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Determinants of Financial Viability of Forest Concession in Brazilian Amazon

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Abstract: This study aimed to assess the financial viability of forest concessions in the state of Pará, Brazil. Two Forest Management Units (FMUs) were analyzed: FMU-2, located in Saracá-Taquera National Forest, and FMU-3, located in Caxiuanã National Forest. Financial indicators were evaluated under different timber productivity scenarios (20 m^3/ha and 25.8 m^3/ha). At a logging intensity of 20 m^3/ha, FMU-2 was not financially viable. However, both FMUs were financially viable at 25.8 m^3/ha. Sensitivity analysis demonstrated that FMU-2 requires a logging intensity of over 22 m^3/ha and a sawmill yield efficiency of at least 45%. The ideal cost for sawn wood would be USD 226.53/m^3, with royalties of USD 16.00/m^3. FMU-3 consistently demonstrated positive financial results, despite fluctuations in production costs. The financial viability of investing in forest concessions in state of Pará depends largely on forest productivity, sawmill yield, royalties, and sawn wood costs.

Keywords: selective logging; tropical forest management; forest concessions; public forests

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1. Introduction

Forest management conducted by private companies has increased significantly in native public forests between 1990 and 2015, as reported by [1]. Over 120 million hectares of native forests have been managed in West and Central Africa, Latin America, and Southeast Asia [2]. The management of these forests is carried out through forest concessions, whose processes may vary among countries, but which generally resemble land concessions and function as instruments for forest management. For example, in Canada, the concession system, considered one of the most successful, involves direct negotiations between interested companies and a public forest board responsible for forest management, rather than a bidding process [3,4].

Latin America has the strictest processes and laws regarding public forest management. Countries such as Costa Rica and Brazil have comprehensive forest laws, unlike Guatemala and Paraguay. In Central Africa, concession forests often face degradation, fail to meet governments' financial expectations, and contribute to possession conflicts and insecurity. However, it has been observed [4–6] that forest concessions in several countries have improved livelihoods for local communities, enhanced conservation efforts, and supported public infrastructure development in remote areas.

In Brazil, the native- and planted-forest sector exerts a substantial impact on the domestic market by supplying products and raw materials to various industries. Despite technological advancements and significant financial investments in planted forests over the past decades, as well as its importance to the national economy, notable criticisms persist due to high rates of deforestation in native forests. These criticisms are often associated with selective logging activities and agricultural practices that contribute to environmental degradation [7–9].

Federal forest concessions in Brazil are managed and licensed by the Brazilian Forest Service (BFS) under specific regulations aimed at ensuring continuous and sustainable production of tropical wood. Under forest concession agreements, land ownership remains with the Federal Government, which grants forest concessionaires the right to manage the forested area [10]. All terms for forest concession agreements in Brazil, including payment for forest products and services, must be discussed in public hearings in surrounding municipalities of areas of interest, which will take benefits from local job creation, financial investments, and infrastructure improvements. Many forest concessions and private forest owners seek Forest Stewardship Council (FSC) certification to demonstrate compliance with rigorous environmental, social, and economic standards [11].

Selective logging in native forests in Brazil is restricted to 25.8 cubic meters per hectare over a cutting cycle of up to 40 years. This forest management approach is considered suitable for natural forest regeneration [12–14]. Once granted, forests must be conserved, and concessionaires are permitted to extract timber and non-timber products, as well as to provide tourism services. An Annual Forest Grant Plan (AFGP) is required for each forest concession, outlining the legal terms of the concession agreement. Currently, there are 21 Forest Management Units (FMUs) across seven National Forests in the Amazonian states of Pará, Rondônia, and Amapá [10].

Legal agreements between logging companies and the Brazilian Forest Service (BFS) must include calculations of the Reference Values of the Contract (RVC) and estimates of annual production based on proposed prices per cubic meter. The Minimum Annual Value (MAV), locally referred to as royalties, ensures a minimum annual payment to forest concessionaires [15]. Sawmills in the Brazilian Amazon typically use timber processing techniques that often yield unsatisfactory results in terms of timber yield, log quality, and cutting efficiency. The level of technology employed is crucial for optimizing raw material utilization. Companies that fail to improve their sawmill yields and make production costs viable risk losing competitiveness and facing operational setbacks [16].

Forest concession agreements must also include an Adding-Value Factor (AVF-FAV) criterion, which promotes and leverages local processing of forest products and higher log and wood prices. AVF calculations compare revenue from processed products with the Minimum Price (MP) for forest products [10,16].

Since the inception of forest concessions in Brazil, the legal procedures established by the Brazilian Forest Service (BFS) have undergone continuous refinement, along with the concession agreements themselves, reflecting a significant learning curve. Nevertheless, some forested areas require special attention and more detailed studies. According to [17], the principal challenges in implementing forest concession agreements in Brazil include difficulties in providing and maintaining financial guarantees, competition from the illegal timber trade, insufficient fiscal incentives, inadequate forest inventory data, and the lack of economic–financial balance instruments in contracts. These issues have directly impacted the terms and conditions of several forest concession agreements between the BFS and concessionaires [18].

Currently, the forest sector based on native forests operates at a low financial performance in Brazil. One strategy to improve the forest business is to expand forest companies' participation in national and international markets. This will require opening new markets, optimizing forestry processes, increasing the number of companies, and leveraging the fronts involved in wood processing [19,20]. By improving its performance and efficiency, the forest sector will benefit other segments of the national economy [21].

Additionally, the national and international market has been restricted to a limited group of tree species, resulting in financial insecurity in the second cut-cycle under current market conditions [16]. A forest production below 25.8 m^3/ha of roundwood (the maximum allowed logging volume by forest concession agreements) is not financially viable for most timber companies in the Brazilian Amazon. This is due to the high frequency of hollow timber and non-commercial tree species that are not selectively logged. In this context, selling roundwood typically serves as a complementary financial input for timber companies, allowing them to log the maximum volume allowed and improve their financial security [18].

The primary objective of forest concessions in the Brazilian Amazon is to stimulate economic activity, which can be successful if concessionaires adhere to responsible forest business practices. However, administrative and financial challenges hinder some forest concessionaires, leading to contract disruptions, primarily due to financial unsustainability [10]. Therefore, in this analysis, we aimed to identify the factors that may affect financial viability of investment in forest concessions in Brazil, prevalent in the Amazon region, particularly regarding financial sustainability under sustainable forest management practices.

2. Materials and Methods

2.1. Study Area

The study area is situated in the Brazilian Amazon, specifically in the state of Pará. It comprises Forest Management Units (FMUs) II within the Saracá-Taquera National Forest, operated by EBATA Ltd. (Pará, Brazil). and FMU-III within Caxiuanã National Forest, operated by CEMAL Ltd. (Pará, Brazil), under concession forest contracts signed between these private timber companies and the BFS (Brazilian Forest Service). FMU-II covers 29,769.82 hectares, while FMU-IIII covers 52,168 hectares. Forest contracts for FMU-II were signed in 2010, initiating selective logging operations in 2012, while those for FMU-III were signed in 2016, initiating selective logging operations in 2018.

2.2. Datasets

The data were provided by the companies and are primary, quantitative data. Such data are controlled by the national government, through the Forest Origin Document (DOF), which is a mandatory license for the transport and storage of forest products of native origin. In addition to this document, there is the payment of royalties to BFS.

The data are primarily quantitative, focusing on costs and revenues, which were used to construct cash flows. For FMU-II, two cash flows were developed based on different exploitation scenarios over a 40-year logging horizon. The first scenario considers the maximum timber volume of 25.8 m^3/ha previously approved by the BFS, while the second scenario assumes an average volume of 20 m^3/ha to be selectively logged by the concessionaire timber company.

For FMU-III, the cash-flow projections were based on the maximum volume allowed in the first year of exploitation, with the sale of timber in logs permitted. These analyses were conducted to aid investment decision-making, as future periods are estimated, focusing on the initial decision-making period for committing resources and efforts to the forest concession.

FMU-II's cash flow includes initial investments such as machinery, heavy vehicles, light vehicles, sawmill equipment, and public notice costs. Every ten years, there is a reinvestment cost of USD 334,746.71 in the sawmill. Royalties of USD 20.51/m^3 were initially paid to BFS and kept constant for projection purposes. The timber price was set at USD 252.17/m^3 of roundwood, reflecting the market value at the start of activities, with a sawmill yield of 40% and transportation costs of USD 6.69/m^3 for transporting logs from forest to the sawmill.

FMU-III's cash flow begins with an initial investment of USD 390,537.82 in infrastructure, followed by revenue from log (roundwood) sales, BFS royalties of USD 31.23/m^3,

selective logging costs of USD 42.40/m^3, and annual infrastructure maintenance costs of USD 39,053.78 over 40 years.

Costs for FMU-II include contract acquisition, exploration activities (timber extraction and transportation), machinery and equipment purchase and maintenance, lumber mill construction and maintenance, and royalties. FMU-III's costs are categorized into machinery and equipment purchase and maintenance, infrastructure, logging, royalties, and log sales.

Revenue is primarily derived from timber sales. FMU-II sells lumber produced at the company's sawmill, while FMU-III initially sells roundwood, with subsequent log trading dependent on company performance indicators.

Due to the remote nature of these areas, timber composition and local timber market variations result in the exploitation of various wood species. Despite the species' diversity, exploitation of the FMUs is still under study.

2.3. Methods

Based on the cash flows, the financial indicators NPV (Net Present Value), ANPV (Annual Net Present Value), MIRR (Modified Internal Rate of Return) and APC (Average Production Cost) [16] were calculated, described as follows:

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

$$ANPV = \frac{VLP \, (1+i)^{t} - 1}{1 - (1+i)^{-nt}} \quad (2)$$

$$MIRR = [(\sum_{j=0}^{n} R_j \, (1+i)^{-j} \div \sum_{j=0}^{n} C_j \, (1+d)^{-k})^{1/n} - 1] \times 100 \quad (3)$$

$$APC = \sum_{j=0}^{n} CT \div \sum_{j=0}^{n} QT \quad (4)$$

where NPV = Net Present Value; $ANPV$ = Annualized Net Present Value; $MIRR$ = Modified Internal Rate of Return; APC = Average Production Cost; R_j = present value of revenues; C_j = present value of costs; CT: annualized total cost; QT: total equivalent production; i = discount rate; j = period in which revenues/costs occur; n = project duration; t = number of capitalization periods; d = financing interest rate; and k = discount period referring to the present value of costs.

Determining the discount rate for analyzing forestry projects can be challenging, since there is no universally appropriate method for such analysis. However, the most-chosen range of rates falls between 4% and 15% per year. Refs. [16,22–24] conducted financial evaluations of forestry projects and utilized MARs (Minimum Attractiveness Rates) of 6.75%, 12%, and 4.4%, respectively. For this study, the discount rate was set at 9%. Regarding MTIR (Modified Internal Rate of Return), the financing rate was 7%, and the reinvestment rate was 9%, representing the most appropriate average rate for reinvesting the profits generated.

2.4. Risk Analysis Assessment

In the sensitivity analysis, the most relevant variables in the companies' cash flow were tested and evaluated. While keeping other data constant, the influence of each adopted variable on the profitability of investments was analyzed using NPV analysis. Consequently, various financial scenarios were constructed for the study areas. Based on changes in these values, it becomes possible to assess potential scenarios and situations in line with the reality of each company, as expressed by the NPV.

For FMU-II, the variables considered were the following:

- Sawmill yield values found in the literature [25–28]: 28.4%, 40%, 41.9%, 43%, 44%, 45%, 48%, 49.3%, and 61.8%.
- Productivity: logged timber (roundwood) volumes by the concessionaire company from 2012 to 2017 (13.7 m^3/ha, 17.5 m^3/ha, 21.4 m^3/ha, 22.5 m^3/ha, 22.6 m^3/ha, and 25.9 m^3/ha).
- Royalties: initial value, with the updates specified by legislation, adopting: USD 16.00/m^3, USD 16.73/m^3, USD 17.85/m^3, USD 21.20/m^3, and USD 23.12/m^3.
- Cost of lumber: USD 226.53/m^3, USD 227.09/m^3, USD 229.88/m^3, USD 232.67/m^3, and USD 243.83/m^3.

For FMU-III, the variables considered were the following:

- Sales value of roundwood: based on the values provided by the company, a variation of approximately 10% and 20% was stipulated for all the species sold.
- Royalties: variation of approximately 10% and 20%.

3. Results

3.1. Financial Analysis

Table 1 shows the flows for each FMU, paying attention to the two FMU-II scenarios, and for FMU-II, the projection of its revenues and costs throughout the contract with the BFS.

Table 1. Data provided by the concessionaire timber companies responsible for the forest management activities in the FMU-II within Saracá-Taquera National Forest and FMU-III within Caxiuanã National Forest, state of Pará, Brazil. Scenario 1: considering the exploitation of the maximum volume allowed by law in the forest concession areas; Scenario 2: Considering the actual volume harvested in the field in a forest concession area.

Area	Year	Costs (USD)	Revenues (USD)	Balance (USD)
FMU-II (25.8 m^3/ha) Scenario 1	2009	14,697,719.65	0	−14,697,719.65
	2010	2,246,112.27	2,582,487.04	336,374.77
	2011–2019	2,225,988.10	2,582,487.04	356,498.94
	2020	2,560,734.80	2,582,487.26	21,752.46
	2021–2029	2,225,988.10	2,582,487.49	356,499.39
	2030	3,646,908.48	2,582,487.71	−1,064,420.77
	2031–2039	2,225,988.10	2,582,487.93	356,499.84
	2040	2,560,734.80	2,582,488.16	21,753.35
	2041–2049	2,225,988.10	2,582,488.38	356,500.28
FMU-II (20 m^3/ha) Scenario 2	2009	1,469,868.72	0	−1,469,868.72
	2010–2019	1,984,320.20	2,001,927.94	17,607.73
	2020	2,249,994.40	2,001,927.94	−248,066.46
	2021–2029	1,964,196.03	2,001,927.94	37,731.91
	2030–2039	3,336,168.07	2,001,927.94	−1,334,240.13
	2040	2,249,994.40	2,001,927.94	−248,066.46
	2041–2049	1,964,196.03	2,001,927.94	37,731.91
FMU-III Projection	2018	390,537.83	0	−390,537.83
	2019–2058	508,511.80	0	−508,511.80

After constructing the cash flows, financial indicators were applied, and the results are presented in Table 2, showing the profitability and performance of the analyzed projects.

The NPV and ANPV methodologies demonstrate a positive value for selectively logging for FMU-II and FMU-III, with the maximum allowed harvesting volume of 25.8 m^3/ha, indicating the viability of financial investments in forestry concessions under these specified conditions. Conversely, the indicators showed negative values for FMU-II with the average allowed harvesting volume of 20 m^3/ha, reinforcing the financial infeasibility of

logging activities under this scenario. Furthermore, this scenario showed an MIRR lower than the TMA, the minimum financial target stipulated in the investment planning.

Table 2. Financial indicators for FMU-II scenarios in the Saracá-Taquera National Forest and FMU-II in the Caxiuanã National Forest, Pará, Brazil.

Indicator	FMU-II (25.8 m^3)	FMU-II (20 m^3)	FMU-III
NPV (USD)	1,961,182.02	−1,437,543.32	4,709,106.78
ANPV (USD)	182,310.71	−133,633.45	437,756.72
MIRR (%)	9.7	3.37	16.23
APC (USD)	234.37	269.00	-

Where: NPV = Net Present Value; ANPV = Annualized Net Present Value; MIRR = Modified Internal Rate of Return; APC = Average Production Cost.

In contrast, FMU-II under a logging volume of 25.8 m^3/ha showed an MIRR higher than the TMA, suggesting that these scenarios exceed the planned minimum logging yield target.

The APC indicates the cost incurred by concessionaire companies to produce one unit of product. In the case of lumber production from FMU-II, the APC for scenarios with a harvesting volume of 20 m^3/ha exceeds the revenue obtained from the timber sale, indicating financial losses for the concessionaire company. Similarly, this indicator reflects values surpassing the sale value of timber for areas deemed financially unviable.

3.2. Risk Analysis

When keeping other variables constant, it was observed that forest management is financially viable when exploring the maximum volume allowed (refer to Table 3). Given the concessionaire company's average harvested volume, productivity would need to increase to at least 43% to achieve positive financial results.

Table 3. Sensitivity analysis with the lumber mill yield variable in FMU-II in the Saracá-Taquera National Forest, Pará, Brazil.

Yield	NPV (25.8 m^3/ha)	NPV (20 m^3/ha)
28.4%	−USD 6,095,233.52	−USD 7,682,826.69
40%	USD 1,961,182.02	−USD 437,543.32
41.9%	USD 3,280,767.31	−USD 315,690.45
43%	USD 4,044,737.76	USD 177,616.18
44%	USD 4,739,256.35	USD 716,002.67
45%	USD 5,433,774.92	USD 1,254,389.17
48%	USD 7,517,330.66	USD 2,869,548.65
49.3%	USD 8,420,204.82	USD 3,569,451.10
61.8%	USD 17,101,687.10	USD 10,299,282.30

Based on the productivity history of FMU-II, it has been observed that only since 2014, when the logging harvest of FMU-II exceeded 22 m^3/ha, has the financial investment become viable (Table 4). This threshold value can then be linked to the minimum harvest volume required to ensure the financial viability of management, while maintaining a lumber mill yield of 40%. Negative NPVs, indicating the infeasibility of the investment, were recorded when the logging harvest was below 21.4 m^3/ha.

FMU-II can achieve financial profitability from its forest activity due to constant royalties of USD 16.00 (see Table 5). However, the results in Table 5 demonstrate that annual adjustments of royalties based on the IPCA (Extended National Consumer Price Index, used as a measure of inflation in Brazil) will render the forestry concession financially unviable. Importantly, increases of 10% and 20% in the royalties paid by the concessionaire

company responsible for FMU-III will result in positive NPVs, highlighting them as the most financially restrictive scenarios.

Table 4. Sensitivity analysis based on the productivity variable of the FMU-II in the Saracá-Taquera National Forest, Pará, Brazil.

Year	Volume Explored	NPV
2012	13.7 m^3/ha	−USD 4,094,110.47
2013	17.5 m^3/ha	−USD 2,192,448.37
2014	21.4 m^3/ha	−USD 240,742.52
2015	22.5 m^3/ha	USD 309,738.61
2016	22.6 m^3/ha	USD 359,782.35
2017	25.9 m^3/ha	USD 2,011,225.71

Table 5. Sensitivity analysis considering different values of royalties paid by companies to the BFS.

FMU-II		FMU-III	
Royalties	**NPV**	**Royalties**	**NPV**
USD 16.00	USD 159.34	USD 24.99	USD 7,673,906.32
USD 16.73	−USD 118,248.90	USD 28.12	USD 6,376,806.52
USD 17.85	−USD 321,068.55	USD 31.24	USD 5,079,706.72
USD 21.20	−USD 838,055.87	USD 34.36	USD 3,782,606.92
USD 23.12	−USD 1,147,709.61	USD 37.49	USD 2,485,507.12

We also observed that the maximum production cost for lumber is USD 226.53/m^3 (Table 6), considering the actual conditions of logging harvest and timber processing yield. Therefore, favorable financial returns are feasible under these conditions, ensuring the continuity of logging operations within the forest concession and compliance with BFS regulations.

Table 6. Sensitivity analysis for lumber costs in FMU-II in the Saracá-Taquera National Forest, Pará, Brazil.

Cost of Lumber Product	NPV
USD 226.53	USD 39,446.19
USD 227.09	−USD 8198.63
USD 229.88	−USD 246,422.74
USD 232.67	−USD 484,646.85
USD 243.83	−USD 1,437,543.32

Even with revenues varying by less or more than the actual value practiced, it was evident that the FMU-III concessions remained financially viable (Table 7), with all projected scenarios showing a positive NPV. Scenarios indicating a reduction in the value and sale of logs highlight the investment's viability, particularly when compared to the lumber sales.

Table 7. Sensitivity analysis for the sale price of logs (roundwood) from FMU-III in the Caxiuanã National Forest, Pará, Brazil.

Log Price	NPV
−20%	USD 936,835.15
−10%	USD 2,822,970.97
Real	USD 4,709,106.78
+10%	USD 6,595,242.60
+20%	USD 8,481,378.42

4. Discussion

The financial viability of the investments analyzed hinges on harvesting volumes close to the maximum allowed volume (25.8 m^3/hectare), amortizing the investment over time. Forest concession activities in the state of Pará are economically viable; however, financial viability will not be achieved with logging volumes significantly below expectations [29].

The 29% variation between the volumes allowed in the contract and the actual logged volumes in FMU-II had a negative impact on the logging activity. Criteria such as the presence of hollow trees, protected trees near trees to be felled, and shelter for fauna must be observed during tree cutting, in addition to the company's planning criterion [30].

Hollow trees pose the primary challenge during forest exploration in FMU-II. While replacing hollow trees with healthy ones is permitted, [30] found that the occurrence of hollows does not significantly influence volumetric performance, but rather the replacement of hollow trees by healthy ones. Both the loss of hollow trees and volume frustration have a significant impact on performance and jeopardize the long-term viability of forest management.

Comparing the results for FMU-II and FMU-III reveals discrepancies linked to the ways in which timber is marketed. The low performance and high cost of maintaining lumber mills lead to inefficiency and default, as observed in FMU-II. The sale of logs presents an opportunity to maintain the financial balance of forest concessionaires, strengthen the local market, and establish a positive ongoing relationship between supplier and buyer. Products from concessions are tracked and have a chain of custody guarantee, ensuring compliance with Brazilian legislation and enabling positive financial returns throughout the planning horizon [16].

There is a demand for logs for sawmills in the state of Pará, yet sawmill owners often struggle to keep their activities uninterrupted [31]. When working with wood from suppliers, owners frequently encounter raw material shortages, mostly due to frequent forest inspections. Brazil holds a leading position in the international market for lumber products and it likely to maintain this status, given its vast tropical forested area [32]. It has the capacity to increase legal production, reduce deforestation, and generate income for Amazonian communities, as well as regional and national consumer centers. However, to realize these goals, a more efficient inspection process is needed.

One way to achieve the projected outcomes [28,29] is through collaborative action between law-abiding concessionaires and consumers who can act confidently. This collaborative effort can lead to positive financial returns for both segments. Common problems faced by several countries with forest concessions, such as Cambodia, Indonesia, and Malaysia, include design and implementation flaws, as well as issues with area information, monitoring, and data accuracy [33].

These challenges are closely related to revenue generation. Recommendations were made to the BFS and the Ministry of Environment and Climate Change following an audit process by the Federal Accounting Court in 2012, aimed at assessing bottlenecks and opportunities for the consolidation of concessions [17]. It was determined that the BFS should address factors such as decreased attractiveness due to high initial investment, high minimum prices, delays in document acquisition and contract signing, difficulties in providing guarantees, deficiencies in pre-harvest forest inventories, and unfair competition from illegal logging activities.

- *Lumber Mill Yield*

The timber sector in the Amazon faces significant challenges in maintaining product competitiveness in the market, primarily due to the large number of lumber mills in the region [15]. This is composed of issues such as consumer/buyer species selectivity, outdated technology, unskilled labor, and a high number of undercapitalized companies.

The extent to which logs are processed depends on factors beyond management issues, such as rot, hollows, cracks, pest attacks, and crookedness [19]. Ref. [34] emphasize the need

for innovation in timber exploration in the Amazon region, despite exceptions where companies adopt effective forest management practices to meet increasing market demands.

Studies on the processing yield of native Amazonian species have shown an average yield of 48% in timber processing [35]. This level of productivity results in positive financial returns for FMU-II, even with lumber mills performing below the average value reported in the literature.

When evaluating the log yield of 20 Amazonian species, ref. [28] estimated yields ranging from 41.9% to 61.8% per species. Using the lowest yield described by [28] for FMU-II, the NPVs for the scenarios in Table 5 outperformed projections, assuming a real log yield of 40%. However, this did not result in positive returns for the scenario with a productivity of 20 m^3/ha. Using the highest log yield (61.8%), the NPVs obtained were positive and, therefore, more attractive to investors.

Ref. [27] assessed the splitting yield of 15 Amazonian species, obtaining an average log yield of 49.3%, with productivity ranging from 28.04% to 72.20%. Applying these values to the sensitivity analysis of FMU-II, positive NPVs were obtained for both scenarios.

- *Productivity*

Uncertainties persist regarding the symmetry of information and the sequencing of activities in the forest sector. The diversity among concession agreements and the responsibilities of stakeholders is also significant. In the case of public forest concessions, there is criticism of their management methods, as concessionaires often struggle to achieve the expected benefits and services [36,37].

Brazilian legislation permits a maximum harvest of 25.8 m^3/ha, but companies find it challenging to reach values close to it. Ref. [38] point out that the availability of timber for harvest is influenced by various factors, including the exploration history, the presence of suitable species of commercial interest, environmental and biological factors, and the methodology used in forest surveys.

There is a dearth of studies on forest concessions and their economic aspects in Brazil, hindering a comprehensive understanding of product extraction [39]. Nevertheless, evidence suggests that the unsustainable exploitation of forest resources in the Amazon region is primarily attributable to the high incidence of illegal activities [34,39].

- *Royalties*

The payment of royalties constitutes a specific cost for forest management in forest concessions. In real-world scenarios, only low royalty values lead to positive financial outcomes for FMU-II. Conversely, when working with cash flow projections under ideal conditions, FMU-III demonstrates a positive NPV, even with high royalty values. The tenth clause of the economic and financial rebalancing of the contract with BFS allows for a review of these values, and, according to the LGFP, an assessment of the technical, social, environmental, and economic aspects of the company is conducted five years after the execution of the first PAOF [40].

Log values have been estimated to range between USD 5.24/m^3 and USD 12.41/m^3 in the Lower Amazon [29], and between USD 4.12/m^3 and USD 20.58/m^3 for standing timber on Ilha do Marajó [41], with values depending on the species and the local market. Comparing these values from the literature with the royalties stipulated by Ebata and Cemal, it becomes evident that the bid values exceed market values, contributing to the infeasibility of investments.

To determine the price of standing timber in public forests, which corresponds to the royalties paid to the BFS, economic theory calculations are not utilized. These calculations fail to account for the functioning of the product market and rely on different assumptions than those present in real-world scenarios [29]. The author suggests that price disparities are a consequence of the timber industry operating in oligopolistic competition, resulting in an overestimation of the value of forests.

Forest concessions undervalue the socio-economic and environmental importance of forests, neglect to calculate the value of by-products and environmental services, and

limit effectiveness by hindering the participation of small companies, associations, and traditional communities [28]. Moreover, the prices stipulated for forest concession areas in Brazil incentivize and expedite illegal logging, precisely because they present high and unrealistic prices for standing timber [42].

- *Cost of lumber*

We observed that the cost of lumber yield has a significant impact on the financial viability of forest management in FMU-II. According to the terms of the company's contract with BFS, the company lacks the option to market logs, which could serve as an alternative for the concessionaire.

Forest concession contracts are complex legal documents that involve conflicting interests between the concession holder and the concessionaire. They are based on a set of relationships described as being of great financial and economic importance [43]. This author notes that sales prices are lower than those estimated by the concessionaire, costs are high, and there are inaccuracies in estimates and lower productivity than expected by the companies.

Financial risks also depend on the cost of capital of the concessionaire, rising interest rates, and international crises affecting the national economy and the economies of countries that purchase timber products [16]. This author concluded that the loss of financial capacity to fulfill the contract by the forest concessionaire primarily stems from the amounts owed to the BFS, which fails to account for the adversities and costs of the activity.

- *Selling price of logs (roundwood)*

The sensitivity analysis for the marketing value of logs supports the assertion that the investment was planned under ideal conditions. Even the most restrictive scenarios did not render the investment unfeasible.

The sustainability of a forestry investment depends on the alignment between intended goals and actual achievements [35,44]. Based on this assumption, financial sustainability of forest management could not be achieved. However, despite a lower-than-expected logging harvest, FMU-III remains financially viable, mostly due to the negotiation approach and the initial permission granted to the forestry concessionaire to sell roundwood.

Throughout the forest concession process, the concessionaire submits a technical proposal that must be economically viable, considering its positive impacts on the granting body, management, society, local communities, and the environment [16]. By examining the results from FMU-II of the Saracá-Taquera National Forest and FMU-III of the Caxiuanã National Forest, we observed that federal concessions need some improvements to enable concessionaires to comply with agreed conditions, making them more attractive investments.

- *Study limitations*

The analysis presented was carried out using primary data, which, in turn, was made available by forestry companies. The reliability of the data is the responsibility of whoever collected and organized the values. There was no investigation in the field.

As a suggestion for future research, studies on the stock of commercial wood in sustainable management areas, studies on forest inventory, and the standardization of data treatment and processing are recommended.

It is also recommended that the robustness and scope of similar studies should be enhanced by consulting with the company or individuals who collected field data regarding the methodologies applied. Establishing direct contact to clarify any doubts is crucial. Additionally, it is important to consider whether the data collectors have a digital system.

5. Conclusions

The volume of wood harvested, the yield and costs associated with wood processing in sawmills and the price of standing wood are the determining factors for the financial viability of investing in forestry concessions in Brazil.

Commercializing round wood outside the concession site is a more economically attractive and viable option.

The obsolescence of sawmills in Brazil is a significant issue, leading to very low yields. To maintain the commercialization of higher value-added products, we suggest government investments in modernizing the entire production chain of native timber sawmilling.

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