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ECONOMIC PERFORMANCE OF MOTOR GRADERS IN SUGARCANE (*Saccharum* spp.) PROCESSING PLANTS

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ABSTRACT: Brazil is the world's largest producer of sugarcane for mills. They use tractors with various agricultural of equipment in the mechanized operations of periodic soil preparation, planting, cropping and harvesting. Therefore, several studies have proven the economic importance of the cost generated by these machines. However, few studies highlight the performance of a motor grader, which has both functional and economic importance, due to its wide use in the agricultural activities in the mill. The objective of this study was evaluated of the systemic mode, the influence of economic performance variables in the cost and in time useful lifespan of a motor grader in an agricultural operation. In this study, machines with nominal power of 116 kW (158 cv) and 159 kw (216 cv) were utilized. For this study, a computational model called "*TerraPlanCana*" was developed in electronic spreadsheet and programming language. The results showed that the increase in the useful life in years reduces the fixed annual cost of the machines and when the hours of useful life increase, the hourly cost decreases. The increase of the useful life in year or hour raises the total cost, reducing the gains of the mill.

KEYWORDS: Cost, Agricultural mechanization, Computer model, Income, Fleet renewal.

DESEMPENHO ECONÔMICO DE MOTONIVELADORAS EM USINA DE CANA-DE-AÇÚCAR (*Saccharum* spp.)

Resumo: O Brasil é o maior produtor mundial de cana-de-açúcar para as usinas. Estas utilizam tratores com diversos equipamentos agrícolas, nas operações mecanizadas de preparo periódico do solo, plantio, tratos culturais e colheita. Devido a isso, diversos estudos tem comprovado a importância econômica do custo gerado por estas máquinas. Entretanto, existe a motoniveladora, que tem importância funcional e econômica, devido sua ampla utilização nas atividades agrícolas das usinas e poucos estudos destacam seu desempenho. O objetivo do trabalho foi avaliar de modo sistêmico, a influência das variáveis de desempenho econômico no custo e no tempo de vida útil da motoniveladora em operação agrícola. No trabalho foram consideradas máquinas com potência nominal de 116 Kw (158 cv) e de 159 Kw (216 cv). Para o trabalho foi desenvolvido um modelo computacional, denominado *"TerraPlanCana"*, em planilha eletrônica e em linguagem de programação. Os resultados evidenciaram que o aumento da vida útil em anos reduz o custo fixo anual das máquinas e quando crescem as horas de vida útil o custo horário diminui. O crescimento da vida útil em ano ou em hora eleva o custo total, diminuindo os ganhos da usina.

PALAVRAS-CHAVE: Custo, Mecanização Agrícola, Modelo computacional, Renda, Renovação de frota.

1 INTRODUCTION

In Brazil, the estimated sugarcane cultivated area for 2017/2018 harvest is 8.76 million hectares and a total predicted production in this harvest is 646.34 million tons (CONAB, 2017). According to Garcia, Lima and Vieira (2015), the Brazilian sugar-energy industry has been strongly attracting foreign investments because of ethanol consolidation as a renewable biofuel.

Among the several mechanized agricultural operations for sugarcane cultivation and production in sugarcane/ethanol mills, the ones using motor graders have functional and economic importance. According to Sato & Ripoli (1982) these machines are utilized to make vegetable ditches, build terraces and systemize soil. Gadanha Júnior et al. (1991) stated that it is a very versatile equipment which used in the surface conformation and soil movement, including road opening and maintenance production access and delivering. According to Ribeiro (2005) they are also utilized in repairs and soil surface finishing.

Due to the variety of utilization, motor graders provide costs that influence the mill income; however, they have to be observed as it was done in the computational model developed by Santos et al. (2014a); Santos, Silva and Gadanha Junior (2014b); Santos et al. (2015a); Santos, Fernandes and Gadanha Júnior (2015b), who proved the economic importance of the cost generated for sugarcane mills due to the utilization of agricultural machinery. Nevertheless, costs are provided by a considered number

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of variables of economic performance which are related among themselves and constitute a system. Thus, this study aims evaluate of the systemic mode, the influence of economic performance variables in the cost and in time useful lifespan of a motor grader in an agricultural operation.

2 MATERIAL AND METHODS

In this study, a sugarcane Reference Mill (RM), with an area of 22,000 ha and average sugarcane productivity of 80.00 t ha^{-1} and delivered sugarcane ton price of 17.15 US\$ t^{-1} in the field according to (UDOP, 2015), was considered. The mill has motor graders with nominal potency of e 116 Kw (158 cv), referred as “A”, and 159 Kw (216 cv), referred as “B”. The estimated usable lifespan for the motor graders was 15,000 h, utilized for maintenance of transportation roads, road building, preparation and grading of areas (land plots), as proposed by (SATO & RIPOLI, 1982).

In order to meet the goal of this study and due to the difficulty to carry this study out in field conditions, a computational model called “*TerraPlanCana*” was developed in *Excel*® spreadsheet and in *Visual Basic*® computer language. The *“TerraPlanCana”* is based on the flowchart presented in Figure 1, built according to the characters proposed by (OAKLAND, 2007).

The model starts (1)[*] with the input of data referring to the crop (2): total area, average productivity of the sugarcane cultivation and price of sugarcane ton. Next, data referring to the economic part of the machinery (3) is input: initial and final value, useful lifespan in hours and years, annual interest, factors of lodging, insurance and taxes, repair and maintenance and fuel price. Regarding these data, through the technical characteristic of the machine (4): nominal potency of the motor is obtained to calculate the economic performance of the equipment, item (5): fixed cost per year, hourly and total, mill gross and net income.

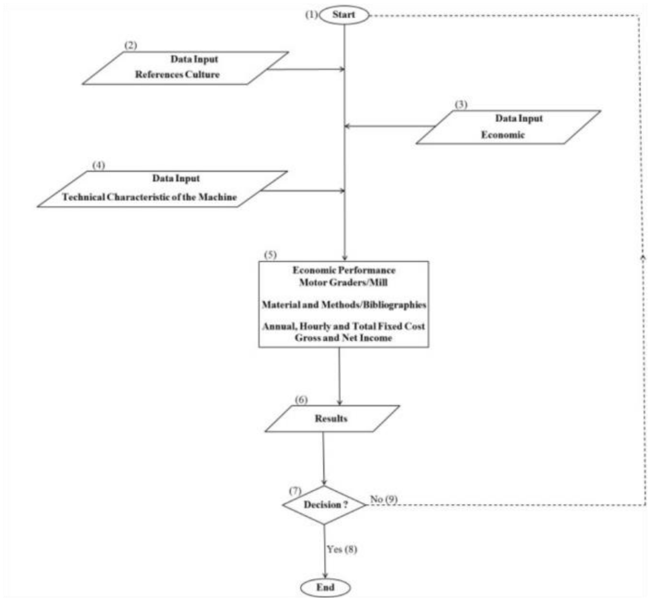

Figure 1 - *General flowchart of the computational model.*

The results of the model (6) allows the user to analyze the economic performance of machinery and decide (7) on their viability (8) or not. In case the equipment does not meet the user’s needs (9), or in case the evaluation of another scenario is desired, new data should be input for the next selection.

2.1 Economic performance

The input of data of the economic performance variable model are shown in Table 1.

[*] The numbers in parenthesis refer to the flowchart in Figure 1.

***Table 1** - Input data of economic performance variables of the model.*

Variables	Acronym	Unit	Motor grader "A"	Motor grader "B"	Source
			Values		
Initial value	Iv	US$	186,363	237,878	Dealers[1]
Final value	Fv	Decimal	0.50	0.50	Pereira et al. (2015)
Usable Lifespan in Years	ULY	Year	10	10	Pereira et al. (2015)
Annual Interest	i	Decimal	0.1350	0.1350	Dealers[1]
Lodging, Insurance and Taxes	LIT	Decimal	0.10	0.10	Insurance Companies[2]
Repair and Maintenance Factor	RMF	Decimal	0.31	0.28	Dealers[1]
Fuel Price	FP	US$ L^{-1}	0.96		ANP (2016)

[1]Data obtained from authorized dealers that sell motor graders in the country.
[2]Data obtained from insurance companies of engineering machines and agricultural of the country.

The fixed cost hourly (FCH) of the machine, calculated by the methodology proposed by ASABE (2011), is determined by the ratio between the fixed yearly cost (FYC), usable lifespan in hours (ULH) and usable lifespan in years (UFY), equation (1).

$$FCH = \left\{ \frac{Iv * \left[(1 - Fv) + \left(\frac{1 + Fv}{2} \right) * i + LIT \right]}{\left(\frac{ULH}{ULY} \right)} \right\} \qquad (1)$$

In which:

FCH - fixed cost hourly of the machine, US$ h^{-1};
Iv - initial value of the machine, US$;
Fv - final value of the machine, in decimal;
i - annual interest, in decimal;
LIT - lodging, insurance and taxes, in decimal;
ULH - useful lifespan in hours;
ULY - useful lifespan in years.

As proposed by ASABE (2011), the variable cost (VC) of the machine is defined as the sum of fuel cost (FC) and repair and maintenance cost (RMC), equation (2).

$$VC = FC + RMC \qquad (2)$$

In which:
VC - variable cost of the machine, US$ h^{-1};
FC - fuel cost, US$ h^{-1};
RMC - repair and maintenance cost, US$ h^{-1}.

The fuel cost (FC) is calculated by multiplying the fuel price (FP) and estimated fuel consumption (EFC), equation (3).

$$FC = FP * EFC \qquad (3)$$

In which:

FC - fuel cost of the machine, US$ h^{-1};

FP - fuel price, US$ L^{-1};

EFC - estimated fuel consumption, L h^{-1}.

The estimated fuel consumption (EFC) is in accordance with Banchi, Lopez and Rocco (2008) who consider two ranges of nominal potencies for motor grader motors, one up to 132 Kw (180 cv) and another over 132 Kw (180 cv).

ASABE (2011) proposed to determine the repair and maintenance cost (RMC) of the machine by the ratio between the repair and maintenance factors (RMF), initial value (Iv) and usable lifespan in hours (ULH), equation (4).

$$RMC = \frac{RMF * Iv}{ULH} \qquad (4)$$

In which:
RMC - repair and maintenance cost of the machine, US$ h^{-1};
RMF - repair and maintenance factor, in decimal.

According to ASABE (2011) is calculated the hourly cost (HC) of the machine, defined by the sum of fixed cost hourly (FCH) and variable cost (VC) (fuel, repair and maintenance), equation (5).

$$HC = FCH + VC \qquad (5)$$

In which:
HC - hourly cost of the machine, US$ h^{-1}.
The total cost (TC) of the machine is determined by multiplying the hourly cost (HC) and usable lifespan in hours (ULH), equation (6).

$$TC = HC * ULH \qquad (6)$$

In which:

TC - total cost of the machine, US$.

2.2 Mill incomes

Santos et al. (2014a); Santos, Fernandes and Gadanha Júnior (2015b) proposed an equation to calculate the gross and net income of sugarcane harvest of a mill, considering the percentage of raw material losses in gross income and the mechanized harvesting cost in the net income.

In this case, to calculate the gross income of the mill (GIM), the proposed was adapted, considering the multiplication of sugarcane price per ton (PT) and sugarcane production (SP), equation (7).

$$GIM = PT * SP \qquad (7)$$

In which:

GIM - gross income of the mill, US$;

PT - sugarcane price per ton, US$ t^{-1};

SP - sugarcane production, t.

3 RESULTS AND DISCUSSION

A Basic Scenario (BS) of the Reference Mill (RM) was considered for the results. Figure 2 presents the effect of number of years on the annual fixed cost (AFC) of motor graders. According to Balastreire (1987); Banchi, Lopes and França (2006a); Hunt (1977); Witney (1988), the cost does not depend on the utilization and is calculated considering depreciation, usable lifespan, interest, lodging, insurance and taxes. However, the cost decreases proportionally with the years of use or not of the machine, due to the amortization of the annual depreciation, year after year.

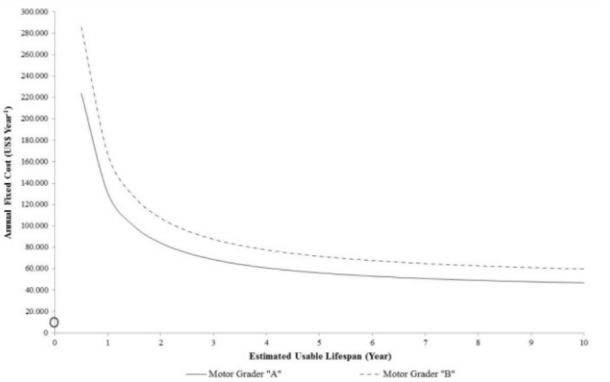

Figure 2 - *Annual fixed cost of motor graders “A” and “B” in function of the lifespan.*

It is observed that in the first year the cost of the machines “A” and “B” are expressive, reaching 130,688 and 166,812 US$ $Year^{-1}$, respectively. In the second year of life, the costs of the equipment decrease considerably, 62.43%. In the tenth year of the lifespan, the motor grader cost reduces to 79.08%, resulting in a difference of 16.65% along the years.

Figure 3 shows the hourly cost (HC) of motor graders in function of the usable lifespan in hours (ULH), which expresses the effect of hours of lifespan on the fixed and variable cost of the equipments. However, as the calculation was done in specific terms, dollars per hour, the variable cost tis constant and independent from the number of worked hours, whereas the fixed cost decreases proportionally with the machine utilization.

In order to define the net income of mill (NIM), the proposed was modified, considering the difference between the gross income of the mill (GIM) and total cost of the machine (TC), equation (8).

$$NIM = GIM - TC \qquad (8)$$

In which:

NIM - net income of the mill, US$.

2.3 Data analysis

The data analysis and *“TerraPlanCana”* validation were done by comparing the results obtained in the simulation with primary data (raw). The model consistency was evaluated in relation to the hourly cost.

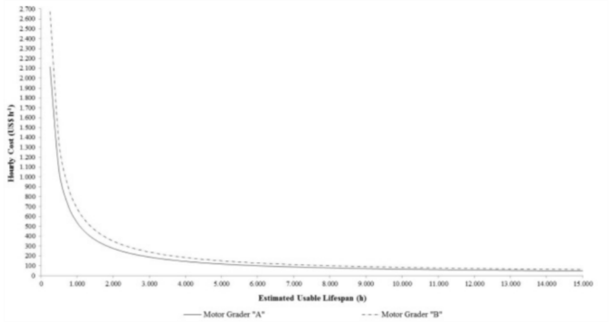

Figure 3 - *Hourly cost of motor graders “A” and “B” in function of the lifespan.*

It is observed in the figure that the cost of motor graders “A” and “B” in 250 h is high and unviable, resulting in 2,116.36 and 2,674.96 US$ h^{-1}, respectively. From 1,000 h on, the machines cost is close and when at 2,000 h there is an expressive decrease of approximately 86.92%. At 10,000 h the cost reduces to 96.85% and at 15,000 h it reaches 97.68%, decreasing slightly with a difference of 0.83%.

For 15,000 h considered in the Basic Scenario, the cost obtained by machine “A” and “B” was 49.08 US$ h^{-1} and 63.01 US$ h^{-1}, respectively. However, Banchi, Lopes and Sales (2006b) obtained an hourly cost of 30.00 US$ h^{-1}, in 24,859 h. However, in the condition shown in the figure, from 2,000 h to 15,000 h of lifespan of motor graders “A” and “B”, it is when a considerable gain in the cost occurs, at 82.00%, of 227.75 US$ h^{-1} and 287.76 US$ h^{-1}, respectively, proving the best viability of equipments utilization in this interval of estimated usable lifespan.

Figure 4 shows the participation of gross income of the mill (GIM), net income of the mill (NIM) and total cost (TC) of motor graders under the Basic Scenario condition. As it is observed, motor grader “B” has higher total cost in the gross income with a participation of 3.13%, whereas motor grader “A” impacts 2.44% in the income, resulting in a slight difference of 0.69% in the income.

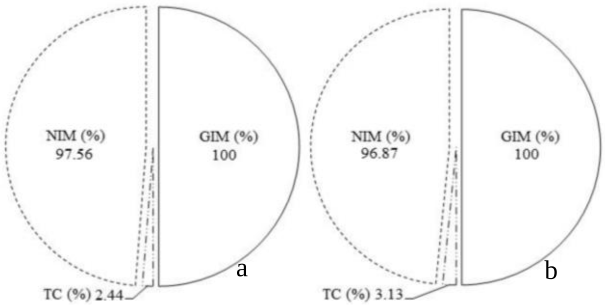

***Figure 4** - Distribution (%) of the gross income of the mill (GIM), net income of the mill (NIM) and total cost (TC) of the machines: Figure 4a - Motor grader "A" and Figure 4b - Motor grader "B".*

For such a condition, gross income was US$ 30,181,333.33. As motor graders "A" and "B" reached the total cost of US$ 736,152.12 and US$ 945,151.52, the net incomes resulted in US$ 29,445,181.21 and US$ 29,236,181.82, respectively. At 15,000 h, the equipments reached their initial value (Iv) and lifespan with approximately 2.5 years, corresponding to 6,000 h per Year^{-1} worked.

4 CONCLUSIONS

Motor grader "B" was the one that mostly impacted the costs.

The increase in useable lifespan in year or in hour increases the total cost due to the influence of variable costs that also rise.

When the equipment reaches its useable lifespan, it is necessary to replace it for a new one; otherwise, it will result in high total cost, reducing the gains of the mill.

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