PERFORMANCE OF THE CLONE *Eucalyptus urograndis* IN A CONVENTIONAL AND SILVOPASTORAL SYSTEM

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Resumo

Desempenho do clone Eucalyptus urograndis em sistema convencional e silvipastoril. O objetivo desse estudo foi analisar a produtividade florestal, comparando a viabilidade financeira de um sistema Silvipastoril *versus* um plantio florestal convencional, ambos utilizando o clone do híbrido de *Eucalyptus urograndis*. Para o levantamento dos dados de volume foram instaladas dezenove parcelas de 40,0 x 15,0 m (600 m²) no plantio convencional e quinze parcelas de 25,0 x 32,0 m (800 m²) no plantio silvipastoril. Foram medidos todos os diâmetros e alturas das árvores de cada parcela. Os modelos de relação hipsométrica foram obtidos pelo método Stepwise e a cubagem das árvores foi realizada através do método de Smalian. Os volumes foram separados em sortimentos, de acordo com as opções de venda para o mercado local. A análise financeira levou em consideração fluxos de caixa do ano de implantação até a idade de corte (7 anos), considerando os custos despendidos para a formação e manutenção da floresta ao longo do ciclo, descontados a uma taxa de juros de 6,75% ao ano e o volume vendido a valor de mercado, considerando a madeira em pé, ao fim do ciclo. Foram avaliados o valor presente líquido, valor anual equivalente, taxa interna de retorno, valor esperando da terra e custo médio de produção. Os dois sistemas de produção foram considerados economicamente viáveis para a rotação de 7 anos sugerida, porém o sistema silvipastoril apresentou resultados que demonstram maior viabilidade financeira ocasionados principalmente pelo menor custo de implantação e manutenção, e também à maior volumetria dos sortimentos com maior valor agregado (S1 e S2).
Palavras chave: Produção florestal, análise financeira, sortimento

Abstract

The objective of this study was to analyze forest productivity, comparing the financial viability of a silvopastoral system versus a conventional forest plantation, both using the clone of the hybrid of *Eucalyptus urograndis*. For the survey of the volume data, nineteen plots of 40.0 x 15.0 m (600 m²) were installed in conventional planting and fifteen plots of 25.0 x 32.0 m (800 m²) in silvopastoral planting. All tree diameters and heights of each plot were measured. The hypsometric relationship models were obtained using the Stepwise method and the trees were cubed using the Smalian method. The volumes were separated into assortments, according to the sales options for the local market. The financial analysis considered cash flows from the year of implementation until the cutting age (7 years), considering the costs spent for the formation and maintenance of the forest throughout the cycle, discounted at an interest rate of 6.75% per year and the volume sold at market value, considering standing wood, at the end of the cycle. The following were evaluated: net present value, equivalent annual value, internal rate of return, expected value of land and average cost of production. The two production systems were considered economically viable for the suggested 7-year rotation, however the silvopastoral system showed results that demonstrate greater financial viability caused mainly by the lower cost of implementation and maintenance, and to the greater volume of the assortments with greater added value (S1 and S2).
Keywords: Forest production, financial analysis, assortment

INTRODUCTION

The Crop-Livestock-Forest Integration has a very important environmental merit for the mitigation and reduction of environmental impacts and greenhouse gas (GHG) emissions. Since 2010, the implementation of this system in Brazil has been encouraged through the ABC Plan (Decree No. 9,578/2018, which replaced Decree No. 7,390/2010). Named as the Sector Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low-Carbon Economy in Agriculture. Its purpose is to organize and plan the actions to be carried out for the adoption of sustainable production technologies, selected with the objective of responding to the commitments to reduce GHG emissions in the agricultural sector.

In 2015, the 21st Climate Conference (COP 21) was held, where Brazil presented a commitment to reduce the number of GHG emissions by 37% by 2025 and by 43% by 2030 (Embrapa, 2018). In contrast to these figures assumed by the country, in 2019, greenhouse gas emissions from the agricultural sector were responsible for 598.7 million tons of CO_2 equivalent, with animal husbandry accounting for 76% of the total, according to data from the Greenhouse Gas Emissions Estimation System (SEEG, 2019), making this crop one of the major bottlenecks in achieving the national goal.

One of the ways of mitigating the emission of these gases, without interfering with livestock production, is the consortium with the forest component, in silvopastoral systems, since they have a positive carbon balance and effectively contribute to reducing the concentration of GHGs in the atmosphere (NETO *et al.* 2017).

The silvopastoral system is a form of land use that combines the forest, pasture and animal components in the same area unit, providing numerous benefits, such as erosion control, thermal comfort for animals, nutrient cycling, promotion of biodiversity and sequestration of carbon (BALBINO, 2011). It is still possible to insert the agricultural component, becoming an agrosilvopastoral system.

With the use of suitable forest and forage species, the introduction of the system can increase the production and quality of the pasture, improve the performance of the animals in weight gain, lactation, health and reproduction, in addition to generating income from the production of forest multiproduct such as firewood, poles, posts, chips and logs (MACEDO *et al.* 2018).

These variations in land use can be an alternative, in addition to being environmentally favorable, also financially viable in the face of forest or conventional livestock production. The analyzes carried out by Ribaski, Hoeflich and Ribaski (2009); Santos and Grzebieluckas (2014); Neto *et. al*, (2017). Trivelin *et. al* (2020), shows good financial performance that provide monetary profitability for the rural producer.

However, despite the advantages presented over these systems, their large-scale implementation is still low. Therefore, studies that evaluate the efficiency of the different components to be introduced are relevant, both in terms of productivity and financial profitability, thus validating the introduction of these production systems in the rural reality of Brazil.

Therefore, the objective of this study was to analyze forest productivity, comparing the financial viability of a silvopastoral system versus a conventional forest plantation, both using the hybrid clone of *Eucalyptus urograndis* (*Eucalyptus grandis* W. Hill ex. Maiden with *Eucalyptus urophylla* ST Blake). In this way, it will be possible to define the best strategy for obtaining income, within an attractive socioeconomic and environmental context.

MATERIALS AND METHODS

Location and characterization of the studied area

Data collection was carried out in the city of Caçapava do Sul, located at 30º 30’ 44” S latitude and 53º 29’ 29” W longitude. The region belongs to the Pampa biome and the climate of the region is classified as subtropical (Cfa), according to the Koppen classification (ALVARES *et al*., 2013). The average annual rainfall is 1588mm and the soils are of the Neosol type (BECKER *et al*.,2017).

Conventional eucalyptus plantation

Conventional planting consists only of the use of the forest component throughout the area. For this experiment, before planting, soil preparation operations were carried out, with the support of a tractor and mower to clean the area, combined with the fight against ants. Regarding fertilization, subsoiling was carried out on the line and 200g of NPK formula 6-30-6 was applied per hole.

The planting operation was manual and in this study, we opted for a spacing of 3.0 x 2.0 m (totaling 6m² per plant), using clones of the hybrid *Eucalyptus urograndis*. After 3 months of planting the seedlings, a topdressing fertilization was carried out with application of 160g per hole of the NPK 5-20-5 formula, as reinforcement fertilization. In the remaining years of the plant's cycle, only weed-competition control and ant combat operations were maintained, operated by the grower himself. The system was implemented in 2009.

Silvopastoral system

For the silvopastoral system, where there is the composition of forest plantation intercropped with space destined for animal pasture, it was also decided to use clones of the hybrid *Eucalyptus urograndis* as a way of maintaining the same comparison of conventional plantations regarding the tree component.

The planting in holes was carried out manually, consisting of strips with three rows of trees with a spacing of 3.0 x 1.5 m (totaling 4.5 m² per plant), with a distance of 10.0 meters between each strip. For planting eucalyptus, harrowing and subsoiling were carried out on the strip, in addition to fighting ants with granulated bait. For pre-planting fertilization, 200g of NPK formula 6-30-6 was used per hole. Three months after planting, topdressing was carried out with 160g per hole using the NPK 20-5-20 formula.

In the ranges determined for the pasture component, there was no type of technological intervention to increase productivity, such as, for example, soil preparation for planting and/or pasture enrichment, fertilization or any management practices, since there was no conversion of the land use of native field (Pampa) for implanted pasture.

In general, the entry of the animal component can only occur after the trees gain strength to prevent traffic and animal trampling from harming the planting. Therefore, this stage occurred after the end of the third year of planting. There was no grazing management, however, the cattle remained in the area for an average of 12 months, accounting for a stocking rate of 1.5 AU/ha (AU = animal unit = 450 kg of live weight). The analysis of the animal component in the system was not carried out, since it was not the focus of the work, neither in terms of production nor income. The system was implemented in 2009, with the entry of animals in 2012.

Data collection - productivity of the forest component in the systems

Data collection was carried out in 2016, at 6.5 years of age of the planting. For the collection of diameter and height data, nineteen plots of 40.0 x 15.0 m (600 m²) were installed in conventional planting and fifteen plots of 25.0 x 32.0 m (800 m²) in silvopastoral planting. All tree diameters and heights in each plot were measured. The hypsometric relationship models were obtained by the Stepwise method, with the aid of the Statistical Analysis System package (SAS, 2004).

The trees volumes were measured using the Smalian method, with sections at positions of 0.10, 0.30, 1.30 and from this point, 1.0 in 1.0 meter, up to the apex of the trees. One tree per class center was sampled, with an interval of 5 cm, as follows: 0-10; 10.1-15.0; 15.1-20; 20.1-25; > 25 cm.

The wood assortments (Table 1) were classified and determined, by integration with the shape function, expressed by a 5th degree polynomial as follows:

a) Volume up to the height where the diameter is 6.0 cm with shell:

$$V_6 = K \int_0^{h_6} f\ (y)^2\ d_{h_6}$$

b) Volume up to the height where the diameter is 18.0 cm with shell:

$$V_{18} = K \int_0^{h_{18}} f\ (y)^2\ d_{h_{18}}$$

c) Volume up to height with diameter between 6.0 and 18.0 cm:

$$V_{6-18} = K \left(\int_0^{h6} f\ (y)^2\ \ d_{h6} - \int_0^{h18} f(y)^2 d_{18}\right)$$

Where: length of the shaft, in meters, up to a diameter of 6 cm with shell (h_6), length of the shaft, in meters, up to a diameter of 18 cm with shell (h_{18}), trunk shape function (f(y)), K = (π/4)/10000.

Heights (hi) were also estimated having the relative heights (hi/h) as the dependent variable and the relative diameters (di/d) as independent variables. The minimum diameters considered were 6 and 18 centimeters.

The calculated model is as follows:

$$\frac{h_i}{h} = b_0 - b_1 \left(\frac{d_i}{d}\right) + b_2 \left(\frac{d_i}{d}\right)^2 - b_3 \left(\frac{d_i}{d}\right)^3 + b_4 \left(\frac{d_i}{d}\right)^4 - b_5 \left(\frac{d_i}{d}\right)^5$$

Where: height up to a specified limit diameter, in meters (h_i), total height of the tree, in meters (h), limit diameter given for the thinnest end of the assortment, in centimeters (d_i), diameter at breast height, in centimeters (d).

Table 1. Assortments ranked in the analysis
Tabela 1. Sortimentos classificados na análise

ASSORTMENTS	GOAL	MINIMUM DIAMETER (cm)	PIECE LENGTH (m)
I	Industry	6,0	2,3
S1	Sawmill	18,0	2,3
S2	Sawmill	18,0	5,5

Financial analysis

The financial analysis considered the costs that were spent referring to the implementation and conduction of each system. The implementation costs include inputs (such as seedlings, fertilizers, and formicides), labor (daily), machinery, area preparation (area cleaning, soil preparation). Maintenance operations mainly refer to ant control and cleaning of the area, which aims to maintain the expected productivity of the genetic material, avoiding competition with other plants.

It is noteworthy that for both systems, the cost of cutting and extraction was not raised, since the sale value for each assortment was defined based on the standing tree component, and as is practiced in the local economic scenario. It is important to emphasize that the opportunity cost of the land was not taken into account, since it was not intended to present an alternative in the sense of replacing the culture, but to present the results regarding the financial profitability of the two systems, aiming at greater income to the producer in the application of this culture, considering the interest rate that enables the implementation of the model, by the prices of costs and revenues involved in the process.

In Table 2 it is possible to verify the summarized information on costs and revenues used to analyze the financial viability of the systems studied.

Table 2. Project implementation costs
Tabela 2. Custos de implantação dos projetos

Forestry technical list			
		COST (R$/ha)	
ACTIVITIES	**YEAR OF OCCURRENCE**	**CONVENTIONAL PLANTING**	**SILVOPASTORAL PLANTING**
Implantation	0	2574,6	1.225,23
Maintenance	1	107,0	64,79
Maintenance	1 e 2	114,0	92,58
Maintenance	3 a 6	51,0	18,87
TOTAL		2846,6	1401,5

Regarding the amount paid for each assortment, a local market survey was carried out, where the following values were found: R$ 25.00/m³ for assortment I; R$35.00/m³ for assortment S1 and R$100.00/m³ for assortment S2.

The proposed interest rate was 6.75% per year, as it is the rate used by the PROPFLORA program (Program for Commercial Planting and Recovery of Forests).

The financial analysis parameters used for the analysis are presented below :

Net present value

The NPV (net present value) measures the difference in the value of revenues minus the value of costs in the present (SILVA and FONTES, 2005):

$$NPV = \sum_{j=0}^{n} R_j (1+i)^{-j} - \sum_{j=0}^{n} Cj(1+i)^{-j}$$

Where: revenue at end of the year "J" (R_J), cost at the end of the year "J" (C_J), project time in years (n), discount rate (i).

Equivalent Annual Value

The AEV (annual equivalent value) modifies the net present value in a stream of constant and periodic costs and revenues (SILVA and FONTES, 2005).

$$AEV = \frac{NPV[(1+i)^t - 1]\,(1+i)^{nt}}{(1+i)^{nt} - 1}$$

Where: net present value (NPV), discount rate (i), number of capitalization periods (t), project time (n).

Internal Rate of Return

The IRR (internal rate of return) is a rate at which the net present value is zero (FILHO and KOPITTKE, 2010).

$$IRR = \sum_{j=0}^{n} R_j(1+i)^{-j} - \sum_{j=0}^{n} C_j(1+i)^{-j} = 0$$

Where: cost at the end of the year j (C_J), revenue at the end of the year j (R_J), discount rate (i), project time in years (n).

Expected Land Value

The ELV (Expected Land Value) represents the NPV of the uncovered land area and takes into account an infinite series (SILVA e FONTES, 2005).

$$ELV = \frac{V_o RL\ (1+i)^n}{(1+i)^n - 1}$$

Where: present value of net revenue that is repeated every cycle (V_0RL), discount rate (i), project time (n).

Average Production Cost

The CMPr (average production cost) is the total production that is related to the total cost and that aims to operate with minimum cost, and that is independent of the time that the investment lasts (REZENDE and OLIVEIRA, 2011).

$$CMPr = \frac{\sum_{j0}^{n} CT_j}{\sum_{j=0}^{n} QT_j}$$

Where: updated total cost (CT_J), equivalent total production (QT_J).

Infinite Net Present Value

The NPV_∞ (infinite net present value) if the annual cost of land is included.

$$\text{NPV}\infty = \frac{NPV(1+i)^n}{(1+i)^n - 1}$$

Where: net present value (NPV), discount rate (i), project time (n).

RESULTS

The 5th degree polynomials of dependent (hi/h) and independent (di/d) variables, adjusted to determine the length of logs up to a diameter of 6 cm and 18 cm at the fine tip for the conventional and silvopastoral systems were, respectively:

Conventional System $\frac{\text{hi}}{\text{h}} = 1{,}16562072 - 2{,}31950113\left(\frac{d_i}{d}\right) + 7{,}11929543\left(\frac{d_i}{d}\right)^2 - 13{,}1525163\left(\frac{d_i}{d}\right)^3 + 9{,}70682899\left(\frac{d_i}{d}\right)^4 - 2{,}42715024\left(\frac{d_i}{d}\right)^5$

Silvopastoral System $\frac{h_i}{h} = 1{,}06886503 - 1{,}60933968\left(\frac{d_i}{d}\right) + 5{,}04744922\left(\frac{d_i}{d}\right)^2 - 10{,}8217872\left(\frac{d_i}{d}\right)^3 + 8{,}733984\left(\frac{d_i}{d}\right)^4 - 2{,}32714\left(\frac{d_i}{d}\right)^5$

Where: height up to a specified limit diameter, in meters (hi), total height of the tree, in meters (h), limit diameter given for the thinnest end of the assortment, in centimeters (di), diameter at breast height, in centimeters (d).

The adjusted polynomial for the conventional system presented a coefficient of determination (R^2) of 0.9775 and standard error of estimate (S_{XY}) of 0.0458, while for the silvopastoral system the values were 0.9645 and 0.0582, respectively. With the integration of the trunk shape function, it was possible to obtain the volume of the assortments (S1, S2 and I) for each system (Table 3).

Table 3. Volume and average annual increment (IMA) in the different assortments and different systems
Tabela 3. Volume e incremento médio anual (IMA) nos distintos sortimentos e diferentes sistemas

SYSTEM	VOLUME (m³/ha)				IMA (m³/ha/year)
	S1	S2	I	TOTAL	
Conventional	6,3	14,7	238,5	259,5	40
Silvopastoral	88,3	20,2	213,2	321,7	49,5

The maintenance and implementation costs differed from each other, due to the differences in density of the two systems, and in the silvopastoral system there was a cost reduction of 49.23% in relation to the conventional system, considering only the forest component..

The two systems were considered viable, based on the values obtained by the financial analysis criteria (Table 4), with the silvopastoral system presenting a superior viability when compared to the conventional system. The value of AEV and NPV were increased by an average of 90.35%, that is, revenues exceeded costs when decapitalized by the applied interest rate, considering the project period (NPV) or in continuous annual installments (AEV).

The IRR exceeded the proposed investment rate, representing the rate of return on capital that was invested in the two projects, being 36.30% higher in the silvopastoral system, with B/C increased by 36.30% and CMP reduced by 23.94%. The ELV presented values 90.35% higher for the silvopastorial system, that is, this implemented project adds value to the land. When considering infinite rotations, it is also feasible by the values of NPV∞ found, which in this case are the same values of ELV, since the opportunity cost of another investment was not presented for the analyzes.

Table 4. Net present value (NPV), internal rate of return (IRR), average cost of production (CMPr), infinite net present value (NPV∞), equivalent annual value (AEV) and expected land value (ELV) for both the projects, analyzing only the forestry component
Tabela 4. Valor presente líquido (VPL), taxa interna de retorno (TIR), custo médio de produção (CMPr) valor presente líquido infinito (VPL∞), valor anual equivalente (VAE) e valor esperado da terra (VET) para ambos os projetos, analisando apenas o componente florestal

	Conventional system	Silvopastoral system
NPV	R$ 2.084,67	R$ 3.968,35
IRR	17,58%	24,42%
B/C	1,68	2,29
CMP	R$ 18,79	R$ 15,16
AEV	R$ 383,45	R$ 729,94
ELV e NPV ∝	R$ 5.680,78	R$ 10.813,86

DISCUSSION

The two production systems were considered economically viable for the suggested 7-year rotation, however, the results demonstrate greater financial viability of the forest component in the silvopastoral system, in relation to the conventional system. As the main factors that can be cited as responsible for the result, it is pointed out the lower cost of implantation and maintenance, related to the greater volumetry of the assortments with greater added value (S1 e S2).

In relation to the average annual increment (IMA) of the conventional system, it presented a value of 40 m³/ha/year. A similar result was found by Ferreira *et al.* (2017) when evaluating the growth and production of the clonal hybrid *E. urophylla* x *E. grandis* at 80 months (6.7 years) of age in a 3 x 2 m spacing, with an MAI of 43 m³/ha/year. Hakamada *et al.* (2015) when evaluating the behavior of planting uniformity of *Eucalyptus grandis* x *Eucalyptus urophylla* at 72 months (6 years) of age in a spacing of 3 x 3 m, the IMA of 50 m³/ha/year was obtained.

As for the silvopastoral system, it was possible to notice many variations in relation to the arrangement (distance between rows, for example), which also influences productivity. Oliveira *et al*. (2008) analyzed a silvopastoral system in Alegrete/RS, presenting triple rows of *Eucalyptus grandis* in a spacing of 3.0 mx 1.5 m and a distance of 14 meters between rows (rows) and found IMA of 28.4 m³/ha/ year to 6 years of age after thinning. Without thinning, Wink *et al* (2018) found IMA of 29.66 m³/ha/year in the 3x2 x 20m arrangement of *E. grandis* x *E. urophylla*, implemented in a silvopastoral system, in the city of Nova Canaã do Norte-MT at 5 years old. These values were lower than those found in this work, of 49.5 m³/ha/year, which allows us to infer that there is an increase variation in silvopastoral systems due to factors such as: implantation location (site), seedling quality, age of the system , species and management practices (such as weed competition and ant control).

Taking into account that there was a greater presence of trees with a larger diameter in the silvopastoral system, these were allocated to the assortment with the highest added value, contributing to the increase in financial income. For the same species, the spacing between plants is responsible for determining the management techniques, the potential growth in height and diameter and the age of stagnation of growth. The greater distance between the lines promotes a reduction in the number of neighboring trees and can benefit growth through greater access to factors that regulate growth such as light, water and soil nutrients (RANIERI *et al*., 2013). Correa *et al* (2020), examining a *Eucalyptus grandis* W. Hill hybrid plantation. x *Eucalyptus camaldulensis* Dehnh at 4.7 years old, implanted in the State of Goiás/BR, showed that increasing values of biomass and volume per hectare with the reduction of planting spacing (3.0x1.5m). However, the highest volume and biomass production per tree was obtained at wider spacings.

Analyzing the financial viability, we can see an increase in income from the forestry component in a silvopastoral system, since all the analysis criteria were superior. However, authors such as Weieman et al. (2017), when evaluating the feasibility through the criteria of NPV, AEV, IRR, B/C and CMPr and a rate of 7.75% per year of the forest component in a silvopastoral system, found that conventional planting is more profitable. Due to the higher density of conventional planting in relation to the system, resulting in a higher income for monoculture. In addition, according to the authors, the implementation of the silvopastoral system had an implementation cost of 19.26% higher than the conventional one. In the present study, the cost of implementing conventional planting was higher than that of the silvopastoral system. Cordeiro *et al*. (2018) also carried out a research to verify the profitability of an agroforestry system with different spacings comparing with conventional eucalyptus plantation, and found that both systems were viable for NPV and IRR, Equivalent Periodic Benefit (BPE) and Benefit Cost ratio (B /C), with monoculture eucalyptus being the most profitable project, considering a 14-year horizon and an interest rate of 8.75% per year.

The information presented as a comparative evidence that the conventional systems were more profitable than the silvopastoral systems, taking into account the forest component, however, an important variable must be analyzed in the discussion. In the studies analyzed as comparative, it is observed that there was no forest inventory by assortment, as performed in the research in question. Information based on the volume of trees by diameter class becomes essential when it comes to the value of the revenue from the forest component, since the larger the diameter of the log, the greater added value it will have, increasing the revenue involved in the system.

In addition, the revenue from livestock was also not evaluated, but it has a positive impact on revenue, as considered by Resende (2014) where he observed that the conventional beef livestock model obtained an NPV of R$442.00 per hectare and an IRR of 5.34% pa. After the introduction of the Livestock and Forestry Integration system, the financial indicators rose to an NPV of R$24,296.00 per hectare and an IRR of 17.57% p.a. The scenario of viability of silvopastoral systems with species of the genus Eucalyptus was also reported by Ribaski, Hoeflich and Ribaski (2009), with a 21-year rotation in the state of Rio Grande do Sul.

CONCLUSIONS

- The production of forest raw material per unit of area was higher in the silvopastoral system (321.7 m³/ha) in relation to the conventional system (259,5 m³/ha).
- The silvopastoral system presented lower maintenance and implementation costs, generating more attractive results of the financial analysis criteria.
- The sale of wood by assortment directly influences the viability of the systems, since the highest volume in assortments S1 and S2 was found in the silvopastoral system, resulting in higher revenue from the sale of raw material with added value.
- The silvopastoral system has favorable economic advantages for its implementation, as well as important environmental benefits. As a suggestion for future studies, it is evident the need to verify the carbon neutralization rate in the silvopastoral system, so that, with concrete data, it is possible to implement these systems effectively, helping to reduce greenhouse gas emissions.

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