fAPAR, SR and NDVI to Characterize the Vegetative and/or Phenologic Stages of Guava (*Psidium guajava* L.) to Forecast Its Yield

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**Abstract**

One SPOT satellite image, and field data of 16 guava orchards and 2 blind sites located at Calvillo, Aguascalientes, were used to find if guava’s photosynthetic activity rate, could be related with the mean value of spectral indices; the blind sites were a production unit of Agave (*Agave tequilana*) and the other one an orchard of peach trees (*Prunus persica* (L)). Two field data collections were performed on March 16 and July 15, 2005. The collected data was: point coordinates, altitude, plantation system and guava’s stage. The spectral indices derived were NDVI (Normalized Difference Vegetation Index), SR (Simple Ratio Vegetation) and fAPAR (fraction of Absorbed Photosynthetically Active Radiation). Consistently fAPAR mean values were more adequate than the other two on describe the phenologic stage of guava where the higher mean value point to “cruise fruit” and the minor to “fruit development”; 0.403 and 0.263, respectively. For *A. tequilana* and *P. persica* (L), the mean values were 0.120 and 0.236, respectively; the lowest mean value for *A. tequilana*, was strong influenced by the lacking of any vegetative cover between the rows of plantation. These results support that it is feasible to characterize the phenologic stages of guava using the fAPAR index as first option instead of NDVI and SR. The fAPAR image will play a key role to scale the field data to image extension to estimate guava’s yield by developing an integration model.

**INTRODUCTION**

Guava is gaining importance in Mexico, which is cultivated in an area of 23,624 ha with production of 140,305 t (SIAP, 2005). In Calvillo, Aguascalientes, there prevails ‘Calmeo’ a drought induced period, which is highly suitable for guava growing because it minimizes the damage caused by low temperature during winter season and also maintains Phenological cycle of guava according to harvesting time to fetch better price for fresh fruit (CEPAB, 1991). The canopy and frame of guava plants varies depending on the production intensity. Host of production systems are based on vegetative development and fruit maturity to fresh market. These stages are related to some spectral signatures and spatial changes in Normalized Difference Vegetation Index (NDVI) (Boissard et al., 1993). The main use of satellite image is to face the scale problem by linking field data with spectral indices like NDVI, Simple Ratio Vegetation (SR) and fraction of Absorbed Photosynthetically Active Radiation (fAPAR), which represents, in an indirect way, the photosynthetic activity rate of soil coverage. Using the absorbed radiation and considering the photosynthesis of leaves, the potential photosynthesis could be calculated (Kroes and Van Dam, 2003). Some articles had reported useful relations between spectral signature and biomass, leaf area index, vegetative coverage and fAPAR. The most common option involves an empirical correlation among these variables and vegetation indices derived from some spectral bands (Inoue, 2003).

Several specific applications in agriculture have been identified ranging from total crop area estimates to mapping of within-field moisture and nutrient deficiencies (Bausch and Duke, 1996; Moran et al., 1997). In this work we focused on finding a relationship
between guava’s vegetative or phenologic stage could be related to mean value of spectral indices derived from satellite images. This would create well expectative to discriminate guava plantations into agricultural border area and also to estimate guava’s yield before harvest time.

MATERIALS AND METHODS

Data Collection
The data were recorded twice to locate and characterize guava orchards on March 16 and July 15, 2005. Coordinate data were obtained using a “Magellan” GPS receiver with ± 5 m precision. The orchard characterization data included vegetative or phenologic stage and plantation frame.

Guava Photoidentification
By applying a supervised classification methodology on satellite images, guava orchards should be discriminated and in GIS environment one can estimate area units stratified by phenologic stage.

Image Data and Spectral Indices
One SPOT 2 satellite image was used to derive the spectral indices. This image has 20 m in spatial resolution and covered almost all the agricultural zone of Calvillo. The image was taken on August 23, 2005. It has three spectral bands, Green, Red and Near Infrared and was treated for geometric and radiometric correction. NDVI, SR and fAPAR indices were derived from image. NDVI index was calculated following:

\[ NDVI = \frac{NIR - R}{NIR + R} \]

where, NIR and R are the reflectance values of Near Infrared and Red bands.

SR index was calculated following:

\[ SR = \frac{NIR}{R} \]

where, NIR and R are the reflectance values of Near Infrared and Red bands.

fAPAR index was calculated following: (Lobell and Asner, 2003)

\[ fAPAR = 0.5 \left( \frac{NDVI - NDVIMIN}{NDVI_{MAX} - NDVIMIN} + \frac{SR - SRMIN}{SR_{MAX} - SRMIN} \right) \left( fAPAR_{MAX} - fAPAR_{MIN} \right) + fAPAR_{MIN} \]

where, NDVI_{MAX} and NDVI_{MIN} are defined as the 2nd and 98th percentiles, respectively of NDVI within the image, while SR_{MAX} and SR_{MIN} are similarly defined based on the SR image. fAPAR_{MIN} and fAPAR_{MAX} were set to 0.01 and 0.95, corresponding to the extremes values of potential canopy absorption of photosynthetically active radiation (Lobell and Asner, 2003).

The mean value of spectral indices was calculated in a 3×3 matrix arrange. Coordinate data was declared as central pixel on the matrix and with an algorithm in Modeler (ERDAS, 2002) the mean value was extracted for each index image.

Yield Prediction
To estimate yield, the fAPAR index value was used despite the other two. A simple model proposed will be applied (Monteith, 1972, 1977):

\[ \text{Yield} = (\Sigma \text{PAR} \times fAPAR \times \Delta t) \times \varepsilon \times \text{HI} \]

where, PAR is incident photosynthetically active radiation (MJ from 400 to 700 nm), fAPAR is the fraction of PAR absorbed by the canopy, \( \varepsilon \) is the light use efficiency in units of gram biomass MJPAR^{-1}, and HI is the harvest index (Lobell et al., 2003)
RESULTS AND DISCUSSION

Data Collection
Regarding to the plantation system 6 field sites were in intensive production system (3m x 3m between trees and rows), 2 field sites in middle intensive (7m × 6 m) and 8 in low intensive production system (5m × 5m). On March 16, 4 guava orchards were on “calmeo” stage and these sites, on the second collection data (July 15, 2005), were on “tie fruit” or “marble fruit” stage. This mean that a period of 4 months is necessary for guava to start the production season once its photosynthetic activity has started. The spatial distribution of the sites followed the central region of the agricultural area in Calvillo. Despite the image showed some clouds, all the agricultural area was clear and useful for the classification methodology.

Guava Identification
The results of extend guava sites signatures showed that 11,678 ha of guava were identified in condition of production.

Spectral Indices
The mean values of spectral indices were according with guava’s cycle (Table 1). The most consistent was for fAPAR index because every stage of guava showed an specific relationship with one particular value. The highest value was for the most photosynthetic stage “cruise fruit” (0.403) and the lowest for the less photosynthetic stage “fruit development” (0.263). For the blind sites, A. tequilana and P. persica, the mean values were of 0.120 and 0.236, respectively (Fig. 1). Both were representative also because for A. tequilana there was no vegetation between rows and for P. persica, the harvest time has passed recently and the tree was in preparation to drop leaves. NDVI and SR indices showed contrast values because their mean values has increased according the stages were passed following the physiology’s tree. Considering guava’s photosynthetic activity rate, it was expected a diminution in their mean value and this never occured. From Figure 1, while darker the color saturation, higher the amount of absorbed energy.

Yield Prediction
Due to the harvest time, November and December, we’ll expect to acquire yield data of sample sites to apply the proposal model and so on calibrate it to extend to image coverage.

CONCLUSION
Spectral indices were adequate to characterize guava’s phenologic stages. fAPAR index mean value was the best option on characterize the phenologic stages of guava and the other two indices (NDVI and SR), showed remarked inconsistencies on characterization because in contrast of what expected they showed an increasing tendency on their values while advanced the guava’s cycle.

Literature Cited


Tables

Table 1. Phenologic stage of guava and mean value of spectral indices.

<table>
<thead>
<tr>
<th>Phenologic stage</th>
<th>n</th>
<th>fAPAR</th>
<th>SR</th>
<th>NDVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise fruit</td>
<td>1</td>
<td>0.403</td>
<td>1.264</td>
<td>0.226</td>
</tr>
<tr>
<td>End of floration</td>
<td>1</td>
<td>0.380</td>
<td>1.300</td>
<td>0.240</td>
</tr>
<tr>
<td>Tie fruit</td>
<td>2</td>
<td>0.297</td>
<td>1.433</td>
<td>0.284</td>
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<td>Marble fruit</td>
<td>9</td>
<td>0.267</td>
<td>1.482</td>
<td>0.298</td>
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<tr>
<td>Development fruit</td>
<td>3</td>
<td>0.263</td>
<td>1.489</td>
<td>0.301</td>
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<tr>
<td><em>Agave tequilana</em></td>
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<td>0.120</td>
<td>1.724</td>
<td>0.368</td>
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<tr>
<td><em>Prunus persica</em></td>
<td>1</td>
<td>0.236</td>
<td>1.530</td>
<td>0.316</td>
</tr>
</tbody>
</table>
Fig. 1. Spatial distribution of field sites and fAPAR index.