Finding the fruit: A spatial model to assess variability within a kiwifruit block.

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ABSTRACT

In the fruit production industry there is a need for improved segregation and traceabiltiy through the supply chain in order to extract the maximum revenue from an increasingly competitive global market. Determining fruit quality to "within block" resolution will assist orchardists not only to manage their orchards, but it will also aid them in selecting a uniform product within a given specification – an important characteristic of a 'quality' product. Currently the lowest resolution of fruit data is at the orchard block level. To achieve sub-block resolution a sound geographical base of the orchard is required. This paper looks at aspects of building a geographical model of an orchard that will enable the analysis of fruit on a spatial basis to the sub-block level. The model takes into consideration the physical reality of the process of fruit collection as well as the collection of data about the fruit.

***Keywords and phrases*:** Information Systems, product tracking, supply chain, kiwifruit, GIS, ArcView,

1.0 INTRODUCTION

To compete in the global marketplace fruit production needs to become more sophisticated. The large inherent range of variability of fruit produce requires that the management of consistent quality needs to take into account a whole range of factors, from weather and soil conditions through to handling, packaging and transport (Praat, *et al*., 2000). A term used to describe the techniques for identifying and managing within orchard spatial and temporal patterns is Precision Agriculture (Cook and Bramley, 1998). Precision agriculture attempts to integrate information and production based agriculture systems to optimise long term, site-specific productivity minimising environmental impacts for the whole unit (McBratney and Whelan, 2001).

The application of precision agriculture has traditionally been the domain of combinable crops such as wheatr and maize. However minimising within-field differences may also be explored through the cultivation of more specialised crops such as grapes, where the quality of the fruit (and hence the wine) may be influenced by factors such as soil, microclimate, slope, exposure, soil water holding capacity and drainage (Johnson *et al*., 1998). Spatially variable crop production, in recent years, has basically been technology driven. Advances in computers electronics, such as Geographical Information Systems (GIS) and Global Positioning Systems (GPS), have led to new tools being applied to agriculture (Whitney et al., 1999). Combining real-time GPS, electronic yield monitors, proximal soil and crop sensors, remote sensors, variable-rate fertiliser seed and pesticide controllers with a GIS, provides a powerful management tool (McBratney and Whelan, 2001). The range of sensors, however, can prove to be too expensive for an individual orchard owner, so simpler, cheaper and easier methods of assessing variability across orchard blocks also need to be investigated.

The final test of fruit quality comes from the consumer. If the fruit can be traced from the consumer back to a location in the orchard, then the orchardist has the opportunity to change his management strategies to improve the overall quality of the fruit. Currently, fruit may be traced from consumer back to a packhouse through bar-

coded packaging, and may then be traced back to an orchard block through packhouse records, but the position in the orchard that a single fruit comes from is lost once the fruit goes into a bin. It is possible to tie the fruit back to a location in a block by incorporating a Geographical Information System (GIS) and tracking the fruit more closely.

The model described in this paper is based on work done for PGSF and Zespri Innovation Ltd. A number of orchard blocks were studied in an attempt to develop a system whereby the variability across a kiwifruit block could be assessed.

To link the fruit from the packhouse back to location in an orchard block required 3 separate stages.

- Modelling the orchard block, including vines and bin extents.
- Recording the position of fruit that goes into particular bin.
- Allocating a bin number to each piece of fruit that goes through the packhouse grader.

These stages, and some of the inherent problems involved, are outlined below. Although the discussion here centres around kiwifruit, the methodology may be equally applicable to other perishable products, such as apples, grapes, and oranges.

2.0 MOVING FORWARD

To improve the segregation and traceability of product through the supply chain, thus extracting the maximum amount of revenue from an increasingly competitive produce market, a finer resolution of analysis is required from the available fruit data (Praat, *et al*., 2001b).

2.1 The Current System

Each bin is given a card with a bar code as it moves onto the block being picked. A record is kept of the bar codes and which orchard block they come from. At the packhouse the bins are tipped in "batches" onto the grader. Generally the batches consist of bins from the same orchard block, but there may be several "batches" to complete a block. The fruit is measured then packed into cartons. The data is summarised by block and this information is sent back to the grower (usually in tabular form).

2.2 An Improved System

Ideally we would like to be able to trace the fruit back to the actual vine that it grew from. However, with our current technology, this is not very practical, or even achievable, but with some work we can trace the fruit back to the bin from which the fruit came, and hence back to an area within a block.

The best practical solution involves dividing an orchard block into "bays" and associating these with the bar-coded "bins", enabling us to identify an area within the block from which the fruit was taken. At the packhouse each bin is weighed allowing us to estimate the proportion of fruit in the bin. This estimate was used to associate the graded fruit back to a particular bin. A representative sample of each bin was then summarised and mapped, giving us a visual interpretation of the block's productivity.

3.0 THE METHOD

Building the model from which the analysis of fruit data can be systematically achieved has to take into consideration the physical reality of the process of fruit collection as well as the collection of fruit data.

3.1 Modelling the Orchard Block

Modelling the orchard block can be achieved in several ways: Global Positioning System (GPS), digitising and automatic generation are but three methods. GPS seems to be today's prominent technology and there seems to be a number of companies toting for business using GPS as *the* means for building spatial models of an orchards down to the level of tree or vine. For cost effectiveness, however, a combination of the three methods mentioned could prove to be the more efficient.

3.1.1 Aerial photography

Aerial photographs were used as a base for building a number of GIS layers. As each orchard was done on an individual basis and we were looking at variability within an orchard block, the photos were not geo-referenced for this pilot project. Instead layers were digitised over the top of an imported image in ArcView, thus giving each set of data it's own coordinate system based on the resolution of the image. A fully integrated system would, however, benefit from a single coordinate system so that use could be made of other underlying GIS layers such as soils, rainfall and topography.

3.1.2 Plant (post) generation

Orchards are generally planted in a grid pattern. Each post (and vine) is planted at a set distance from its neighbours. This pattern lends itself to being generated very easily using mathematical formulae. By knowing three points (the beginning of the first row, the beginning of the last row and the end of the last row) the location of all the posts can be calculated and hence plotted. By using the aerial photograph as the base (whether it is geo-referenced or not), an orchard block is quickly plotted by locating the three points mentioned earlier. Each "post" is given a unique value within the block, along with its "row" and "row position". Posts are represented in a "point" layer.

3.1.3 Bay building

Although kiwifruit grow on "vines", when it comes to picking a tractor will drive between the rows, and fruit may be placed into the bins behind the tractor from either side. A more realistic view of an orchard then, may be in terms of "bays", where a "bay" is enclosed by four neighbouring posts (see Figure 1). "Bays" are represented as a "polygon" layer. How the objects are represented influences the methods used to display the results.

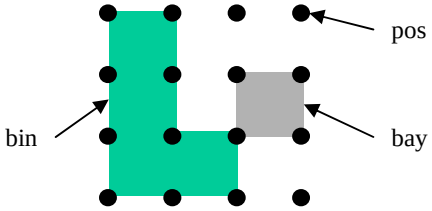
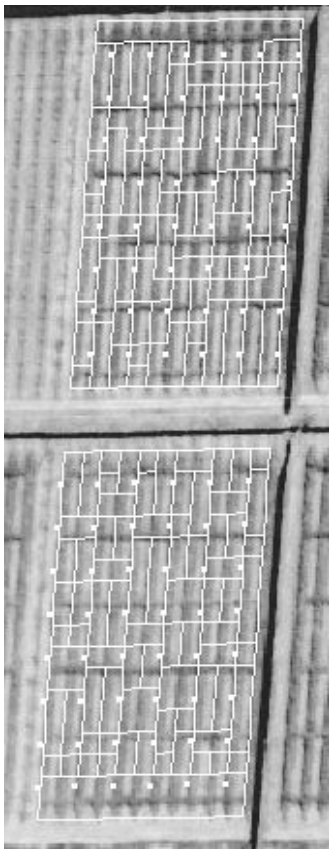


Figure 1: Posts, bays and bins.



Note: An ArcView extension was specifically written to generate the posts and create the bays.

3.1.4 Bin assignment

It may take several "bays" to fill an individual "bin". On the other hand, a "bay" may also contribute to more than one "bin", so we have a many-many relationship with bins and bays. When the fruit was picked the contributing bays for each bin were noted and a table of bin-bays generated (Praat, *et al*., 2001a). The "bay" layer was dissolved[1] using the bin bar code and the results were mapped over the aerial photograph (see Figure 2).

3.2 Collecting the Data

Data collection occurred in two locations, out in the field prior to the fruit being picked, and back at the packhouse when the fruit was being packed. The analysis here concentrates on the data collected at the packhouse.

3.2.1 Measurement in the Packhouse

As the bins were tipped into the grader their weights were recorded, both full and empty, thus enabling the determination of the net weight of the fruit in the bin. As the fruit passed through the grader, a series of measurements were made including weight, brix, dry matter and size. These measurements were linked to the appropriate bin in the current batch and hence back to a location on the orchard block.

[1] Using the Dissolve function in ArcView's Geo-processing extension.

Figure 2: Sample fruit locations and bin extents overlaid on aerial photo.

3.2.2 Reassigning bin numbers to a fruit

Bins of fruit are tipped so that they pass through the grader in a continuous stream. To retrieve the link between the fruit measurements and the bin, each fruit had to be reassigned the number of the bin it came from. Each bin was weighed and the proportion of fruit it contained over the batch was calculated. A Java program was written to process the bin-weight data and the grader data so that a link could be re-established between the fruit and the bin by knowing the sequence of the bins and what proportion of fruit in a particular batch each bin held. Only the middle 50% of each bin was used for analysis to lessen the problem of mixing between bins.

3.2.3 Summarising the data

The graded fruit data was summarised by bin. The average brix, dry matter and size were calculated along with the standard deviation. Other indexes, such as a Dry Matter Index and a Ripeness Index, were then calculated using these figures. Finally the summaries were related back to an area in the Orchard block through the GIS (see Figure 3).

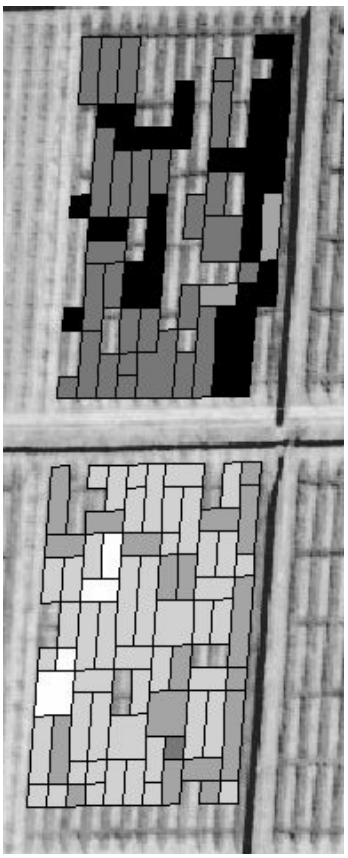


Figure 3: Summarised brix values overlaid on aerial photo (dark is high, light is low).

4.0 AREAS OF CONCERN

In obtaining this data a number of areas were identified where errors needed to be minimised, either by improving the technology providing the data, or adapting new technology to automate the collection of data. Assumptions were also made that will need further investigation.

4.1 Accuracy of bin location

The manual task of assigning "bays" to "bins" proved intensive and, in some cases, very confusing. This could be improved by introducing technology to automate the process. Possible options include GPS and/or the use of barcodes or radio frequency tags to mark posts and/or overhead struts. The pickers in the orchard would also need to be more disciplined in their picking.

4.2 Bin weighing machine

Missing data from the bin weighing machine at the packhouse gave rise to "holes" in the summarised data (see Figure 3). Where feasible these numbers were estimated, but this may have had an affect on the proportion of fruit in the bin or the sequence of bins passing through the system.

4.3 Grader Data

There were some problems with erroneous data from the grader; weights were above what was physically possible, and zero values for brix and dry matter were the two main errors. Records with these types of errors were removed before the summaries were made. An assumption that these errors occurred randomly, and hence were evenly distributed throughout the grading process, was made to simplify the reassignment of fruit back to bin numbers.

4.4 The mixing of fruit between bins was less than 25%

The results are based on allowing a mixing factor of 25%; i.e. the summaries are based upon only the middle 50% of fruit for each bin being summarised. An investigation into the mixing properties of kiwifruit for a specific grader has yet to be carried out, along with looking at the effect on the results of changing the mixing factor.

5.0 CONCLUSIONS

Ultimately it would be desirable if the quality of a fruit could be related back to the vine it came from. However, with our current state of technology, this is not practical. With some work, and the introduction of some new

technology into the orchard environment, however, it is possible to relate the quality of fruit back to an area within a block.

There is still work to be done on all three of the stages required to link the fruit from the packhouse back to location in an orchard blocks. The modelling of an orchard block is progressing with automatic vine creation and bay generation, but the bin extents also need to be automatically generated and the aerial photos need to be geo-referenced. Associating the orchard bays with a bin needs to be automated to improve the rate and quality of capture, and ways of doing this are being investigated. Finally, the packhouse grader and bin weighing machines need to be improved to give more consistent and reliable results.

More sophisticated fruit measurements, such as those used for grading kiwifruit, require more sophisticated means of analyses and visualisation. The initial results using a GIS look promising and it is hoped to develop the model further in the coming season.

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The GIS work was done in ArcView with the aid of the following extensions

- Geoprocessing — Standard ArcView extension
- JPG (JIFF) Image Support — Standard ArcView extension
- Mila Grid Utilities (1.3) — From ESRI free download site
- Spatial Analyst — Optional ArcView extension
- Orchard — Own ArcView extension

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