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Optimizing Transport Fleet Size for Mechanized Sugarcane Harvesting

Optimización de la flota de transporte en la cosecha mecanizada de caña de azúcar

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ABSTRACT: This study aims to determine the optimal number of transport vehicles required for mechanized sugarcane harvesting, considering different transport distances, field yields, and the capacity of the 60-ton transport vehicles used. The DCMT automated system was used for the evaluation. This system employs the maximum time utilization coefficient as its optimization criterion, ensuring that the harvester does not stop during harvesting due to a lack of transport vehicles, thus maximizing the synchronization between them. The results revealed that the number of 60-ton transport vehicles required, depending on the distance, varies between 3-4, 3-5, and 3-7, for yields of 40, 60, and 80 t/ha, respectively.
Keywords: Sugarcane, Harvest Logistics, Harvest Modeling, Time Efficiency, Agricultural Transport.

RESUMEN: El presente trabajo tiene como objetivo determinar la cantidad de medios de transporte óptima, en el proceso de cosecha mecanizada de la caña de azúcar, para diferentes distancias de transportación, rendimiento del campo y capacidad de los medios de transporte empleados de 60 t. Se utilizó para la evaluación el sistema automatizado DCMT el cual emplea como criterio de optimización los máximos valores del coeficiente de utilización del tiempo, garantizando que la cosechadora no se detenga durante el corte por falta de medios de transportes, es decir, que la sincronización entre estos sea la más racional. Los resultados revelaron que la cantidad de medios de transporte de 60 t en función de la distancia, varían entre 3-4, 3-5 y 3-7, para rendimientos de 40, 60 y 80 t/ha respectivamente.
Palabras clave: caña de azúcar, eficiencia del transporte, logística de cosecha, modelación de la cosecha, transporte agrícola.

INTRODUCTION

Mechanized harvesting is one of the most important stages in sugarcane production. Its objective is to collect the available raw material in the field with minimal losses and high efficiency, guaranteeing a timely supply of sugarcane in sufficient quantity to the mill, with the shortest possible time between harvesting and milling, low levels of foreign matter, and the lowest possible costs. All of this is aimed at obtaining high-quality sugar at competitive prices. Its impact on production costs has always been significant, so any variation at this stage will have a major impact on the profitability of the crop. Therefore, as a process, it demands a high degree of organization and coordination of all the factors involved, from the field to the weighbridge (López *et al.*, 2021; 2022).

The harvest-transport process does not directly influence the sugarcane production process itself, but it does determine the economics of the production process. This is because the process relies on a set of technical resources, including harvesters and means of transport (tractors and/or trucks with trailers or carts), which, if not rationally organized, negatively impact total production costs (Rodríguez *et al.*, 2019).

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According to Castillo *et al.* (2021), evaluations of agricultural machinery are generally carried out according to standard NC 34-37 (2003), using the photo-time method. This allows for the identification of the times used in the production process and the definition of performance indicators for agricultural equipment and self-propelled machinery (sugarcane harvesters). Among these studies are those conducted by the following authors: Suárez *et al.* (2006); Matos & López (2011); Daquinta *et al.* (2014); de La Rosa et al. (2014) and others.

At the "Héctor Molina Riaño" Basic Business Unit, problems have arisen not only in the industrial sector, but also in the organizational and production areas (Rodríguez *et al.*, 2019).

In the case of transportation, the biggest problem is defined by the high rate of transportation interruptions, which averages around 50%. This is due to waiting for sugarcane deliveries, combine harvester breakdowns, and waiting to unload at the tipper (Suárez *et al.*, 2006; Matos *et al.*, 2010; Matos & López, 2011).

With a view to determining the optimal number of transportation vehicles de las Cuevas et al. (2016), developed the SMCTCA mechanized system, which performs an analytical modeling of the sugarcane harvesting and transportation process. This modeling determines the system's operational and economic indicators for different organizational and production conditions of the technological process.

Subsequently, de las Cuevas et al. (2022; 2024), developed an automated system and a mobile application to determine the amount of transportation resources needed for mechanized sugarcane harvesting.

These systems allow for the rapid, accurate, and reliable evaluation of the quantity of transportation resources required for the conditions established in the technological process analysis. Considering the above, the objective of this work is to determine the optimal quantity of transportation resources in the mechanized sugarcane harvesting and transportation system for different transportation distances and field yields.

MATERIALS AND METHODS

Characterization of the technological process of the mechanized sugarcane harvesting and transport system.

During the sugarcane harvesting by the combine harvester, a tractor with a self-dumping trailer moves parallel to it while being filled. Subsequently, the tractors, fully loaded, travel to the head of the field, filling the truck and the trailers attached to it, where the trailer trains are formed. Next, the truck is transported to the mill's tipper where unloading takes place.

Methodology used for the development of the CMT application

To determine the number of transport vehicles, the automated DCMT system (de las Cuevas et al., 2022) was used. The maximum values of the time utilization coefficient during the technological process were chosen as the optimization criterion, ensuring that the combine harvester does not stop during harvesting due to a lack of transport vehicles; that is, that the synchronization between them is the most efficient.

Using DCMT software, different trials were conducted for various operating conditions and transport capacities of 60 t (20 t in the truck and two 20 t trailers). Performance curves were defined for different distances from the field to the mill's tipper (20, 30, 40, 50, 60, 70, and 80 km) and six field yields (40, 60, and 80 t/ha).

RESULTS AND DISCUSSION

The analysis of the variation in the optimal number of transport vehicles, based on the criterion of maximizing the time utilization coefficient of the combine harvesters, was conducted using the automated DCMT system.

The evaluation was performed on the CASE combine harvester, for field yields of 40, 60, and 80 t/ha, with 60-ton capacity transport vehicles and distances from the field to the tipper up to 80 km.

Figure 1 shows the behavior of the number of 60-ton transport vehicles (Cmt) as a function of the distance from the field to the tipper at the central facility, measured in kilometers.

It can be seen that the most optimal number of transport vehicles (Cmt) for a field yield of 40 t/ha is three up to 40 km, and subsequently increases to four from 50 to 80 km. This behavior is acceptable, since as the transportation distance increases, a greater number of transport vehicles is needed to ensure a stable time utilization coefficient (TUC) of around 80%. This allows for stable harvester productivity and minimal operating costs for the mechanized sugarcane harvesting and transport system.

For field yields between 60 and 80 t/ha, a similar pattern occurs. The difference is that the number of transport vehicles is greater with higher yields. Figure 1 shows that for 60 t/ha, the TUC values vary between three and five. And for 80 t/ha, between three and seven 60-ton transport vehicles are required.

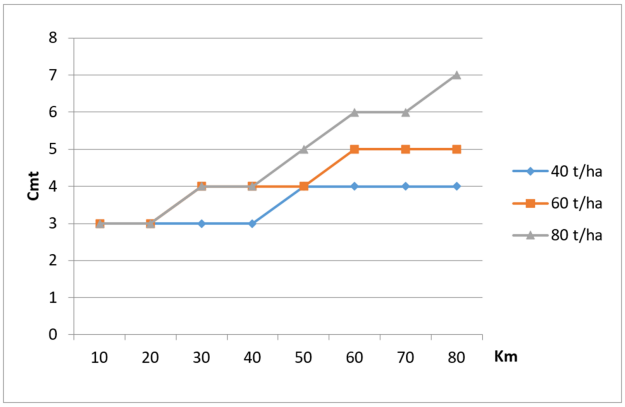


Figura 1. Cantidad de medios de transporte (Cmt) en función de la distancia.

CONCLUSIONS

- The automated DCMT system allows for defining the number of transport vehicles, based on the criterion of maximizing harvester utilization time, in the mechanized sugarcane harvesting and transport system, for different operating conditions.
- The number of 60-ton transport vehicles, using the CASE combine harvester, for distances between 20 and 80 km and a yield of 40 t/ha, varies between three and four.
- The number of more efficient transport vehicles increases to between three and five; and to between three and seven, for yields between 40 and 80 t/ha, respectively.

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