# Analysis of spectral response patterns of Kiwifruit orchards using satellite imagery to predict orchard characteristics of commercial value before harvest

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## ABSTRACT

Several characteristics of kiwifruit determine its value to the kiwifruit marketing company, Zespri Ltd, and to the grower. The foremost of these is the dry matter content. Much effort is expended in predicting the final dry matter content of the fruit as early in the season as possible so that the optimal dry matter content can be achieved. Dry matter content is currently measured through a destructive 90-fruit protocol that may be repeated several times in a season on each maturity block.

Remote sensing data available from modern satellites can provide four-colour (red, green, blue and near-infrared) data with resolution down to 1-2m, less than the size of one kiwifruit vine. Many indices can be created from these and correlated to the characteristics of plants with indifferent results.

This thesis presents the development of an index wherein the four colours are used to create a three-dimensional unit colour vector that is largely independent of light level. This transform was used to allow the direct visualisation of data from a number of satellite images of the Te Puke kiwifruit growing area in New Zealand over five years, for which dry matter content values were available from the 90-fruit protocol.

An attenuation model was chosen to correct the top-of-atmosphere light intensities recorded by the satellite cameras to those at ground level. The method of Hall *et al*., (1991) was found to reduce the variation of fiduciary pixels by the largest amount and was used.

The visualisation revealed that there was an axis along which dry matter was ordered by magnitude. A regression line of best fit was applied to this data producing an $R^2$ value of 0.51 with a standard mean-square error of 0.76. This is significantly lower than the average mean-square error of 1.05 for the 90-fruit protocol.

Comparison of the predictive power of other indices, based on one image, showed a range of $R^2$ values of 0.008 to 0.49. The method developed in this thesis produced an $R^2$ of 0.70 for the same data.

## CERTIFICATE OF AUTHORSHIP

I, Linda Mills, hereby declare that this submission is my own work and that to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made.

……

Linda Mills


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## ABBREVIATIONS AND DEFINITIONS

| | |
|---|---|
| *Actinidia chinensis* | *Actinidia chinensis* is a fruiting vine native to China. The first commercialised cultivar in New Zealand was *Hort16A,* licensed by Zespri International Limited.) *Hort16A* is also referred to as Gold in this study. |
| *Actinidia deliciosa* | *Actinidia deliciosa* is a fruiting vine native to China. The predominant cultivar grown in New Zealand for export is *Hayward* which was commercialised in the 1940's. *Hayward* is also referred to as Green in this study. |
| AgFirst BOP | AgFirst Bay of Plenty is an independent company based in Katikati, New Zealand that provides services to the New Zealand Kiwifruit Industry. www.agfirstbop.co.nz |
| Brix | Brix is the soluble sugar content (SSC) of a fruit as measured by a refractometer. A refractometer uses light refraction to measure different sugar concentrations providing a value with the unit of measure of degrees brix. |
| DM | Dry Matter is what is left of a slice of fruit after it has been dehydrated, weighed in grams. |
| DN | A Digital Number represents the intensity of the signal received by the satellite sensor as reflected or emitted by a given area of the earth's surface. |
| ISO Week | International Organisation for Standardisation leap week calendar system that is part of the ISO 8601 date and time standard with the week with the year's first Thursday in it being ISO Week 1. |
| MDM | Measured Dry Matter |

| | |
|---|---|
| MSE | Mean Squared Error, measures the average of the squares of the "errors", that is, the difference between the estimator and what is estimated |
| %DM | Percentage Dry Matter, the dry weight of a material, in this case kiwifruit, expressed as a percentage of the fresh weight. |
| PDM | Predicted Dry Matter |
| Psa | The bacterial kiwifruit vine disease Pseudomonas syringae pv actinidiae. |
| R | Correlation coefficient |
| $R^2$ | Coefficients of determination |
| RMSE | Root Mean Square Error is the square root of MSE or the standard deviation |
| SE | Standard Error |
| TE | Tray Equivalent, unit of measure of kiwifruit quantity being the number of pieces of fruit of a certain size that fit into a standard tray based on weight |
| TZG | Taste Zespri Grade |
| Yield | TE per hectare |
| Zespri | Zespri International Limited. |