ECONOMIC EVALUATION OF FOREST HARVESTING WITH HARVESTER AND FORWARDER[1]

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ABSTRACT – Due to the high cost of acquisition and preservation of machines used in the operations of forest harvest, it is necessary to know the profitability of its purchase and up to what point its usage is profitable. Thus the aim of this work was to evaluate economically the activities of felling and timber extraction held by skidders harvester and forwarder up to approximately 30,000 hours of work. Seventeen forest machines were used: 5 harvesters John Deere model 1270D, and 5 harvesters John Deere model 1470D, with power of 215 hp (160 kW) and 241 hp (180 kW), respectively, and 7 forwarders John Deere model 1710D, with power of 215 hp (160 kW). The data base supplied by a forestry company located in the state of Minas Gerais, Brazil, containing all the necessary information to obtain the equilibrium point, the annual equivalent cost (AEC) and the internal return rate (IRR) was used. The equilibrium point was used to determine the amount of minimum hours the machines should work. The AEC was used to determine the profitability of the operation. In 2013 it was not possible to find a number of working hours that did not cause loss for either the harvester or the forwarder. The substitution point for the harvester or the forwarder through the AEC was not found. The harvester presented investment profitability in 2011 of 67.43%. The forwarder presented an internal rate or return of 34.00% in 2011.

Keywords: Forestry Economics; Equivalent annual cost; Internal rate of return.

AVALIAÇÃO ECONÔMICA DA COLHEITA FLORESTAL MECANIZADA COM HARVESTER E FORWARDER

RESUMO – Em razão do alto custo de aquisição e preservação das máquinas utilizadas nas operações de colheita florestal faz-se necessário conhecer a rentabilidade de sua compra e até que momento seu uso é lucrativo. Sendo assim o objetivo deste trabalho foi avaliar economicamente as atividades de corte e extração da madeira realizada pelos tratores florestais ***harvester*** *e* ***forwarder*** *até aproximadamente 30.000 horas de trabalho. Foram utilizadas 17 máquinas florestais: 5* ***harvesters*** *John Deere modelo 1270D, e 5* ***harvesters*** *John Deere modelo 1470D, com potência de 215 hp (160 kW) e 241 hp (180 kW) respectivamente, e 7* ***forwarders*** *John Deere modelo 1710D, com potência de 215 hp (160 kW). Foi utilizada a base de dados fornecida por uma empresa florestal situada no estado de Minas Gerais, contendo todas as informações necessárias para obtenção do ponto de equilíbrio, do custo anual equivalente (CAE) e da taxa interna de retorno (TIR). O ponto de equilíbrio foi utilizado para determinar a quantidade de horas mínimas que as máquinas deveriam trabalhar. O CAE foi utilizado para determinar o ponto de substituição da máquina e a TIR foi utilizada para determinar a rentabilidade da operação. No ano de 2013 não foi encontrado um número de horas* *de trabalho que não resultasse em prejuízo para o **harvester** e **forwarder**. Não foi encontrado o ponto de substituição do **harvester** e **forwarder** através do CAE. O **harvester** apresentou rentabilidade de investimento em 2011 de 67,43%. E o **forwarder** apresentou uma taxa interna de retorno em 2011 de 34,00%.*

Palavras-chave: Economia Florestal; Custo anual equivalente; Taxa interna de retorno.

1. INTRODUCTION

Forest harvest is exposed to several climatic and biological factors which are related to the man-machine system, which can influence the machines productivity as well as the production costs (BURLA et al., 2012). The increase in mechanization has inverted the operational cost percentages, where the costs with machines and equipment are bigger than the ones with labor (MALINOVSKI, 2010).

Currently the harvest mechanization degree is linked to the area declivity, volume per tree, amount of stems by stump and purchase power of forestry companies. Since the big companies have more funds available, they use highly mechanized and sophisticated harvest systems; the medium-sized companies use machines and equipment that are little sophisticated and specialized labor; the small companies still use rudimentary methods, with little or no labor qualification (MACHADO et al., 2014).

Regardless their mechanization degree the companies should satisfy the necessities of the consumer Market, besides providing return to their investors, partners or shareholders, once they are interested in the results of their ventures (VEY; ROSA, 2004).

The economic assessment of machines and equipment is an important tool when determining the profitability of the forestry activity. Some analyses that compose this evaluation are: the equilibrium point, the equivalent annual cost (EAC) and the investment internal return rate (IRR).

The equilibrium point is used to determine the amount of work effective hours that a machine needs to have and if it doesn't achieve the value found in this analysis, its purchase is not recommend, since it is more viable to outsource the activity. From the equivalent annual cost (EAC) the ideal moment to either exchange or substitute the machine can be determined. And with the obtained data from the internal return rate it is possible to identify the profitability of the investment.

This information is highly relevant when planning and programming efficient usage of forest machines and decision-making where managers and shareholders are concerned regarding the profitability of the investment as a result of the acquisition of new machines and when is the best time for them to be changed.

In this context, the aim of this paper was to economically assess the activity of forestry harvest carried out by forestry machines harvester and forwarder up to approximately 30,000 hours of work.

2. MATERIALAND METHODS

The research was done in a forestry company, located in the State of Minas Gerais, Brazil. Seventeen forestry machines were used: 5 harvesters John Deere model 1270D, and 5 harvesters John Deere model 1470D, motor John Deere 6090HTJ, with 215 hp power (160 kW) and 241 hp (180 kW), respectively, six-wheel-drive and conveyor belts linking the four front tires, with head John Deere model H270 harvester. Seven forwarders John Deere model 1710D, motor John Deere 6081H, with 215 hp power (160 kW), eight-wheel-drive and conveyor belts linking the four back tires, with Hultdins grapple 360S with 0.36 m² of area. The data used for the calculation for the total cost of the evaluated machines schedule were taken from a scientific paper written by Santos (2014).

2.1 Point of Equilibrium (H)

In order to identify the number of hours the machine should have worked per year to justify its acquisition, that is, the number of annual working hours which will make its purchase viable, Equation 1 was used (SILVA et al., 2012; LEITE, 2012).

$$H = \frac{CF}{Ph - CV} \quad (1)$$

in which

H = worked hours per year (h year^{-1});

CF = fixed cost (US\$ h^{-1});

Ph= average price of worked hour (US$ h^{-1}); and,

CV = variable cost (US$ h^{-1}).

2.2 Equivalent annual Cost (EAC)

This cost was used to determine the optimum point in years in order to substitute the used machine for a new one, and this point is the one that minimizes the equivalent annual cost value (OLIVEIRA, 2000). The EAC was the value present in all the costs in "n" periods, multiplied by the factor of capital recovery ($\frac{ia(1+ia)^n}{(1+ia)^n - 1}$) (VALVERDE; REZENDE, 1997) according to Equation 2.

$$EAC = \left[\frac{Iv - Vr_n}{(1+ia)^n} + \frac{\sum_{i=1}^{n}(CO_i + MR_i)}{(1+ia)^i}\right]\left[\frac{ia(1+ia)^n}{(1+ia)^n - 1}\right] \quad (2)$$

in which

EAC = equivalent annual cost (US$ $year^{-1}$);

Iv = Investiment (US$ $year^{-1}$);

Vr_n = Annual residual value (US$ $year^{-1}$);

ia = annual simple interests (decimal);

CO_i = Operational cost of the machine (US$ $year^{-1}$); and,

MR_i = Maintenance and repair cost (US$ $year^{-1}$).

2.3 Internal Return Rate (IRR)

In order to determine the return rate of the invested capital, that is, the investment average growth rate, Equation 3 was used (REZENDE and OLIVEIRA, 2013).

$$\sum_{j=0}^{n} R_j (1 + TIR)^{-j} = \sum_{j=0}^{n} C_j (1 + TIR)^{-j} \quad (3)$$

in which

R_j = current revenues value;

C_j = current costs value;

i = interests rate;

j = period in which the revenue or cost occur; and,

n = total number of periods.

3. RESULTS

3.1 Harvester

3.1.1 Point of Equilibrium (H)

In order to determine the point of equilibrium for the harvester the price paid (US$) for the activity of wood harvest with Market harvester (US$ 8.61 m^3) was used. The results can be seen on Table 1.

It is possible to observe that from 2007 to 2011 the number of hours to enable the purchase of the machine was smaller than the number of hours that were effectively worked by the harvester. Only in 2012 this value was above that (8,797.23 h $year^{-1}$).

3.1.2 Equivalent annual cost (EAC)

The point of substitution of the machine was not found (Table 2). The EAC occurred in an increasing way throughout the years.

3.1.3 Internal Return Rate (IRR)

The harvester presented investment profitability of 67.43% in 2011, 65.49% in 2012 and 58.05% in 2013 (Figure 1).

Table 1 – Number of effective hours (H) that the harvester should work to justify their acquisition and effective number of hours of actual work.
Tabela 1 – *Número de horas efetivas (H) que o harvester deveria trabalhar para justificar sua aquisição e número de horas efetivas de trabalho real.*

	2007	2008	2009	2010	2011	2012	Average
H (h $year^{-1}$)	726.28	1,308.57	3,316.33	1,431.91	1,201.28	8,797.23	2,796.93
h $year^{-1}$ real	3,345.52	3,870.02	3,970.07	4,256.41	4,052.02	3,578.44	3,845.41

Table 2 – Equivalent annual cost (EAC) of the harvester.
Tabela 2 – *Custo anual equivalente (CAE) do harvester.*

	2007	2008	2009	2010	2011	2012
EAC (US$ $year^{-1}$)	501,269	580,057	643,490	662,748	678,838	690,783

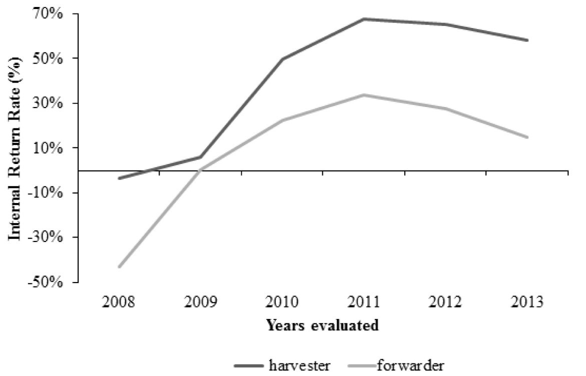

Figure 1 – Internal Return Rate (IRR) of the harvester and forwarder.
Figura 1 *– Taxa interna de retorno (TIR) do harvester e forwarder.*

3.2 Forwarder

3.2.1 Point of Equilibrium (H)

In order to determine the point of equilibrium for the forwarder the price paid (US$) for the activity of market wood extraction (US$ 4.64 m³) was used. The results can be seen on Table 3.

One can observe that only in 2012 the number of necessary hours to make the acquisition of the forwarder viable was superior to the number of hours that were effectively worked.

3.2.2 Equivalent annual cost (EAC)

On Table 4 one can observe that the EAC was increasing.

3.2.3 Internal Return Rate (IRR)

The highest internal return rate of the investment of the forwarder was obtained in 2011 in a percentage of 34% (Figure 1).

4. DISCUSSION

4.1. Harvester

4.1.1 Point of Equilibrium (H)

The smallest number of hours to be worked can be justified once the price paid for the tree-cutting and the market wood processing was superior to the cost of production obtained by the company.

In 2013 the data were not presented because they were negative. This took place due to the high variable costs, and as a consequence, they obtained a negative value for the calculation of the point of equilibrium, that is, for the productivity of 17.15 m^3 h^{-1} of wood and the price of the market machine of US$ 8.61 m^3. There aren't a number of hours that does not result in loss for a variable cost of US$ 242.64 h^{-1}.

These results differed from the ones presented by Leite (2012), when the number of hours worked by the machine operating uphill and downhill with a value of 3,800 h $year^{-1}$ and 4,527 h $year^{-1}$, respectively, were evaluated. However, the price paid for the activity of tree-cutting and the wood processing used by this author was US$ 5.00 m^3.

When pursuing to evaluate economically eight harvesters from 2007 to 2013, Silva (2015) found a point of equilibrium only in the years 2010 and 2011 and these values were 2,037.13 h $year^{-1}$ and 3,310.10 h $year^{-1}$, respectively. For the remaining years, due to facts such as the high cost of the machines resulting from a smaller number of worked hours and a high variable cost, a point of equilibrium for the machines was not found.

4.1.2 Equivalent annual cost (EAC)

The fact that the EAC happened in an increasing way throughout the years can be explained once linear

Table 3 – Number of effective hours (H) that the forwarder should work to justify their acquisition and effective number of hours of actual work.
Tabela 3 *– Número de horas efetivas (H) que o forwarder deveria trabalhar para justificar sua aquisição e número de horas efetivas de trabalho real.*

	2007	2008	2009	2010	2011	2012	Average
H (h $year^{-1}$)	1,365.38	1,496.80	1,876.19	1,878.22	1,824.02	10,939.54	3,230.03
h $year^{-1}$ real	3,533.52	4,350.23	4,589.37	4,494.93	4,209.29	3,812.34	4,164.94

Table 4 – Equivalent annual cost (EAC) of the harvester.
Tabela 4 *– Custo anual equivalente (CAE) do harvester.*

	2007	2008	2009	2010	2011	2012
EAC (US$ $year^{-1}$)	476,138	489,439	527,380	548,349	567,832	583,456

depreciation in order to obtain the cost of investment was used. This made this cost occur in a constant way, since the EAC is the result of the sum of the investment cost and the operational costs used each year, thus, the EAC followed the same tendency of the operational costs which increased according to the machine lifespan.

4.1.3 Internal Return Rate (IRR)

Based on the data obtained from the IRR, one can observe that the best moment to substitute or change the machines would have been in 2011, once the highest IRR was found during the five first years of the harvester, and after that period there was a reduction of this percentage. This can be explained by an increase of the variable costs and the reduction on the amount of the hours that were effectively worked per year as well as the productivity of the machine.

Leite (2012), found a profitability of 34.565 when he evaluated a harvester working uphill and 6.26% working downhill. These values differed from the ones found in this paper, once the machine worked in the area as a whole (both uphill and downhill), resulting in a total population profitability independent from the direction of the operation.

4.2 Forwarder

4.2.1 Point of Equilibrium (H)

From 2007 to 2011 the smallest number of hours found for the machine purchase viability when compared to the number of hours that they really worked may be due to the cost of the company extraction being smaller than the Market values used in this paper. In 2012, since the machines were not able to work enough to enable their purchase, it would have been better if the company had outsourced the operation.

In 2013 due to the fact that the average variable cost was high (US$ 175.92 h^{-1}), there wasn't a number of worked hours that resulted in profit for an average labor productivity of 25.16 m^3 and market rent price of US$ 4.64 m^3.

Leite (2012), when evaluating the point of equilibrium for the forwarder working uphill and downhill, observed that it should work 5,038 h $year^{-1}$ and 2,417 h $year^{-1}$, respectively. From these data this author noticed that in order to enable the purchase of this machine, the operation downhill should be avoided.

4.2.2 Equivalent Annual Cost (EAC)

When Simões et al. (2013) analyzed the behavior of the equivalent annual cost due to the application of different depreciation methods, they also found an increasing EAC for the five years the *fowarder* was evaluated. Silva (2015), like in this paper, did not find a point of machine change. The EAC occurred in an increasing way from 2007 to 2010 and in a decreasing way until 2013.

4.2.3 Internal Return Rate (IRR)

Through the IRR one can notice that the evaluated machines should have been changed at five years of age due to the fact that a higher profitability of the operation occurred in 2011 and after that period this percentage reduced.

Leite (2012), found a profitability of 13% for the uphill direction and 122.86% for the downhill direction operations when evaluating a forwarder. These values differed from the ones found in this paper, once the total profitability was obtained independently from the direction of the operation and the increase on the variable costs in the first year obtained by a smaller amount of effective worked hours (1,380.13 h $year^{-1}$) by one of the evaluated machines.

5. CONCLUSION

- From 2007 to 2011 the number of the harvester and forwarder worked hours were enough to enable their acquisition. On the other hand, in 2012 the company should have chosen the outsourcing of the operations. In 2013 a number of hours of work that would enable the acquisition of the machines were not found.

- The point of change for either the harvester or the forwarder was not found when the EAC was used.

- The highest profitability of the harvester and the forwarder was obtained in 2011, with percentages of 65.49% and 34.00%, respectively, indicating the best moment for the substitution of this harvest module.

- Overall, the used methodology was efficient when evaluating the profitability of the tree-cutting and wood extraction operations and the determination of the ideal moment to substitute the harvester and the forwarder.

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