Scientific Article

PRODUCTION AND FINANCIAL FEASIBILITY IN SILVOPASTORAL SYSTEM IN SMALL RURAL PROPERTY

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ABSTRACT – The implementation of silvopastoral systems (SPS) on properties that have family farming is an alternative to diversify land use, to acquire more than one production good, and diversify income generation. Therefore, the objective of this study was to evaluate the financial viability and quantify the volume of the forest component in an SPS with a spacing of 3.0 m x 20.0 m for multiple uses, carried out at 4 years of age for a 16-year rotation. For the analysis of financial viability, we used project analysis criteria such as: net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR) for a 16-year horizon with rate benchmarks interest rate of 3%, 4.5% and 10%. Based on the financial analysis criteria, the tree component of the system is viable, as it presented an NPV greater than zero, IRR exceeding the minimum attractiveness rate and BCR greater than 1 for all rates analyzed. The estimated production of the forest component was 257.28 m^3/ha in 16 years. Thus, it can be concluded that the forest component in the arrangement of 3.0 m x 20.0 m at 16 years of age, provides a financial return for the small rural property. Therefore, it is a system that brings several economic and environmental advantages, optimizing the use of land, diversifying the production of the small property, generating income, bringing benefits to the reduction of methane gas (CH_4) emissions, and assists in carbon sequestration (CO_2).

Keywords: Family farming; *Eucalyptus*; forest production.

PRODUÇÃO E VIABILIDADE FINANCEIRA EM SISTEMA SILVIPASTORIL EM PEQUENA PROPRIEDADE RURAL

RESUMO – A implantação de sistemas silvipastoris (SSP) nas propriedades que possuem agricultura familiar é uma alternativa para diversificar o uso da terra, para adquirir mais de um bem de produção e diversificar a geração de renda. Sendo assim, o objetivo desse estudo foi avaliar a viabilidade financeira e quantificar o volume do componente florestal em um SSP com espaçamento de 3,0 m x 20,0 m para uso múltiplo, realizado com 4 anos de idade para uma rotação de 16 anos. Para análise de viabilidade financeira utilizou-se os critérios de análise de projetos como: valor presente líquido (VPL), taxa interna de retorno (TIR) e relação benefício custo (B/C) para um horizonte de 16 anos com balizadores de taxa de juro de 3%, 4,5% e 10%. A partir dos critérios de análise financeira o componente arbóreo do sistema é viável, pois, apresentou um VPL maior que zero, TIR superando a taxa mínima de atratividade e B/C maior que 1 para todas as taxas analisadas. A produção estimada da componente florestal foi de 257,28 m^3/ha em 16 anos. Assim, pode-se concluir que o componente florestal no arranjo de 3,0 m x 20,0 m aos 16 anos de idade, proporciona retorno financeiro para a pequena propriedade rural. Sendo assim, é um sistema que traz diversas vantagens econômicas e ambientais, otimizando

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o uso da terra, diversificando a produção da pequena propriedade, gerando renda, trazendo benefícios para a redução das emissões de gás metano (CH_4) e auxilia no sequestro de carbono (CO_2).

Palavras-Chave: Agricultura familiar; ***Eucalyptus****; Produção florestal.*

1. INTRODUCTION

From the intensive use of agricultural practices, the soil changes its characteristics and loses quality, requiring the adoption of sustainable techniques (Terra et al., 2019). Extensive livestock farming is the activity with the highest occupation of the agricultural border area, through the creation of cattle on pasture, due to its low cost and greater efficiency to ensure the possession of large tracts of land (Dias-Filho, 2012).

It is estimated that in Brazil, 50% of pastures are degraded (Macedo et al., 2013); and during the 26th Conference of the Parties (COP26), United Nations Framework Convention on Climate Change (UNFCCC), Brazil committed to reducing 50% of carbon emissions by 2030, one of its strategies being to recover 30 million hectares of degraded pastures (BRASIL, 2021).

In this sense, the Silvopastoral Systems (SPSs), characterized by having forest, farming, and livestock components in the same space, can be helpful in recovering degraded pastures (Karvatte et al., 2016). And in these systems, the mitigation of greenhouse gases occurs because sequestering carbon ends up reducing methane emissions per kg of beef (Balbino et al., 2011). Silvopastoral systems are alternatives to the livestock that predominates in Brazil, as they bring environmental benefits, improve the quality of life of family farmers, sequester carbon, as well as present great economic and environmental potential for farmers and society (Nascimento et al., 2014).

In addition, this relationship through the system becomes a great alternative for income and a beneficial environmental practice for rural producers. Silva and Ribaski (2012) highlighted that these new markets can help both the strategies that hinder the economic side of the Brazilian agribusiness sectors focused on the livestock sector and the forest-based sector. In this way, this system must be well planned, considering some important points such as capital, microclimate, soil, qualified assistance, tree species, and issues of economic return (Lustosa, 2008).

Studies related to SPSs are considered a good alternative for income diversification, as it involves more than one culture. In addition to generating extra income, it also brings several environmental benefits. These benefits are cycling of nutrients in the soil, carbon sequestration (CO_2), reduction of methane gas (CH_4), among others. Thus, improving the quality of life of rural producers, bringing social, environmental, and economic benefits.

Thus, the objective of this work was to quantify the forest production of *Eucalyptus grandis* W.Hill ex Maiden and analyze the financial viability for the small rural property, at different interest rates (3.00%, 4.50% and 10.00%), in a 4-year Silvopastoral System, for a 16-year rotation.

2. MATERIALS AND METHODS

The research was carried out in the municipality of Agudo, located in the state of Rio Grande do Sul in the physiographic region of the Central Depression, located in the Atlantic Forest Biome.

The study was carried out on a rural property characterized as family farming, in the following coordinates: latitude 29°33'16.21" S and longitude 53°07'19.68" W. The property comprises a total of 60 hectares, 8 hectares of pasture planted with ryegrass, and has two silvopastoral systems (one of 2 ha and the other of 1 ha), with a monoculture of *Eucalyptus grandis* W. Hill ex. Maiden. The research was carried out in the silvopastoral system (SPS) which has 2 hectares, where the forest component is composed of *E. grandis* (clone GPC 23) at a spacing of 3.0 m x 20.0 m, in the east-west direction. The planting of the seedlings was carried out in November 2015 and the collection of tree data was performed when the tree component was 4 years old.

The climate of this region is Cfa type, that is, humid subtropical, with hot summers without a defined dry season, according to the Köppen classification (Alvares et al., 2013), and an average rainfall of 1712 mm annually (Heldwein et., 2009).

To quantify forest production, a forest inventory was carried out through a forest census. The circumference at breast height (CBH) was measured with a tape measure and the total height of all trees using the Vertex digital hypsometer.

The SPS has a density of 166 trees per hectare and the volume was calculated at 4 years of age. To make it possible to calculate the volume of the system at 4 years old, it was decided to carry out the standing cubing method, using a Finnish bracket attached to a ruler, from the dg tree (average basal area tree), that is, the representative tree of the SPS for the determination of the form factor (Table 1).

To estimate the volume of trees in the system at 16 years of age, the volume was projected based on the production table by Finger (1997) for *Eucalyptus grandis* in the first rotation. The total individual volume with shell was considered, in which the density at 16 years was multiplied by the individual volume found in the production table.

Table 1 – Equation table.
Tabela 1 *– Tabela de equações .*

Model	Equation
Volume by Smalian	$V_i = \left(\frac{g_i + g_{i+1}}{2}\right) * L_i$
Tip Volume	$V_{p=} \frac{g_n * l_n}{3}$
Stump Volume	$V_{t=} g_0 * l_0$
Rigorous Volume	$V_{rigorous=} V_t + V_n + V_p$
Cylinder Volume	$V_{cylinder} = g * h_t$
Form factor (1,30m)	$f = \frac{V\ rigorous}{V\ cylinder\ 1{,}30}$
Tree volume	$V = g * h_t * f$
Total volume per hectare	$V_t = \frac{\sum V}{Area}$

Where: V_i: volume by Smalian; g_i: cross-sectional area at the base of the i-th log (m^2); g_{i+1}: cross-sectional area at the top of the i-th log (m^2); L_i: length of the i-th log (m); V_P: tip volume (m^3); g_n: basal area at the base at the position of the last log (m^2); l_n: last log length (m); V_t: stump volume (m^3); g_0: basal area at the base of the stump (m^2); l_0: length from base of stump to first section (m); V_rigoroso: rigorous volume (m^3); V_t: stump volume (m^3); V_n: sections volume (m^3); $V_{cilindro}$: cylinder volume (m^3); g: basal area (m^2); h_t: total height (m); *f*: form factor; $V_{rigoroso}$: rigorous volume at 1.30 meters from the ground (m^3); *V*: tree volume (m^3); h_ttotal height; V_t: total volume per hectare ($m^3\ ha^{-1}$); ∑v: sum of total volume (m^3); Area: inventoried area of the silvopastoral system (ha).
Source: Authors.
Onde: V_i: volume por Smalian; g_i: área da seção transversal na base da i-ésima tora (m²); g_{i+1}: área da seção transversal no topo da i-ésima tora (m²); L_i: comprimento da i-ésima tora (m); V_P: volume da ponteira (m³); g_n: área basal na base na posição da última tora (m²); l_n: comprimento da última tora (m); V_t: volume do toco (m³); g_0: área basal na base do toco (m²); l_0: comprimento da base do toco até a primeira seção (m); $V_{rigoroso}$: volume rigoroso (m³); V_t: volume do toco (m³); V_n: volume das seções (m³); $V_{cilindro}$: volume do cilindro (m³); g: área basal (m²); h_t: altura total (m); f: fator de forma; $V_{rigoroso}$: volume rigoroso a 1,30 metros do solo (m³); V: volume da árvore (m³); h_t: altura total; V_t: volume total por hectare (m³ ha⁻¹); ∑v: somatório do volume total (m³); Área: área inventariada do sistema silvipastoril (ha).
Fonte: Autores.

Diameter classes were calculated at 2.5 cm intervals to obtain the relative frequency (Table 2). This method was carried out with the aim of identifying individuals who possibly do not tend to reach the volume that was estimated at 16 years of age. It was decided to exclude 20% of the individuals referring to the classes (7.44 ≤ D ≤ 9.94; 9.94 ≤ D ≤ 12.44 and 12.44 ≤ D ≤ 14.94) so as not to compose the final volume and, consequently, the final revenue of the 16-year cycle. Therefore, the final density at 16 years will be 134 trees/ha.

For the realization of the cash flow, implementation costs, maintenance, and revenues from the forestry component were considered. Costs and revenues per hectare were also considered, implementation costs include costs with seedlings, soil preparation, fertilization, ant combat, planting, control of invasive plants, and labor; and maintenance costs include weeding and ant control.

The final product, a rotation of 16 years, was destined for the sawmill. The sales value of R$ 100.00 per m^3 was considered for the sawmill, sales values in the region where the study was carried out. Prices are in line with standing wood, where the buyer is responsible for cutting and transporting the logs for processing.

To carry out the financial feasibility calculations, an interest rate of 3.00% per year was used, adopted by the Pronaf program in 2019, with an interest rate aimed at strengthening family farming. Pronaf was chosen because it is a program developed and aimed at offering credit to family farmers.

Table 2 – Relative frequency of silvopastoral system diameter classes in the 3.0 x 20.0 m array at 4 years of age.
Tabela 2 *– Frequência relativa de classes de diâmetro do sistema silvipastoril no arranjo de 3,0 x 20,0 m aos 4 anos de idade.*

CLASS	Frequency %
7,44 ≤ D ≤ 9,94	1,79
9,94 ≤ D ≤ 12,44	3,58
12,44 ≤ D ≤ 14,94	15,82
14,94 ≤ D ≤ 17,44	40,30
17,44 ≤ D ≤ 19,94	30,15
19,94 ≤ D ≤ 22,44	6,87
22,44 ≤ D ≤ 24,94	1,19
24,94 ≤ D ≤ 26,90	0,30

Source: Jesus, 2020.
Fonte: Jesus, 2020.

A sensitivity analysis was also carried out for comparison purposes, using an interest rate of 4.50% per year and an interest rate of 10.00% per year. For the financial analysis, the following project evaluation methods were applied:

Net Present Value – NPV

The net present value (Equation 1) is the difference in the value of revenues minus the value of costs in the present. An NPV greater than zero is economically viable in relation to the interest rate taken as the basis for the analysis, and the project with the highest NPV is considered the best (Silva, 2002).

$$NPV = \sum_{j=0}^{n} R_j\,(1+i)^{-j} - \sum_{j=0}^{n} C_j\,(1+i)^{-j} \qquad \text{Eq.1}$$

Where:

NPV = net present value (R$ ha^{-1});

R_j = current value of income (R$ ha^{-1});

C_j = current value of costs (R$ ha^{-1});

i = interest rate (%);

j = period in which revenue or cost occurs (R_j or C_j);

n = number of periods or project duration (years).

Internal Rate of Return – IRR

The annual rate of return (Equation 2) on invested capital, is the discount rate that equals the present value of revenues and costs. It can also be interpreted as the average rate of return on investment (Rezende; Oliveira, 2013).

$$IRR = \sum_{j=0}^{n} R_j\,(1+IRR)^{-j} - \sum_{j=0}^{n} C_j\,(1+IRR)^{-j} = 0 \qquad \text{Eq.2}$$

Where:

IRR = internal rate of return (% by year);

R_j = current value of income (R$ ha^{-1});

C_j = current value of costs (R$ ha^{-1});

n = number of periods or project duration (years).

Benefit-Cost Ratio – BCR

Defines the relationship between present income and present costs. If BCR (Equation 3) > 1 the investment is considered viable (Rezende; Oliveira, 2013).

$$BCR = \frac{\sum_{j=0}^{n} R_j\,(1+i)^{-j}}{\sum_{j=0}^{n} C_j\,(1+i)^{-j}} \qquad \text{Eq.3}$$

Where:

BCR = Benefit-cost ratio;

R_j = current value of income (R$ ha^{-1});

C_j = current value of costs (R$ ha^{-1});

i = interest rate (%);

j = period in which revenue or cost occurs (R_j ou C_j);

n = number of periods or project duration (years).

Data were submitted for analysis of variance (ANOVA), and the means were compared by Tukey's test and by linear regression, at a 5% error probability. The statistical program R and the SAS program were used.

3.RESULTS

From the forest inventory and the tree size, it was possible to obtain the production at 4 years. For the age of 4 years, the diameter, height and form factor are from the dg tree of the silvopastoral system, that is, the average tree representative of the system; and production at age 16 are data from the production table (Table 3).

The implementation cost was R$ 799.20, whereas the maintenance costs were R$ 332.50 and occurred in two periods (1 to 3 and 4 to 6), after this period no interference will be carried out, thus, without additional charge. With this, it is estimated a revenue of R$ 25,728.00 at the end of the 16-year cycle, as shown in Table 4.

The financial feasibility analysis presents a positive result in relation to the silvopastoral system by the NPV, IRR and BCR criteria. The NPV value was positive, so revenue exceeds costs when decapitalized by the interest rate of 3%, 4.5% and 10% considering a horizon of 16 years (Table 5).

The IRR represents the return on capital that was invested in the project and exceeded the minimum attractiveness rate (3%, 4.5% and 10%). The BCR was greater than 1 at the rate of 3%, where for each R$ invested there is a return of R$ 9.32. For the rate of 4.5%, he showed that for each R$ invested, there

Table 3 – Dendrometry measurements and volumes at 4 and 16 years of the silvopastoral system in a 3.0 m x 20.0 m arrangement in a single line.
Tabela 3 *– Medidas dendrométricas e volumes aos 4 e 16 anos do sistema silvipastoril em arranjo de 3,0 m x 20,0 m em linha simples.*

AGE	AVERAGE DBH (cm)	AVERAGE HEIGHT (m)	FORM FACTOR	INDIVIDUAL VOLUME (m^3)	VOLUME (m^3/ha)	DENSITY (trees/ha)
4 years	19,70	16,00	0,39	0,19	31,54	166
16 years	42,00	38,00	-	1,92	257,28	134

Source: Jesus, 2020.
Fonte: Jesus, 2020.

Table 4 – Gross costs and revenues of the forest in a silvopastoral system in the arrangement of 3.0 x 20.0 m in single lines, real data.
Tabela 4 *– Custos e receitas brutas da floresta em sistema silvipastoril no arranjo de 3,0 x 20,0 m em linhas simples, dados reais.*

ACTIVITIES	YEAR OF OCCURENCE	COST (R$/ha)	REVENUE (R$/ha)
Implementation	0	799,27	-
Maintenance	1 a 3	252,50	-
Maintenance	4 a 6	80,00	-
Wood selling	16	-	25.728,00

Source: Jesus, 2020.
Fonte: Jesus, 2020.

Table 5 – Net present value (NPV), internal rate of return (IRR) and Benefit-Cost Ratio (B/C), of the forest component of the silvopastoral system in the arrangement of 3.0 m x 20.0 m in a single line.
Tabela 5 *– Valor presente líquido (VPL), taxa interna de retorno (TIR) e Razão Benefício Custo (B/C), do componente florestal do sistema silvipastoril no arranjo de 3,0 m x 20,0 m em linha simples.*

CRITERIA	RESULTS		
	3%	4,5%	10%
Net Present Value (NPV)	R$14,312.26	R$11,035.61	R$4,022.49
Internal Rate of Return (IRR)	19,79%	19,79%	19,79%
Benefit-Cost Ratio (BCR)	9,32	7,55	3,55

Source: Jesus, 2020.
Fonte: Jesus, 2020.

will be a return of R$ 7.55. And for the 10% rate, the return for each R$ invested was R$ 3.55, showing the financial viability.

4. DISCUSSION

The financial feasibility analysis showed that the forestry component is viable at rates of 3%, 4.5%, and 10% for all criteria used. The IRR is 19.79%, that is, 9.79 percentage points above the 10% rate applied. Thus, in the spacing of 3.0 m x 20.0 m, there is a low density of trees, 166 trees per hectare, which ends up transforming into a low cost of implantation and maintenance since trees in greater spacing tend to gain a greater increment in diameter resulting in a greater gain in the sale of wood.

Studies have found that consortium systems are financially viable (Oliveira et al., 2008, Weimann, Farias, Deponti, 2017). In comparing the financial feasiblity between an agrosilvopastoral system and conventional planting in a small rural property at a rate of 7.5% per year for a 15-year rotation, it was verified that the agrosilvopastoral system was viable with an NPV of 10,848.88 R $/ha and IRR of 24.83% per year and BCR of 6.80 at a density of 500 trees per hectare (Weimann, Farias, Deponti, 2017). Oliveira et al. (2008), when evaluating the financial viability of a 4-year-old silvopastoral system with *Eucalyptus grandis* planted in triple rows with a spacing of 3.0 x 1.5 m between trees and 34 m in rows (density of 500 individuals per hectare), with an interest rate of 6% per year and a horizon of 21 years, found an NPV of 7,239.06 R$/ha, proving to be viable from this analysis criterion.

Garcia et al. (2021) analyzed biodiverse agroforestry systems that reflect the reality of family farming over a period of 20 years, and found that both SAF's 1 and 2, with NPV values of R$ 11,018.24 and 40,377.04 respectively, presented conditions of financial viability. The same authors highlighted that SAF 2 was slightly more profitable compared to the other, since its BCR was 1.2, different from SAF 1, which was 1.1.

Thus, these values imply confirming that the SAF's are profitable, in order to guarantee the rural producer, if well planned and closely monitored, optimal conditions for food production and income generation.

Cordeiro et al. (2018) performed a simulation to analyze the financial profitability in different spacings of the forest component of an agrosilvopastoral system with eucalyptus, rice, soybeans, and cattle. The authors used net present value, internal rate of return, benefit-cost ratio, and equivalent periodic benefit as financial analysis criteria. For the system with eucalyptus at a spacing of 10.0 x 6.0 m (density of 166 trees per hectare) at an interest rate of 8.75% and a horizon of 14 years, he found NPV of 12,979.14 R$/ha and a 22% IRR.

Ribaski et al. (2009) evaluated the internal rate of return of a silvopastoral system and considered a minimum rate of attractiveness of 3.72% per year for a planning horizon of 21 years of eucalyptus planted in triple rows with a spacing of 3.0 x 1.5 m and 14 meters between triple lines and eucalyptus planted in triple lines with 3.0 x 1.5 m spacing and 34 meters of lines. The two configurations of silvopastoral systems presented IRR higher than TMA when the value of the land purchase was not considered and thinning was performed, except for the configuration of 3.0 x 1.5 m between trees and 34 meters between rows, which was not viable. The study by Ribaski et al. (2009) considered the costs of the animal component and forage component of the system and the income.

5. CONCLUSION

The forest in a silvopastoral system provides a positive financial result, in addition to a production projection at 16 years of age of 257.28 m3/ha, with a final density of 134 trees/ha. Several benefits stand out here, such as extra income for small properties, diversification of production, animal comfort, and carbon retention by the forestry component. In this way, we can highlight that SPSs are fundamental for family farming, as they can generate financial security for these families, thus enabling better living conditions and another income generation.

AUTHOR CONTRIBUTIONS

L.C.J and J.A.F elaborated the idea of the research and applied methodology. D.B., M.M.Z. and E.B.W participated in the data analysis and contributed to the writing.

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