The Use of Vegetation Indices to Establish the Land Use

Iosif VOROVENCII, Assoc. Prof. PhD. Eng. Ec – University "Transilvania" of Brasov, Romania, icatop@yahoo.com
Maricel PALAMARIU, Prof. PhD. Eng. Ec. – "1 Decembrie 1918" University of Alba Iulia, Romania, mpalamariu@uab.ro
Levente DIMEN, Assoc. Prof. PhD. - "1 Decembrie 1918" University of Alba Iulia, Romania, ldimen@uab.ro
Magdolna Eva KONCSAG, Lect. PhD. Stud. Eng. - "1 Decembrie 1918" University of Alba Iulia, Romania,

Abstract: *In this paper are presented a series of aspects regarding the vegetation indices the most used in analyses of land use and land cover. The use of this in differentiation of vegetation is a convenient and fast way for knowledge inventory and evidence of land cover changes on vested surfaces. In this way, between the most used vegetation indices are Ratio Vegetation Index (RVI), Normalised Difference Vegetation Index (NDVI), Perpendicular Vegetation Index (PVI), Global Environment Vegetation Index (GEMI), Transformed Soil Adjusted Vegetation Index (TSAVI), Soil Adjusted Vegetation Index (SAVI) and other indices. Some of this are presented in this paper and also are presented relations between them. For analysis of vegetation indices are used the satellite images Landsat TM and ETM+ which have a 30 meter spatial resolution. The analyses of satellite images was conducted to point out some aspect regarding the land use and land cover like density of vegetation, the bare soil, percentage cover, biomass, leaf area index.*

Keywords: *satellite images, vegetation indices, land use, land cover, spatial resolution, isovegetation lines, leaf area index*

1. Introduction

Processing and interpretation of satellite images may reveal both the contained information and some beneficial results in terms of quality interpretation, time saving and costs. The use of vegetation indices for image interpretation and validation with "in situ" data leads to the impartiality of interpretation and to the increase of these benefits. The effectiveness of vegetation indices to interpretation of satellite images is the subject of many researches. Experimentation with different combinations of ratios of bands using indices of vegetation leads to the optimization of results in various soils and vegetation. The use of vegetation indices consists in presenting the information contained by the spectral bands through a single variable.

Considered as the simple relationships between bands, the vegetation indices allow a uniform analysis of vegetation in some variety of scenarios using data acquired from a large number of satellite platforms. Their success and the simple comparison between them show their similarity. They can be compared with other combinations of spectral bands that can lead to similar results.

Land use and **land cover** are two ways of describing the nature of land. Land use is a grouping of land with the same economic destination, naturally or artificially, which has a certain code. Compared to this, land cover is the biophysics material that covers the land's surface in any location. Records on land use and land cover give information that seated together express a good indication of the environment and of processes that occur in a given place. Chronological thematic maps on categories of land use/land cover provide information on the scale of change, the type and place they occurred. Precise and in time mapping of land use/land cover provide important information on the environment, development trend and wildlife habitat.

In specialized literature there are many works related to vegetation indices and correlations between the remote data and biophysics properties of plants, some of them are directed on development and comparison of indices. Some researchers (Perry and Lautenschlager, 1984) compared 20 indices and found that many of them are functionally equivalent. Others (Coppin and Bauer, 1994) have suggested that vegetation indices can be grouped into three categories: brightness, greenness and wetness. Also Wallance and Campbell (1989) showed that indices derived from an analysis may even be wrong in different situations. For example, in the semiarid environment it was found that transformation Tasselled Cap does not improve the accuracy compared to the separation of raw data Landsat TM. In this situation, using SAVI index may be much closer to a much greater percentage of found soil compared with areas with associated vegetation. Other researchers (Qi et al., 1995) have shown that only some vegetation indices present biophysics information.

In recent years several indices were arranged while others have been improved by using spectral data taken on narrow bands. In this category are included the *Modified Soil Atmospherically Resistant Vegetation Index* (MSARVI), *Photochemical Reflectance Index* (PRI) and *Normalized Pigments Chlorophyll Ratio Index* (NPCI). The MSARVI Index normalizes spectral data to mitigate the influence of atmosphere and soil background. NPCI and PRI indices are sensitive to plant pigments (chlorophyll a and b, carotenoids), which allow a more direct estimation of photosynthesis and biomass accumulation.

Vegetation indices were used in studies on vegetation in different parts of the world. The most used index of vegetation is the *Normalized Difference Vegetation Index* (NDVI) which was obtained on the base of measurements using the spectrometer land and satellite images. It was used to study the pasture effects, burns and depth of soil with different biophysics properties. It was also studied the effect of mower and the fertilization of high herbaceous productivity using NDVI and *Greenness Vegetation Indexes* (GVI). Weiser et al. (1986) used the near infrared/red (NIR/red), GVI and NDVI indices for characterizing properties of biophysics areas with a lot of grass. Frank and Aase (1994) found a strong relationship between the accumulation of dry biomass and a number of vegetation indices, including the NIR/red and NDVI. Todd and Hoffer (1998) found that NDVI is influenced more than GVI by the soil moisture. Variation of NDVI in relation to *leaf area index* (LAI) on grass was evaluated by many researchers (Walthall and Middleton, 1992).

Lauver and Whistler (1993) have shown that the Landsat TM raw data compared with the Tasseeled Cap and NDVI are more suitable for the differentiation of the land covered with grass of high quality than those with poor quality. They showed also that the TM2, TM3 bands and *Tasseled Cap Brightness Index* (BI), selected by differential analysis, are best for identifying the types of land covered with grass of high or low quality. Other researchers (Price et al., 1992, 1993) have examined the relationship between measurements made with spectroradiometres in narrow bands (1.4 nm) and the biophysics measurements of six types of land covered with grass in eastern Kansas. They showed that the band with a 792.2 nm wavelength is strongly correlated with biomass and leaf area index LAI (r = 0.78 and 0.85).

2. Materials and methods

In the paper were used two satellite images, one Landsat 5 TM taken in 1989 and the other Landsat 7 ETM + taken in 2000. Spatial resolution of these recordings is of 15 meters in panchromatic and 30 meters in multispectral and the radiometric resolution is of 8 bits. Both records contain approximately the same area of the Bucegi Mountains and Piatra Craiului where they appear as categories of land use, pasture, meadow, agricultural land, forest (resinous and leafy), wooded pasture, built land, land covered by water, unproductive land.

Image processing was done with the Erdas Imagine 8.6.

The methods used are specific to remote sensing satellite and direct visual interpretation.

3. Vegetation Indices Review

The Normalized Differential Vegetation Index (NDVI) is an improvement in the ratio vegetation index (Rousse and others, 1974) and is calculated by the relationship:

$$NDVI = \frac{IR - R}{IR + R} \quad (1)$$

The Perpendicular Vegetation Index (PVI), proposed by Richardson and Wiegand (1977) is defined as the perpendicular distance between a point representing green vegetation (R_{veg}, IR_{veg}) and soil line. It can be considered a generalization of the different vegetation index (DVI) which allows the soil line to take different slopes. It was found that PVI is quite sensitive to atmospheric variations (Qi et others, 1994) so that a comparison of the values of these indices for the data taken at different times is risky without the prior atmospheric correction.

As a perpendicular index on the line of the ground whose slope is arbitrary and passes through origin and the isovegetation lines are parallel to it, PVI is defined by the AB segment that is calculated from coordinates with the relationship:

$$PVI = \sqrt{(R_{sol} - R_{veg})^2 + (IR_{sol} - IR_{veg})^2} \quad (2)$$

where R_{veg}, IR_{veg} – the reflection of vegetation in red and near infrared band and R_{sol} , IR_{sol} – the reflection of soil in red and near infrared band.

Quantitatively, the perpendicular vegetation index ranges from zero for dry soil to values less than zero for water and more than one for vegetation.

Ratio Vegetation Index (RVI), first described by Jordan (1969), is defined by the ratio of reflected infrared in band (IR) and reflected red in band (R), respectively:

$$RVI = \frac{IR}{R} \quad (3)$$

RVI may take the values in the range from zero to infinity, depending on the reflection.

Global Environmental Monitoring Index (GEMI), made by Pinty and Verstraete (1992), helps to minimize atmospheric effects through a combination of non-linear reflection of the red band. This index value is expressed by the formula:

$$GEMI = n \cdot (1 - 0{,}25 \cdot n) - \frac{R - 0{,}125}{1 - R} \quad (4)$$

where *n* is a coefficient that takes into account reflected bands of red and near infrared and is given by the report:

$$n = \frac{2 \cdot (IR^2 - R^2) + 1{,}5 \cdot IR + 0{,}5 \cdot R}{IR + R + 0{,}5} \quad (5)$$

Soil Adjusted Vegetation Index (SAVI) was suggested by Huet (1988) who intended to minimize soil background effects and expressing SAVI as:

$$SAVI = \frac{IR - R}{IR + R + L}(1 + L) \quad (6)$$

Huet has highlighted that the isovegetation lines do not converge into one point and he decided that the *term L* is the *adjustment factor* due to the influence of soil whose result is NDVI, with another origin of the axes in which the reflection in red and infrared starts from zero. For dense vegetation the factor *L* is zero and for a rare ground vegetation becomes one. In practice, for most applications 0.5 is considered appropriate to an intermediate plant carpet. The appearance of this term in the formula makes SAVI index have the same range of values as NDVI which was presented above.

Transformed Soil Adjusted Vegetation Index (TSAVI) is one of the perpendicular vegetation indices, defined and continuously improved by Baret, etc. (1989, 1991). Basically, it is calculated by the expression:

$$TSAVI = \frac{a \cdot (IR_{veg} - a \cdot R_{veg} - b)}{R_{veg} + a \cdot IR_{veg} - a \cdot b + x(1 - a^2)}$$

(7)

where x = 0.08, value that provides the minimization of the effects of soil; the remaining terms have been explained above. For a = 1 and b = 0, TSAVI is NDVI.

4. Results

The tests have taken into account the actual processing of the two Landsat satellite images through the NDVI and IPV and the approach of the theory of the other indices presented above.

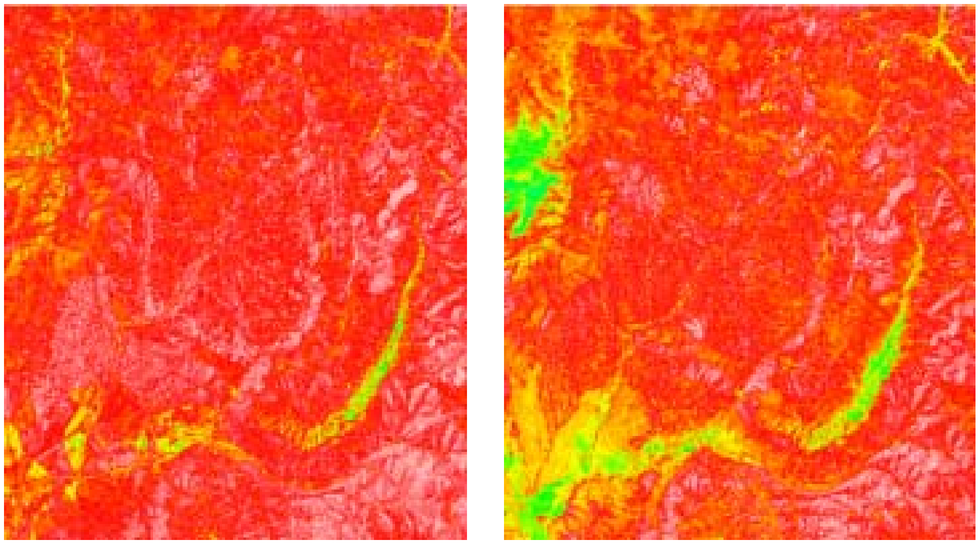
Index of Normalized Differential Vegetation NDVI was calculated for the Landsat 5 TM image (1989) and Landsat 7 ETM + image (2000) (Table 1).

Table 1. NDVI values for Landsat images

Image	NDVI values	
	minim	maxim
Landsat Frame 5 TM 1989	- 0,375000	0,761364
Landsat Frame7 ETM+ 2000	-0,605769	0,617021

As value, in terms of theory, it ranges from - 1 to 1 with the typical range of positive values between 0.1 and 0.6 for active vegetation. To the empty ground, found and rocks that reflect the same amount of infrared radiation and red, NDVI index value is zero and for the clouds, snow and water the values are negative because their reflection is more visible than in the infrared. In the present case there were obtained both negative and positive values for the two images.

Besides the mathematical values that this index may take have been achieved images that give the spectral behavior of different categories of service in the studied area (fig. 1). In this way were analyzed the most important factors which influence the establishment of land use on the base of NDVI index and which are listed below.



a. b.

Fig. 1. Images obtained by using differential normalized index of vegetation (NDVI): a – Landsat 5 TM; b – Landsat 7 ETM+

The type of land use influences within certain limits the NDVI values and therefore it permits to determine them. In both images bare soil without vegetation, unproductive (stones, his stone) have a NDVI value near to zero and they appear in different shades of red color. Pastures in the area (The Lower Clăbucet and The Upper Clăbucet) are always expressed in yellow color which indicates a low NDVI. Note that between meadow and pasture, two close land uses which differ by the fact that the first has a higher index, the images are rendered with a shade of closed green.

Soil background affects the NDVI values, especially in heterogeneous scenes. Since the difference on absorption and reflection between the bands 3 (red) and 4 (near infrared) are high enough, the extreme variations reflected in the soil background can lead to artificial NDVI values larger or smaller than normal. Pixels which are close to background soil color have a lower reflection.

In the same way, a brilliant background of soil, such as quarry stone from the River Mouth, the Grohotiş area of the Bucegi Mountains and the unproductive land areas taken in the study, may increase reflection though NDVI values of vegetation may be artificially lower than similar areas in terms of rich vegetation which have the background of soil almost dark. This effect increases as the vegetation is rare and the soil is bare.

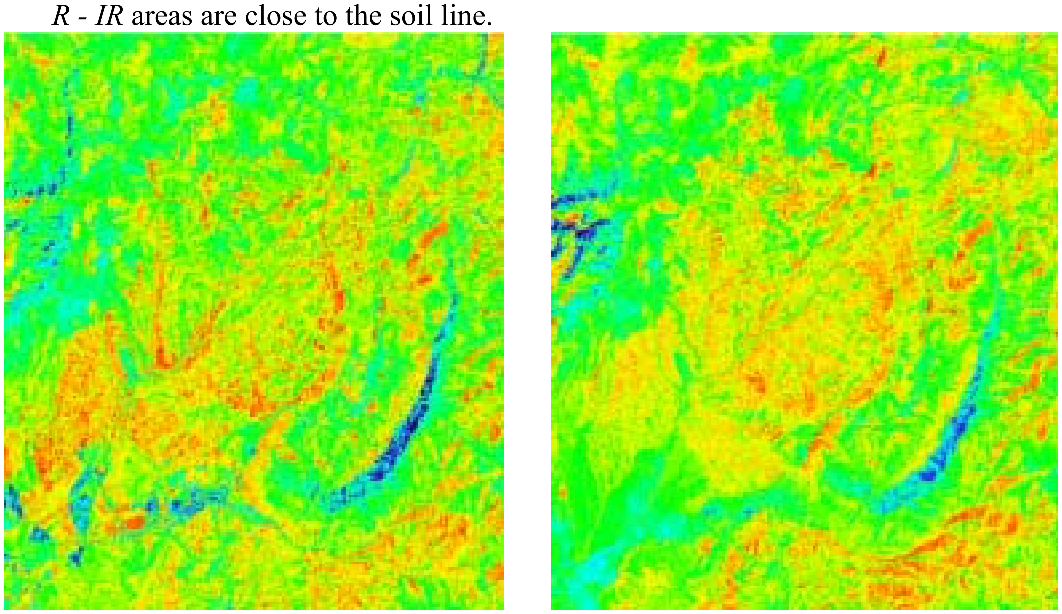
The type of plant carpet and its structure lead, obviously, to different values for the NDVI index. It was noted that the value for a pixel is the sum of radiation reflected by all categories of use contained in this. But with some exceptions, such as large hay-field areas, pixels have a single homogeneous region. NDVI is an indicator of the conditions of vegetation of the recorded area, different values coming from the fact that there are many categories of use that alternate. Each category of service has different spectral behaviour, as such in the case of alternation of various land use with varying types of structure were obtained differentiated values of the NDVI.

Density of vegetation and soil type may limit the correct interpretations for rare land vegetation whereas in such situations the light reflected from the ground can have a significant effect on the NDVI, affecting its value as a percentage of over 20%. It was found that, in general, in the lands with blocks and detritus of the stone quarry at River Mouth, the amount of radiation reflected from the soil is naturally bigger and as a consequence NDVI values are reduced. In the same spirit, in the case of two soils with similar vegetative conditions the one with a greater reflection will cause lower values for NDVI and vice versa.

Researches conducted on areas of interest highlighted the influence of these two limiting factors. Thus, on the same land covered with vegetation but with different consistency the NDVI values vary. These are explained whereas on areas with rare vegetation unlike those with high consistency the soil participates to reflection. Obviously, in areas with rocks for both images were obtained NDVI values close to zero.

The Perpendicular Vegetation Index (PVI) has been established for both recordings (fig. 2). The images obtained were visually interpreted in conjunction with the legend shown for each determination. There were established links between certain colors, index’s values and land use:

- *the open red nuances* represent the forest (beech brush and mixed brush) and the *intense red* also shows forest (leafy brush) but located on the south and south-eastern slope. In these cases we meet the highest values of the PVI index (80-120). Lower values of the index (40-80) are met in the case of resinous forest (spruce) thing explicable because resinous have the spectral response less than leafy;
- *blue nuances* represent the vegetation located on shadow slopes and the land where vegetation is very little represented as for example the alpine gaps. In the case of these areas we meet the lowest values of PVI index (1-15) and in the dimensional histogram *R* - *IR* areas are close to the soil line.



a. b.

Fig. 2. Images obtained by using the perpendicular vegetation index (PVI):
a – Landsat 5 TM; b – Landsat 7 ETM+

Isovegetation lines represent lines of equal vegetation which were obtained by calculating and quantifying the PVI index; greater the value is richer the vegetation. These lines can be superimposed over the two-dimensional histogram made in the red-near infrared spectral space in order to obtain a suggestive representation compared with the NDVI index. In case of Landsat 5 TM image of 1989 the minimum value is 1.29474 and it represents the ground with a very rare vegetation, such as dull pastures and those of alpine gaps, the isovegetation line being close to the soil line, almost close to it, and the maximum value is

81.8625 which shows a rich vegetation, such as unmowing hay-field or cultivated land. In the case of Landsat 7 ETM+ image of 2000 the minimum value is close that of 1989 (1.47367) and the maximum value are much higher (124,138). For both images were reported some negative values characteristic for watercourses in areas that were taken into consideration.

Actual values of PVI index represent the perpendicular distance from the soil to the coordinates (*R, IR*) that gives the vegetation in the two-bidimensional histogram. In consequence, low index values are expressed by a small distance, as a result we have weaker vegetation, and in the case of high values vegetation is rich. In conclusion the higher the values are the distant are they beyond the soil line.

5. Conclusions

The usage of vegetation indices obtained after processing satellite images in defining the categories of land use can be made with the precision of certain things. Firstly, it must emphasize that in the processes were used satellite images with medium spatial resolution (30 m) and which were processed with the available means. Secondly, such an analysis had taken into account large target areas and, as such, the defining of the categories of land use was extended on a large area because of the given spatial resolution images. Thirdly, there were identified several categories of use (pasture, meadow, arable, forest, built) that existed in the work area without seeking to identify the subclasses of land use, which probably would have led to poor results because of the spatial resolution images that were used.

In general, it was found that differentiation can be made on the basis of vegetation indices in relation to categories of land use. As shown, after satellite images of medium satellite resolution, the categories of service can be appreciated on large areas without leading to detailed analysis as for images of high spatial resolution (Ikonos 2, Quikbird, GeoEye, Orbview). Therefore, such processes must be seen both in relation to the areas size which is measured and the costs they claim. In this sense, the images of medium spatial resolution are shown in the processing of vegetation indices for preliminary studies that reveal the categories of land use if these tests are made on large areas because of their low cost. The results of these tests can be general maps, at *regional* or *global scale*, depending on the purpose and which provides images of the whole.

As for the two indices used in processing here are some clarifications. Their usage for highlighting the land use is influenced and dependent on a number of factors that sometimes can be limited.

After processing it was found that the two indices, NDVI and PVI, are related to biophysics parameters as *density of vegetation, percentage cover, biomass, FAPAR* (Fraction of Absorbed Photosyntetically Active Radiation) and *leaf area index*. Their relations with biophysics parameters are often specified and they sometimes change with the optical properties of the soil and land use defined by the spectral response of vegetation, the angle under which they are registered, located. In addition, the relative positions of the sensor and of the Sun are also elements that affect the relationship between these indices and biophysics parameters in determining and characterize the land use.

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