HYPERSPECTRAL REMOTE SENSING IMAGES APPLIED TO THREE CASES IN THE CENTRAL ZONE OF CHILE

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1. Introduction

Remote sensing is the technique by means of which the acquisition of distant images allows to obtain information about the Earth's surface without being in contact with it, as it uses the physical properties of the observed objects, in particular its optical properties (Casadesus et.al 2004). Besides, it provides the possibility of going beyond the structural items and the description of the ecological systems functional aspects, particularly at the ecosystems level (Cabello, 2008).

The use of remote sensing techniques becomes a very useful tool to study the characteristics of the dynamic processes which take place on the Earth's surface. For this remote observation to be possible it is necessary the occurrence of some kind of interaction between the objects and the sensor (Chuvieco, 2004). In the case of passive remote sensing it is provided by the energy flow caused by the solar light and the energy reflected by the observed object.

The remote sensing can be a viable and fast alternative to access vast spatial information of inaccessible places, making remote sensing an invaluable tool for the identification of different elements of the earth's surface. Besides, if adding to this advantage, the information extracted from the physical features which made them up, through the using of hyperspectral sensors of high spatial and spectral resolution, the vegetation health condition and essential characteristics of the water resources can be determined.

The hyperspectral sensors receive information about the earth's surface characteristics simultaneously to hundreds of spectral adjacent bands, which allows obtaining continuous spectral information of the remote sensored object without having to resort to extrapolation protocols of detailed measurements (Paruelo, 2008). The above mentioned allows to widen the information rate for the interpretation of some kind of coverage in particular either analyzing each band separately or generating rates by the combination of these ones.

Through the hyperspectral images analysis it is possible to point out the differences among ground, vegetation, water bodies or other element from the landscape, besides the spectral response can be related to productivity, seasonality, phenology, irrigation efficiency, vegetation stress, forest species identification, fire risk, invader species, temporal and spatial variation of terrestrial and aquatic habitats, plantation condition depending on the ground type, discrimination of non - photosynthetically active vegetation, among others. The present study is applied to hyperspectral sensing to 3 cases: i) agriculture stress, ii) fire fuel index and iii) aquatic habitats identification.

2. Objectives

2.1 General

Generating methodologies for high resolution hyperspectral images exploitation applied to hydric and agroforestry resources in the Central Zone of Chile.

2.2 Specific

a) Using of specific indexes to determine agriculture stress in avocado trees and fire fuel in the sclerophic forest and forestal plantations, b) Estimating areas with higher or lower forestal fire occurrence and the lost of vegetation associated to these events, and c) To research different water indexes for determining aquatic habitats.

3. Methodology

3.1 Material and Methods: It was used for this study: i) a remote sensing hyperspectral image of 128 bands (400 to 1000 nm) for the AISA-Eagle Specim sensor over an aerial platform (Piper bimotor) from Valle del Maipo area – Rapel River Mouth, in the Central Zone of Chile, ii) a digital elevation device from the area and iii) site information.

3.1.1 AISA-Eagle Specim Sensor Characteristics

This sensor, besides having advantages over the conventional satellite systems regarding the spatial and spectral resolution, it bears the advantage which is crucial for environmental studies, the temporal resolution. Acquiring the image does not depend anymore from a predetermined satellite orbit, instead when it is airborne in medium-sized airplanes (ej: Pipper bimotor, Cesna mono-motor) makes it more versatile being able to adapt the image capture moment to the study requirements or to inconvenient climate factors as the cloud cover.

Table 3.1.1 technical characteristics and spatial and spectral resolutions which are possible to reach with the sensor.

Sensor	**specification**
Spectral rate	400 – 900 nm
Spectral resolution	2.3 – 10 nm (selectable during flight)
Nº spectral bands	1 – 256 (selectable during flight)
Operative Mode	Hyperspectral and Multispectral
Image rate	> 100 Hz (selectable during flight)
Spatial Scanning	960 pixels

3.2 Hyperspectral image preprocess and analysis

First of all the radiometric and topographic corrections were applied to the image. Through this last process the orto-rectified image was obtained, After that the agricultural stress and fire risk indexes were generated. . With this, two of the specific objectives were achieved. Therefore for the third one the indexes used were generated according to the spectral response of the different aquatic habitats (Figure 3.1).

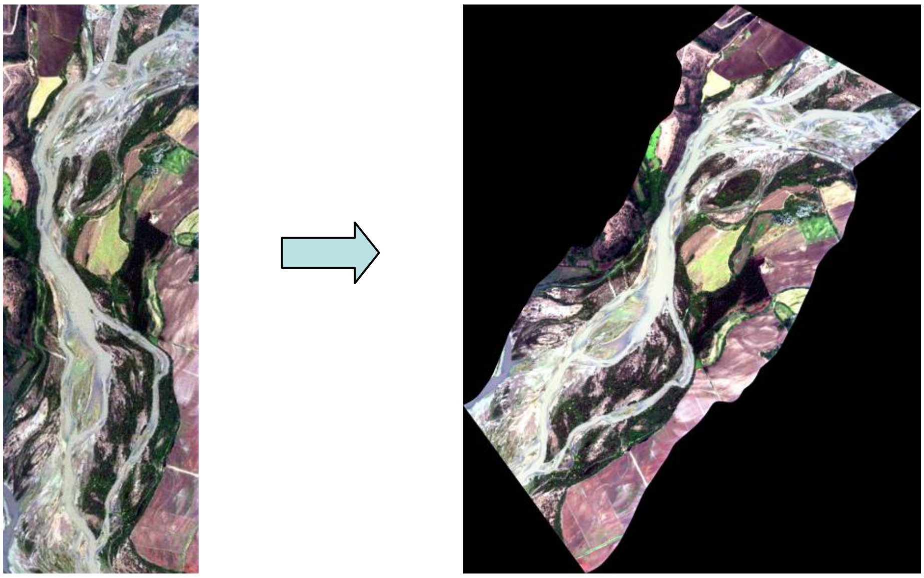

Figure 3.1. Radiometric and orto-rectified image

3.3 Agricultural stress:

In general terms, the vegetation index is the addition, the difference or lineal combination of a reflection factor or radiance observation between two or more bands of the electromagnetic spectrum (Sebem 2005). The most used bands are the ones of the red and the near-infrared, as the combination of both generates a determined absorption pattern for the pigments and the internal structure. The leaves reflection characteristic signal is also extrapolative for a canopy (Casadesus et. al. 2004).

Thanks to the use of hyperspectral images, the vegetation indexes have being boosted regarding the identification of factors that affect the plants condition, this is the case of the **agricultural stress tool** (ENVI 4.4), which uses 4 types of vegetation indexes:

a) **Canopy water content**, WBI (*water Band Index*) as water content raises the absorption is increased about 900 to 970 nm, that's why the equation which defines it uses the following relation (*Rx indicates reflection to x nm).

$$WBI = R900/R970*$$

b) **Vigorousness, NDVI** (*The Normalized Vegetation Index*). This one is related to the biomass or the vegetation vigor (Jensen, 2000 in Polidorio, 2005). For its calculation the red and near-infrared bands are used. High vigor areas (vegetal density) have a higher reflectivity (response) in the near-infrared and a lower reflectivity in the red. The delivered vigorousness values by this relation vary between -1 and 1. If the value comes closer to 1 is indicating vigorous and healthy vegetation, the values closed to zero are related to fractional to bare soil, and negative values generally correspond to clouds or water bodies. By using this index we can identify different degrees of vegetal covers. The index is calculated using the following equation:

$$NVDI = (900 – R679)/(R900+R679)$$

c) **Foliar pigments, SIPI** (*The Structure Insensitive Pigment Index*) this index uses the relation of the spectral response of the carotenoids and vegetation chlorophyll. An increase of this index indicates stress in the canopy. It is mainly used for monitoring the vegetation health condition and agriculture production. The following equation defines it:

$$SIPI = (R800-R445)/(R800-R698)$$

d) **Efficiency regarding the use of light**, PRI *(Photochemical Reflectance Index)* measures the sensibility to the pigments changes in the foliage, these ones are indicative of the vegetation photosynthetic activity, this is useful for vegetal stress and productivity studies. The values obtained vary from – 1 to 1, the green vegetation bears values between -0.2 and 0.2. For its calculation the following equation is used:

$$PRI = (R531 – R570)/(R531 + R570)$$

As an experiment, a cultivation of *American Persea* was evaluated, in which the agricultural stress tool was applied and furthermore the cultivation was selected by deleting those pixels identified as ground, by means of which a thematic map of those vulnerable cultivation zones was generated.

3.4 Fire fuel:

The first methodological step was the creation of a hyperspectral image sub-scene through the generation of an exclusion mask of the vegetation using the NDVI index, as a fire can only be started where there is fuel for it. This was achieved by using the **fire fuel identification tool,** which uses the vegetation vigor index (NDVI), canopy water content (WBI) and senescent plant reflectance PSRI (Plant Senescence Reflectance Index) the one that outstands the vegetation senescence condition through the relationship between carotenoids and clorophil, the following equation describes it:

$$PSRI = (R680-R500)/R750$$

This tool was used in a sclerophil forest and in a forestal cultivation, with this a thematic map with the possible fire routes and high vulnerably zones was designed.

3.5 Aquatic habitats identification:

The specific methodology has as an objective to discriminate the terrestrial from the aquatic fraction, and on a second approach to identify habitats and physical, chemical and/or biological processes that can be detected according to its spectral response.

The spectral analysis was carried out bands algebra which increases the contrast between different types of targets. With this methodology was possible to discriminate between different components on water, such as clear water, algae-laden water or turbid water by suspended solid loads. In the Figure 3.2, there is an example of few specific wavelengths at bands around 470, 550, 680 and 705 nm producing the maximum differences between two types of water characteristics.

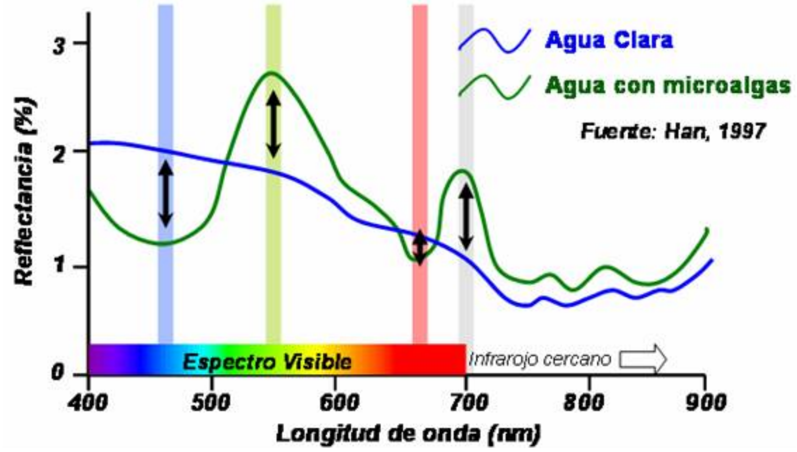

Figure 3.2. Spectral signature of clear water and alga-laden water.(Han, 1997)

4. Results

The use of the **agricultural stress tool** allows identifying the stress condition of the *American Persea* cultivation, a high heterogeneity was established in the health condition on the cultivation area, identifying specific sites with a high stress degree mainly located in the border areas in internal paths as well as in the border of the cultivation area. In the Figure 4.1 there were identify two main sites with trees older than ten years, with different values of agricultural stress. At the site 1.A the average stress was 4.4 while the site 1.B showed a higher stress of 5.2.

Within the quarter with trees of two years (Figure 4.2), there were noticed two different sites: an inner depressed site (2.A) with average values of 7.7, and the adjacent sites (2.B) showing less stress with an average value of 5.9.

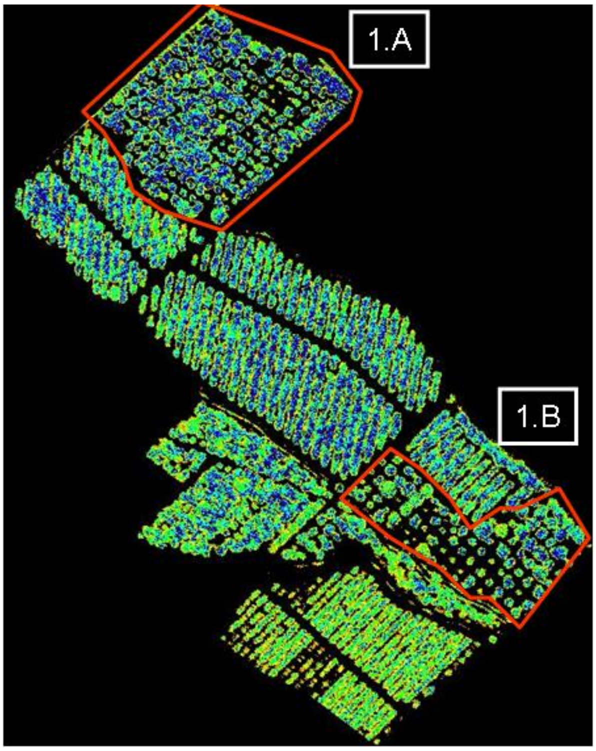

Figure 4.1. Agricultural stress tool of the *American Persea* cultivation. Polygons 1.A and 1.B show sites with trees older than ten years. Data collected during June and August 2009. Central Region, Chile.

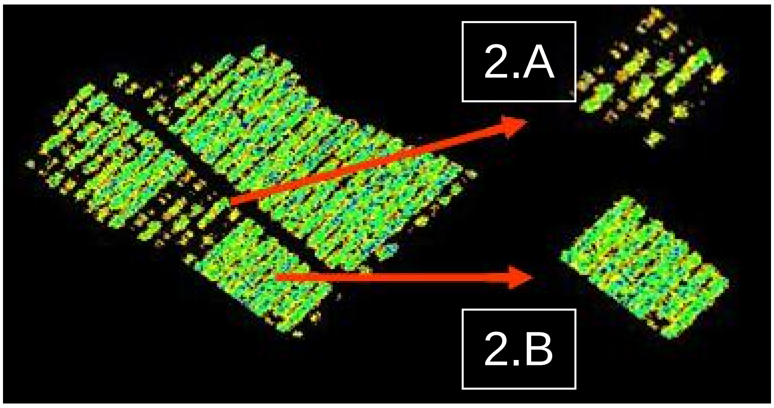

Figure 4.2. Agricultural stress tool of the *American Persea* cultivation. Polygons 2.A and 2.B show sites with trees of about two years. Data collected during June and August 2009. Central Region, Chile.

The **fire fuel tool** allows identifying the high vulnerability of the border areas, in the sclerophil formation as well as in the forestal cultivation areas. The thematic map indicates the priority points for the fire control management in the natural areas and in the forestal cultivation area as well (Figure 4.3).

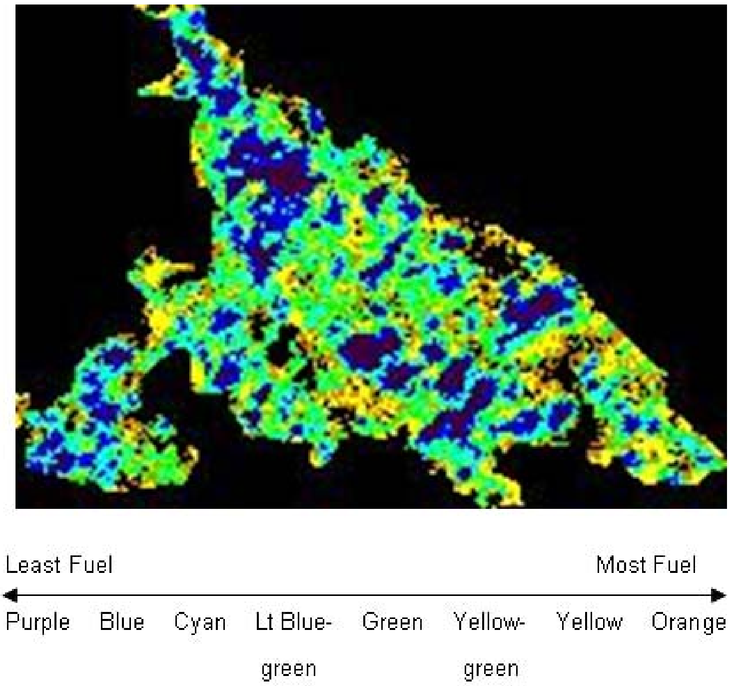

Figure 4.3. Fire fuel tool in the sclerophil formation. Data collected during June and August 2009. Central Region, Chile.

In relation with **water resources application**s, the use of bands algebra according to the utilized indexes showed certain specific wavelenghts around the red edge (670 to 710 nm) that are related with water, chlorophyll *a* and suspended solids absorption and reflectance of the spectrum. In the Figure 4.4 is shown some spatial maps of Laguna de Aculeo (central region, Chile) with different spectral bands for data collected during June and August 2009.

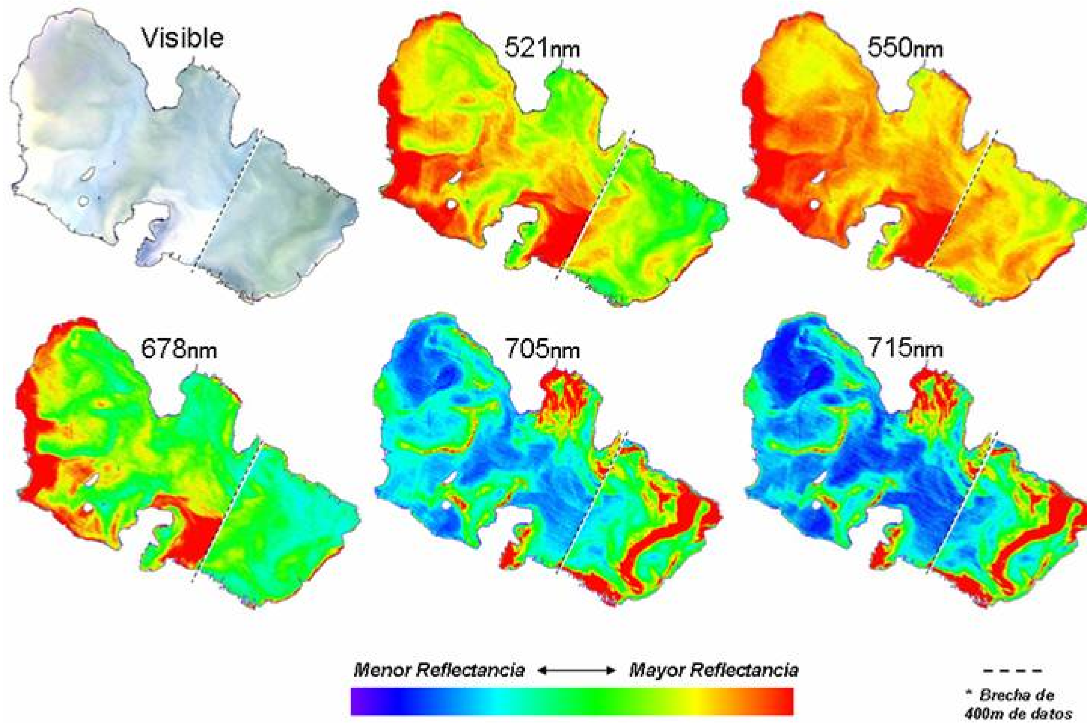

Figure 4.4. Maps of spectral response at different wavelengths at Laguna de Aculeo, Central Region, Chile. Data collected during June and August 2009.

Han (1997) and Thiemann & Kaufmann (2000) have studied the spectral response of water, phytoplankton and suspended sediments. Depending on the concentration of algae or suspended solids, there were differences on the spectral signature. For identifying the algae-laden water patterns, the index Chla = R705/R678 was applied. On top of this, the red-edge showed a greater reflectance due by a specific sediments loads coming from a stream inflow. In the Figure 4.5 there is a map of relative concentration of algae, and the signature of three sites with different patterns: a) West site with relative clear water, b) Central site with algae-laden water, and c) East site with algae-laden water with suspended solids load.

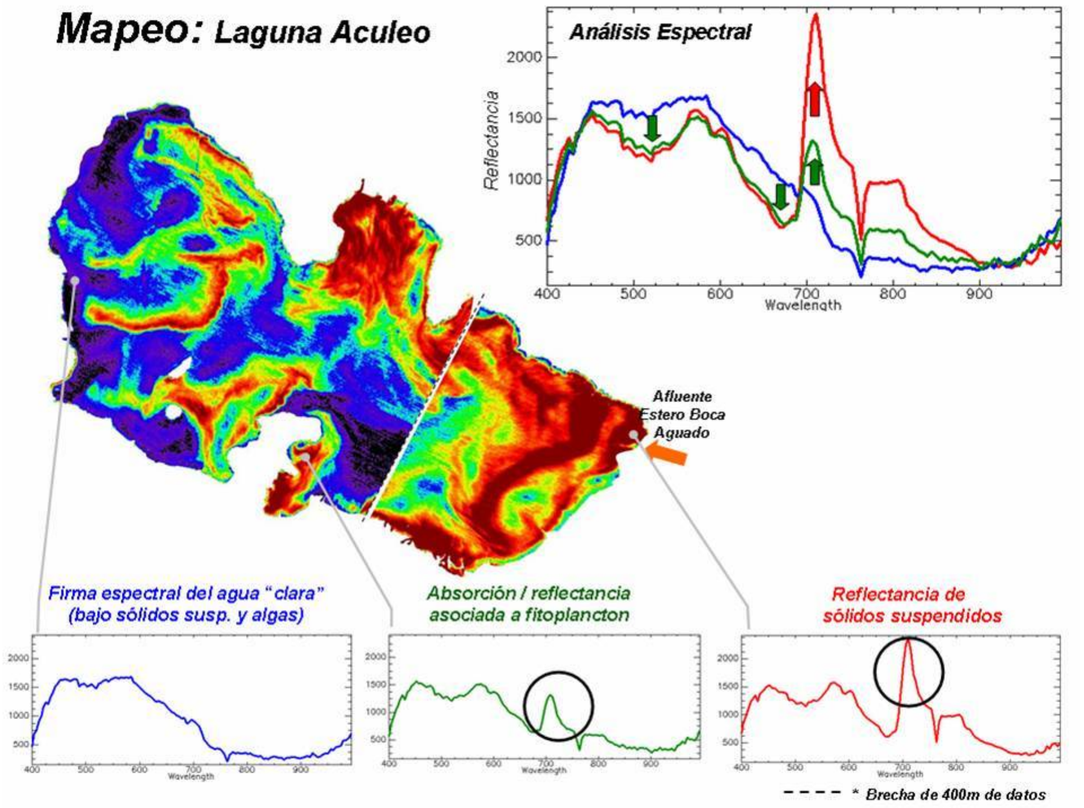

Figure 4.5. Relative algae concentration map, and spectral response of three characteristic sites. Laguna de Aculeo, Central Region, Chile.

5. Conclusions

The results showed the applicability of the spectral analysis associated to the hydric resources in the central region of Chile. The aquatic habitat identification as well as other physical, chemical and/or biological processes, is highly important in the aquatic eco-systemic analysis, for baseline characterization mapping and for the implementation of functioning models as well.

The use of the hyperspectral sensor AISA Eagle Specimen is just opening a door for the application of spectral, spatial and temporal resolution to support the ecosystem knowledge.

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