Characterization of harvesting systems and development of yield maps for citrus

J.P. Molin, L.S. Mascarin, F.P. Povh, J.R. Amaral, A.S. Oliveira

University of São Paulo, Dept. of Rural Engineering, College of Agriculture – ESALQ/USP, Av. Pádua Dias, 11, Piracicaba-SP, Brazil
jpmolin@esalq.usp.br

Abstract

Citriculture is important for the Brazilian economy due to its expressive participation on exporting and for the generation of a number of job positions. Routine generation of yield mapping for citrus is necessary for implementing precision agriculture practices. The objective of this research was to promote the correct understanding of harvesting systems, their useful characteristics and limitations, also propose and test a methodology for collecting data to attain yield maps without interfering in the process. A method was evaluated and the results were considered acceptable; the method is considered simple and efficient for data collection and yield maps generation.

Keywords: orange, precision agriculture, data acquisition.

Introduction

Brazilian citriculture activity generates a great number of job positions and is important to the economy due to its expressive participation on exporting. According to FAO (2005), the orange world production is 63 millions of t, with Brazil in first place, producing 18.2 millions of t, followed by USA, Mexico, India and China. The cultivated area with orange in Brazil is approximately 820.300 ha distributed in 27 thousand rural properties. Manual harvesting is nowadays realized in all of this area and it requires a great quantity of labor.

Generating and collecting the right data related to spatial variability of crops followed by the correct interpretation is the most difficult and important stage of precision agriculture, always seeking the factors responsible of the variability, and the intervention when viable, or coexistence when they are not economical and practical.

The absence of techniques and resources for yield maps generation in citrus is one of the difficulties of a wider precision agriculture system implementation. It creates barriers to adoption of integrated management strategy of inputs and outputs, and do not allow the measurement of variable rate technology effects, which would in return justify the effort of using techniques and equipments for citrus yield maps generation.

Initial works for orange yield mapping were realized by Whitney et al. (1998). Horrom (2000) defined management zones in fields, monitored for five years, with a yield monitor installed in a mechanical harvester, in Florida citrus. Two weighting systems were compared by Miller & Whitney (1998), one using load cells under the truck and another with load cells in the hydraulic arm used to load the truck. The methods showed to be adequate, but presented limitations which required improvements. In Brazil, Balastreire et al. (2002) used a weighting system of big bags with load cells, which was adequate but not practical.

The objective of this work was to develop and test a procedure for data acquisition for yield mapping, seeking for simple and efficient procedures, which would respect manual harvesting routines in place.

Materials and methods

Nowadays the determination of product quantity harvested, in order to realize the payment is estimated with a technique where the responsible of a team (pointer) uses a graduated ruler (Figure 1) and measures, at the end of a journey, the volume of fruits harvested every day by each worker, who each one fills separated bags. The ruler is graduated by boxes (27.2 kg) where he measures the big bags height, estimating the volume that the fruits represent.

Figure 1. A graduated ruler (boxes) used by the pointer for estimating the amount of fruits harvested by each worker.

With the intention of determining the level of success and reliability of the estimation, 65 big bags were weighed from two different harvest teams (1 and 2). The estimated mass was obtained by the pointer and the weighting was made with a load cell LU – 2TE (Kyowa Electronic Instruments), previously calibrated in the lab, and installed in an agricultural tow attached to a tractor. Each big bag was raised and the mass reading was taken from a digital display after stabilization.
Data were statistically analyzed using Student’s t-test and dispersion graphics between the two treatments. Regression equations were obtained, with variance analysis by F-test for linear function, hypothesis test with 5% significant level and coefficient of determination (R^2). For the comparative analysis of mass error estimated by the pointers between the harvest teams, it was obtained the difference between treatments for each harvest team and the difference between the teams.
Later on a field was monitored at harvesting. It consisted in georeferencing all the big bags using a GPS receiver AgGPS 132 (Trimble Navigation Limited) and obtaining the estimated mass by the ruler method, realized by the pointer at the same time in a 15.9 ha field (22º24’S, 48º04’W). The 14 years old orchard had plants approximately 3.7 m

high and canopy width of 4.7 m, planted with the orange variety "Valência", spaced 3.5 m between plants and 7.5 m between rows, totalizing 5.796 plants.
To determine the yield attributed to each big bag its area was determined as the half distance between two points multiplied by the harvest strip width, usually 30 m, equivalent to the number of rows from each harvest front. Yield values were found dividing the estimated mass by the contribution area of each big bag.

Results and discussion

The results obtained with the mass measurements of big bags realized with the load cell and the estimation made by the pointer with the ruler method, for both harvest teams is presented on Table 1. It shows that group had no statistical difference for both teams and the coefficients of variation were similar. The difference between treatments showed that, on average, the estimated mass of team 1 was 19.25 kg and team 2 was 22.71 kg lower than the load cell values. The difference, from a total of 65 bags of each team was of 3.42% and 3.89% for team 1 and 2, respectively. Statistical analysis from the differences obtained from the subtraction of estimated values and load cell mass values from teams 1 and 2, -19.25 kg and -22.71 kg, respectively, was not significant.

Table 1. Descriptive statistics of big bags mass from the two harvest teams.

		Estimated by the pointer (kg)	Load cell (kg)	Difference (kg)
Team 1	Mean	540.69 a*	559.95 a	-19.25 A**
	CV (%)	26.03	26.55	
	Sum	35,145	36,396	-1,251 (3.42 %)
Team 2	Mean	560.15 a	582.87 a	-22.71 A
	CV (%)	23.98	22.29	
	Sum	36,410	37,886	-1,476 (3.89 %)

* Means fallowed by the same lower case letters in lines have no significant difference with 5% level by t-test
** Means fallowed by the same capital letters in rows have no significant difference with 5% level by t-test

It is clear that differences refer to the pointer, always estimating lower values, avoiding attributing a value over the real, what may create problems when computing the mass of each harvester and consequently in his payment; any mistake is responsibility of the pointer and is discounted from his payment.
The regression graphics between the estimated weight from the pointers and the load cell weights are presented in Figure 2, showing a linear behavior statistically significant with positive inclination and an $R^2 = 0.96$ for both harvest teams. It indicates that the estimation quality do not depend on the person who realizes it, however, it must be considered that both pointers were already well trained. Adjustments to the consistent error observed are easy to obtain by eliminating the risk and the estimation may result in even better information.
Another way to obtain mass information from bags would be using load cells in the loader. Considering the current operation, measurements must be done dynamically, with the loader arm under movement. In the beginning of the project a load cell was installed on the loader arm for a test. Many difficulties were observed and the conclusion was that the work done by the loader is too fast and abrupt, not allowing the

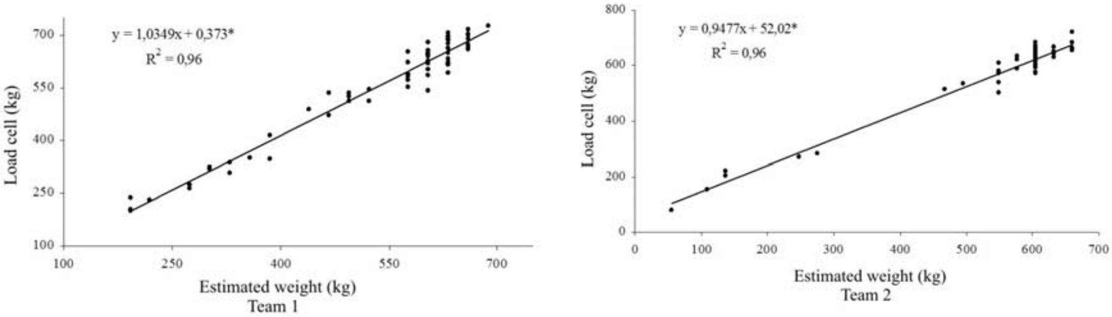

Figure 2. Linear regression between estimated and real weight of the bags for both harvesting teams.

load cell stabilization for reading, generating reading errors and committing the information. A weighting system installed in sugarcane loaders, similar to the one used in orange, was tested by Cugnasca et al. (2000). They obtained errors of about 12% in the weighting compared to the real value and it was attributed to the system dynamics. They also used sensors installed in the machine but identified errors of difficult corrections due to the influence of the lateral movement of the loader arm as it turned to reach the truck to unload it, and influence of abrupt stop and deceleration of the arm when arriving at the top; these problems interfered in the sensors response. The mean error observed was 2%; although under certain test conditions the machine operation introduced perturbations with errors up to 10%. Considering that the errors found in the estimated values by the pointer (3 to 4 %) are lower than 12%, found by Cugnasca et al. (2000) and close to their value of 2%, with the use of load cell and sensors for correction, it allows concluding that the information obtained by the pointer is consistent. Average differences were between 3 and 4% of deviation and considering it as a non-instrumented method, the error may be acceptable.

The 683 points collected in the field were divided in 30 harvest strips. They were plotted inside the field boundary in a GIS (Figure 3). Initial points were created on the border line to allow starting the computation of distances between bags.

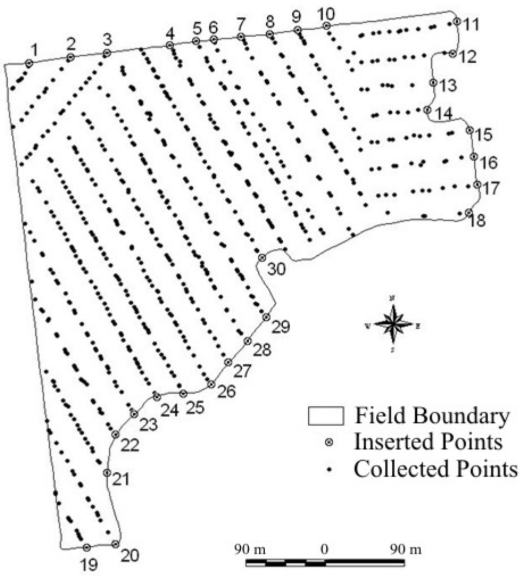

Figure 3. Map with collected points and initial points inserted on field boundary.

Yield data had a mean of 25.28 t ha^{-1} and a high coefficient of variation of 56.9%. Yield values varied between 1.54 and 101.08 t ha^{-1}. It was observed a few values above 60 ton ha^{-1}, that, according to the farmer, is the maximum mean yield value found in different years in that farm. Extreme values are reference to bags located too close to each other, indicating areas of high production. Figure 4 presents the yield points map and the interpolated (inverse distance) map, indicating that areas with higher density of points (big bags) are regions of high yield, and regions where the points are more spaced represents lower yields. Whitney et al. (2001) and Schueller et al. (1999), georeferencing harvest containers also found high yield regions represented by higher density of points.
According to the values computed by the farmer, total production obtained in the field was 363.65 ton, totalizing a mean yield of 22.8 ton ha^{-1} and considered low in relationship to annual historical records of the farm.

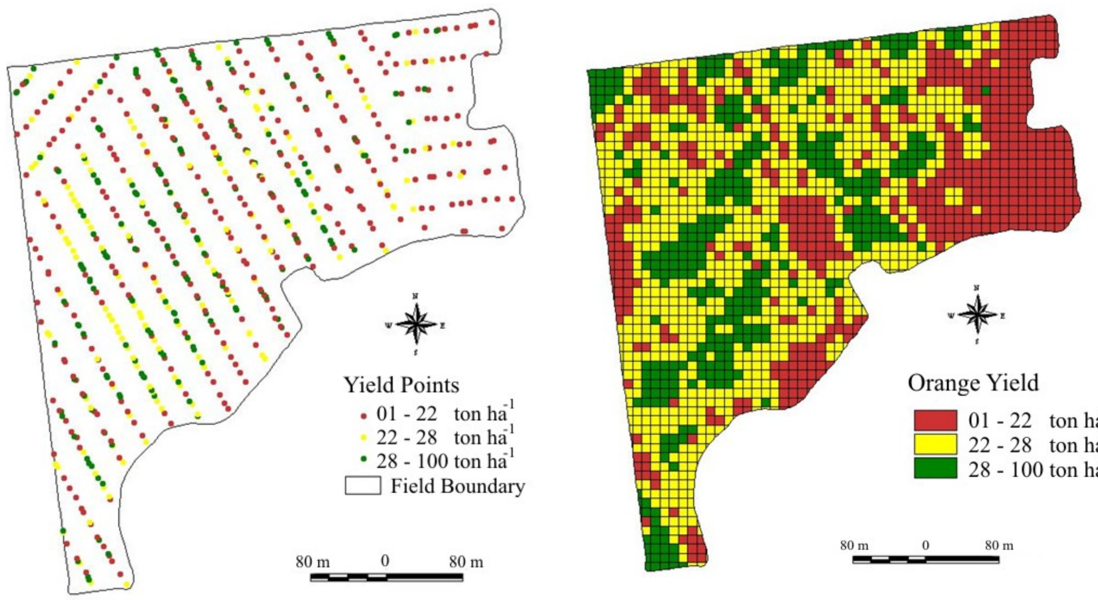

Figure 4. Yield maps of points and surface.

It is possible to observe a sensible spatial variability of orange production in this field, identifying regions of high and low yield. It indicates that the areas are not uniform and must be treated individually, as also observed by Whitney et al. (1998) and Schueller et al. (1999). Delineation of different yield regions inside the field may conduct to investigations that allow identifying causes of such variability.

Conclusions

The information obtained by the pointer related to the bags mass estimation, with the graduated ruler technique, presented an error of 3 to 4%, consistently underestimating the harvested quantity. It may be acceptable for yield estimation because it is a simple and low cost method. At the present study, the estimation did not differ between pointers. The method has shown to be valid for data acquisition and yield maps generation calculating the distance and representation area of bags. From the yield map it is possible to observe the spatial variability, identifying regions with high and low yields, demonstrating the non uniformity and the need of differential treatments inside the area.

References

Balastreire, L.A., Amaral, J.R. and Esquerdo, J.C.D.M. 2002. Agricultura de precisão: mapeamento da produtividade de uma cultura de laranja (Precision Agriculture: yield mapping for orange crops). In: Balastreire, L. A. Avanços na agricultura de precisão no Brasil no período de 1999-2001 (Advances in precision agriculture in Brazil in the period 1999-2001), Piracicaba.

FAO - Food and Agriculture Organization of The United Nations. FAOSTAT data. 2005. Available at: <http:/faostat.fao.org/>. Accessed in: June 15, 2005.

Horrom, N. 2000. Citrus yield monitoring and mapping. In: International Society of Citriculture Congress 2000. Orlando – Florida, Proceedings.

Miller, W.M. and Whitney, J.D. 1998. Development of yield monitoring systems for Florida citrus. ASAE Annual International Meeting, Orlando, paper nº 981098.

Saraiva, A. M., Hirakawa, A.R., Cugnasca, C.E., Pierossi, M.A. and Hassuani, S.J. 2001 A weighing system for grab loaders for sugar cane yield mapping. Precision Agriculture 3 293-309.

Schueller, J.K., Whitney, J.D., Wheaton, T.A., Miller, W.M. and Turner, A.E. 1999. Low-cost automatic yield mapping in hand-harvested citrus. Computers and Electronics in Agriculture 23 145-153.

Whitney, J.D., Wheaton, T.A., Miller, W.M., Salyani, M. and Schueller, J.K. 1998. Precision farming applications in Florida Citrus. Proceedings of Florida State Horticultural Society, Orlando, v.111, p.148-150.

Whitney, J.D., Ling, Q., Wheaton, T.A. and Miller, W.M. 2001. A citrus harvesting labor tracking and yield mapping system. Applied Engineering in Agriculture 17(2) 121-125.