MEASUREMENT OF COLOR IN HYPERSPECTRAL IMAGES (AVIRIS) USING THE CIE (COMMISSION INTERNATIONALE D'ÉCLAIRAGE) SYSTEM

Ana Paula Ferreira de Carvalho[1,2]
Osmar Abílio de Carvalho Júnior[3]
Renato Fontes Guimarães[3]
José da Silva Madeira Netto[4]
Mercedes Maria da Cunha Bustamante[1]

[1]Departamento de Ecologia - Universidade de Brasília (UnB)- Campus Universitário Darcy Ribeiro, Asa Norte, 70910-900, Brasília, DF, Brazil
[2]INCRA – SBN Ed. Palácio do desenvolvimento, sala 1205, 70057-900, Brasília, DF, Brazil
[3]Departamento de Geografia - Universidade de Brasília (UnB)- Campus Universitário Darcy Ribeiro, Asa Norte, 70910-900, Brasília, DF, Brazil osmana@tba.com.br
[4]Embrapa/CPAC-Centro de Pesquisa Agropecuária dos Cerrados - Caixa Postal 08223, BR 020, km 18, Rodovia Brasília/Fortaleza, 73301-970, Planaltina, DF, Brazil madeira@cpac.embrapa.br

Introduction

A new concept in the digital processing of images is appearing due to the spectroscopy image. The AVIRIS sensor (Airborne Visible/Infrared Imaging Spectrometer) developed by NASA in 1983 (Vane *et al*., 1984) was the first imaging system capable of continually acquiring bands. This sensor captures along the portion of the reflected solar spectrum from 0.4 μm to 2.5 μm. The system was developed to obtain data that could be used in the several areas of geosciences. AVIRIS became operational in 1988 after some fittings and corrections accomplished by researchers at JPL (the Jet Propulsion Laboratory), NASA.

AVIRIS was brought to Brazil in 1995 for the SCAR-B (Smoke, Clouds and Radiation - Brazil), mission with the purpose of evaluating atmospheric effects. This activity was accomplished by NASA, INPE (National Institute of Space Researches) and AEB (Brazilian Space Agency) (Kaufman *et al*., 1998).

Hyperspectral remote sensing is a recent technology that has been growing fast and provides a constant proliferation of new methods and algorithms for analysis. In those images, the large quantity of information allows for a wide propagation of methods in order to improve the detection and quantification of the materials that compose the scene.

During the SCAR-B mission, the AVIRIS sensor over-flew the Niquelândia area on August, 16th 1995, generating images of areas with supergenic mineral concentration (nickel lateritic). This high concentration of nickel has marked effects on the distribution of vegetation types. The flight line was accomplished longitudinally to the Niquelândia complex, crossing the geological units.

The aim of this work was to adapt and test the employment of the CIE color system in AVIRIS hyperspectral images to differentiate vegetation patterns. The employment of the color concept provides a reduction of the spectral space, concentrating the information, and it allows for better interactivity with the analyst because of the visual approach.

Characterization of the Study Area

The distribution and physiognomy of vegetation in the Niquelândia Massif represent a strong geological control, described by Brooks *et al.* (1990). At this site, extensive areas of ultramafic rocks are covered by herbaceous vegetation dominated by grasses (*campo rupestre*: Photo 1). The fires that occur during the driest months (June - August), might influence the physiognomy of the vegetation. However, fires alone do not explain the abrupt limit among the gabroic rocks (mafic) and the ultramafic substrate.

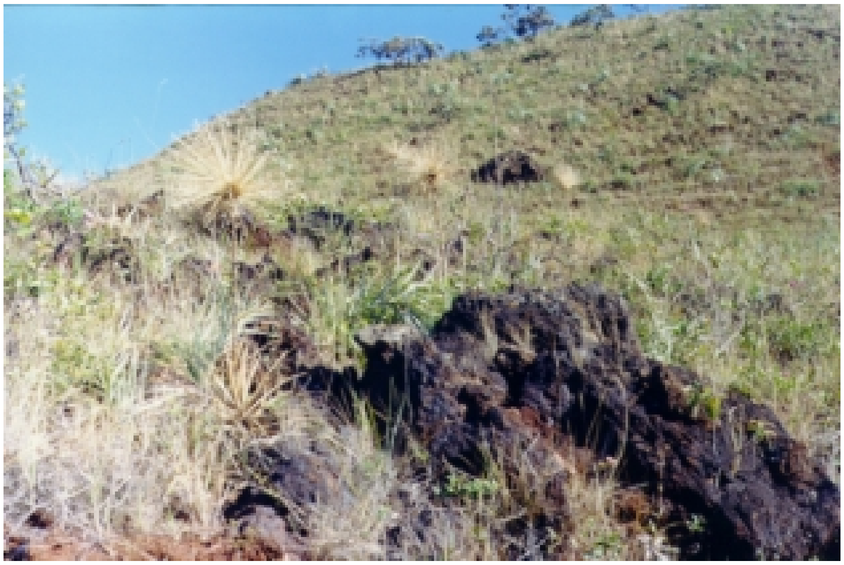

Photo 1 – Vegetation on ultramafic rocks.

Different types of forests can be found along the streams and valleys. The existence of these areas demonstrates the ability of many species to tolerate soils originated from ultramafic rocks if soil depth and humidity are appropriate and some fire protection exists (Photo 2).

Photo 2 – The forest along streams and valleys.

In this environment/community the first hyper-accumulator of nickel in South America was identified. This species of *Cnidosculus*, described as *C. bahianus*, is a scrub from 1.5 to 2 m height, with thorny leaves and fruits. It produces large amounts of white latex, in which was later found 1.35% of nickel (dry matter basis). The leaves of *Cnidosculus* are much less rich in nickel than in latex, with 0.01-0.11% of Ni. Similar accumulation pattern was found in *Sebertia acuminata (Sapotaceae*) that occurs on serpentine soils, in New Caledonia. *S. acuminata* has a blue-green latex with more than 25% of nickel in the dry matter and 1.17% in the leaves. These species are similar to *C vitifolius* widely distributed in *Americano do Brasil* and *Barro Alto* (central Brazil) where there are large deposits of nickel.

The canopy does not surpass 1 m height in the highest areas of the ultramafic massif. Among the most frequently occurring plants are the species of *Paepalanthus (Eriocaulaceae)*, *Heteropteris (Malpighiaceae)* and *Vellozia (Velloziaceae)*. Several species of *Vellozia (canela-de-ema)* occupy varied substrates in the highest altitudes of central Brazil.

The CIE System

The CIE (*Commission Internationale d' Éclairage*) color system represents an international consensus. This system of colors has been used in radiometric studies in order to characterize soils (Madeira Netto, 1991). With this new technique for the spectroscopic image, the spatial distribution of CIE values can be obtained with greater accuracy.

The color equation to radiometric data in terms of red, green and blue, for human vision involves negative values, which hinders its use. With the adoption of the CIE system, the occurrence of negative values is eliminated (Evans, 1948). However, it generates a virtual system that doesn't clearly translate to the behavior of the human eye. Presence of negative values can be a source of occasional errors (Wright, 1944), i.e.:

- the negative signs not only occur in the chromaticity coordinates but also in the distribution coefficients;
- the calculation for specification of the values tri-incentives involves the product of the sum of positive and negative amounts; and
- the negative values hinder the development of colorimeters.

That system adopts as pattern for the international use:

- a curve of relative brightness,
- curves of color mixtures for three normalized imaginary lights; and
- a specific distribution of energy for a source of basic light.

Figure 1 gives the brightness curve for the reference observer.

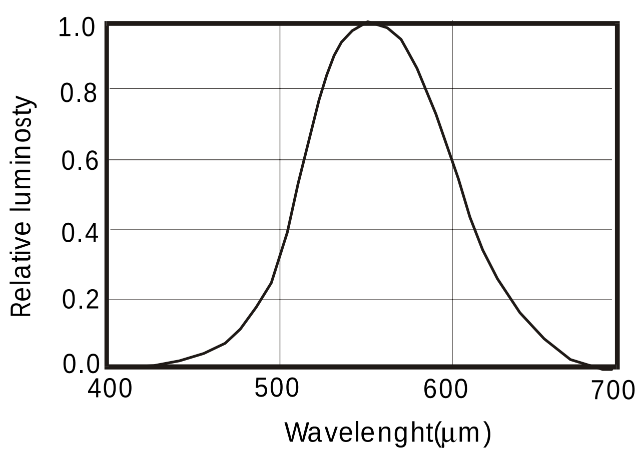

Figure 1 – Brightness curve (source: Evans, 1948)

The curves of the tri-stimulus of primary CIE in relation to wavelength are presented in **Figure 2**.

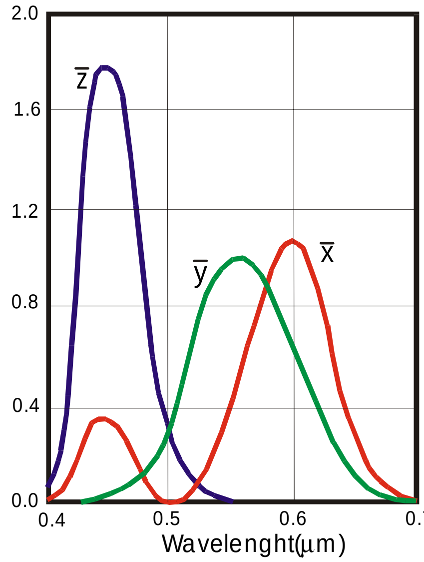

Figure 2 – CIE tri-stimulus values, x, y, and z for the spectral colors. (Source: Evans, 1948)

The procedure to derive a color specifies the tri-incentive (X, Y and Z) starting from a spectral composition E(λ). It can be algebraically expressed in the following way:

$$\mathbf{X} = \sum \mathbf{E}\lambda * \overline{\mathbf{X}}\lambda$$
$$Z = \sum E\lambda * \overline{Z}\lambda$$
$$Y = \sum E\lambda * \overline{Y}\lambda$$

And the chromaticity coordinate x, y e z is expressed by:

$$x = \frac{X}{X+Y+Z}$$
$$y = \frac{Y}{X+Y+Z}$$
$$z = \frac{Z}{X+Y+Z}$$

To calculate the values of X, Y, Z, x, y and z in the ambit of this work, an algorithm in IDL language from the ENVI program was developed. This program was tested to distinguish vegetation patterns in the Niquelândia area (GO), in Central Brazil.

The z value can be discarded, once it can be obtained from x and y.

$$\mathbf{1 = x + y + z}$$

$$\mathbf{1 - z = x + y}$$

Analysis of the Vegetation in the Niquelândia Area

In the image used, the atmospheric effect was corrected by the Green method. That method proposed by Green (1990) was specifically developed for AVIRIS hyperspectral images.

The Green method provides an estimate of the atmospheric parameters and a calculation of the apparent reflectance of the surface using the code of radioactive transfer together with a model of non-linear adjustment for the square mean (Green, 1991, Green *et al*., 1993a,b).

After the atmospheric correction, an estimate was made of the CIE chromatic coordinate (x, y, z and Y). The images x, y and z and Y are presented in **Figure 3**. The x image presents larger values for red colors and points out the areas with exposed soil that are visually associated with that color. The larger value of the y image corresponds to the green objects and points out the presence of green vegetation that occurs along the waterways. It also occurs in areas of more fertile soils that are correlated to the basic rocks. The z and Y components point out the areas with vegetation of *campo rupestre* that are dry during this time of the year.

In **Figure 4**, the RGB color compositions are presented starting from the CIE images. It can be observed that the two-composition xyY allowed the identification of vegetation patterns that occur in different substrata. The composition that uses the brightness (xyY) allows a better differentiation of the vegetation that occurs on the ultrabasic rocks and appears as a purple color.

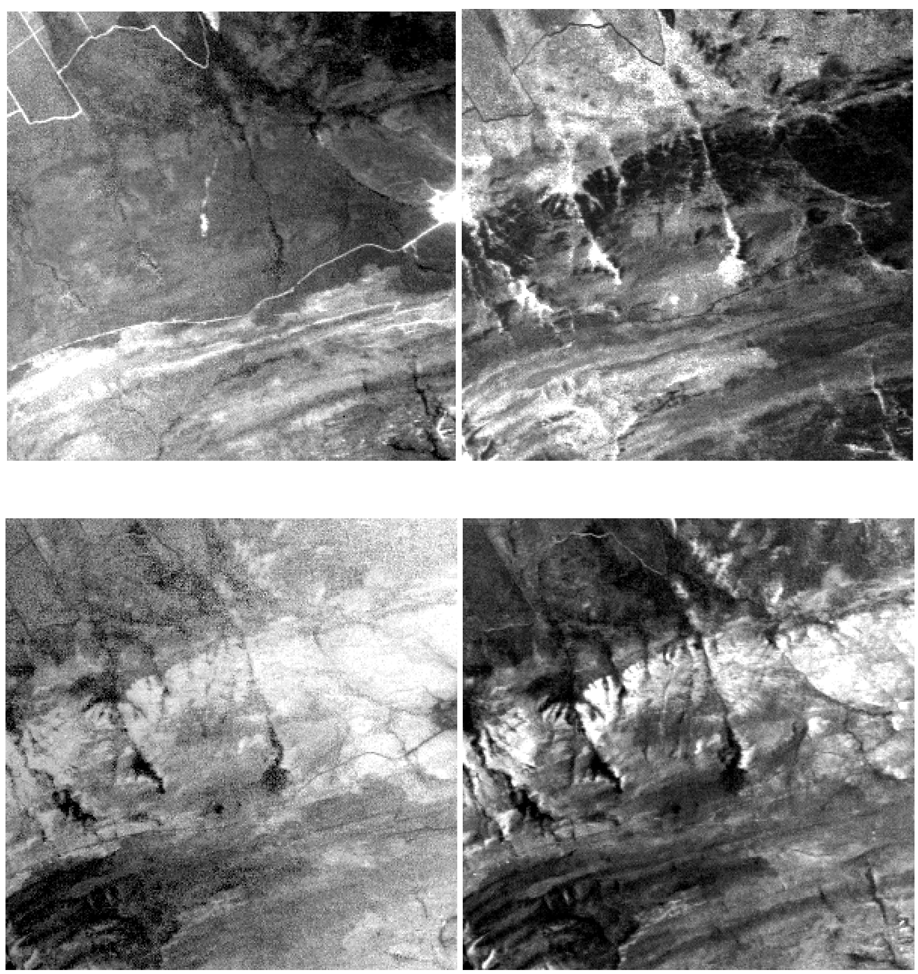

Figure 4– Niquelândia area CIE Image: a) x, b) y, c) z e d) Y.

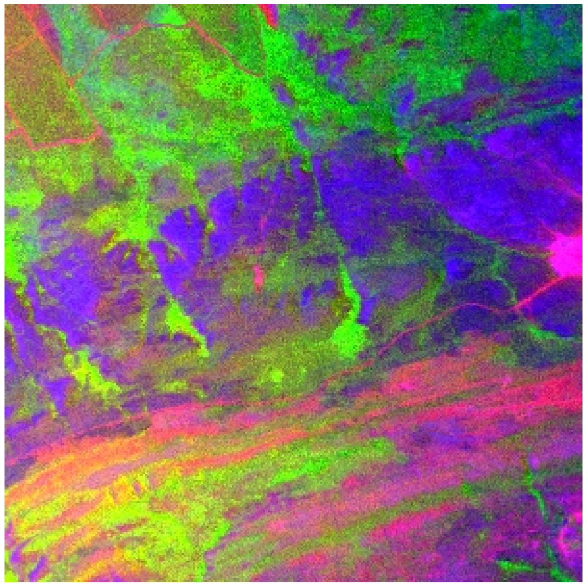

Figure 5 - Color Compositions RGB: a) xyY.

Conclusions

The main advantages of the employment of the CIE color system are:

1. Spectral dimensionality reduction;
2. Determination of chromatic values, which are easily understood by the human eye, allowing a cognitive interpretation; and
3. Establishment of values according to the international pattern that allows for comparisons among different areas. This characteristic is not obtained by other methods of dimensionality reduction such as the analysis of principal components and MNF (Minimum Noise Fraction - Green *et al*., 1988).

For the Niquelândia area it was possible to separate for the parameters of CIE vegetation patterns in soils originated from ultramafic or mafic rocks.

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