Economic impact of sugarcane (*Saccharum* spp.) loss in mechanical harvesting

Impacto econômico da perda de cana-de-açúcar (*Saccharum* spp.) na colheita mecanizada

Neisvaldo Barbosa dos SANTOS[1;2]; Haroldo Carlos FERNANDES[3]; Casimiro Dias GADANHA JÚNIOR[4]

[1] Parte da dissertação de mestrado do primeiro autor;
[2] Autor para correspondência (Corresponding author), Mestre em Máquinas Agrícolas, Prof. Assistente da Universidade Federal do Piauí (UFPI), Campus Professora Cinobelina Elvas, Rodovia Municipal Bom Jesus - Viana, Km 01, Planalto Horizonte, CEP. 64.900-000, Bom Jesus, PI; neisvaldo@gmail.com;
[3] Doutor em Energia na Agricultura, Prof. Titular da Universidade Federal de Viçosa (UFV), Departamento de Engenharia Agrícola, Avenida P.H. Rolfs, s/nº, Campus Universitário, CEP.36.570-000, Viçosa, MG; haroldoufv@gmail.com;
[4] Doutor em Energia na Agricultura, Prof. Doutor da Escola Superior de Agricultura Luiz de Queiroz (ESALQ/USP), Departamento de Engenharia de Biossistemas, Avenida Pádua Dias, 11, CEP.13.418-900, Piracicaba, SP; cdgadanh@usp.br

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Abstract

In Brazil, sugarcane intended for ethanol and sugar mill shad 3.6% increase in the total area directed toward agricultural production. Among the mechanized harvest machines, harvester is most costly of purchase, especially with two lines, whose price is 50% higher than the one-line type. Given the difficulty of evaluating the economic impact caused by sugarcane loss in the process of mechanized harvest in the field, the present study has assessed it by using the computer model *"ColheCana"* that was developed and validated in an *Excel®* spreadsheet, and in *Visual Basic®* programming language. Initially, the operational speed was determined to access the production cost with and without loss of raw material. The harvester considered has two lines and 251 kW output (342 cv). Increasing the operation speed reduces the production cost, but augments sugarcane loss.

Additional keywords: cost; harvester; raw material.

Resumo

A cana-de-açúcar no Brasil destinada às usinas apresenta aumento de 3,6% na área total direcionada a produção agrícola. Entre as máquinas que constituem o sistema mecanizado de colheita, a colhedora é a que possui maior custo de aquisição, principalmente a de duas linhas, cujo valor pode ser 50% superior ao de uma linha. O presente trabalho tem como objetivo avaliar o impacto econômico causado pela perda de cana-de-açúcar no processo de colheita mecanizada. Para alcançar tal objetivo, optou-se por utilizar o modelo computacional denominado *"ColheCana"*, que foi desenvolvido e validado em planilha eletrônica do *Excel®* e em linguagem de programação pelo *Visual Basic®*. Ao início, foram determinadas as velocidades de operação para obter o custo de produção com e sem perda de matéria-prima. A colhedora considerada possuía duas linhas e potência nominal de 251 kW (342 cv). O aumento da velocidade de operação reduz o custo de produção, embora eleve a perda de cana-de-açúcar.

Palavras-chave adicionais: colhedora; custo; matéria-prima.

Introduction

In Brazil, the sugarcane culture directed to mills has an area and total production estimated for 2014-2015 harvest of 9.13 million hectares and 671.69 million tons, respectively (CONAB, 2014).

According to CONAB (2008), Brazilian international leadership in sugarcane production for sugar and ethanol manufacturing and commercialization is due to the organizational ability of economic agents, such as industry, market, farmers and rural workers. Although the sugarcane sector has undergone changes, which according to KOHLHEPP (2010) happened by recent development in the bio fuels sector, the country has been passing through an extensive transformation process, leading not only to enormous economic consequences, but also to domestic politics.

For agricultural equipment management, computer modeling adoption has been very viable. According to WILLIAMS (2008), modeling is a tool that simplifies the development of the idea proposed, in order to represent structures and develop scenarios. According to OKSANEN (2007), an agricultural machinery planning and management computer model is designed to provide acceptable solutions, in order to solve the problem.

The sugarcane mechanized harvesting system operates commonly in single spaced crops, although recently this system has also adopted the dual row spacing, which is formed by two rows adjacent to each other, in which a two-row harvester is used. According BRAUNBECK & OLIVEIRA (2006), the acquisition value of a harvester varies according to row number, with the initial value of a two-row harvester machine reaching up to 50% more than a one-row harvester.

The dual row spacing adoption occurs due to the operational and economic gain obtained from the machines. However, it is important to note sugarcane loss influence in mechanized harvesting, which denominated indirect factor, as did SILVA et al. (2008) while evaluating the sugarcane mechanized harvesting process, with an average yield of 62.3 and 64.4 t ha^{-1}, on operating speeds of 1.56 and 2.08 m s^{-1} and with a total raw material loss in the range of 6.3 and 12.8%, respectively.

Field rehearsals with harvesters are essential to measure losses in real operating conditions. VIATOR et al. (2006) rehearse a harvester prototype in the fastest primary extractor speed and concluded that there was an increase in the sugarcane losses when compared with the extractor lower speeds. NEVES et al. (2004) used a visible losses monitoring system in a sugarcane harvester and concluded that the monitor allowed the monitoring of losses in function of the primary extractor rotation.

MAGALHÃES et al. (2008), while using a harvester and transship synchronizer, found a significant reduction regarding grinding wheel loss. NEVES et al. (2006) evaluated sugarcane invisible losses in the harvest and concluded that it was significant with the varieties rehearse.

RAMOS et al. (2014); SEGATO & DAHER (2011) studied sugarcane losses in mechanical harvesting and observed that it increases with increasing work speed. However, rehearsals found a linear correlation between operating speed and raw material losses in the field, according to (RIPOLI, 1996).

In this context, rehearsals performed by MAZZONETTO (2004); YADAV et al. (2002) showed that losses are related to work speed, crop spacing, variety, productivity and sugarcane plantation port variables and, according to NEVES et al. (2003); VOLPATO et al. (2002) it also occurs in function of the harvester base chopping system.

However, once raw material loss (indirect cost) is associated with machinery cost, which is called direct cost, this study has the aim to evaluate the economic impact caused by sugarcane loss in the mechanical harvesting process.

Material and methods

The methodology used in this study was computational modeling, as it was easier and with lower costs, not counting that it would be difficult to perform such a work under field conditions. Thus, it was decided to use the computer model called *"ColheCana"*, developed and validated in *Excel*® electronic spreadsheet, and in programming language by *Visual Basic*®.

Modeling was adopted because it simplifies reality (in field conditions), as it presents the best result as well as it makes possible to identify and evaluate possible problems that may occur in the sugarcane mechanized harvesting system. However, the model allows the identification and assessment of the impacts that affect production cost and the Reference Mill gross and net income through operational and economic performance variables.

The model was prepared with sugarcane mechanized harvesting system basic characteristics. The validation was performed through programming language routine verification and correction, and through the comparison of data generated in the simulations, with primary (gross) and secondary (bibliography) data. Variables sensitivity and model consistency analysis was evaluated according to production cost.

"ColheCana" has its basic operation presented by the flowchart in Figure 1, prepared in accordance with the characters proposed by OAKLAND (2007). The model starts (1)[1] its operation with data entries concerning culture (2): area, average productivity and crop spacing. In the following, it works with data entries related to technical/operational characteristics of the machine (3): rows number, work speed and efficiency of field.

The association of culture and technical/operational characteristics data determine the harvester operating performance (4): Operational field and production capacity, harvested sugarcane amount and total loss. Operational performance results associated with economic data entries in the machine (5) provides the calculation result of the harvesting system economic performance (6): fixed hourly cost; cost per area and ton; harvested sugarcane total loss cost; mechanical harvesting income.

The economic part entry data (5) refer to: initial and final value; equipment life; accommodation, insurance and taxes factors; repair and maintenance. Model results (7) allow the user to analyze production cost, sugarcane loss and the mechanized harvesting gross and net income, and decide (8) for viability (9) or not. In case it is not viable (10), or the user wishes to evaluate another

[1] Numbers in parentheses refer to the flowchart of Figure 1

scenario, new data must be entered for a new simulation.

The equipment considered for sugarcane mechanical harvesting system was a two-row harvester with an engine rated power of 251 kW (342 cv) and an estimated initial value of US$ 582,959.64.

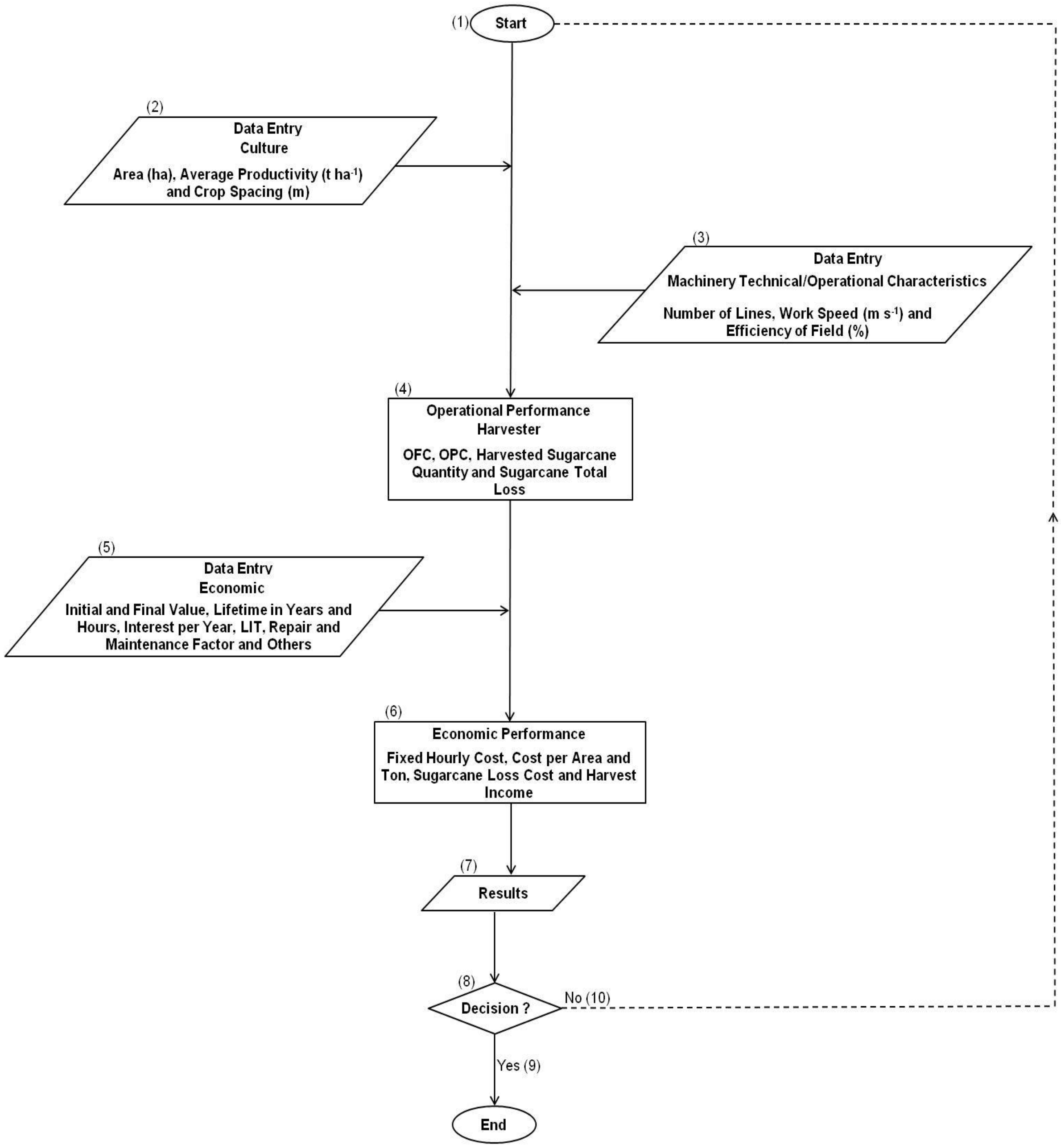

Figure 1 - Flowchart of operation of the *"ColheCana"*. OFC - (Operational field capacity), OPC - (Operational production capacity) and LIT - (Lodging, insurance and taxes).

The sugarcane mechanical harvesting system operational and economic performance, which is expressed by *"ColheCana"*, is based on ASABE (2011) and MIALHE (1974) proposals.

According to MIALHE (1974) methodology, the harvester operational field capacity (OFC) is calculated through the association with the harvester line number (HLN), cultivation spacing (CS), operating speed (OS) and efficiency of field (Ef), equation (1).

$$OFC = \left[\frac{HLN \times CS \times (OS \times 3.6)}{10}\right] \times Ef \qquad (1)$$

Where OFC is the harvester operational field capacity (ha h^{-1}), HLN is the harvester line number (one or two), CS is the cultivation spacing (m), OS is the operating speed (m s^{-1}) and Ef is the efficiency of field, in decimal.

The methodology of ASABE (2011) is used to calculate the machine fixed hourly cost (FHC), defined by the annual fixed cost (AFC) and the number of hours worked per year (NHWY), equation (2).

$$FHC = \left(\frac{AFC}{NHWY}\right) \quad (2)$$

Where FHC is the machine fixed hourly cost (US$ h^{-1}), AFC is the annual fixed cost (US$ yr^{1}) and NHWY is the number of hours worked per year (h yr^{-1}).

According to ASABE (2011), the machine hourly cost (MHC) is also determined, which is defined by FHC and the equipment variable cost (fuel, repair and maintenance) (EVC) sum, equation (3).

$$MHC = FHC + EVC \quad (3)$$

Where MHC is the machine hourly cost (US$ h^{-1}) and EVC is the variable equipment cost (US$ h^{-1}).

Through MIALHE (1974) the harvester operational cost (HOC) is calculated, being determined by the ratio between MHC and OFC, equation (4).

$$HOC = \frac{MHC}{OFC} \quad (4)$$

Where HOC is the harvester operational cost (US$ ha^{-1}).

According to MIALHE (1974) the equipment production cost (EPC) is defined, which is calculated by the ratio between MHC and the operational production capacity (OPC), equation (5).

$$EPC = \frac{MHC}{OPC} \quad (5)$$

Where EPC is the equipment production cost (US$ t^{-1}) and OPC is the operational production capacity (t h^{-1}).

Sugarcane total loss (SCTL) is calculated in function of OS, according to RIPOLI (1996), equation (6). In the bibliography (state of the art) there is no other equation to measure sugarcane total loss, even in function of work speed or other factors. This occurs due to the huge variability of sugarcane crops in the field, which makes the use of primary (gross) raw material loss data inconsistent and impractical in equations development. In the near future, this difficulty may be remedied through precision agriculture, using a yield monitor for sugarcane harvesters.

$$SCTL = -0.03228 + 3.03606 \times (OS) \quad (6)$$

Where SCTL is the sugarcane total loss (%).

The harvest gross income (HGI) is determined by sugarcane production (SCP), sugarcane ton price (SCTP) and the difference in sugarcane total losses (SCTL), equation (7).

$$HGI = \{(SCP \times SCTP) - [(SCP \times SCTP) \times (SCTL/100)]\} \quad (7)$$

Where HGI is the harvest gross income (US$), SCP is sugarcane production (t) and SCTP is the sugarcane ton price (US$ t^{-1}).

Harvest cost (HC) is calculated by the combination of HOC and the area to be harvested (AH), equation (8).

$$HC = HOC \times AH \quad (8)$$

Where HC is the harvesting cost (US$) and AH is the area to be harvested (ha).

The harvest net income (HNI) is defined as the difference between HGI and HC, equation (9).

$$HNI = HGI - HC \quad (9)$$

Where HNI is the harvest net income (US$).

Results and discussions

For the results, a Reference Mill with a 22,000 ha area, 80 t ha^{-1} average yield and 2.5 m dual row spacing was considered. The estimated price per sugarcane ton delivered in the field (and not in the mill) was of 23.78 US$ t^{-1}, according to UDOP (2012), and the efficiency of field reference was of 80%.

Figure 2 shows the two-row harvester production cost in two operating conditions: harvesting without sugarcane loss and with losses, with the latter resulting from work speed under normal conditions. It is observed that at low operating speeds, 0.56 m s^{-1}, the production cost was of 4.15 US$ t^{-1} and 4.08 US$ t^{-1} for the harvester operating with and without losses, respectively, providing a relative difference of 1.71%. The values are almost equal and losses in that speed correspond to 1.65%, resulting in the Mill gross and net income of US$ 41,168,606.42 and US$ 31,948,106.06, respectively, with a relative difference between it in the order of 28.86%.

Relevant to mechanized sugarcane harvesting rehearsals, NERY (2000) rehearse a single row machine, with a working speed of 0.37 m s^{-1} and recorded total losses of 6.10%. With the same harvester type, GARCIA & SILVA (2010) rehearse the operation speed of 1.39 m s^{-1}, which resulted in losses on the order of 4.18% after simulated. Under these conditions, while simulating the respective speeds with a two-row machine, the production cost with and without losses was of 8.88 and 8.34 US$ t^{-1}, 8.28 and 7.93 US$ t^{-1}, with a relative difference of 7.25 and 5.58%.

With increasing operating speeds, it is observed that losses are linearly increased and the production cost decreases, due to the higher operating capacity obtained. To a 1.39 m s^{-1} speed, losses represent 4.18%, with a difference in the cost with and without losses of 0.08 US$ t^{-1}. Under these conditions and with a 1,760,000 t production to be harvested, losses correspond to US$ 1,854,375.46. However, raising the work speed will provide gain in operational and economic performances, although it is important to consider whether sugarcane losses will be detrimental to the Mill income.

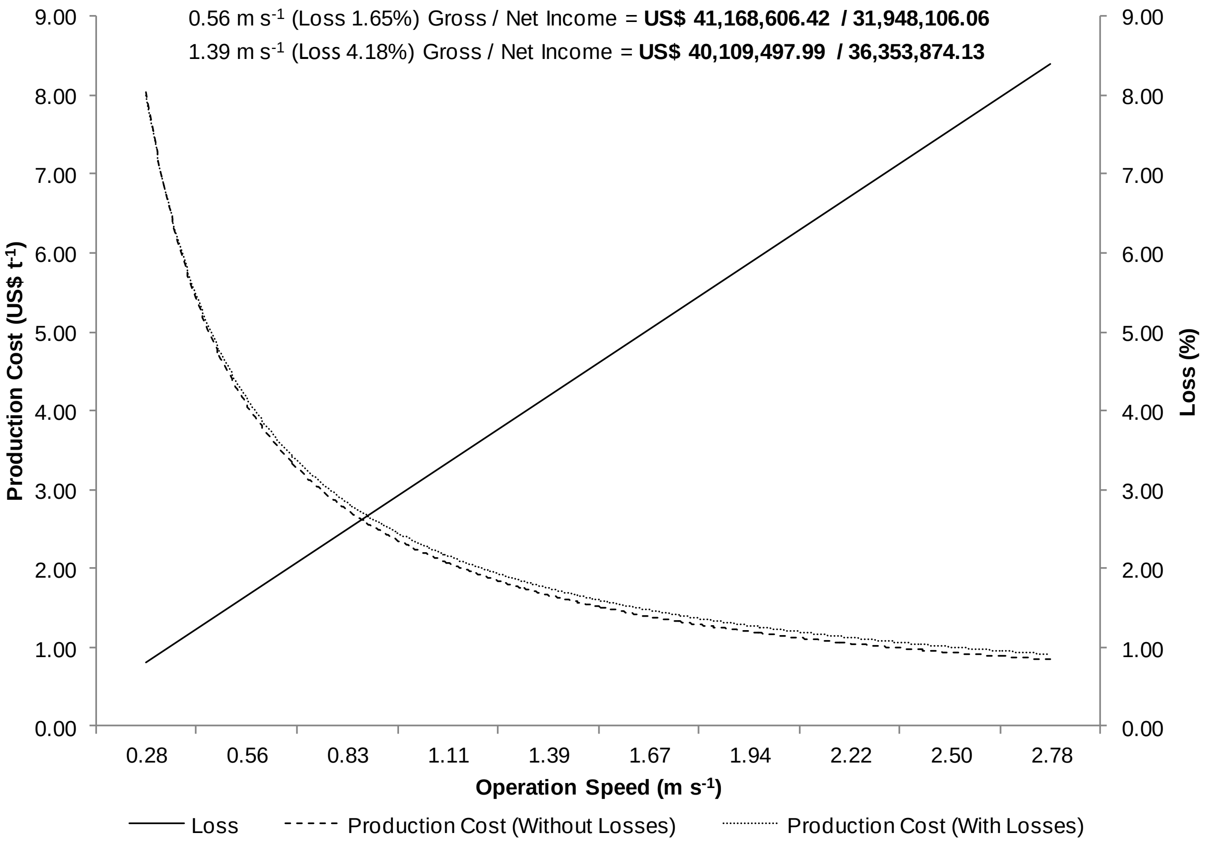

Figure 2 - Simulation of the production cost of the harvester and sugarcane loss in function of the operation speed.

Curves intersection shows that from that corresponding operating speed, raw materials losses increase significantly, providing a tendency of an increase in the difference between production cost with and without losses. The optimal point is in the work speeds of 0.56 and 0.83 m s^{-1}, with losses of 1.65 and 2.50%, respectively, as it is when the production costs with and without losses are significantly reduced. Thus, it is proved by BENEDINI et al. (2009), who classified sugarcane losses of less than 2.5% as low, between 2.5 and 4.5% as average and above 4.5% as high.

Conclusions

The increase in the machine operating speed increases the machine operating performance, reduces production costs and increases sugarcane losses.

Low operating speeds present lower raw material losses and provide a higher gross income to the Mill.

"ColheCana" is viable, because it meets its objective-function, leading to results that correspond to reality, which can be used for Mills agricultural management.

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