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SITE-SPECIFIC YIELD MAPPING FOR FLORIDA CITRUS

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Abstract. **In 1997, a research project was initiated at the Lake Alfred CREC to investigate possible precision agriculture applications in Florida citrus. This has been a cooperative effort between researchers, manufacturers, and growers. Accurate site-specific yield mapping is the first step to establish if sufficient variations in yield warrant changing practices within a block. If site-specific inputs are modified, then accurate mapping of yields should be continued to validate whether the change improved the situation. This paper will discuss cooperative efforts to develop an accurate, site-specific yield mapping system using conventional manual harvesting practices. Also, other precision agriculture activities like tree canopy mapping which may be integrated into the precision agriculture management system, are discussed.**

Florida citrus trees are generally managed uniformly by the block or grove. Precision agriculture involves the management of crops and soils on the basis of a smaller, site-specific land area than a whole field. Cultural practices generally are applied by the block or grove, and yield and fruit quality information are also recorded by the same area.

One example of cultural practices which is a form of site-specific management is the application of foliar pesticides utilizing ultrasonic/laser sensors (e.g., Tree See®, Smart Spray®). These real-time sensors match the spray pattern to the tree canopy height as the sprayer moves down the tree row. The sensors minimize overspray on shorter tree canopies thus reducing the nontarget deposition and waste of pesticides. Ultrasonic sensors are being utilized in a similar manner to control the application rate of fertilizers on different size trees. Manual spot herbicide spraying of weeds and grasses and selective tree replacement may be considered forms of site-specific management. Most of these activities are not recorded on a per tree or small area basis in an informational data base. Site-specific management practices are used b cause of the great variability often found in a citrus grove an the availability of economical methods for the site specifi treatments. Utilizing available technology in global positio ing systems (GPS) and geographic information system (GIS), such site-specific activities could be recorded, store mapped, and displayed as useful layers of information fo management purposes.

Are there other site-specific practices which can improv grove management? Gross returns are determined by yield and fruit quality, which usually are tabulated by the block o grove. A yield mapping system on a site-specific basis would b very important to characterize variable yields within blocks o groves. This information would cause the grower to look fo reasons causing the variability in yield. The most obvious fac tors are tree size, age, health, spacing, soil type, fertility, wate availability, scion/rootstock, hedging, topping practices, pes pressures, etc. These and other characteristics which affec yield should be mapped. GIS allows this information to b overlaid with the yield map to help the grower determine spe cific locations of the variability. Remote sensing technique and aerial photographs may be economical sources of infor mation about some of these grove characteristics and may b helpful in selecting areas within a grove where site-specifi management practices may be warranted. A yield mappin system using manual harvesting could show locations of fille containers (tubs or pallet bins of fruit from one or mor trees) in the grove. This information can be interpolated t provide a more meaningful map showing yields in boxes/ acre. The system could incorporate a method to record infor mation important for payroll purposes and harvester manage ment. It could also incorporate a method of weighing each container with fruit in the grove, which could be used fo trailer weight tallying, correlation with some internal fruit characteristic such as juice content, and a means of improving the accuracy of yield maps by verifying where containers with fruit were loaded. In fresh fruit harvesting, the locations of pallet bins with fruit could be mapped and fruit quality information for each bin tracked through the packinghouse. Fruit quality information could be mapped for the grove and also linked with the harvester who picked the fruit. In processed fruit harvesting, all internal fruit quality attributes related to full container weight could be mapped. A yield and fruit quality map may show low yields and poor fruit quality in some areas justify management changes. Likewise, the yield and fruit quality mapping history of a block or grove would provide important information about whether areas tend to alternate bear, a common problem in Florida citrus. A feasible yield and fruit quality mapping system would allow the grower to measure changes in yield response to changes in production inputs. The grower could experiment with various production practices, perhaps repeated by 2-row beds within a block in the flatwoods rather by the whole block, to determine controlling factors for optimum yield. With mechanical harvesting, yield information could be determined on individual trees and mapped.

Soil pH, often an important factor affecting yield and fruit quality, could be mapped on a grid or area basis and correct-

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ed in these site-specific areas with variable rates of lime application. Individual tree mapping to include location and canopy size would provide valuable information about individual tree growth, particularly in early development. For mature trees, tree growth responses to site-specific cultural practices could be measured. Combining the canopy size and yield maps would indicate how efficiently the tree is using the occupied volume to produce fruit.

Tracking and recording cultural practices would be a helpful tool for the grove manager. Tracking capabilities would reduce the need for on-site supervisors to check on the progress of numerous grove activities which might be separated by considerable distances. Recorded tracking activities would provide valuable information to determine if irregularities occurred in cultural practices and could be important in miligating environmental problems which may be related to cultural practices.

Yield and soil fertility mapping have been discussed along with variable rate nutrient and herbicide applications in horticultural crops (Righetti, 1997). Yield mapping for citrus crops has been proposed in the USA and Australia. However, outside of some experiments in a commercial grove in Florida and the work on deciduous tree fruit in the Pacific Northwest, there does not appear to be much research or commercialization. As with other crops in which precision agriculture techniques are being developed, yield mapping of citrus is an essential first step.

During the 1997-98 harvest season, we assembled and field tested the components of a yield mapping system using conventional harvesting equipment and personnel. The objective of this paper is to report the results from these field tests.

Materials and Methods

A modified citrus yield monitor from GeoFocus (Gainesville, Florida) with a Trimble GPS unit was mounted on a conventional "goat" truck. It could be programmed to record and store (actuated by a push button) the GPS latitude, longitude, time data and analog to digital input voltage signals from 1 of 2 weighing systems (see schematic Fig. 1). Each of the 2 weighing systems was designed to weigh the truck lift bed which was mounted on a pantograph lift mechanism. The first weighing system utilized four Artech 10,000 lb capacity shear beam load cells, one at each corner of the truck lift bed. The voltage output of this system was recorded and stored by the modified yield monitor (GeoFocus Goat Unit). The second weighing system used a Barksdale 2,000 psi pressure transducer to measure the hydraulic pressure required for the one lift cylinder to elevate the bed an inch above the Artech load cells. The voltage output of pressure transducer was measured with a digital voltmeter. Because the load was supported by either the first or second system, measurements with these two weighing systems were taken in sequence.

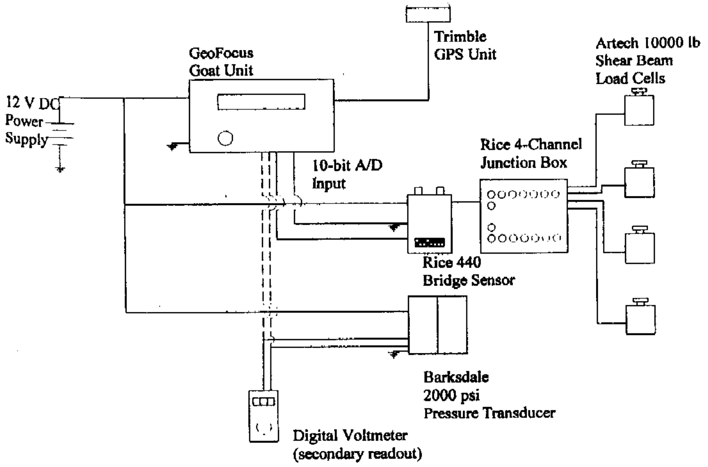

Figure 1. Schematic of two weighing systems for citrus.

The two weighing systems were calibrated by adding 1000 lb pallets of citrus to the lift bed and recording voltage outputs. Calibration of both weighing systems indicated a sensitivity of about 0.4 mV/lb. After calibration, several field tests were conducted in commercial harvesting operations to determine the accuracy of the two systems on 500 box loads of fruit which were weighed on certified scales at the packinghouse or processing plant. The modified yield monitor was programmed to record 10 load cell voltage readings at 0.1 sec intervals. Mean voltage from these 10 values, discarding minimum and maximum readings, was used to calculate the weight for the first system. For the second weighing system with the pressure transducer, one voltage reading was recorded manually after the digital display had stabilized (typically <3 sec), and that reading was used to calculate the weight. To calculate the fruit weight for a loaded semi-tractor trailer, the net voltage changes for each goat truck load that was loaded onto the semi-tractor trailer were added and a weight calculated from the calibration curves. This reading was compared to the weight boxes certified for the semi-tractor trailer at the packinghouse or processing plant. Additional information about the two weighing systems can be found in Miller and Whitney (1998) and Whitney, et al. (1998).

The latitude, longitude, and time data locating the full containers (pallet bins or tubs) in the grove were down loaded off the modified yield monitor, differentially corrected by post processing, and yield maps were developed using ArcView 3.0A. Aerial photographs of the grove area were scanned and geo-referenced to be overlaid on the yield map.

Results

Weighing System Accuracy. Weights from the packinghouse and processing plant fruit loads were in the range of 45,000 to 55,000 lb. The calculated load cell weights were 1:5 to 6% lower than those at the certified scale. The calculated pressure transducer weights were 0.8% less to 1.6% greater than those at the certified scale. It would appear the pressure transducer (second weighing system) was more accurate, although the method of recording voltages was different and may have been biased in favor of the pressure transducer.

Yield Maps. Figure 2 is a geo-referenced aerial photograph of an 8-acre orange grove showing the tree rows with the fruit container locations from the GIS data. The dots representing the container locations were assumed to be 10 boxes each and were used to generate a contour surface interpolation yield map which was overlaid on the aerial photograph (Fig. 3). Contour yields varied from 425 to 800 boxes per acre. In Fig. 2, the lower density of dots in the upper right center and the higher density of dots in lower right and upper left corners correspond to lower and higher yielding areas in Fig. 3. Further inspections of Fig. 3 indicate that there were correlations of yield magnitude and canopy width or canopy size. An-

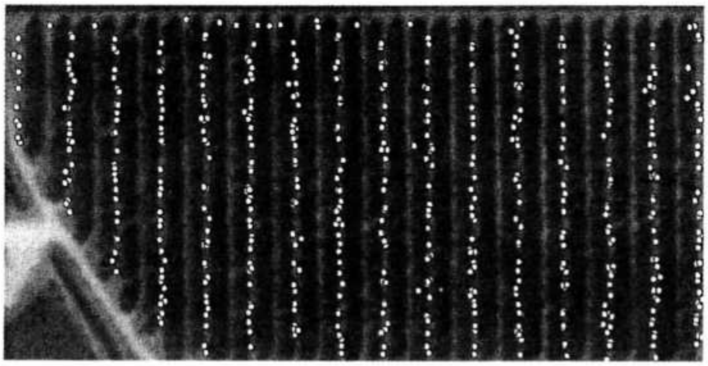

Figure 2. Geo-referenced aerial photograph overlaid with fruit container locations in an 8-acre grove.

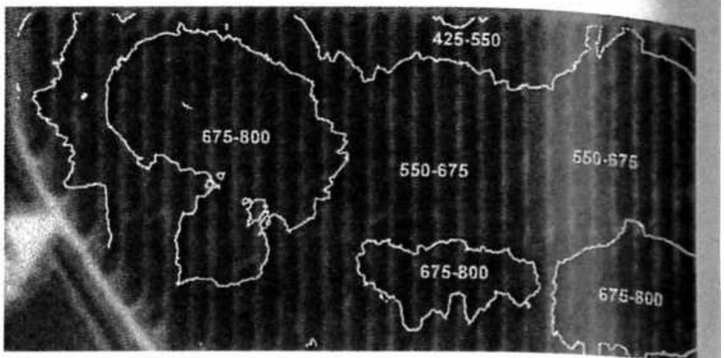

Figure 3. Surface interpolation yield map of 8-acre grove in boxes/acre from fruit container locations in Fig. 2 overlaid on geo-referenced aerial photograph.

other layer of information (soil type, not shown) indicated the lower yielding area in the upper right center of Fig. 3 corresponded to a poor soil type area for citrus and may in part be a cause for the lower yields. Yield maps can be displayed as color coded maps or as yield contours which are sometimes better for black and white printed media.

Future Research Needs. Accurate yield maps can be prepared with manual harvesting only if the location of pallet bins and tubs with fruit is recorded when they are picked up. With the system we were using, the goat truck operator did not always push the button at the proper time and location, and this is a weak point in the procedure which needs to be automated. Time data indicating when the button was pushed often revealed several button pushes within a few seconds at one location. In these cases, the operator was probably catching up on pushes that had been missed. In some cases, GPS locations of pallet bins and tubs were found outside the harvested area. Visual evidence of this was provided when the locations were overlaid on the boundary of the harvested area as determined from geo-referenced aerial photographs. Although these location errors were common, it was apparent that all goat truck operators kept fairly accurate mental tallies of the number of pallet bins or tubs they had loaded in a day.

Recording the location of pallet bins or tubs needs to be automated. This could be triggered by some event such as, dumping, weight increase, etc. which always occurs when a container with fruit is loaded on the goat truck. This event could be giving the harvester credit for the container when it is loaded. If this event is recorded and stored along with a harvester identification number, harvesters could be tracked and this information could be integrated with yield mapping to make the entire system more useful and reliable for the harvester and grower. The accuracy and reliability of the weighing systems needs to be evaluated to determine if they can be used to map weight yields by container and by truck load. Tree canopy mapping either by real time sensors, aerial photography, or remote sensing, needs to be developed as part of the GIS data base to assist with tree management and inventory. Eventually, integrated systems such as the example in Fig. 4 may be feasible.

DATA	INFORMATION	ACTIONS
GPS (Differentially corrected)	Maps	Strategic
Container Locations	Nonspatial Summary Data	Boundaries
Container Weights	Real-Time Control	Rootstock Selection
Fruit Quality	Algorithms	Soil Modification
Soil Type & Parameters		Drainage
Tree Size		Replant (Reset)
Tree Canopy		Tactical
Remote Sensing		Irrigation
Pest Pressure		Fertilization
Available Soil Moisture		Pesticide Application
Weather		Operation Scheduling
		Marketing

Figure 4. Example of integrated system which may be used in precision agriculture for citrus.

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