HONEY CROP ESTIMATION FROM SPACE: DETECTION OF LARGE FLOWERING EVENTS IN WESTERN AUSTRALIAN FORESTS

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Introduction

Recent studies have shown that in the spectral space there is often a better spectral separation between leaves and flowers and even between flowers of different species than between leaves of different species. In this study we assess the ability of satellite remotely sensed data to detect the flowering of Red Gum trees (*Corymbia calophylla*) in Western Australia, the state's largest annual honey crop.

As the species occurs across a large portion of the South-West Floristic Province, the ability to remotely detect where Red Gum trees are flowering may help apiarists to better manage their seasonal apiary movements and thereby increase production honey.

Data Collection

325 Spectral reflectance data were acquired at three sites in State Forest areas between Spring 2015 and Autumn 2016 using an ASD FieldSpecPro 3 spectroradiometer. White reference measurements (Spectralon) were collected at least every 10 minutes and 10 records taken and averaged per measurement. Median spectra for leaves, flowers and groundcover are shown in Figure 1.

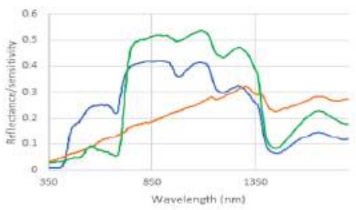

Figure 1: Median spectra recorded. Green = leaves, blue = flowers, orange = groundcover

Spectral Separation of Red Gum Flowers

Spectra from the three target types were initially analysed using the analysis of variance (ANOVA) method, to reduce data dimensionality before more complex separation assessment was performed. The ANOVA analysis showed that reflectances were significantly statistically different for:

- 94% of the Flower vs Ground wavelengths
- 98% of the Flower vs Leaf wavelengths
- 92% of the Flower vs Ground AND Leaf wavelengths

Separation of wavelengths that passed the ANOVA test were then calculated using the Jeffries-Matusita (JM) Distance. Wavelengths with progressively higher difference between means were tested and, using the criteria of minimum JM Distance of 1.9 for sufficient separation for reliable classification, the best separation were achieved between wavelengths 518 – 557 nm.`

Multispectral Separation Assessment

Several studies have shown that flowers are most detectable when repeated measurements are used to track temporal variations. To test the ability of space-borne sensors with moderate to high temporal resolution to detect flowers, each raw spectra acquired with the FieldSpecPro were convolved with the spectral response functions of a range of different multispectral satellite-borne sensors. This produced 325 synthetic pixels of the hypothetical measured reflectance of flowers, leaves and ground classes for each sensor.

Satellite	Spectral resolution range (min and max bandwidth)	Highest median JM Distance
AVHRR	60 – 1,000 nm	0.17
Sentinel 2	15 – 180 nm	0.37
Landsat 7	60 – 2,100 nm	0.47
CBERS	60 – 2,100 nm	0.49
Landsat 8	20 – 1,100 nm	0.81
ASTER	40 – 700 nm	1.11
Sentinel 3	2.5 – 40 nm	1.56
VIIRS	15 – 600 nm	1.82
MODIS	10 – 1,000 nm	2.00

Table 1: Median JM Distance results for common multispectral satellite sensors

JM Distance calculations of bands for these classes for 9 difference satellites showed that only the MODIS bands had a distance of greater than 1.9 (see Table 1). This result correlates with the spectroradiometer JM Distance calculations as, while the majority of the wavelengths between 350 nm to 1800 nm are statistically different based on ANOVA analysis, only a small portion of the wavelengths are able to reliably separate the target classes. The highest distances were for MODIS Band 4 (538 – 568 nm) and Band 11 (519 – 540 nm). These bands are either within or contain a high proportion of the spectroradiometer wavelengths with the highest JM Distances.

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Minimum Detectable Flower Coverage

While the JM Distance analysis has indicated that the MODIS sensor is capable of spectrally separating Red Gum flowers from background reflectance, the very high spatial resolution of the data in this analysis (field of view typically less than 50 cm^2) means that the flowers made up almost the entire field of view of the spectroradiometer. With the optimum MODIS bands having a spatial resolution of 500 m (Band 4) or 1,000 m (Band 10), it is considered improbable that a single MODIS pixel would consist entirely of Red Gum flowers.

In order to estimate the percentage flower cover required for flowers to be detected, the percentage of flower coverage was calculated to increase the reflectance by 1 standard deviation (SD) for backgrounds ranging from 0 – 100% leaf cover. This was done for the MODIS bands with the highest JM Distance (bands 3, 4, 10, 11, and 12), as well as for several derived spectral products. These derived products included calculated NDVI and EVI products, as well as other combinations of MODIS bands.

The results, shown in Figure 2, show that most MODIS bands, or even adding bands together, require almost 30% flower cover per pixel to change the reflectance by 1 SD. The vegetation indices require minimum 50% leaf cover to detect flowers.

The most sensitive results to flower cover come from dividing the MODIS visual bands by Band 8 (405 – 420 nm). A look at the median spectra for each class in Figure 1 shows that the flowers have the highest reflectance for the visual bands, and the lowest for the Band 8 region. By dividing visual bands by Band 8, both differences are highlighted. As a result, less than 2% coverage can be needed for a change of 1 SD.

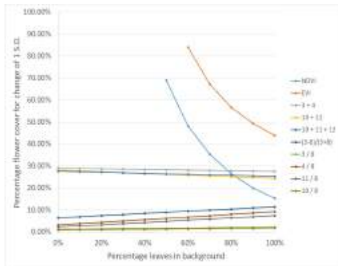

Figure 2: Percentage cover of flowers require to change the reflectance by 1 standard deviation for different background ratios of ground and leaves for MODIS derived indices

Correlation of MODIS and Honey Harvest Data

To assess the ability of MODIS data to detect flowering Red Gum trees in a real-world situation, the Band 10/Band 8 metric was compared with honey harvest data from an apiary site near Mundaring, Western Australia. Honey harvest data were recorded by ranking annual harvests from 2003 – 2017 as good, medium or poor. Daily MODIS data for the month of February (peak flower intensity for Red Gum trees) were downloaded for the apiary site and the surrounding 9 km^2 and the median metric calculated for each year.

The box and whisker plot of the comparison of these two datasets (see Figure 3) showed a clear difference in the median value for each harvest quality category, but some overlap between the quartiles and the minimum and maximum values. An ANOVA analysis of the categories showed a statistically significant difference between the good and moderate vs poor years, but not the moderate vs good years.

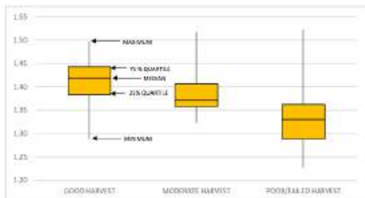

Figure 3: Outcome of MODIS data into three levels of harvest quality

The rainfall and average maximum temperature data were also retrieved for each honey harvest year, to assess the impact of annual weather variations on honey harvest data.

It was found that a combination of rainfall was a good indicator of harvest volume, with almost all poor years having rainfall of greater than 40 mm in February, or an average daily maximum of greater than 32°C.

Summary

- Flowers have a statistically difference reflectance to leaves and groundcover for the majority of wavelengths between 350 – 1800 nm (highest separation 518 – 557 nm).
- The most sensitive measure of flower coverage is MODIS (Band 10 / Band 8).
- MODIS data showed a statistically significant difference between honey harvest quantity for good and moderate vs poor harvests from a test site at Mundaring, Western Australia. There is good correlation with annual weather variations too.

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