready for harvest.

Pasture implantation and recovery costs are high and the integrated crop livestock systems were effective in amortizing these costs. In the ICL and ICLF-1L, the sale of soybean and corn silage in the system implementation contributed to the total amortization of costs, it can be observed in the system with trees it was also possible to amortize the costs of eucalyptus implantation.

In the ICLF-3L, the implementation costs were higher than the other systems, due to the larger number of trees, which made it possible amortize in part the costs with the sale of corn silage and soybean. Even if there is no total amortization, the result is positive, because in conventional systems, which do not use the crop for implementation, pasture recovery and tree planting, it is necessary a high initial investment with a longer financial return.

6. Acknowledgement

APTA, Polo Regional Extreme West - Andradina/SP for logistical, infrastructural support and assistance during the experiment. To the Coordination for the Improvement of Higher Education Personnel - CAPES for the scholarship.

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