Short Research Article

ANALYSIS OF REBUILD DRIVING METHODS IN EUCALYPTUS PLANTS UNDER FOREST REGENERATION

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ABSTRACT

Both manual and semi-mechanized systems are used for operations involved in coppice remodeling. Thus, there is a paradigm about the higher yield of semi-mechanized operations compared to manual operations. However, the small volume of research on this subject does not present data which is capable of confirming this hypothesis. Thus, the present study aimed to perform a technical analysis of costs, quality and productivity of different methods for conducting regrowth in *Eucalyptus grandis* x *Eucalyptus urophylla* hybrid plantations under coppice regeneration in areas of forest fostering. The experiment was conducted under a completely randomized design with four treatments (sprouting methods) and four replications in plots of 360m² each. The methods used were: brushcutter, sickle, machete and hand digger. An analysis of variance at the 5% significance level was performed to analyze whether the average time spent performing the different methods significantly differed. An estimate of the costs per hectare was subsequently obtained in each offspring method and the quality of the operation was evaluated by observing the frequency of damage to the remaining trunk. The mean operation time of the methods did not differ significantly ($p > 0.05$). The brushcutter presented the highest cost per hectare and the excavator presented the lowest. Spreading with the brushcutter presented the lowest percentage of mechanical damage (6.88%) and the sickle obtained the highest (20.63%). Since mechanical damage caused during de-sprouting operations may lead to a loss of quality of the final product, it is recommended to use the semi-mechanized method to maintain planting quality.

Keywords: Coppice; forestry techniques and operations; operating profit; regrowth driving.

1. INTRODUCTION

The participation of the forest based sector in Brazilian agribusiness has been increasing and has become more important over the last decades. This has attracted numerous investments from national and international business groups. These groups have induced the production and/or production of modern technologies whose incorporation into the usual production systems has led to a significant growth in the productivity of the main commercially planted forest species [1-3].

Eucalyptus species are the most commonly used in commercial plantations in Brazil and most of their species have lignotubers, a structure which gives them the ability to sprout when cut [4-5]. This capacity enables implementing the sprout conduction regime, known as coppice management [6-7]. According to Gadelha et al. (2015) [8] and Gonçalves et al. (2017) [9], conducting sprouts does not require seedling purchase and soil preparation costs, in addition to reducing the need and consequently the costs of fertilization. Given this, coppice management has lower cost and lower environmental impacts than settlement reform.

Both hand tools and (semi-mechanized) machines can be used for sprouting operations. There is a paradigm that operations performed semi-mechanically present higher yield. However, few studies aim to prove this question and therefore do not present data which confirm the higher yield of operations performed in a semi-mechanized manner.

In this context, it is noted that the paradigm that regrowth conduction operations using semi-mechanized methods present higher yield is only based on empirical knowledge, without experimental proof. Therefore, the need for scientific studies which prove or disprove such statement is evident, and would providie reliable information to the forest sector.

Given the above, the present work aimed to perform a technical, cost, quality and productivity analysis of different regrowth conduction methods in *Eucalyptus grandis* W. Hill ex. Maiden x *Eucalyptus urophylla* S.T. Blake under regrowth.

2. MATERIAL AND METHODS

2.1 Study area characterization

The study was conducted in a rural property located in the municipality of São José do Calçado, Espírito Santo, Brazil. The area is located between meridians from 41º38'0” to 41º37'55'' west longitude of Greenwich and the parallels from 20º56'10'' to 20º56'05'' south latitude (Figure 1).

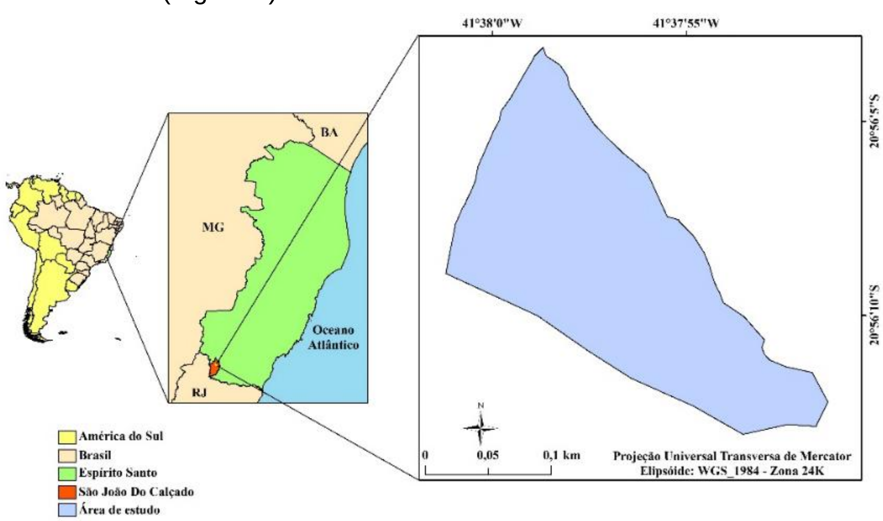

Figure 1. Location map of the study area in the municipality of São José do Calçado, Espírito Santo, Brazil.

The property has plantations from a forest promotion contract with the purpose of producing and selling wood for pulp. The species cultivated in the property comes from the *Eucalyptus grandis* x *Eucalyptus urophylla* hybrid planted at initial spacing of 3mx3m. The first rotation was harvested at the age of seven, and later regenerated by coppice management. The total planting area is 17.62 ha, with 10.03 ha referring to the area where the plots were installed for this study.

2.2 Experiment characterization and operational time determination

The offshoot operation began six months after the harvest of the first rotation, being performed on plants with an average height of 1.3 meters. The operation consisted of cutting the shoots, leaving only one shoot per strain, which was selected due to its higher height and less tortuosity.

The experiment was set up under a completely randomized design to perform the technical analysis of the cutting methods in the evaluated property considering four cutting methods (1: brushcutter; 2: scythe; 3: machete; and 4: digger) in four plots each (repetition), totaling 16 plots. Each plot covered an area of 360 m², in which 40 strains were measured.

An evaluation of the average time spent performing each method during the shoot removal operation was performed using a stopwatch, where the time spent in each method per plot was initially counted for subsequent determination of the average operation time of each method. A percentage of 20% pauses per day was considered for all methods.

2.3 Operational costs

the values for the acquisition and resale of equipment and tools corresponding to each method and the value of the working day (eight hours) of an operator plus social costs were calculated in order to estimate the average operations cost for each offspring method employed in the region for 2017. Two-stroke fuel and oil consumption were also considered in the case of the brushcutter.

The brushcutter used in the experiment had a 24.4 cm³ two-stroke single cylinder engine with 255 mm disc blade. The purchase price in the local market is approximately US $343.94. The blade used can be purchased for $24.36. The rate of a brushcutter operator in the local market, considering the charges, is $42.99.

The hand tools used in the experiment were a sickle, a digger and a machete. On average, a corded sickle can be purchased for $10.03; a 14-inch machete can be purchased for $6.88, and a wood handle digger can be purchased for $10.89. The daily rate of a rural worker in the local market, considering the charges, is US$ 22.93. The cost of depreciation of equipment per effective hours of use was also determined according to Equation 1:

$$Dp=\frac{(Va-Vr)}{(Hf \times N)} \qquad (1)$$

In which:
Dp = depreciation per effective hour of use (US$ h^{-1}).
Va = acquisition value (US $).
Vr = resale value (US $).
Hf = actual hours of annual use (hours).
N = useful life (years).

An extrapolation for one hectare was calculated from this information and the data obtained by evaluating the average operating time of each method, and thus the costs per hectare were obtained. A useful life of five years and 480 effective hours of annual use was considered for all methods, as the equipment can also be used in other property activities. A price of US $143.31 was considered for the semi-mechanized method for resale value and US $0.00 for the hand tools.

2.4 Productivity and quality of operation

We considered the data of time spent per hectare and the planting spacing to determine the productivity of each of the evaluated methods, according to Equation 2.

$$P=\frac{\left(\frac{10.000}{E}\right)}{T} \qquad (2)$$

In which:
P = productivity per effective hour of use (ha h^{-1}).
E = spacing (m²), 10,000 is the area constant of one hectare (m²).
T = time taken for each operation (h ha^{-1}).

A qualitative analysis based on a visual appreciation was applied to evaluate the quality of the operation in the considered methods. Thus, four quality classes were established based on this analysis, being determined according to the mechanical damage caused by the methods, according to Table 1.

Table 1. Cutting operation quality classes as a function of the mechanical damage caused.

Class	Description of mechanical damage	Damage classification feature
1	No damage	The remaining sprout was not damaged in the sprouting operation
2	Light mechanical damage	Part of the bark is removed in the cutting operation
3	Deep mechanical damage	Part of the wood is reached in the offshoot operation
4	Chopped off	All shoots are removed in the sprouting operation

The damage percentage per class was calculated in each evaluated method after an analysis and survey of the frequency of damage caused.

2.5 Statistical Procedures

Statistical analysis was performed using the SISVAR 5.6 program. An F-test ($p < 0.05$) was performed to verify the differentiation between treatments for a given characteristic after verifying the normal distribution of data and homogeneity of variances.

The means were compared by analysis of variance at the 5% significance level to analyze if there was significant difference between the operating times in the analyzed methods.

3. RESULTS AND DISCUSSION

Figure 2 shows the results obtained for the average time per plot, quality and productivity of the offshoot operations in *Eucalyptus grandis* x *Eucalyptus urophylla* clonal planting using the brushcutter, sickle, machete and digger methods.

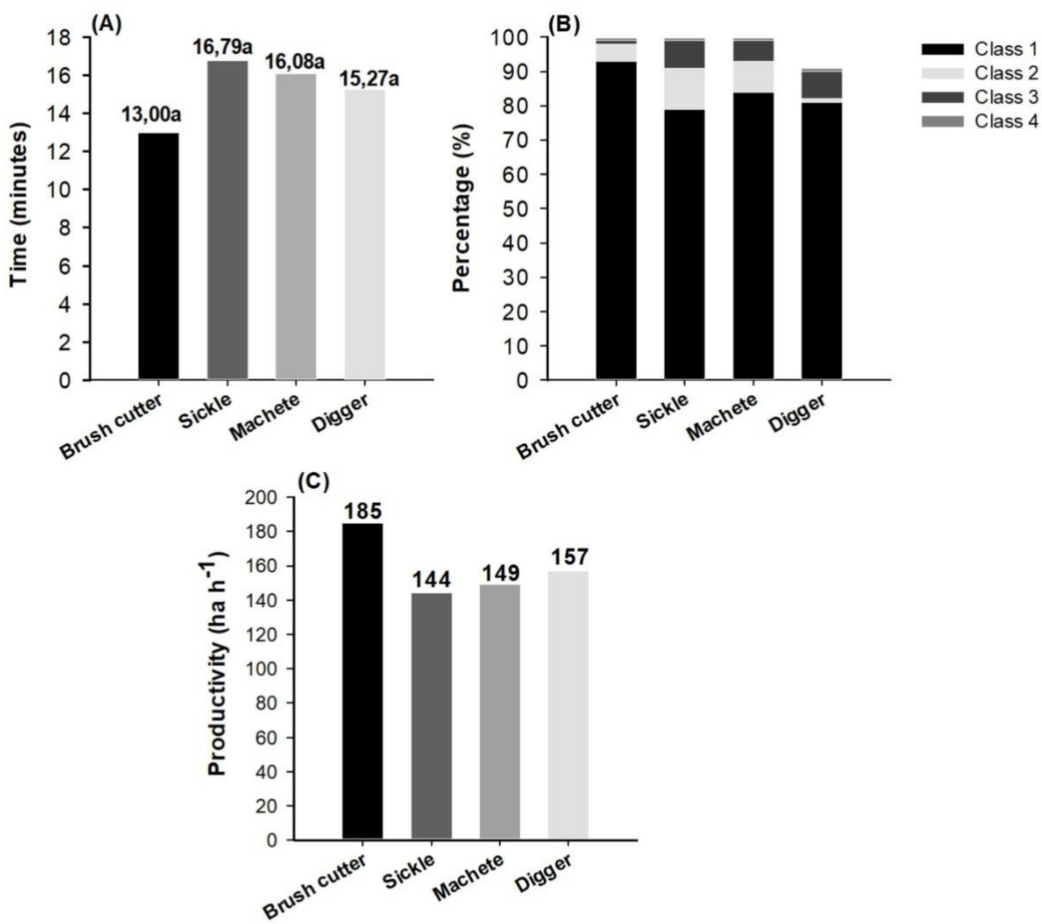

Figure 2. Average operating time per plot (A), damage percentage in each class (B) and productivity per hectare (C) for each of the evaluated methods.

* Means followed by the same letter (1A) do not differ from each other ($p > 0.05$) by the F-test.

There was no significant difference ($p > 0.05$) according to the results for the average time of the cutting operation between the analyzed methods. Regarding the quality of the offshoot operations, it was found that the brushcutter provided a lower percentage of damage compared to the other analyzed methods. The brushcutter also provided better performance for productivity, followed by the digger, machete and sickle. However, the brushcutter was the most expensive method in relation to costs, according to the results listed in Table 2.

Table 2. Costs of the coppice operations of the *Eucalyptus grandis x Eucalyptus urophylla* hybrid for the different analyzed methods.

Method	Cost Description	Cost amount
Brushcutter	Depreciation ($\text{US\$ h}^{-1}$)	0.09
	Fuel ($\text{US\$ h}^{-1}$)	1.05
	2 stroke oil ($\text{US\$ h}^{-1}$)	0.53
	Maintenance ($\text{US\$ h}^{-1}$)	0.05
	Operator ($\text{US\$ h}^{-1}$)	4.94
	Total cost ($\text{US\$ h}^{-1}$)	**6.65**
	Time spent (h.ha^{-1})	6.02
	Total cost ($\text{US\$ ha}^{-1}$)	**40.06**
Sickle	Operator ($\text{US\$ h}^{-1}$)	2.63
	Depreciation ($\text{US\$ h}^{-1}$)	0.01
	Total cost ($\text{US\$ h}^{-1}$)	**2.64**
	Time spent (h.ha^{-1})	7.73
	Total cost ($\text{US\$ ha}^{-1}$)	**20.38**
Machete	Operator ($\text{US\$ h}^{-1}$)	2.63
	Depreciation o ($\text{US\$ h}^{-1}$)	0.01
	Total cost ($\text{US\$ h}^{-1}$)	**2.64**
	Time spent (h.ha^{-1})	7.44
	Total cost ($\text{US\$ ha}^{-1}$)	**19.61**
Digger	Operator ($\text{US\$ h}^{-1}$)	2.63
	Depreciation ($\text{US\$ h}^{-1}$)	0.02
	Total cost ($\text{US\$ h}^{-1}$)	**2.64**
	Time spent (h.ha^{-1})	7.07
	Total cost ($\text{US\$ ha}^{-1}$)	**18.65**

There is a limitation for discussions with similar or adverse results given the deficiency of scientific studies carried out in the context of forestry activities in forest species under coppicing. Thus, discussions of the present work will mostly be made with the data and results of the work itself.

The results found in the present study showed a superiority of the semi-mechanized system over the manual system in the evaluated operations. Leite et al. (2014) [10] explain that semi-mechanized systems tend to have higher individual productivity in relation to manual systems. This is because this type of system is not only dependent on human conditions, meaning they promote greater productivity by the fact that the service is done more homogeneously and constantly.

Regarding the activity duration (Figure 2), although the statistical difference was not significant for this amount of evaluations, the brushcutter performed better than the other equipment, presenting 5.8% less than the scythe, which in turn was the most costly for time. Although the weight of the scythe is lower than that of the brushcutter, the blade used by the machine does not require physical force in the cutting operation, delaying muscle fatigue and allowing more efficient work by the operator. In addition, the maneuvers required to achieve the thrust needed to make the impact of hand equipment sufficient to complete the activity do not exist in the semi-mechanized system, directly influencing the operating time of each.

When the average time values per hectare are extrapolated for the entire area of the property, the time difference found for each operation is important. In this case, 14, 17, 17, and 16 days would be necessary for the brushcutter, sickle, machete, and digger operations, respectively, to complete all designated activities.

Regarding costs (Table 2), the need for qualified labor, fuel, lubricating oil and mechanical maintenance ended up negatively influencing the total cost per hour worked by the brushcutter. The semi-mechanized system presented 27.59% higher costs for this variable than the operations performed with sickle and machete, and 27.57% more than the digger.

According to Cunha et al. (2015) [11], manual systems tend to have lower relative productivity when compared with mechanized or semi-mechanized systems. This is because this variable can be influenced by the workability of the operation team. This fact is corroborated by the productivity values presented in the present study, where the semi-mechanized system obtained 6.43%, 5.55% and 4.32% higher productivity than for the sickle, machete and digger, respectively.

Although the productivity of the brushcutter is higher than the others (Figure 1), the higher costs (Table 2) of this system reduce the viability of its use. Manual systems do not require high investment, fuel or lubricating oil costs, and skilled labor. These factors show that it would take a very long time for the brushcutter to reach the same economic value as the other systems.

Regardless of any factor, the operation quality should ensure as little damage as possible to the remaining shoots, since damage favors contact with pests and diseases. There was no significant difference between the average time per plot for each operation in the present study due to the need to avoid damage to the remaining stems and shoots, which caused a longer delay in execution.

The brushcutter operation stood out in quality, presenting 93% of damage class 1 (without damage), while the sickle, machete and digger presented 79%, 84% and 81% respectively of this class. Class 3, in which the wood is injured, was also a highlight of the research, because the brushcutter again presented better results than the others (1%). In this case the digger (8%) and the sickle (8%) were the tools which caused the most damage to Eucalyptus wood.

4. CONCLUSION

The quality of operations directly influences execution times. The brushcutter operation was the most productive, but its high cost favored the digger as being the most suitable for this type of activity. The digger provided satisfactory results for all variables, especially total cost (US $18.65) and productivity (1.57 ha h^{-1}).

COMPETING INTERESTS

The authors declare that there are no competing interests.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration with all authors. All authors performed the corrections and revised the drafts of the manuscript, and approved the final manuscript.

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