A MODEL TO ESTIMATE COMBINE HARVESTER AND INFIELD TRANSPORT PERFORMANCE AND COSTS

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Abstract

A user friendly, computer based program has been developed to estimate the performance and cost of sugarcane combine harvesters and associated infield transport vehicles. The model was originally developed to assess the effect of various field parameters, infield cultural practices and also the number and capacity of infield transport vehicles on harvester output. A costing program was subsequently added to the model to estimate the impact that these factors have on overall harvesting and transport costs. The model has demonstrated that factors such as cane yield, crop condition, field layout, agronomic practices and the number and capacity of haul-out vehicles have a pronounced affect on the performance of combine harvesters. The model is a useful tool for assessing the viability of introducing a fully mechanised harvesting system under different agronomic and management situations.

Keywords: mechanical harvesting, sugarcane, harvesting, model, modelling

Introduction

South African sugarcane growers first showed interest in chopper harvesting systems during the early seventies, but these fully mechanised harvesting systems were not widely accepted for various reasons, including their inability to compete economically with manual labour based harvesting systems. However, with rising labour costs and, in some regions, a labour shortage or unwillingness to harvest cane manually, there has been, in some areas of the industry, a resurgence of interest in combine chopper harvesting systems.

During the past season several combine harvesters were again imported into the country. It was decided, following many grower enquiries as to harvester performance and harvesting costs, to develop a model to assess the effect that crop and field conditions impose on harvester performance. Computer based harvesting-transport models have been developed and used successfully in the sugar industries of both Australia (Ridge and Dick, 1985; Ferguson and Wise, 1987) and Louisiana (Salassi and Champage 1996). However, when this project was initiated, the models were not available to South African growers.

On successfully completing this first module of the program, it was decided to add value to the model by attaching a machinery costing module. Its incorporation enables the user to evaluate immediately the effect on total harvesting costs that the many crop, field and harvester and infield transport variations and options have.

The model

The model has been developed to operate as a spreadsheet-based program using LOTUS 123 (5) or Microsoft Excel software for Windows 95. Both packages are in widespread use and offer powerful modelling possibilities.

Model inputs

Crop, field and operational inputs

Numerous factors affect the performance and cost of a chopper harvester system. The main factors can be listed as follows:

Harvester	Infield transport
Cane yield	Number of transport units per harvester
Row length	Payload capacity
Row spacing	Haulout distance
Harvesting speed	Harvesting rate
Turning time	Travelling speed
Haulout distance	Turning time
Waiting for infield transport	Offloading time
Down time	Down time.

Global factors that are common to both the harvester and infield transport include:

Annual cane tonnage throughput
Operating hours per day
Length of milling season
Field and cane conditions.

All the above factors are considered in the model, and can be altered at will to match local or simulated conditions.

Machinery inputs

Machinery inputs such as purchase price, interest rate, operator, fuel and tyre costs are entered and can be changed at will, when different machines or options are evaluated.

Machinery costing method

This is based on the classical costing procedures (de Beer and Booysen, 1977; Salassi and Champage, 1996). Fixed costs include depreciation, interest on capital invested, licence, insurance and the operator. Variable costs cover fuel, tyres, maintenance and repairs.

When the annual usage of the machine has been calculated by the first module, the second module determines the machine's estimated average annual ownership and operating costs, based on numerous parameters inserted into the costing sections of the model. Once again, all the costing parameters can be varied selectively if so required. On completing the assessment, a hard copy of the exercise can be printed out.

Typical model outputs

Using the model, it is possible to select and change various factors that influence harvester performance. The effect that row length and cane yield have on harvester performance is graphically illustrated in Figure 1. This assumes that other operational parameters such as harvesting speed and turning time remain constant, and that infield transport is not limiting.

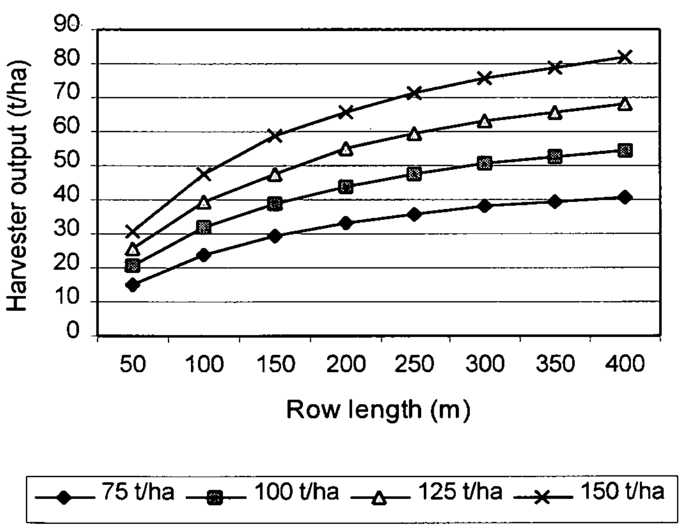

Figure 1. Harvester performance versus row length and cane yield.

As can be seen from Figure 1, row length has a significant impact on harvester performance. When fields of average row lengths varying between 50 and 400 metres are harvested, harvester output increases by about 166%, irrespective of cane yield, provided the harvester's forward speed remains constant. However, in practice one would expect the harvester's forward speed to be higher for the lower yielding crops.

Another factor that influences harvester output is its forward speed. The effect of harvester forward speed and row length on harvester performance, based on a cane yield of 100 t/ha, a row spacing of 1,5 m, constant turning time, and assuming and that infield transport is not limiting, is shown in Figure 2.

It can be seen that that harvester output increases by 140, 167 and 191% when speed increases from 4 km/h to 5 km/h and 6 km/h respectively for row lengths varying between 50 and 400 metres. It has been shown that harvesting rates increase and costs decrease to a row length of approximately 500 m, after which cutting rates decrease and costs increase slightly due to additional travel time for haulouts entering and leaving the field (Ridge *et al.*, 1996).

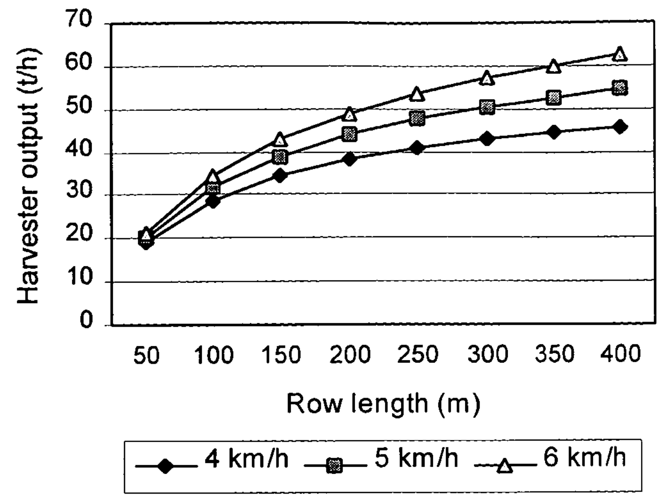

Figure 2. Harvester output versus row length and harvesting speed.

One of the most important factors determining the viability of introducing a fully mechanised chopper harvesting system is cane throughput per machine (Meyer, 1997). Using the model and given acceptable input standards, it is relatively easy to predict harvesting costs and daily operating times for a range of annual tonnages. An example based on various constant parameters such as harvesting speed, turn time, haulout distance and non-limiting infield transport capacity (3 x 6 ton haulouts), is shown in Figure 3. The trends shown are supported by Australian researchers (Brennan *et al.*, 1997) using a 'throughput-cost' model, which clearly showed that by increasing group size harvesting costs were significantly reduced.

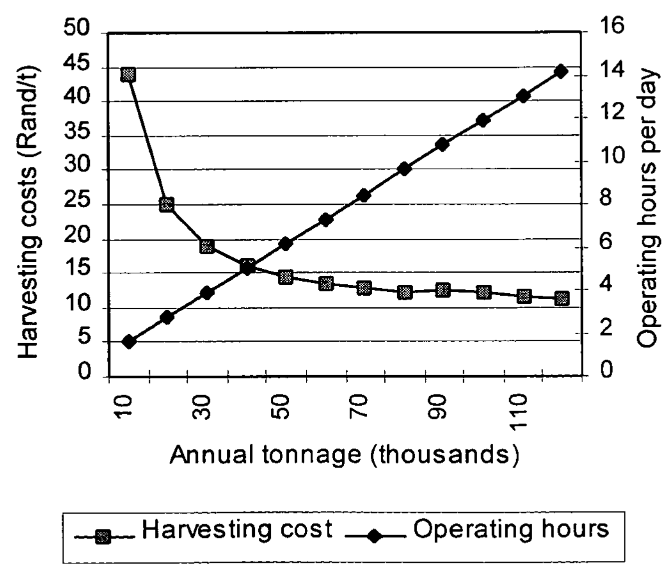

Figure 3. Harvesting cost versus annual cane throughput and daily operating hours.

Using a similar model, researchers in Australia showed the effect of different haulout systems and haulout distances on the percentage of harvester cutting time lost due to waiting for infield haulout units and harvester hourly cutting rates (Ridge and Dick, 1985). In more recent research a 'harvest-transport' model has been successfully used to illustrate the effect of increased haulout vehicle capacity on harvester throughput (Ridge *et al.*, 1996).

Conclusions

A wide range of factors affect the performance of chopper harvesters and the accompanying infield transport systems. This user friendly model has not only proved an effective research tool, but should also provide useful information to contractors, estate managers, machinery operators, farm planners and machinery agents in evaluating the factors affecting harvester and infield haulout units. It should help also in assessing the overall viability of introducing a fully mechanised harvesting system for varying agronomic and managerial situations.

It has been shown that the model, which has been verified by time and motion studies, can be used successfully to estimate with reasonable accuracy the performance of a combine harvesting system. The ultimate success of a chopper harvesting system for sugarcane will depend on the practical expertise of those responsible for field and mill operations. In order to achieve success, managers need to have before them a set of objectives that will lead to the desired financial outcomes. The training of supervisors and operators to produce the desired results cannot be overlooked if one wishes to leave the field ready to produce another crop, avoid excessive losses, and to deliver quality cane to the mill in a timely manner at an acceptable cost. The model is one of the means at his disposal of setting these standards and goals.

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