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Economic potential of *Eucalyptus* spp. plantations in Livestock–Forest Integration systems (iLF) in the Amazon

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Abstract. The search for profitable and sustainable alternatives for production in the Amazon directs attention to Livestock–Forest Integration Systems (iLF), which may present, depending on the species used, high economic viability. Thus, the objective of this study was to evaluate the economic feasibility of establishing different hybrids of *Eucalyptus* spp. in a Livestock–Forest Integration system (iLF). The study was conducted at Fazenda União, located in the municipality of Pimenta Bueno, state of Rondônia, in an area of nine hectares. Three scenarios were proposed: scenario 1 (C1) and scenario 2 (C2), with rotations of four years and seven years, with the assortment destined for energy biomass, and scenario 3 (C3), ten years, destined for structural timber. The program SisILPF_Eucalipto was used to estimate production. The economic criteria used were: Benefit–Cost Ratio (B/C); Net Present Value (NPV); and Internal Rate of Return (IRR). A sensitivity analysis was performed by applying three different annual interest rates: 7.44%, 8.50%, and 12.90%. The establishment cost was R$3,211.28 ha^{-1}, with estimated production for C1, C2, and C3 of 81.14 st ha^{-1}, 184.86 st ha^{-1}, and 261.43 st ha^{-1}, respectively. Thus, the economic evaluation criteria applied to all scenarios were viable, regardless of the interest rate used, with C3 demonstrating higher economic returns. Therefore, these analyses provide support for the development of this type of enterprise in the region and state, being important to motivate producers, identifying potential returns and encouraging the adoption of silvicultural practices.
Keywords: Forest investment evaluation techniques, Net Present Value, Benefit–Cost Ratio, Internal Rate of Return.

Introduction

The Amazon is recognized as the largest tropical forest in the world, holding high biodiversity, and the conservation of this ecosystem is important for the perpetuation of species, as well as for the maintenance of global ecological balance (Souza *et al.*, 2021; Souza & Brasileiro, 2023). However, the adoption of sustainable techniques for managing this forest still constitutes an obstacle, in which, as a means of reducing deforestation, legal procedures are established, thus authorizing the harvesting of the forest component (Ribeiro; Fonseca; Pereira, 2020).

Deforestation in the Amazon has led to the loss of large areas of vegetation, resulting in degradation, mainly caused by intense agricultural and livestock activities (Reisch, 2021; Guimarães; Silva; Santana, 2024). The excessive use of forest resources, combined with pressure on natural forests, results in environmental problems, including biodiversity loss and the release of large amounts of stored carbon, which contributes to climate change (Gouvêa, 2024; Li, 2025).

In this context, efforts have emerged to create sustainable land-use options that reduce the impact on natural forests. Among the options, the use of Livestock–Forest Integration Systems (iLF) stands out, capable of relieving pressure on natural resources and diversifying production in the Amazon. This system consists of the spatial and temporal integration of forest trees, pastures, and animals in the same area, aiming to optimize land use and promote production diversification (Santos *et al.*, 2024). The implementation of iLF in the Amazon presents several benefits, such as increased land productivity, recovery of degraded areas, mitigation of climate change, and income generation for producers (Santos *et al.*, 2024; Reis *et al.*, 2025).

Incorporating fast-growing species, such as *Eucalyptus* spp., into these systems is a promising option. The versatility and adaptability of eucalyptus are widely recognized, serving both the energy biomass market and the production of structural timber. This contributes to the recovery of degraded areas and the preservation of the environment (Esteves & Martins Ferreira, 2020; Almeida *et al.*, 2021; Silva *et al.*, 2021).

However, for these systems to be attractive, careful economic analysis is crucial, enabling investors and producers to make decisions based on estimates of economic feasibility. Instruments such as Net Present Value (NPV), Internal Rate of Return (IRR), and the Benefit–Cost Ratio (B/C) are essential criteria that guide these investments, providing a clear perspective of long-term economic return, a common characteristic of forest projects. Studies show that these criteria are essential to minimize risks and uncertainties in agroforestry investments, help producers and investors make more informed decisions (Fazriyaz, Nurmansah, Putri, 2024).

In order to contribute to identifying the potential returns of this type of enterprise in the region and to provide support for the adoption of sustainable and profitable practices in the Amazon biome, the objective of this study was to analyze the economic feasibility of establishing hybrids of *Eucalyptus* spp. in iLF systems in the Amazon, based on three different management scenarios.

Material and methods

The study was conducted on a farm located in the municipality of Pimenta Bueno – Rondônia, Brazil (Figure 1). The climate of the region is Tropical (Aw), with a predominant dry winter subclimate (Beck *et al.*, 2018), where average temperatures range between 24 °C and 26 °C (Alvares *et al.*, 2013), with annual precipitation ranging between 1,728.9 mm and 1,843.7 mm per year, with the highest concentration occurring between the months of November and March (Franca, 2015).

The farm was selected for the experiment due to its favorable conditions, since, after its acquisition in 2020, when its original vegetation, consisting of secondary forest at an advanced stage, was removed and the area prepared for agricultural activities. Soil preparation included clearing, harrowing, correction, and leveling, followed by the planting of pasture with *Brachiaria brizantha*, facilitating livestock integration. In 2022, eucalyptus hybrids were introduced as part of the Livestock–Forest Integration system (iLF), aiming to provide shading and thermal comfort for the animals, which contributes to livestock welfare and productivity.

The spatial arrangement in single rows, with 2.0 meters between plants and 15 meters between rows, oriented East–West, a spacing that favors the maximization of forage and wood production, covers nine hectares with an approximate density of 3,000 trees. These factors justify the choice of the area for the study, providing support for both the forest component and livestock production (Figure 2).

The hybrids established in the Livestock–Forest Integration system were *Eucalyptus pellita* × *Eucalyptus* sp.; *Eucalyptus urophylla* × *Eucalyptus camaldulensis*; and *Eucalyptus urophylla* × *Eucalyptus grandis*, with the genotypes originating from the genetic improvement program of the company Eletrogoes S/A, located in Pimenta Bueno, Rondônia, Brazil.

To estimate tree volume, the program SisILPF_Eucalipto, designed for Crop–Livestock–Forest Integration systems (iLPF), was used, applying the following volume equation: 7.854E^-5D^20.39*H (Oliveira; Silva & Ribaski, 2018), considering 333 trees per hectare and an initial survival rate in the first year of 100%. The age interval varied according to the three scenarios evaluated: rotations of four years (C1) and seven years (C2), with assortments destined for energy biomass, and ten years (C3), with assortments destined for structural timber (fence posts, poles, and roundwood, among others), considering the main uses of these products in the regional market. Based on this definition, a production simulation was performed as a reference for the calculations of the economic feasibility of the enterprise.

For the evaluation of the production cost of the forest component, data related to the establishment cost and commercialization of timber forest products were obtained. It was not possible to estimate the intermediate costs of the production cycle due to the absence of systematized regional records on maintenance and forest management expenses, which made it unfeasible to construct a detailed annual cash flow. Thus, the analysis was restricted to establishment costs and the estimated revenue at the time of wood commercialization.

The quotation of costs related to services and the acquisition of inputs was carried out in loco, through consultations with cooperatives and agricultural establishments. The selling price in the region for *Eucalyptus* spp. destined for energy biomass is R$157.14 per stere (st), and R$170.00 per st for structural timber, considering the commercialization of standing timber. The values adopted correspond to the prices effectively practiced in the region during the data collection period, obtained from local agents in the forestry sector. Although market fluctuations are recognized, there are no consolidated regional historical series that allow the deflation of values or the definition of consistent intervals for sensitivity analysis. Thus, the use of point prices was adopted as an approximation of real market conditions within the temporal scope of the study, and the results should be interpreted under this delimitation. The data was tabulated in the Microsoft Office Excel® program, applying descriptive statistics for the analysis.

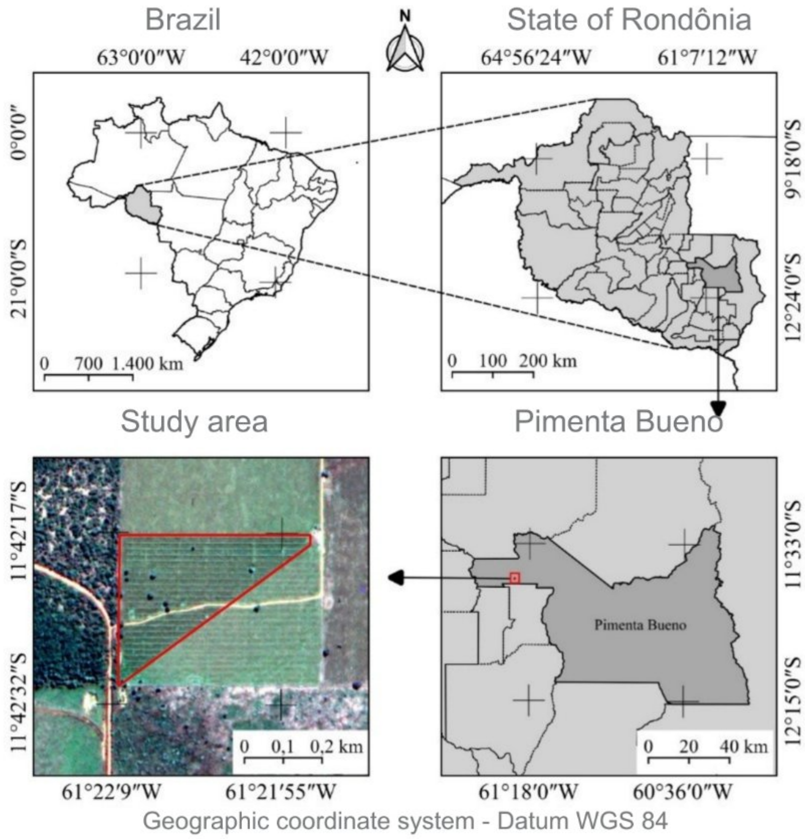

Figure 1. Location of the area where the *Eucalyptus* spp. hybrids were established, with a spatial arrangement of (2.0 m × 15 m), in an integration system, in the Southwestern Amazon, 2024.

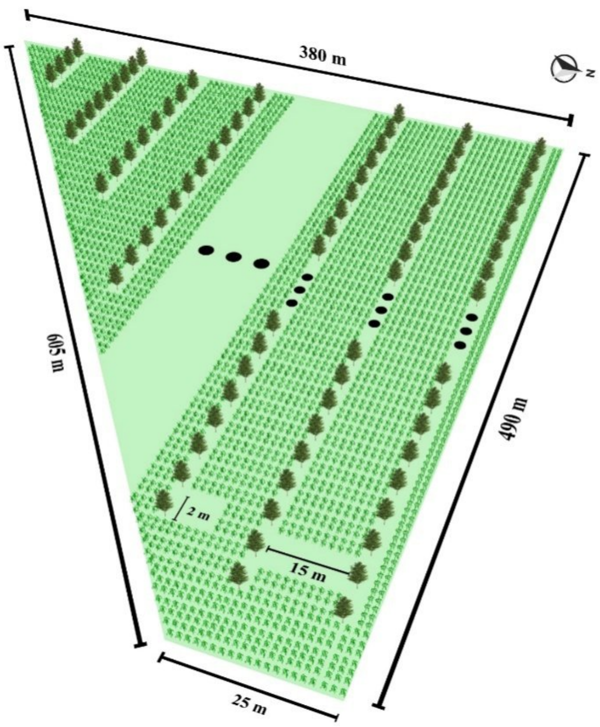

Figure 2. Spatial arrangement of the establishment of *Eucalyptus* spp. hybrids with a spatial spacing of (2.0 m × 15 m), in an integration system, in the Southwestern Amazon, 2024.

To evaluate the economic feasibility of the forest enterprise under study, economic evaluation criteria that consider the variation of capital over time were used. To compare the different scenarios, with distinct planning horizons, the Equivalent Annual Value (EAV) (Jones & Smith, 1982; Cui, 2025) was calculated, which corresponds to the annualization of the NPV over the planning horizon, converting the result into a uniform annual flow. This indicator is especially recommended for comparisons between projects with different durations, as it eliminates the effect of time on the absolute value of the return. For this criterion, the following formula was used:

$$EAV = NPV \times \frac{i(1+i)^n}{(1+i^n)-1}$$

where: EAV = Equivalent Annual Value, NPV = Net Present Value; i = discount rate; n = number of periods.

EAV allows the direct comparison of projects with different durations by converting the NPV into an equivalent annual cash flow.Additionally, the Benefit–Cost Ratio (B/C) (Silva; Jacovine; Valverde, 2005) and the Net Present Value (NPV) (Schwab & Lusztig, 1969; Rezende & Oliveira, 2013; Farias *et al.*, 2023) were calculated. The Benefit–Cost Ratio (B/C) expresses the relationship between the present value of revenues and the present value of costs. Values greater than 1 indicate that the updated benefits exceed the updated costs, characterizing the economic feasibility of the investment. The formula used for the Benefit–Cost Ratio was as follows:

$$R/C = \frac{\sum_{(j=0)}^{n} Rj}{\sum_{(j=0)}^{n} Cj}$$

where: B/C = Benefit–Cost Ratio; Rj = revenue in period j; Cj = cost in period j; n = number of periods. The B/C ratio indicates the efficiency of the investment, demonstrating the return obtained for each monetary unit invested.

The NPV was used to measure the economic return of the project in absolute terms, considering the difference between the present value of revenues and the present value of costs, discounted at a rate that represents the opportunity cost of capital. Positive NPV values indicate that the enterprise remunerates capital above the adopted rate, being economically feasible. For this criterion, the following equation was used:

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

where: NPV = Net Present Value; Rj = present value of revenues; Cj = present value of costs; i = interest rate; j = period in which revenues or costs occur; n = number of periods.

A positive NPV indicates that the project is profitable, while a negative NPV indicates a loss.Finally, the Internal Rate of Return (IRR) (Schwab & Lusztig, 1969; Rezende & Oliveira, 2013; Farias *et al.*, 2023) was also calculated, which represents the discount rate that equates the present value of revenues to the present value of costs, making the NPV equal to zero. When the IRR is higher than the Minimum Attractive Rate of Return established for the project, the investment is considered economically attractive. The equation used here was:

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

where: Rj = revenue at the end of year or period “j” considered; Cj = cost at the end of year or period “j” considered; n = project duration in years or in number of periods; j = period; IRR = Internal Rate of Return in %.

Although the Internal Rate of Return (IRR) was calculated for all scenarios (C1, C2, and C3), its application aimed only at the isolated verification of the feasibility of each scenario, and not the comparison between them, since the analyzed scenarios present different planning horizons (4, 7, and 10 years, respectively). An IRR higher than the Minimum Attractive Rate of Return (MARR) indicates the economic feasibility of the project.

The MARR of the project was defined based on the real rate offered by the Treasury bond IPCA+2045, which is 6.65% per year (Tesouro Direto, 2024), plus a risk premium based on the EMBI+ Brazil Risk rate, which on July 30, 2024 was 2.28% (Ipeadata, 2024). Thus, the minimum attractive rate, corresponding to the real interest rate, was 8.93%.

For the economic feasibility and sensitivity analysis, the cash flows were adjusted according to the inflation projection for the year 2024, recorded by the General Market Price Index (IGP-M) at 4% (FGV, 2024), and thus were calculated considering different interest rates. The savings rate applied in 2024 by the Credit, Savings and Investment Cooperative Univales – Sicredi MT/RO (Sicredi), of 7.44% per year (nominal), corresponds to 3.33% per year (real). The rate of 8.50% per year (nominal), which applies to financing aimed at investments that reduce environmental impacts through Renovagro – Financing Program for Sustainable Agricultural Production Systems (BNDES, 2024), corresponds to 4.33% per year (real). Finally, the rate of 12.90% per year (nominal), which represents the average variation of the Selic Rate in the period from December 2022 to March 2024 (BACEN, 2024), corresponds to 8.61% per year (real), considering an annual inflation of 4.00% in the year 2024.

Results and discussion

For the establishment of the eucalyptus hybrids, the initial costs were inserted in year zero (Year 0), and the economic analysis was performed based on the aggregation of these costs by activity, allowing a better visualization of the composition of the initial investment (Table 1).

Table 1. Distribution of establishment costs (Year 0) of *Eucalyptus* spp. hybrids in a Livestock–Forest Integration system, in the Southwestern Amazon, 2024, by activity (R$ ha⁻¹).

Activity	Cost (R$ ha^{-1})	Participation (%)
Soil correction and preparation	1,347.33	41.97
Establishment and planting	1,039.99	32.39
Fertilization (base and topdressing)	520.11	16.20
Phytosanitary control	264.29	8.23
Energy inputs	39.55	1.23
Total	3,211.28	100.00

The total establishment cost for the area was estimated at R$ 28,901.52, of which R$ 23,185.52 (80.2%) refer to the acquisition of inputs and R$ 5,716.00 (19.8%) are related to operational services. A predominance of inputs in the total cost is observed, especially fertilizers and soil amendments, indicating that the nutritional component constitutes the main expenditure factor in the initial phase of the Livestock–Forest Integration system.

The aggregation of costs by activity (Table 1) shows that the stages of soil correction and preparation and establishment/planting concentrate the largest share of the initial expenditure, jointly representing 74.36% of the total establishment cost. Fertilization accounts for 16.20%, while phytosanitary control corresponds to 8.23% of the total cost. This approach allows a better understanding of the economic structure of the system and provides a more consistent basis for technical comparisons and sensitivity analyses.

Livestock–Forest Integration (ICLF) presents significant economic impacts, especially in the initial phase, mainly related to soil chemical correction and stand establishment, which represent the highest costs before wood commercialization. Studies indicate that integrated systems such as ICLF offer better long-term economic performance in Brazilian biomes such as the Cerrado and the Amazon, with higher profitability, higher internal rates of return, and lower sensitivity to fluctuations in commodity prices compared to traditional systems of extensive livestock farming and large-scale agriculture (Reis *et al.*, 2023; Reis *et al.*, 2025).

It is noteworthy that harvesting and transportation costs were not incorporated, since, at the time of the study preparation, there was no consolidated and systematized regional information that would allow technically supported estimates for these operations. Thus, it was decided to consider the commercialization of standing timber, a common practice in the region, limiting the analysis to the gross revenue at the time of sale.

The estimated revenues are attributed to the total volume of wood produced, the destination of assortments, and the commercialization price per stere, at the end of the rotation of each scenario (Table 2).

Parte superior do formulário

Parte inferior do formulário

Table 2. Estimated gross revenue (R$ ha^{-1}) of the forest component in a Livestock–Forest Integration system, considering different rotations, assortments, and discount rates (Nominal and Real) in the Southwestern Amazon, 2024.

	Interest rates (% per year)					
	Nominal	Real	Nominal	Real	Nominal	Real
Year	7.44	3.33	8.5	4.33	12.9	8.61
	C1 – Energy Biomass (R$/ha)					
4	15,814.04	13,912.67	12,286.74	13,459.31	18,349.61	11,366.08
	C2 – Energy Biomass (R$/ha)					
7	44,681.41	35,555.77	47,392.47	33,217.68	60,158.16	25,154.09
	C3 – Structural timber (R$/ha)					
10	84,780.50	61,025.35	92,612.50	55,516.48	132,448.62	37,129.78

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Revenues were determined exclusively by the product between the commercialization price and the quantity produced (Revenue = P × Q), without being directly influenced by the discount rate. Interest rates were used only to update cash flows in the determination of the Net Present Value (NPV) and the Equivalent Annual Value (EAV).

For the evaluated eucalyptus hybrids, intended for energy biomass production, the revenues at the end of the rotations are determined by different interest rates, covering all establishment costs.

In scenario C1, the estimated production was 81.14 st ha^{-1}, with a total estimate of 730.29 st for the area, while in scenario C2 the estimated production was 184.86 st ha^{-1}, representing a significant volumetric increase due to the longer growth period. In scenario C3, production reached 261.43 st ha^{-1}, totaling 2,353 st for the total area, in addition to including allocation for structural timber, which has a higher unit market value, adding value to the product.

The increase in production observed in the scenarios with longer rotation time is consistent with the expected behavior for eucalyptus plantations, where volumetric growth tends to intensify in the first years and gradually stabilize throughout the production cycle. In agroforestry or silvopastoral systems, longer rotations allow the production of logs with larger diameters and better technological wood quality, enabling allocation to products with higher added value, such as structural timber. Recent studies indicate that eucalyptus plantations in agroforestry systems can reach productions between approximately 30 and 288 m^3 ha^{-1}, with a significant increase in economic return as the rotation period is extended (Kumar *et al.*, 2024).

With longer rotations, trees reach larger diameters and improve their technological characteristics, which adds value to the product and increases the estimated gross revenue. Studies show that extending the rotation period from 15 to 20 or 25 years can increase the combined benefits of timber and carbon sequestration by up to three times, especially when associated with an optimized planting density that favors the growth of larger trees (Bai *et al.*, 2024). In addition, the extension of the rotation allows the production of higher-quality sawn timber, which may justify significant price premiums to compensate for the additional costs of delayed harvesting (Regmi *et al.*, 2021), and the use of genetically selected material combined with longer rotations also contributes to greater economic gains due to the increase in volume and quality of the wood produced (Isaac-Renton *et al.*, 2025).

Considering that the evaluated scenarios have different planning horizons (4, 7, and 10 years), direct comparison using Net Present Value (NPV) may generate misleading interpretations, as discussed in the literature on forest project evaluation (Schwab & Lusztig, 1969; Rezende & Oliveira, 2013; Farias *et al.*, 2023). Thus, NPV, the Benefit–Cost Ratio (B/C), and the Internal Rate of Return (IRR) were used for individual verification of the feasibility of each alternative, while the Equivalent Annual Value (EAV) was adopted as the comparative criterion between scenarios.

Under this methodological approach, all scenarios showed economic feasibility, with indicators compatible with the established Minimum Attractive Rate of Return. Among the analyzed alternatives, scenario C3 stood out for presenting the highest annualized return, demonstrating higher relative profitability when compared to the four- and seven-year rotations (Table 3).

The B/C Ratio considering the different scenarios and adjusted according to the evaluated interest rates were > 1, indicating that they are economically viable. C3, regardless of the annual interest rate applied, presents the highest ratio, in which for every R$ 1.00 invested the economic return of the enterprise is greater than R$ 12.00.

The Benefit–Cost Ratio (B/C), calculated from the cash flows and the interest rates considered, presented values greater than 1 in all scenarios, indicating economic feasibility. Scenario C3, regardless of the discount rate applied, presented the highest B/C ratio, showing that, for every R$ 1.00 invested, the discounted economic return exceeds R$ 12.00.

Table 3. Results of the economic evaluation criteria for individual feasibility analysis (NPV, B/C and IRR) and comparative criterion between different planning horizons (EAV), for plantations of *Eucalyptus* spp. hybrids in an iLF system, Southwestern Amazon, 2024.

Year	TxN* (%a.a.)	B/C	NPV (R$/ha)	EAV (R$/ha)	IRR (%)	TxR* (%a.a.)	B/C	NPV (R$/ha)	EAV (R$/ha)	IRR (%)
				C1 – Energy Biomass						
4	7.44	3.70	86,56.76	2,581.15	48.97	3.33	4.33	10,701.39	2,877.62	43.24
	8.50	3.66	8,540.81	2,607.41	50.07	4.33	4.19	10,248.03	2,890.16	
	12.90	3.52	8,082.80	2,711.75	54.61	8.61	3.54	8,154.80	2,968.45	
				C2 – Energy Biomass						
7	7.44	8.42	23,826.12	4,489.06	45.66	3.33	11.07	32,344.49	5,222.86	40.06
	8.50	8.34	23,561.97	4,603.28	46.89	4.33	10.34	30,006.40	5,179.39	
	12.90	8.01	22,518.55	5,075.85	51.99	8.61	7.83	21,942.81	5,061.77	
				C3 - Structural timber						
10	7.44	12.88	38,154.00	5,543.28	38.73	3.33	19.00	57,814.07	6,804.70	33.39
	8.50	12.76	37,749.88	5,753.37	39.96	4.33	17.29	52,305.20	6,623.15	
	12.90	12.26	36,153.52	6,636.11	45.06	8.61	11.56	33,918.50	5,162.34	

*TxN: Nominal Interest Rate, **TxR: Real Interest Juros

The Net Present Values (NPV) estimated for the three scenarios were positive at all discount rates considered, indicating individual economic feasibility of the projects. As theoretically expected, a reduction in NPV was observed as the discount rate increased, reflecting the greater weight attributed to the opportunity cost of capital.

The EAV, in turn, showed an increase with the rise in the discount rate. This behavior results from the capital recovery factor used in the annualization of the NPV, whose effect may exceed the reduction in present value in projects with finite horizons. Thus, the EAV does not necessarily follow the same monotonic trend as the NPV in relation to the discount rate, although both are mathematically consistent with each other.

Considering that the scenarios have different planning horizons (4, 7, and 10 years), the Equivalent Annual Value (EAV) was adopted as the criterion for comparison among alternatives, since this indicator allows the economic standardization of projects with different production cycles, being used in recent studies on the economic evaluation of forest projects (Silva *et al.*, 2020). For scenario C1, the NPV was higher under the rate of 7.44% per year, decreasing progressively under the rates of 8.50% per year and 12.90% per year. A similar behavior was observed in scenarios C2 and C3, confirming mathematical consistency with the formulation of the indicator.

The Equivalent Annual Value (EAV), as it is directly derived from the NPV, presented consistent behavior, decreasing as the discount rate increased. As the scenarios have different horizons (4, 7, and 10 years), the EAV was adopted as the main criterion for comparison among alternatives, as recommended in the literature on the economic evaluation of forest projects.

The Internal Rate of Return (IRR) was calculated individually for each scenario, representing the discount rate that makes the NPV of the project equal to zero. Unlike the NPV and the EAV, the IRR does not vary according to the discount rate used in the analysis, as it is determined exclusively by the cash flow of the enterprise.

For scenario C1, the estimated IRR was 48.97%; for C2, 45.66%; and for C3, 38.73%. All rates were higher than the Minimum Attractive Rate of Return (8.93%), indicating the economic feasibility of the three projects.

It is observed that the IRR shows a decreasing trend as the planning horizon increases. This behavior is expected, since projects with longer duration dilute the percentage return over time, although they may generate greater absolute return value, as evidenced by the NPV and the EAV.

In the comparison among alternatives, scenario C3 presented the highest EAV, indicating a higher annualized return on invested capital, a result associated both with the higher produced volume and the higher unit value of structural timber.

However, a relevant factor to be considered is the possibility of performing early harvesting of the forest component, driven by financial needs. Thus, the producer does not need to wait until the tenth year for harvesting the trees, since in the four-year and seven-year scenarios the timber production of the enterprise provides high economic returns.

Among the analyzed discount rates, a behavior consistent with economic theory was observed: the lower the rate, the higher the Net Present Value (NPV), due to the lower penalization of future cash flows. Thus, the rate of 7.44% per year resulted in the highest NPVs, followed by the rate of 8.50% per year, while the rate of 12.90% per year presented the lowest present values.

The rate of 8.50% per year, linked to the Renovagro Program, kept the projects economically feasible, with positive NPV and EAV greater than zero, demonstrating that even under a higher cost of capital, the enterprise remains attractive.

In turn, the rate of 12.90% per year, corresponding to the average Selic Rate during the analyzed period, represents a more conservative scenario, in which the opportunity cost of capital is higher. In this context, the reduction in NPV results from the higher discount applied to future cash flows, and not from a change in the productive capacity of the project.

It is noteworthy that the discount rates were considered constant throughout the entire planning horizon. This assumption was adopted due to the impossibility of accurately predicting future macroeconomic conditions, such as variations in interest rates and inflation. The use of constant rates is widely employed in economic feasibility analyses, as it allows the standardization of the evaluation of cash flows and ensures comparability among different investment scenarios.

In this context, the definition of the most appropriate rotation depends on the productive objectives of the forest enterprise and on the economic conditions of the system. The producer may opt for shorter rotations aimed at energy biomass production, or for longer cycles that enable the production of timber with larger diameters and higher added value. The choice of the optimal rotation should therefore consider economic criteria associated with productive efficiency, cost structure, and return on invested capital, as discussed in recent studies on economic efficiency in timber production and optimization of the wood value chain (Tham; Darr; Pretzsch, 2021; Wieruszewski *et al.*, 2023).

The results obtained for NPV, EAV, IRR, and the B/C ratio indicate that all analyzed scenarios present economic feasibility, regardless of the discount rate considered. This performance confirms the economic potential of the forest component in integrated systems, a result also observed in recent studies conducted in Brazil, in which forest–livestock integration presented positive NPV and internal rates of return higher than the minimum attractive rate, demonstrating the capacity of these systems to diversify income and increase farm profitability (Reis *et al.*, 2022).

The economic attractiveness of eucalyptus plantations is also associated with the growing demand for energy biomass, industrial wood, and solid wood products. In this context, the high average productivity of eucalyptus in Brazil and the market appreciation of these products contribute to consolidating forestry as a competitive activity capable of generating consistent financial returns for producers (Jambers *et al.*, 2025). In addition, recent analyses indicate that the economic performance of integrated systems can be favored by the adoption of rural credit policies and financial instruments that reduce the cost of invested capital, increasing the feasibility of the enterprise (Cunha *et al.*, 2025).

In the specific case of livestock–forest integration systems, structural factors of the production arrangement may also influence economic results. Tree density, for example, may affect animal performance and system productivity, so that arrangements with lower tree density tend to provide better zootechnical performance and higher total revenue of the production system (Trivelin *et al.*, 2020). In addition to economic benefits, these systems also present relevant environmental gains, such as greater carbon sequestration, reduction of pressure for deforestation, and contribution to productive sustainability in regions of agricultural expansion (Manono *et al.*, 2025).

Despite the observed economic feasibility, forest projects remain subject to different sources of risk, including variations in timber prices, operational costs, and market fluctuations (Schettino *et al.*, 2021). Recent studies indicate that timber price volatility and productivity levels are determining factors for the profitability of commercial eucalyptus plantations (Melo *et al.*, 2025). In this context, risk assessments indicate that livestock–forest integration systems may present low economic risk when adequate planning and technical assistance are adopted in the management of the production system (Ansolin *et al.*, 2022).

In general, the economic analysis carried out indicates that the planting of *Eucalyptus* spp. hybrids in an integrated system (iPF) constitutes an economically viable alternative in the different evaluated scenarios. In addition to ensuring financial return to the producer, this production model allows diversification of farm activities and contributes to expanding the production of wood destined for energy biomass and structural timber. Given the growth of forest plantations in Rondônia, integrated systems of this nature may play an important role in strengthening regional production and in the economic development of the forestry sector in the state.

Conclusion

In the economic evaluation of the planting of *Eucalyptus* spp. hybrids, all scenarios demonstrated economic feasibility, regardless of the annual interest rates applied. The interest rates of 7.44% per year and 8.50% per year enable higher economic returns, resulting in lower discounts being applied compared to the rate of 12.90% per year, with the ten-year rotation, with the assortment destined for structural timber, being the one that provides the greatest profitability for the enterprise.

With the increase in forest plantation areas in the region and in the state, economic feasibility evaluations still represent a gap, since there are favorable areas for eucalyptus planting in the state. Thus, there is a need to conduct studies that corroborate this scenario to encourage producers and guide investments, considering local particularities, harvesting age, and the demand for forest products.

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