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ECONOMIC FEASIBILITY OF THE USE OF TRACTOR/AGRICULTURAL IMPLEMENTS FOR BUILDING TERRACES

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ABSTRACT

The objective of this work was to analyze the operational costs of agricultural mechanization in the construction of terraces as well as its purchase economic feasibility. This experiment was conducted in the city of Montes Claros, Minas Gerais. It evaluated the operating costs considering the availability of implanting three terraces: Manghum, Nichols and Wide Base terraces. A three-fixed-disc plow was adopted for the Manghum type, a three-reversible-disc plow was used for the Nichols type and a drag-plow was used for the Wide Base. Even with higher hourly-costs (R$ h^{-1}), the drag-plow provided a lower total cost (R$ terrace^{-1}) and consequently more terraces were built per hour due to its higher efficiency. The Leveling Point has shown that for the Manghum terrace, to purchase the tractor and the fixed disc plow is feasible if the number of worked-hours exceeds 219.3 hours per year; for the Nichols terrace type, to purchase the tractor and the reversible disc plow is only possible when the number of hours is higher than 247.7 hours per year and, for the Wide Base terrace, to purchase the tractor and the drag-plow is viable with a number of hours exceeding 167.8 hours per year.

Palavras-chave:
avaliação econômica
máquinas agrícolas
mecanização agrícola

VIABILIDADE ECONÔMICA DO USO DE TRATOR/IMPLEMENTOS AGRÍCOLAS NA CONSTRUÇÃO DE TERRAÇOS

RESUMO

O objetivo deste trabalho foi analisar os custos operacionais do uso da mecanização agrícola na construção de terraços, bem como a viabilidade econômica da compra. O trabalho foi realizado no município de Montes Claros - MG. Os Custos Operacionais foram avaliados considerando a possível implantação de três terraços: Manghum, Nichols e Base Larga. Adotou-se um arado fixo de três discos para o tipo Manghum, um arado reversível de três discos para o tipo Nichols e um terraceador para o de Base larga. Mesmo com maior custo horário (R$ h^{-1}), o terraceador proporcionou menor custo total (R$ terraço^{-1}) e consequentemente maior número de terraços construídos por hora, devido à maior eficiência deste implemento. O Ponto de Nivelamento demonstrou que para o terraço tipo Manghum será viável adquirir o trator e arado fixo, se o número de horas trabalhadas superar 219,3 horas anuais, no terraço tipo Nichols será viável adquirir o trator e arado reversível com número de horas trabalhadas superior a 247,7 horas anuais e o terraço tipo Base Larga será viável adquirir o trator e terraceador, com número de horas superior a 167,8 horas anuais.

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INTRODUCTION

Water erosion is one of the main forms of degradation of agricultural soils in Brazil. It is a process of runoff by water, in which there is a disaggregation, transport and deposition of soil particles, nutrients and organic matter (OM) (DECHEN *et al*., 2015).

Many are the practices used to control water erosion in agricultural soils. They are usually divided into edaphic, vegetative and mechanical practices, which have their potential enhanced when used in an integrated manner (MAGALHÃES, 2013).

Terracing is a mechanical practice used to control water erosion that, according to Oliveira *et al*. (2012), is the most widespread practice among farmers.

The construction of the terraces involves the use of machines and implements that demand time and significant expenses. Tractor, plow of fixed discs, plow of reversible discs and drag-plow are among them.

According to Rabelo, Souza and Oliveira (2017), among the costs involved in agricultural production, the costs of agricultural machinery and inputs stand out. Fixed Costs are those that do not depend on the use of equipment such as Depreciation, Interest, Accommodation and Insurance, while Variable Costs are those that vary with the amount used by the equipment such as fuels (diesel oil), liquid lubricants, grease, repairs and maintenance, salary of the tractor-driver, among others.

These costs can be higher or lower depending on the way the equipment is being used. Baio *et al*. (2013) cite that the choice of the most suitable equipment for a given farm is one of the most important stages of the production process. The correct adjustment of the machine's capacity in relation to the area is extremely important, as it directly affects the production costs.

Barbosa, Homem and Tarcitano (2014) describe the importance of controlling production costs in most crops, highlighting that any item can contribute significantly to the final cost and that by looking at the items within the recipe, one can choose the best alternative when purchasing products or choosing a particular service.

Borges, Mainardi and Velasquez (2013) report that the cost in agribusiness, in addition to allowing a better assessment of the productive system and providing information for decision making, it also provides for the adoption of alternative measures in order to increase the profitability of the enterprise.

Castro, Reis and Lima (2006) have already described the cost of production as the one that allows the control by the farmer entrepreneur, who, after an analysis of the items that compose it, can seek alternatives with the objective of reducing it.

Correia *et al*. (2018), when evaluating the operational and economic performance of terracing of small farms with disc-plows concluded that regardless of the number of discs, the reversible plows provided greater operational efficiency and effective field capacity.

This work is expected to be make it feasible the purchase of an equipment plus the tractor instead of renting it.

The objective of this work was to analyze the operational costs of using agricultural mechanization in the construction of terraces as well as the economic feasibility of buying a mechanized set to perform such activity.

MATERIAL AND METHODS

The work was carried out in the municipality of Montes Claros - MG. The economy of the city is focused on industry, commerce and the agricultural sector. It has an altitude of 678 m and an average annual rainfall of 1060 mm. The predominant soil is the Red-Yellow Latosol.

To evaluate the Operational Cost in the implantation of the terraces, an experimental area with an average slope of 10%, typical of the region, was considered. The implantation of three terraces was evaluated, two of which were of medium base with the purpose of infiltration, one of the Manghum type and the other of the Nichols type and a third at the Wide Base level.

The equipment was selected as recommended by Pires and Souza (2003), taking into consideration the type of terrace. One equipment was a fixed three-disc plow for the Manghum type, a reversible three-disc plow for the Nichols type and a terracing for the Wide Base terrace.

The tractors to be used were estimated considering the model most used in the region by the famers s, with a 4 x 2 TDA of 55.2 kW (75 hp) for both plows and a 4 x 2 TDA of 73.6 kW (100 cv) for the drag-plow both duly ballasted.

Firstly, the horizontal spacing, vertical spacing and terrace length calculations were performed in order to determine the operation of the machines.

In the determination of the vertical spacing, the Bentley equation was adopted, according to Pires and Souza (2003) represented in Equation 1:

$$EV = \left(2 + \frac{d}{X}\right) \times 0{,}305 \qquad (1)$$

Where,

EV = vertical spacing, m;
d = slope of the terrain, %; and
X = factor resulting from the interaction among soil, slope, vegetal cover and type of terrace.

Equation 2 was used for determining the horizontal spacing, according to Pires and Souza (2003):

$$EH = \frac{EV \times 100}{d} \qquad (2)$$

Where,

EH = horizontal spacing, m.

The length of the terraces was also determined according to Pires and Souza (2003) represented in Equation 3:

$$L = \frac{10.000\,\mathrm{m\,ha^{-1}}}{EH} \qquad (3)$$

Where,

L = terrace length, m ha^{-1}.

After the configuration of each terrace, the construction costs for each one were calculated. The assessment was based on obtaining the Fixed and Variable Costs together with the determination of the Leveling Point.

In the assessment of Fixed Costs, Depreciation, Interest and Accommodation and Insurance Rates were considered.

Depreciation, which refers to the devaluation of the machine over time, was determined by means of the Straight-Line Method according to Equation 4:

$$D = \frac{Va - S}{Vu} \qquad (4)$$

Where,

D = depreciation, R$ h^{-1};
Va = purchase value of the equipment, R$;
Vu = useful life of the equipamet, h; and
S = scrap value, R$.

The scrap values were based on research carried out in the region in markets for the purchase and sale of farming machinery, 20% for the tractor, 10% for the plows and 5% for the drag-plow machine.

Interest was determined considering the current value of 6% according to the current market represented by Equation 5:

$$J = \left(\frac{Va + S}{2 \times H}\right) \times i \qquad (5)$$

Where,

J = interest, R$ h^{-1};
i = decimal, annual interest rate; and
H = annual hours of equipment use, h $year^{-1}$.

Costs with housing and insurance were set according to Balastreire (1990), Equation 6:

$$AS = \frac{0{,}02 \times Va}{H} \qquad (6)$$

Where,

AS = costs with housing and insurance, R$ h^{-1}.

The determination of Variable Costs involved the Operator's Salary, Fuel Consumption and Repairs and Maintenance.

The salary of the tractor driver was estimated according to Balastreire (1990), Equation 7:

$$ST = \left(\frac{(1{,}5 \times SM) + 20\%}{nt}\right) \tag{7}$$

Where,

ST = tractor driver salary and social charges, R\$ h^{-1};
SM = current minimum wage, R\$ month $^{-1}$; and
nt = number of worked hours in the month, h $month^{-1}$.

Fuel consumption was determined, according to studies among the various brands in the market, with an average value of 7.5 L h^{-1} for the 55.2 kW (75 hp) tractor and 10 L h^{-1} for the 73.6 kW (100 hp).

The power in the drawbar was considered to be 60% of the gross power in the flywheel in accordance with ASAE D497.4 (1999), considering a plowed soil. Diesel prices, on the other hand, were considered, according to market research, to be R\$ 3.50 a liter.

Repair and Maintenance costs were estimated according to the multiplication factor established by Pacheco (2000), which was a percentage of the purchase price considering the entire useful life of the implement according to Equation 8:

$$RM = \frac{Gr \times Va}{Vu} \tag{8}$$

Where,

RM = cost with repairs and maintenance, R\$ h^{-1}; and
Gr = multiplication factor for repair and maintenance, decimal.

According to Pacheco (2000), the multiplication factors used were 100% for the tractor and 60% for the other equipment.

A survey was carried out in the region on the rental of implements and agricultural machinery, adopting the value of R\$ 90.00 per hour for the tractor/plow set and R\$ 110.00 per hour for the tractor / drag plow set.

The production time for the construction of each terrace was based on the speed of each implement, 5 km h^{-1} for the two plows and 6 km h^{-1} for the drag plow, equivalent to 83.3m min-^{1} and 100m min^{-1} respectively based on ASAE Standard D497.4 (1999). The number of passes of each implement was 15 passes for the two plows and 10 passes for the drag plow (Equation 9).

$$TP = \frac{L \times N}{v \times Ef} \tag{9}$$

Where,

TP = production time of each terrace, min $terrace^{-1}$;
L = Length of each terrace, m;
v = speed of each implement, m min^{-1};
N = number of passes, dimensionless; and
Ef = efficiency of each implement, decimal.

Efficiency of 40% was adopted for the fixed plow and of 75% for the reversible plow. For the drag plow, it was used 80%.

The construction effective capacity of each terrace was determined according to Equation 10, adapted from Correia *et al.* (2018).

$$CEC = \frac{60 \text{ min h}^{-1}}{TP} \tag{10}$$

Where,

CEC = effective capacity of terrace construction, terrace h^{-1}.

Then, the Operational Cost was obtained, according to Correia *et al.* (2018), using Equation 11:

$$COT = \frac{Ch}{CEC} \tag{11}$$

Where,

COT = operational cost per terrace, R\$ $terrace^{-1}$; and
Ch = hourly cost with the machinery, R\$ h^{-1}.

The economic availability of purchasing the equipment was evaluated using the Leveling Pint according to equation 12:

$$PN = \frac{\sum CF}{Pa - CV} \tag{12}$$

Where,

PN = leveling point, h $year^{-1}$;
ΣCF = sum of the annual fixed costs; R\$ $year^{-1}$;
Pa = price charge for the rent of each implement in

the region, R$ h^{-1};
CV = hourly variable costs, R$ h^{-1};

It was used two equations that allows the construction of the lines representing the rent and machinery purchase, respectively, according to Equations 13 and 14:

$$Al = Pa \times Tu \tag{13}$$

$$Aq = \sum CF + CV \times Tu \tag{14}$$

Where,

Al = rent; R$;
Pa = price charged for the rent of each implement in the region, R$ h^{-1};
Tu = use time, h;
Aq = purchase, R$;
ΣCF = sum of the annual fixed costs; R$ $year^{-1}$; and
CV = variable cost, R$ h^{-1}.

RESULTS AND DISCUSSION

Pasture is the predominant crop in the region due to the strong livestock practice. Therefore, a value of 2.5 for the three terraces according to Pires and Souza (2003) was obtained as a result of the interaction between soil, slope and terrace type.

For the 10% slope, values of 1.8 m for vertical spacing, 18 m for horizontal spacing and 555.5 m for the length of the terraces were found.

The market values for the equipment can be seen in Table 1 together with the values adopted for scrap, interest, working hours, accommodation and insurance according to Conab (2010).

It is observed a difference in the purchase price between the two tractors of different powers. The terracing tractor was the equipment with the highest purchase price.

Table 2 shows the Fixed Costs (R$ h^{-1}) obtained by the equipment in the construction of the terraces in the respective worked hours.

The drag plow was the equipment that presented the highest Fixed Costs, even than the two tractors, followed by the reversible plow and the fixed plow. This is explained due to the fact that, although the tractors have a higher acquisition value, they have a greater number of worked hours and a longer useful life than the drag plow, making the latter with a higher Fixed Cost.

Depreciation was the highest cost obtained in all equipment, followed by Interest and Accommodation and Insurance, corroborating the results of Rabelo, Souza and Oliveira (2017).

Table 3 shows the values of Variable Costs according to each implement used in the construction of the three terraces.

Table 1. Variables used in the Operational Costs evaluation

Equipments	Va (R$)	Vu (h)	H (h)	S (R$)	i (%)	v (km h^{-1})
Tractor 1 (55,2 kW)	128,500.00	10,000	1,000	25,700.00	6	--
Tractor 2 (73,6 kW)	150,000.00	10,000	1,000	30,000.00	6	--
FP	7,500.00	2,000	400	750.00	6	5
RP	11,143.00	2,000	400	1,114.30	6	5
DP	32,770.00	2,500	170	1,638.50	6	6

Legend: FP =Fixed plow; RP = Reversible plow; DP = Drag-plow; Va= Purchase value of the equipment; Vu = Useful life of the equipment; H = Annual Use hours of the equipment; S = scrap; i = annual interest rate; v = speed.

Table 2. Fixed costs (R$ h^{-1}) of the equipment

Equipments	D (R$ h^{-1})	AS (R$ h^{-1})	J (R$ h^{-1})	Total (R$ h^{-1})
Tractor 1 (55,2 kW)	10.28	2.57	4.63	17.48
Tractor 2 (73,6 kW)	12.00	3.00	5.40	20.40
FP	3.37	0.38	0.62	4.37
RP	5.01	0.56	0.92	6.49
DP	12.45	3.86	6.07	22.38

Legend: D = Depreciation; AS = Housing and Insurance; J = interest.

Among the soil-moving implements, the drag plow was again the equipment that demanded the highest values, followed by the reversible-plow and the fixed-plow. In this case, the highest value found in the use of the drag plow can be explained due to the high cost of acquisition of this equipment in relation to the fixed and reversible plows. Fuel Consumption was the highest value found within Variable Costs.

Once more, the tractor with the highest power was the one that provided the highest variable cost due to the higher acquisition cost

The estimates of the Production Time of the terraces can be seen in Table 4.

It is observed that the plows have a longer Production Time, which can be explained due to the greater number of movements and lower efficiencies in the operation than the drag plow.

Table 5 shows the Total Costs of the construction operations of the terraces.

The lowest Operating Cost in the construction of the terraces was obtained by the drag plow, followed by the reversible plow and the fixed plow. The values obtained by the reversible and fixed plows corroborate the results found by Correia *et al*. (2018) who concluded that, regardless of the number of discs, the reversible plows provided greater operational efficiency and effective field capacity.

Despite its greater total hourly cost, 109.44 R$ h^{-1}, the drag plow obtained a lower Operating Cost than the others, 127.25 R$ $terrace^{-1}$. This fact can be explained due to the smaller number of movements made with this implement, combined with its greater cutting width, greater operating speed and greater efficiency, resulting in a larger number of terraces built per hour unit.

Considering the rent of R$ 90.00 for the use of the tractor with the plows and R$ 110.00 for the tractor with the drag-plow in the region, the Leveling Point was calculated.

Table 3. Variable costs (R$ h^{-1}) of the equipment

Equipments	ST (R$ h^{-1})	RM (R$ h^{-1})	CC (R$ h^{-1})	Total (R$ h^{-1})
Tractor 1 (55,2 kW)	8.80	12.85	26.25	47.90
Tractor 2 (73,6 kW)	8.80	15.00	35.00	58.80
FP	0.00	2.25	0.00	2.25
RP	0.00	3.34	0.00	3.34
DP	0.00	7.86	0.00	7.86

Legend: ST = tractor driver's wage; RM = Repairs and maintance; CC = Fuel Costs

Table 4. Terrace Production Time

Variables	FP	RP	DP
Movements	15	15	10
Terrace Lenght (m)	555.5	555.5	555.5
Production time (min $terrace^{-1}$)	251.2	134.0	70.0

Table 5. Total operational cost per tractor/implement set

Equipments	CEC (terrace h^{-1})	CH (R$ h^{-1})	COT (R$ $terrace^{-1}$)
Tractor 1 (55,2 kW) + FP	0.24	72.00	300.00
Tractor 1 (55,2 kW) + RP	0.45	75.21	167.13
Tractor 2 (73,6 kW) + DP	0.86	109.44	127.25

Legend: CEC = terrace effective construction capacity; CH = total hour cost; COT = Operational cost per terrace.

Figures 1, 2 and 3 show the Leveling Point at the intersection of the graph lines also acquired by Equation 12 for the three built terraces.

It can be seen in Figure 1 that in the construction of the Manghum-type terrace, the purchase of a fixed plow/tractor set will only be feasible if the number of worked hours is greater than 219.3 hours per year.

It can be seen in Figure 2 that the purchase of reversible plowed/tractor set for the construction of the Nichols-type terrace will only be feasible if the number of worked hours is greater than 247.7 hours per year.

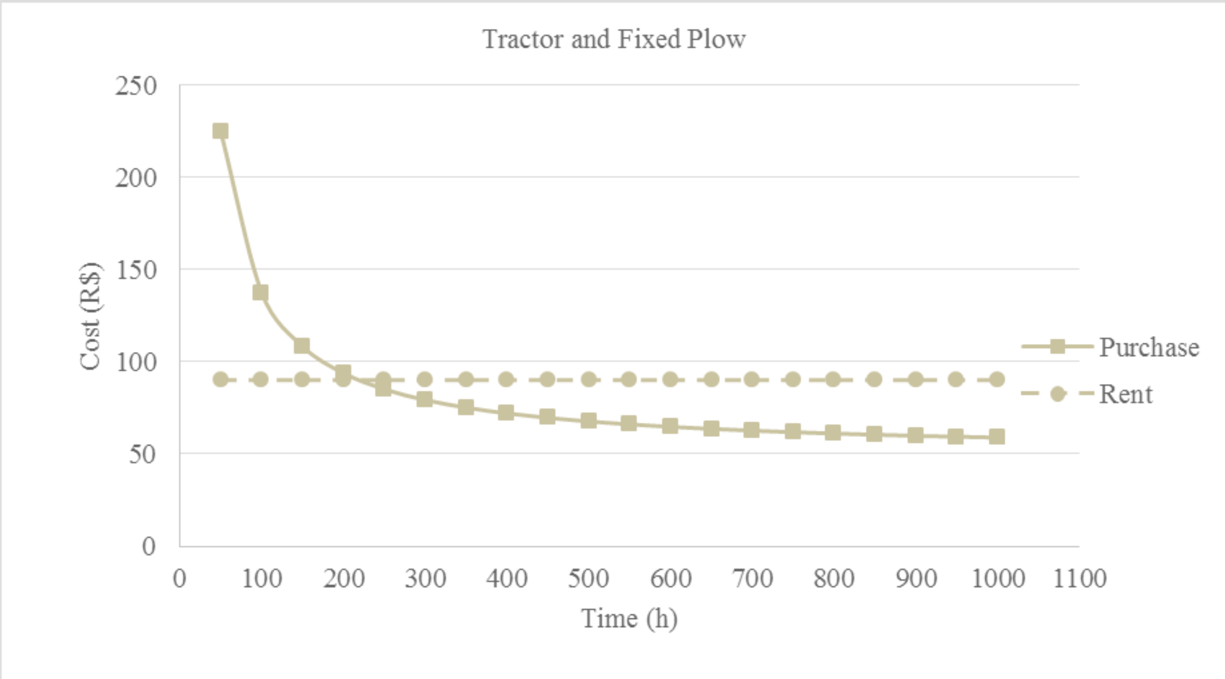

Figure 1. Leveling point for the tractor/fixed plow set

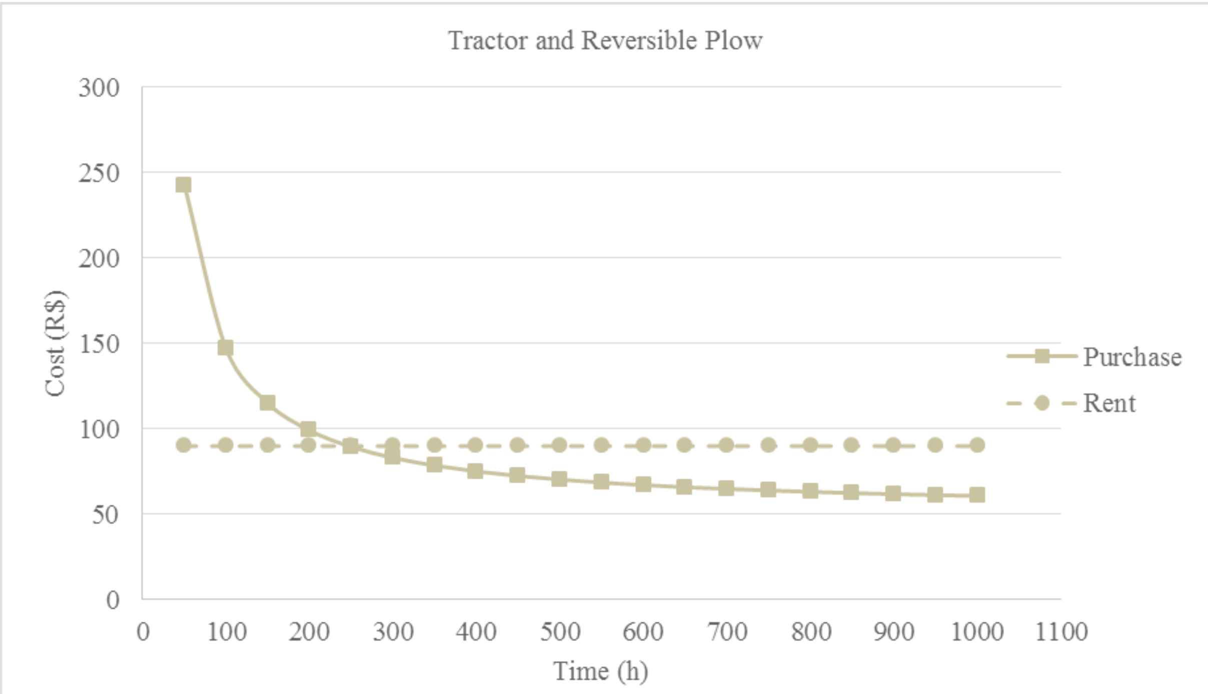

Figure 2. Leveling point for the tractor/reversible plow

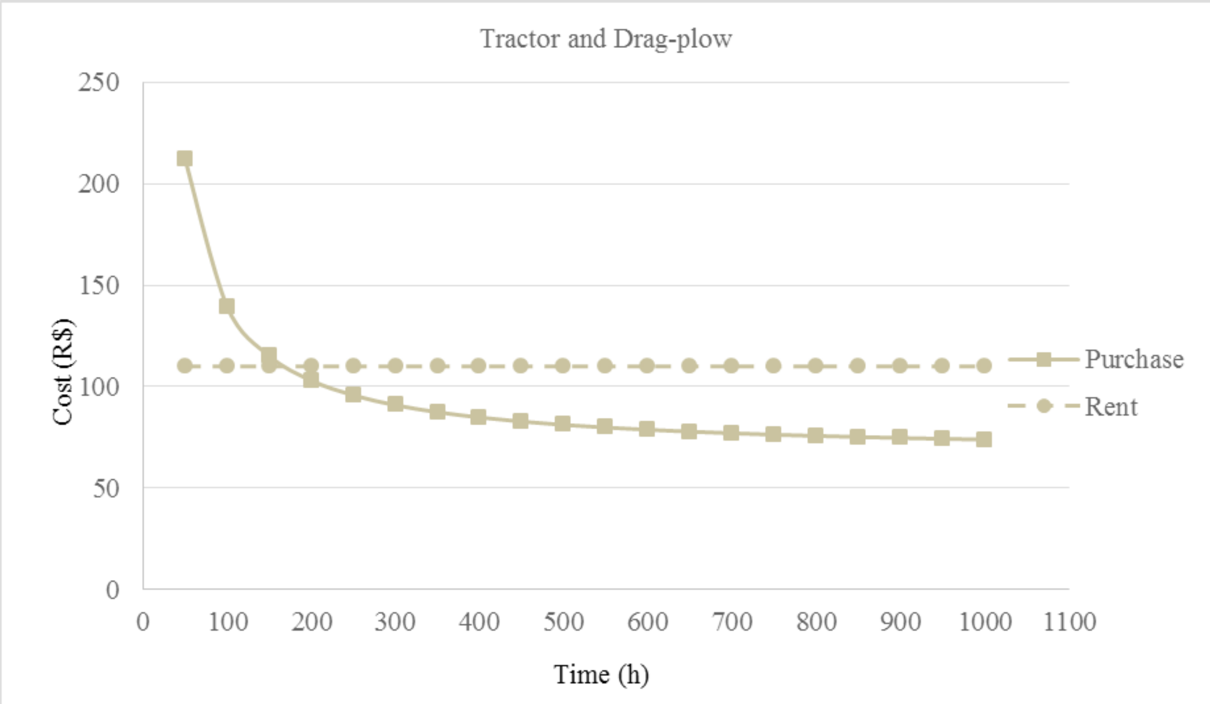

Figure 3. Leveling point for the tractor/drag plow set.

For the construction of the wide-Base type terrace, Figure 3, the purchase of the fixed-plow/tractor set will only be feasible if the number of worked-hours is greater than 167.8 hours per year.

CONCLUSIONS

- Although a higher hourly cost (R$ h^{-1}) was obtained when working with the drag-plow, it provided a lower cost per terrace (R$ $terrace^{-1}$) as it operated with a greater efficiency than the others, resulting int the construction of more terraces per worked hour.
- For the Manghum-type terrace, the tractor/fixed plow set will be purchased only if the number of worked-hours is greater than 219.3 hours;
- For the Nichols terrace, the tractor/reversible plow set will only be purchased if the number of worked-hours exceeds 247.7 hours per year;
- For the Wide-base type terrace, it will be possible to purchase the tractor/drag-low set, with a number of worked-hours greater than 167.8 hours per year.

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