Spectral signature of Diatraea saccharalis attack in sugarcane using Landsat 8 image and in-situ data.

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Abstract

The sugarcane crop production and processing represents a large part of Brazilian agricultural business. The objective of this work was to evaluate the spatial signature of sugarcane damaged by different incidences of sugarcane borer using Landsat 8 images and in-situ data collection. The experiment was carried out at Vista Alegre do Alto, SP, Brazil in March of 2014. The Atmospheric Topographic Correction for Satellite Imagery was used to perform atmospheric corrections of the images and calculate meteorological indices. The sugarcane borer infestation was quantified in five georeferenced points and compared with the reflectance in the bands 2, 4 and 10 and also ground albedo, latent heat and net radiation. Based on summary statistics and regression analyses, there was increased correspondence between borer infestation and meteorological indices. The points with lower borer infestation, presented lower reflectance in band 2 and 4 , medium wavelengths 0.483 and 0.655µm respectively and lower surface temperature and ground albedo. Nevertheless latent heat and net radiation were higher in points with less borer infestation. Probably, the sugarcane borer larvae consumed plant tissue, diminishing the amount of water and nutrients translocated in the plant. For that reason, the evapotranspiration was lower in points with higher borer infestation.

Keywords: Saccharum officinarum, remote sensing, heat flux, ground albedo, reflectance signature.

1. Introduction

The sugarcane (*Saccharum officinarum* L.) crop is highly important in Brazil due to alcohol and sugar production. Monitoring diseases and pests may contribute to the definition of strategies and tactics to the integrated pest management in sugarcane production system. The sugarcane borer, *Diatraea saccharalis,* is native in the western hemisphere and causes indirect damage to plant population density. The borer opens a gallery and is a vector of fungi stalk rot, *Colletotrichum falcatum. T*his microorganism uses the sacarose for its metabolism, therefore stand density decreases between 16% till 32%, with a reduction of sugar production up to 2.5 metric tonnes per hectare Ogunwolu et al. (1991). There are a few problems over different life stage of the plant and the insect. The cycle begins with eggs being deposited on both the lower and upper surface of the leaves. The egg stage last 4 to 6 days. Than the larvae tend to gather in the whorl to drill into the stalks. This stage takes 25 to 30 days to develop the pupa. Pupation takes place inside the plant, leaving a thin layer of plant tissue for the adult insect crack at emergence, during 8 to 9 days. The adults are nocturnal and oviposition starts at dusk and lasts throughout the evening for up to 8 days. In mature plants, the borer debilitates or kills the tops. For young plants, the internal whorl kills the leaves causing the condition known as “dead hearth”. There are two problems of damage by tunneling inside the stalk. The first, affects the purity and amount of nectar that can be extracted and the borers can lower the sucrose yield from 10% to 20%. The second, makes the plant susceptible to secondary invaders like bacterial, viral disease and fungi to enter and increase the damage Capinera, (2011).

Remote sensing data has a large potential for monitoring crop production due to the periodicity of the satellites. This information can be used to alert the farmer about pest infestation before the threshold point, in order to assist the farmer in the decision making process. In February 2013, Landsat 8 was launched and it can generate images in the Spectral bands of 1, 2, 3, 4 (visible), 5 (NIR), 6, 7, 9 (SWIR) with resolution of 30 meters. Panchromatic band 8 has a resolution of 15 meters and Thermal Infrared Bands 10 and 11 (TIR) have a resolution of 100 meters. The satellite orbits the Earth at an altitude of 705 km in a polar orbit and provides global coverage in 16 days after returning to the first location Loveland and Dwyer (2012).

2. Materials & Methods

2.1 Study area

The experiment was located in Vista Alegre do Alto, coordinates . This south central region is well known for sugarcane planting and processing in Sao Paulo state, which is the largest producer of sugarcane in Brazil, with 5,303,342 hectares in 2010/2011 Rudorff et al. (2010). The area has the sugarcane variety RB 86-7515 in the fourth month of development, in a total area of 10,13 ha. The studied had 5 geo-referenced points (Figure 1) fairly spaced between each other and removed from the road, in order to diminish the interference of the surrounding areas in the pixel image. The infestation of sugarcane borer was quantified in 10 meter lines, counting the number of insect larvae inside the plants.

2.2 Satellite images

Landsat 8 OLI / TIRS images were selected to evaluate the spectral signature of sugarcane and the infestation of sugarcane borer (*Diatraea saccharalis)*. The spectral signature of all the points shows the peaks of lower and higher reflections [Figure 2]. This study compared the bands 2, 4 and 10 versus infestation of sugarcane borer and these band were chosen because the optimum wavelengths for chlorophyll A functioning is 0.43 and 0.66 µm. For chlorophyll B, the values are 0.45 and 0.64 µm. The Glovis scene ID LC82200732014094LGN00, from 4th April 2014, NASA (2014) was acquired and then processed with Atmospheric / Topographic Correction for Satellite Imagery (ATCOR) methodology to estimate several vegetation and energy balance indices that assist in characterization of the earth surface. The surface energy balance or net radiant energy Rn, can be obtained by sum of the following heat fluxes: ground albedo, sensible heat flux and latent heat. The quantity of energy employed in photosynthesis is minimum, hence it is ignored here. The ground albedo covers 10% to 50% of net radiation and it is obtained using the green, red, and near-infrared wavelength. The sensible flux can cool or warm the surface and it is conditioned on the difference of air and surface temperature. The latent heat measures the energy available to evaporate water from the surface, evapotranspiration Richter and Schläpfer (2014). The reflected energy versus sugarcane borer infestation for ground albedo, latent heat and net radiation were the analyzed heat fluxes.

3. Results and Discussion

The sugarcane borer was found in different quantities along the experimental area. The Reflectance signature presented distinct patters of reflectance in each band, according to the borer infestation. The increase in sugarcane borer infestation directly influences the reflectance, which also augmented with the infestation. The data show a small variation in the band 2, minimum and maximum value 3.30% and 3.73%. Nevertheless bands 4 and 10 had a reasonable variance with variations from 4.79% - 5.74% in band 4 and 31.5^{o} - 32.50^{o} Celsius in band 10 [Figure 3].

According to Alves (2012), in Brazil's Mato Grosso state, the damaged caused on maize by nematodes and dark sword-grass had a divergent spatial signature with peaks of higher reflectance within the middle wavelengths of the bands 1, 3 and 4. The regression analyses of the data indicated correlation between reflectance and sugarcane borer infestation. In the band 2, the r-squared value R^2 = 0.839, showing high correlation between infestation and reflectance. The band 2 spectrum is similar to the chlorophyll B absorption, consequently the reflectance will be higher in plants with less chlorophyll. There was an ascendant linear trend line, which describe the strong correlation between the points [Figure 4.a]. The band 4 spectrum covered the peak of absorption by chlorophyll A and B. Healthier plants are associated with a lower reflectance once most of the radiation is absorbed. The occurrence of sugarcane borer and reflectance had an elevated, with R^2 = 0.957, evidenced by the linear trend line [Figure 4.b]. The thermal band 10 suffered influence by the vegetation density, because the areas with less vigorous vegetation absorbed less heat, making the reflectance higher. A linear trend line shows the link among the plants sanity and heat flux, R^2 = 0.951 [Figure 4. c].

The heat flux was directly influenced by the presence of sugarcane borer. The ground albedo had a decreasing value along the infestation level, with R^2 = 0.802, the linear trend line indicates connection between infestation and ground albedo [Figure 4.d]. This pest damages plant tissue, which led to a decrease in heat absorption. The ground albedo represents the heat variation on the surface. A healthy canopy maintained an expressive part of the heat and released it slowly, whereas bare soil retained less and lost heat quickly. The latent heat was higher for healthier plants, decaying along the infestation (Figure 4.e), R^2 = 0.982. The sugarcane borer larvae consumed plant tissue, that diminishing the amount of water trans-located inside the plant. For that reason the evapotranspiration was lower in the points with higher borer infestation. The evapotranspiration is the latent heat flux. The water flux from the surface to the atmosphere come by soil evaporation and plants evapotranspiration, which happens by leaf stomata transpiration, where most of the water absorbed is lost by transpiration. There are several factors influencing the evapotranspiration, such as vegetation development stage, management, plant architecture, cultivation practices, ground cover, canopy characteristics, insect damage and diseases Teixeira (2010). The net radiation, Rn, was higher for healthier plant, declining with the infestation [Figure 4. f], $R^2 = 0.952$. The Rn available is determined by shortwave radiation, which causes air and surface temperature changes. The Rn is the radioactive energy available at the surface that influences biological and physical processes. The Rn may be positive or negative. A negative Rn means fluxes of energy from the surface and a positive Rn indicates energy flux to the surface Lima et al (2012).

4. Conclusion

The monitoring of agricultural zones using satellites gives a new perspective of the plants and pests biology. Considering that there is a great demand for agricultural remote sensing products, there are several issues of interest. We addressed in this paper some new knowledge about the spectral signature of borer attack in sugarcane and heat fluxes of sugarcane with incidences of sugarcane borer using Landsat 8 and field data. The performance of bands 2, 4 and 10 and also ground albedo, latent heat and net radiation were evaluated for detecting pest damage. Further studies are necessary to fully understand the co-relation among sugarcane borer infestation and the reflectance in the spectral bands.

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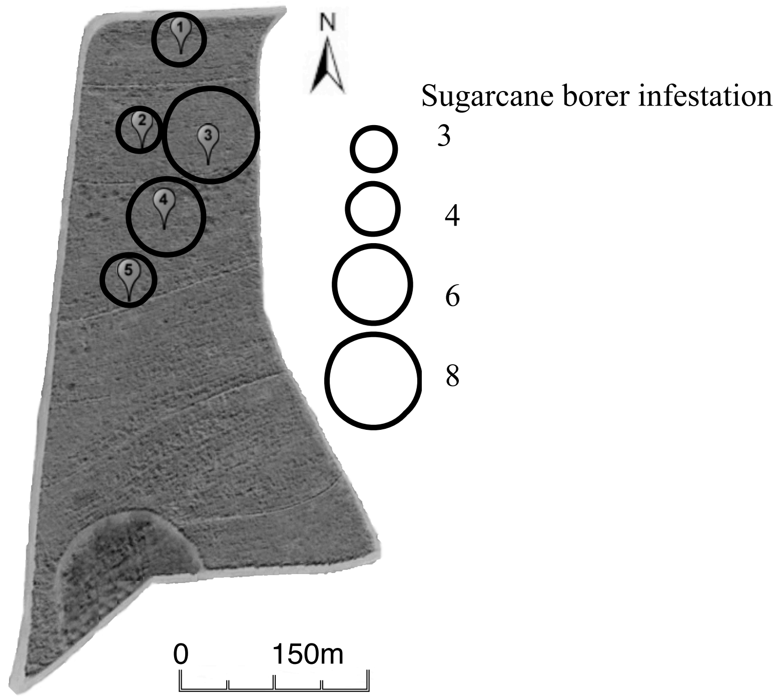

Figure 1. Location of the georreferenced points. Google earth image - 2014 CNES / Astrium.

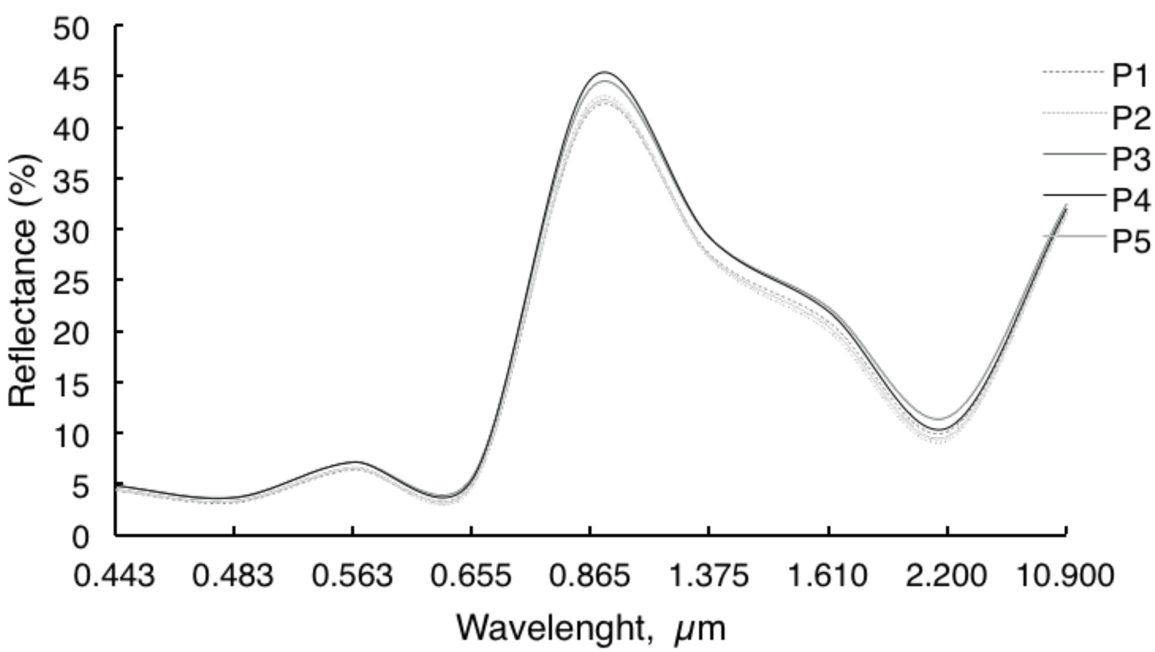

Figure 2. Reflectance signature of the 5 georreferenced points in wavelength 0.443μm till 10.90 μm.

Band	**1**	**2**	**3**	**4**	**5**	**9**	**6**	**7**	**10**
Resolution	30m	30m	30m	30m	30m	30m	30m	30m	100m
Wavelenght	0.443 μm	0.483 μm	0.563 μm	0.655 μm	0.865 μm	1.375 μm	1.610 μm	2.2 μm	10.9 μm
Minimum	4.38	3.39	6.54	4.79	41.81	27.13	20.00	9.35	31.50
Mean	4.56	3.50	6.84	5.25	43.03	28.06	21.13	10.29	31.89
Maximum	4.81	3.73	7.20	5.74	44.75	29.13	22.30	11.58	32.50
Stdeviation	0.20	0.19	0.31	0.37	1.25	0.98	0.95	0.85	0.39

Table 1. Characteristic of Landsat 8, bands 1, 2, 3, 4, 5, 9, 6, 7 and 10, pixel resolution and medium wavelength. Descriptive statistics, minimum, mean, maximum maximum and standard deviation for 5 georrefenced points.

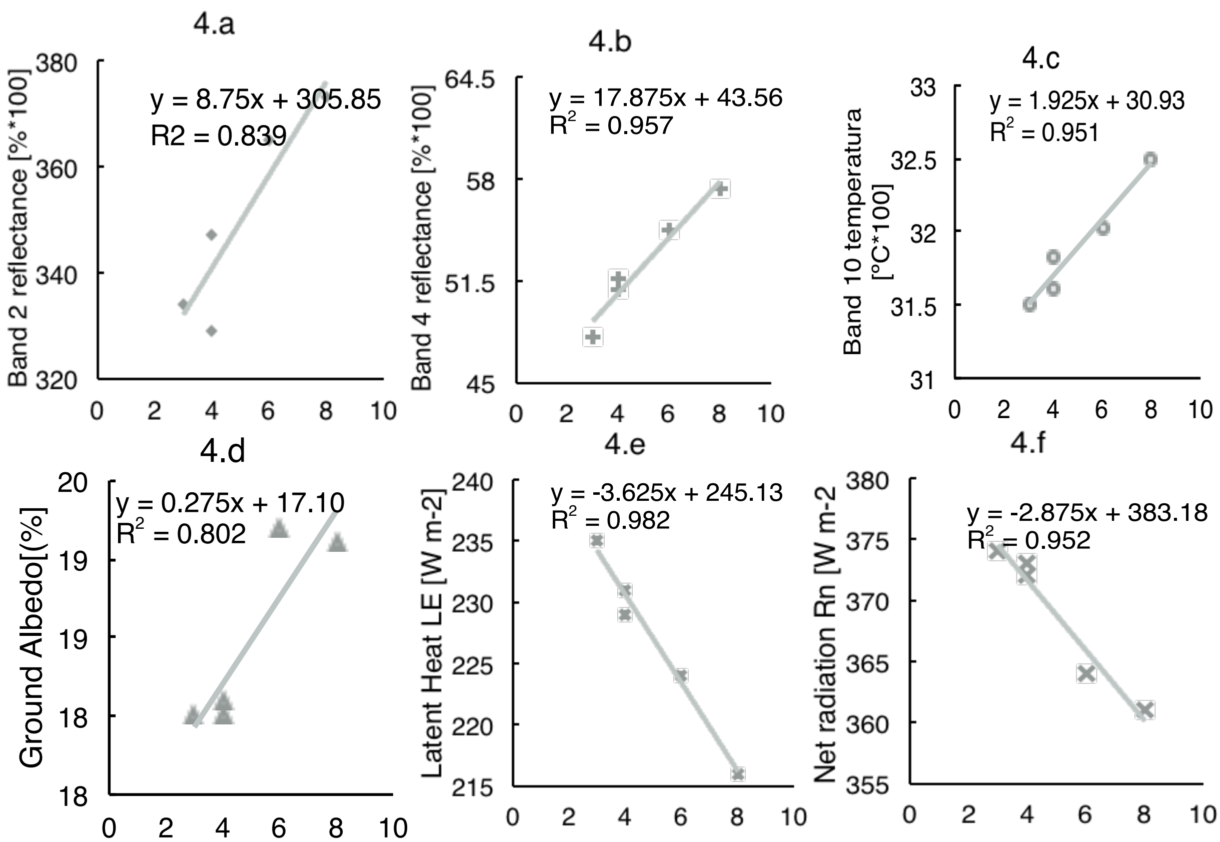

Figure 4. Infestation of Diatrea saccharalis vs band 2 reflectance (a), band 4 reflectance (b), band 10 temperature ºC (c), ground albedo (d), latent heat (e), net radiation (f). Linear trend line with the equation and coefficient of determination ($R^{2)}$.

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