TECHNOLOGICAL IMPROVEMENT ON SUGAR CANE YIELD MONITOR

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ABSTRACT

This paper presents the technological improvement on sugar cane yield monitor. The system designed employs load cells as an instrument for weighing billets, set up on the side conveyor of the harvester before the sugar cane billets are dropped into a field transport wagon. This data, along with the information gathered by GPS installed on the harvester, enabled the elaboration of a digital yield map using GIS. In order to improve the yield monitor a re-design of the first prototype was accomplished. To evaluate the accuracy of the yield data obtained, field tests were carried out during 2006/2007-harvest season. The weight attained showed a mean error of 8.7 %. A yield map of 28.1 ha area plot was drawn. The yield monitor was tested during six months without presenting any fault, evidencing that the technological alterations performed on the equipment made it more robust and reliable.

Keywords: **S**ugar cane harvester, yield map, weighing instrumentation

INTRODUCTION

Sugar cane growing in Brazil covers an area of 6.2 million hectares in almost all States, reaching a production of approximately of 470 million tons during the 2006/2007 harvesting season (CONAB, 2006), which represents a quarter of the world production. From that on, 423.4 million tons (90.1 %) are used for sugar or alcohol production and the remaining 46.4 million tons are used for other purposes such as animal feeding, stem sections for planting, manufacturing of cane spirits, etc. Brazil is now witnessing a huge expansion in the sector, new areas are being converted into sugar cane crops, and at least 50 new sugar mills/distilleries are currently under construction.

Although highly mechanized, this crop has yet been well explored by precision agricultural techniques. Moreover, the most important information for the implementation of precision agriculture (PA) is the yield map (Molin, 2001), which is usually determined by employing a specific yield monitor. Magalhães & Cerri (2007) have presented a yield monitor specifically designed for the implementation of precision agriculture within sugar cane crops. The overall system includes a mass flow sensor, a global positioning system receiver, and a data acquisition system. The system was mounted on a sugar cane harvester, and in order to evaluate the accuracy of the system, each loaded truck was weighed on an electronic platform scale upon arrival at the sugarcane mill. The results showed that the output of the sugar cane yield monitor and the harvested load weight hold a good correlation. The performance of the system was stable during tests, though it was evident that some improvements were required in order to turn it into a more reliable one.

MATERIALS AND METHODS

The working method

The Sugar Cane Billets Weighing System (SCBWS) developed employs load cells as instruments for weight determination of harvested raw material and can measure the flow of sugar cane billets transported by the conveyor before dropping them into a field transport wagon. This data, along with the information obtained from a GPS installed on the harvester and aided by a GIS, enable the elaboration of a digital map that represents the production surface of the harvested area. Besides this equipment, sensors installed on the machine indicate the conveyor rotation, the elevator angle and the operational status. This information is essential for the dedicated software, installed on an embedded computer located inside the cabin of the harvester, to administer the information in order to eventually generate a database that represents the yield of the harvested area. This equipment assembly that has been named "Sugar Cane Yield Mapping System"(SIMPROCANA) was installed on the harvester as shown in Figure 1.

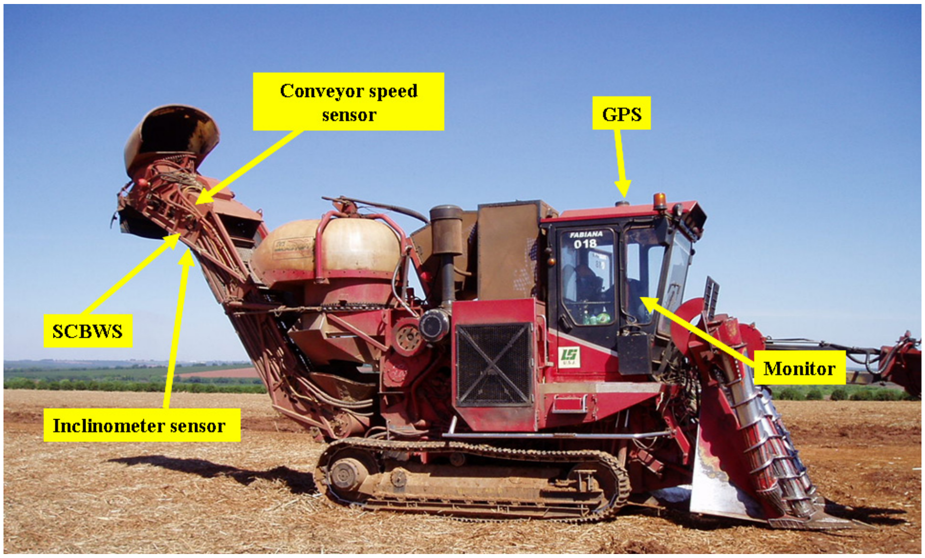

Fig. 1. Harvester adapted with the yield mapping system.

On-board Electronics

Besides the sensors and the equipment described under The Working Method item, two micro-controlled modules connected by a CAN bus were installed on the machine.

The first module, placed on the harvester elevator, receives the signals from the two load cells of the SCBWS, from the accelerometer that measures the inclination of the elevator angle and from the speed sensor located on the conveyor. The signals are processed on this module, and sent by CAN bus to the second module, which has been installed inside the cabin of the harvester. This second module receives the signals from the status sensor located on the harvester, processes these and converts the information into an RS-232 serial interface. The software installed in the embedded computer (Figure 2) located inside the cabin of the harvester, receives the information from the serial interface, and calculates the weight of the harvested sugar cane, the harvested area, and the yield. The results are displayed on an interface graphics and are saved on a database along with the geographical information obtained by the GPS. The GPS employed is a Trimble Ag114 model with differential correction signal provided by OmniSTAR.

Fig. 2. Embedded computer located inside the cabin of harvester.

SCBWS re-design

Aiming at converting the SCBWS into a more robust one for operations under adverse field conditions without the need for the intervention of specialized labor, the re-designing of the system was carried through. This work was accomplished based on previous experiences and on the observations of tests performed under factual harvesting circumstances. The new system includes a safety system to avoid an overcharge on the load cells in the SCBWS, an adjustable mechanical set point which limits the maximum load on the transducer, a protective system against strange matter (straw, sugar cane, soil) and the covering of the weighing plate with UHMW material (Ultra High Molecular Weight), which has a high resistance to abrasive and a low friction coefficient.

During this stage, the structure for fixing the weighing system onto the harvester elevator floor was designed in a way that makes possible its installation on any harvester, by replacing the original floor for the one equipped with the weighing system. In Figure 3, the SCBWS assembled on the harvester elevator can be seen.

Fig. 3. Weighing system installed on the harvester.

Accuracy evaluation of the system

In order to evaluate the accuracy of the yield data obtained from SIMPROCANA, field tests were performed during 2006/2007 harvesting season, on a 28 ha area at the São Domingos Mill, located in Catanduva/SP. Thus, a comparison was carried out between the sugar cane weight measured by the SIMPROCANA weighing system and the one obtained by weighing the field wagons with the help of a DIGITRON model UL-PSR 20,000 kg x 5 kg scale (Figure 4) specially designed for this purpose.

Fig. 4. Scale for weighing the field wagon.

The data obtained from the weighing of each field wagon assembly was considered as real weight and the data from the system SIMPROCANA during the filling up of each wagon assembly was considered as calculated weights. From these two values, the error in percentage was calculated and the correlation between them was verified.

Besides the weighing of the field wagon, a crop row was randomly chosen in order to evaluate the accuracy of the system and the time of response. Within this row, a length of 50 m was also randomly selected where the sugar cane was cut by hand at ground level. A graph indicating the productivity over time as well as the starting and finishing points of the yield alteration was drawn, employing the data stored by the system.

In order to generate the yield map, the total area was divided into smaller sections, named cells, and assuming an average speed of harvester of 1.38 $m.s^{-1}$, a distance between sugar cane rows of 1.5 m, and a sample rate of 10 s., the average cell size may well be estimated as approximately 20 m^2.

The sugar cane productivity was measured within each one of these cells. In doing so, a XML file was generated, displaying the following variables: a) acquisition number, b) timetable, c) latitude and longitude of central points of each cell, d) the speed of harvester ($m.s^{-1}$), e) accumulated weight (Mg), f) harvested area (m^2), g) yield ($Mg.ha^{-1}$).

The XML files were transformed into one unique file to be tabulated on an Excel chart. Due to the automation and the large amount of information obtained, several mistakes occurred during the harvest process. The elimination of these mistakes is an important factor for achieving a good quality result (BLACKMORE & MARSHALL, 1996). Thus, before generating the yield map, the filtering stage of the gross data, was carried out in order to eliminate points with yield values out of the established limits, according to the methodology proposed by Tukey (1977), which determines the superior and the inferior limits for discrepant data based on the first and the third quarter.

After filtering the data, a new file with DBF extension was created, which was employed by the ArcGis 8.3 geographic information software for designing the yield map of the harvested stretch.

RESULTS AND DISCUSSION

The correlation between the real weight and SIMPROCANA results can be observed in Figure 5.

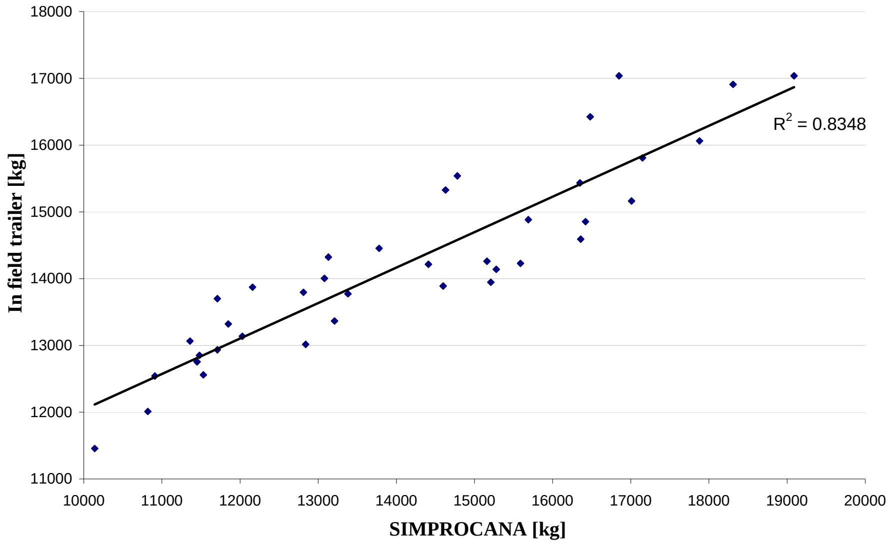

Fig. 5. Correlation between SIMPROCANA and the field wagon weights.

According to Figure 5 it is observed that, the correlation coefficient between the weight measured by SIMPROCANA and the real weight of each field wagon was 0.83 and from this data, it was possible to calculate the mean error in percentage, which was 8.7 %. In order to improve this error that may have been caused by some low vibration from the harvest movement, an accelerometer for dynamic weighing compensation was developed and will be tested next season.

The graph in Figure 6 shows the test result where a length of 50 m within a sugar cane row was cut by hand to identify if the system was sensitive enough to detect this yield alteration.

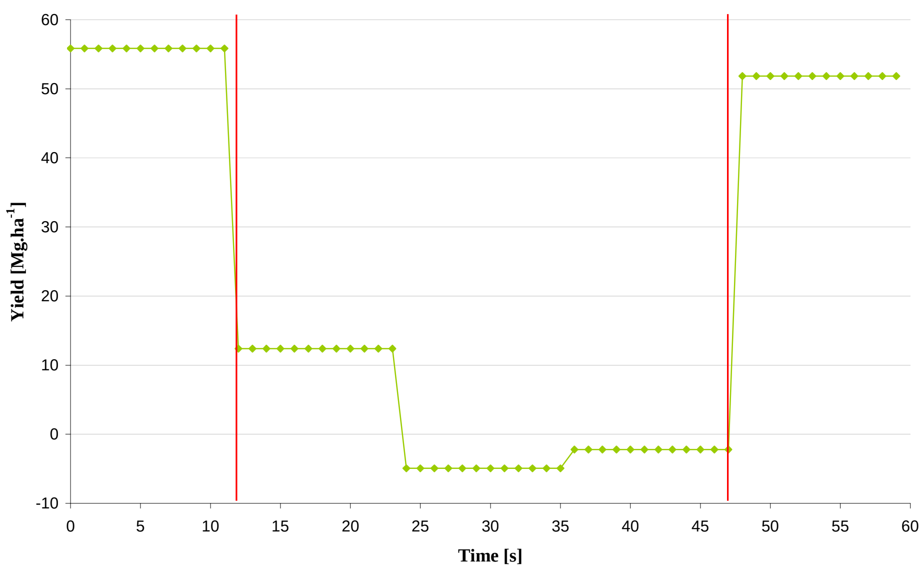

Fig. 6. Response of a system to the yield alteration; the red lines represent the beginning and the end of a stretch where sugar cane was harvested by hand.

By analyzing Figure 6, it may be noticed that SIMPROCANA responded to the abrupt alteration in yield within a range, and that the productivity within the area where there were no sugar cane planted varied between 14 $Mg.ha^{-1}$ to -6 $Mg.ha^{-1}$. It was observed that the first 10 s after entering in the area with no sugar cane, the system abruptly reduced the yield, however not down to zero. This may be justified due to some remaining sugar cane billets inside the harvester still being processed.

Figure 7 evidences the geo-referenced points at the end of the filtering of data for an area of 28 ha.

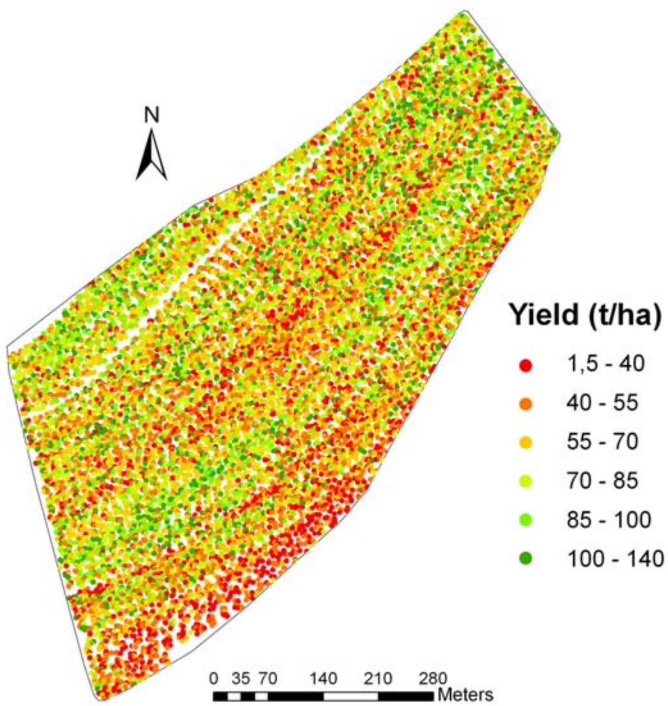

Fig. 7. Sugar cane yield ($Mg.ha^{-1}$) in geo-referenced locations related to the filtered data.

Figure 8 shows the sugar cane yield map obtained by kriging interpolation method.

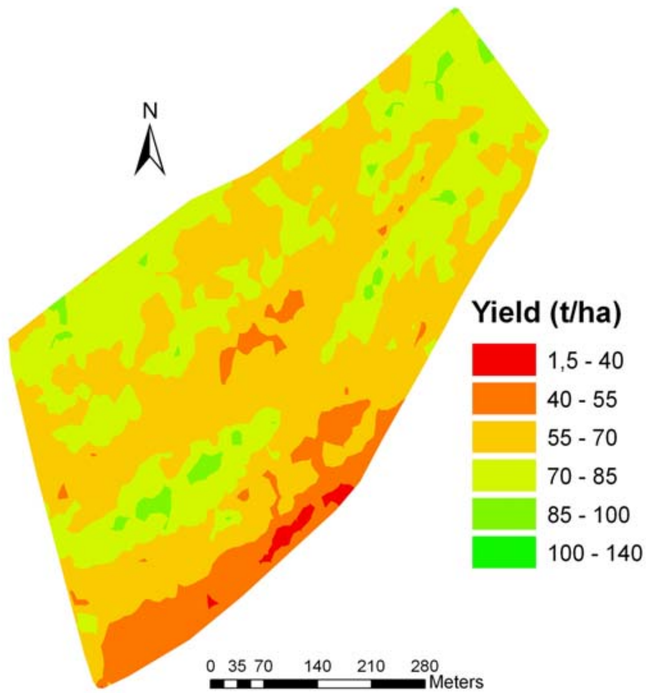

Fig. 8. Sugar cane yield map of 28 ha area.

In analyzing the map shown in Figure 8 and by the statistical analyses of the data performed by ArcGis, it is observed that the average yield was 72 $t.ha^{-1}$.

CONCLUSIONS

This paper has described the design of a sugar cane yield monitor and its performance. The results show its potential to be employed in precision agriculture. Performance evaluation reports that mean error detected without any compensation was 8.7 %. In order to improve these errors an accelerometer for dynamic weighing compensation is being designed and will be tested next season. The results show that the SIMPROCANA is sensitive to display the spatial variability of the sugarcane production. The yield monitor showed an acceptable correlation with the harvested load weight (coefficient of correlation 0.83) and the performance of the system was stable and reliable during tests.

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