CHANGE DETECTION IN THE MIXED OMBROPHILOUS FOREST USING MULTISPECTRAL RADIOMETRIC ROTATION APPROACH

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ABSTRACT:

The main task is to apply in the *Araucaria angustifolia* (Brazilian pine) biome, the multi-temporal change detection algorithm "RCNA multi-spectral", using TM/Landsat-7 and CCD/CBERS-2 images. The study area is located in Central-South Paraná State, characterized by remnants of Mixed Ombrophilous Forest formations and by a traditional agricultural and cattle raising activities. The approach of change detection is based on the multivariate analysis (two spectral bands), with data from two sensor systems TM/Landsat image (8th Aug., 1999) and CCD/CBERS-2 (8th Aug., 2006). The multi-spectral RCNA is based in angular parameters, those angles are calculated in function of the axis formed by the straight line of regression of those points labeled in the field survey as no-change.The image for detection was transformed from a continuous image (floating-point) to thematic, through a slicing and labeling process. Hence it is possible to discriminate five thematic classes: two related to degradation, two referring to regeneration and one of no-change. The change detection map shows: in the timeframe studied 10.6 % of all area under study presents degradation patterns, derived from the clearcut activity, followed by changes of land use, with the complete removal the Mixed Ombrophilous Forest. In conclusion, we found out that the application of both multi-sensor and multi-spectral RCNA technique in Brazilian Pine landscape is robust and that the complex radiometric correction is not necessary. This simplifies the operational use of RCNA technique, demonstrating that the results can be adapted, considering the complexity of the area under study.

1. INTRODUCTION

The south Brazilian forest domain suffered high deforestation rates due to the exponential growth of agriculture, cattle raising and timber exploration activities. Considering the remote sensing techniques available, a working group of three institutions was set up to develop a study on the Mixed Ombrophilous Forest: the University of Central-West Paraná State (UNICENTRO), National Institute for Space Research (INPE), and National Institute for Amazon Research (INPA). In this frame and considering, the Brazilian government's opening and release of imagery coming from the China-Brazil Earth Resources Satellite (CBERS-2), data is now provided to the South American community, completely free of cost, with rapid delivery (taking in the worst case only a few hours). This data is offered at the website <www.inpe.br>. The Brazilian mapping and monitoring experience was acquired historically, along the last three decades with LANDSAT data, and it is now necessary to integrate the information obtained by this sensor to data of the CBERS-2 satellite series. In the same technological capacity building process, improving evaluation of disturbances to the forest cover, the scientific community are also offered unlimited access to semi-automated algorithms for the detection of changes (Singh, 1989; Maldonado et al., 2002; Lorena et al., 2002; Coppin et al., 2004; Le Hégarat-Mascle and Seltz, 2004). In this case study, a new algorithm is applied, which belongs to the family of the linear transformations, and is called the Radiometric Rotation Technique for the no-Change axis multi-spectral (Santos et al., 2005; Maldonado et al., 2007) . This algorithm does not require radiometric pre- processing in any of its digital image processing. The technique in question does not require extensive training in the pre-processing works. Therefore we apply the algorithm in the Mixed Ombrophilous Forest which can be implemented to evaluate the change detection by regional offices of forest control in South Brazilian biome.

2. AREA UNDER STUDY

The study area is located in the province of Irati, located at Center-South Paraná State (West Longitude 50º 26' to 50º 45' and South Latitude 25º 14' to 25º 30'). The total area under study reaches to 915 square kilometers. This region is characterized by a very hilly terrain, with a rich drainage from the basin of *Rio Tibagi*. The climate, according to Köppen, is of Cfb type (temperate), with frequent frost during winter and rainfall distributed along the year. Temperatures oscillate between a maximum average of 24ºC and a minimum average of 11ºC, the average monthly rainfall and the average relative humidity are 194 mm and 80%, respectively. The economy is based on the agricultural production (soybean, maize, potato) and cattle raising. There is a predominance of small properties, but there are large properties with mechanized agriculture. At the central part of the area under study is the Irati National Forest (size 3,495 ha) which belongs to SNUC (National System of Nature Conservation Units), where there are ~1,300 ha remnants of Mixed Ombrophilous Forest, which is important to maintain the biodiversity of this biome (Servello et al., 2007).

3. METHODOLOGICAL APPROACH

TM/Landsat-7 image for the first date 1 (Aug. 8th 1999) and CCD/CBERS-2 images for the second date (Aug 8 th 2006) were used to understand the anthropic process, that is suffering the Irati study area. The multivariate RCNA algorithm in our case uses the spectral bands red, and NIR (0.63 – 0.69 and 0.76 – 0.90 μm). The methodological approach of the present study is subdivided in three parts as follows: pre–processing, application of the radiometric rotation controlled by no-change axis (RCNA), and the linear complementary operations. Finally the univariate image detection is obtained, sliced and labeled. The software in all the processing used was ERDAS Image.

The first step involves all the pre-processing work, in the application of multi-spectral RCNA, is not necessary to carry out the atmospheric correction. Registration technique was carried out using a polynomial of first order with the method of nearest neighbor, to get a precision of 0,25 pixels, which represents in the normalized images a minor error of 14 m, simultaneous the spatial resolution was normalized to 60 m.

The second step started with the conversion of the integer number to floating point of de DN of both satellite images, as well as the application of multi-spectral RCNA, that is based in the obtaining of the angular parameters of rotation for each bi-temporal pair, those angles are calculated in function of the axis formed by the straight line of regression of those points labeled in the field survey as no-change (Maldonado et al., 2007). This axis describes the correlation between pixels of no-change in the images of first and second date for each spectral band (red and NIR). The angular parameters of rotation (α) control the RCNA algorithm, which is obtained by calculating the arch-tangent of the slope of the regression line of no-change previously identified on the terrain. The rotation process generates intermediary images (rotated images), that is easily understandable following the mathematical expressions for the intermediary images.

$$Iint(n) = - Data1 * \sin \alpha + Data2 * \cos \alpha$$

Where:
(n) → spectral band used (red y NIR)
Iint (n) → intermediary image detection of the spectral band "n"
Data 1 → spectral band of date 1 of the same band
Data 2 → spectral band of date 2 of the same band
sin α → sine of the angle of rotation of the same band
cos α → cosine of the angle of rotation of the same band

The third step, the complementary linear operations after the generation of two intermediary images, needs to interact for getting the image detection, although previously the intermediary images were affected for weights or proportions, that rest or increment the importance of this spectral band in the final interaction. When soil is bright the weight for NIR is minor than zero, in case of dark soil the weight for red band is minor than zero.

$$Iint(bn) = [- (bnData1) \sin \alpha + (bnData2) \cos \alpha] * weight(bn)$$

Where: bn = spectral band used

The intermediary images obtained for achieving a final change detection image, must interact after adapting to the new orthogonal axis, characteristic of the rotation; contributing with spectral peculiarities of change detection in a multidimensional space of "n" variables, which denote the high variance contained in the 2nd PC. Then we applied to these new images the sum algorithm described in the following mathematical simple equation:

$$I\ Detection\ brute = I\ int.B3 + I\ int.B4 \quad (format\ float)$$

Where:
I int = intermediary image

Hence, after the interaction of the intermediary images, we get the detection image derived of the integration of multi-sensor and multi-spectral data. Therefore the final process is completely independent to the rotation technique. It corresponds to the labeling and slicing, which is based on an univariate classification. The result of the whole rotation and interaction process of the spectral components of change detection analysis, generates an image in gray tones (DN), in continuous format, in which the changes in the landscape are outstanding. The image is then sliced and labeled in thematic format. The slicing and final labeling of the image detection was done, based mainly in the form of the frequencies histogram. In this histogram, the central maximum value shows the areas of no-change. The threshold classification, considered two patterns deviation as much to the left as to the right of the classification histogram. This is labeled in two classes of regeneration (moderate and high), two classes of degradation (moderate and high) and a class of no-change, whose borders and respective legend are based on the knowledge of the interpreter, and on the different levels and patterns of changes of the study area. The accuracy assessments have been done, by using *kappa* statistics.

Field survey was done in order to label and analyze the thematic trustworthiness of land cover patterns. Such information was obtained by 100 observation samples, appropriately geo-referenced using GPS II Plus-Garmin. The type of vegetation recovery or degradation was defined by a combined analysis of floristic composition and of the vertical vegetation structure of sampled sites, recording the occurrence of scars of land use, as well as the degree and actuation time of human occupation process.

The change detection map was integrated with geo-morphometric information (slope and altimetry), derived from a modified DEM (Digital Elevation Model) obtained from SRTM (Shuttle Radar Topographic Mission). The hypsometric map of this area presents altitude variations distributed in 4 classes: (a) 775-850m; (b) 850-925m; (c) 925-1,000m; and (d) 1,000-1,075m. The area under study is located at 93% within classes (b) and (c). The topography of the area includes 4 slope classes: >10°; 10.5°- 21°; 21°-31.5°; and 31.5°-42°. This situation allows to understand how the landscape dynamics, specially the degradation and forest recovery related to height distribution, occurred in the timeframe considered. The conjunction of thematic information derived from the change detection map and of the geo-morphometric variables are important subsidies for studies of intensity and direction of flows from edaphic materials and also from sunshine intensity, which influence the eco-physiology of vegetation, for both the management and priorities for the conservation of the remnants from this mixed forest.

4. RESULTS AND DISCUSSION

Figure 1 shows the dispersion of radiometric values derived from the image combination of the first date (August., 8th 1999) of TM *and the second date* (Jul., 8th 2006) of CBERS-2 (Figure 2). At the Figure 1 one observes the regression line that corresponds to the no-change pixels of vegetation cover, as well as the rotation angle for each bi-temporal pair. The application of the RCNA multi-spectral algorithm is controlled by the angular parameter of rotation, anti-clockwise of the orthogonal axis of the scatterplots of the image distribution (*date 1 = axis X and date 2 = axis Y*) until axis "*x*" becomes parallel to the no-change axis from the angle found.

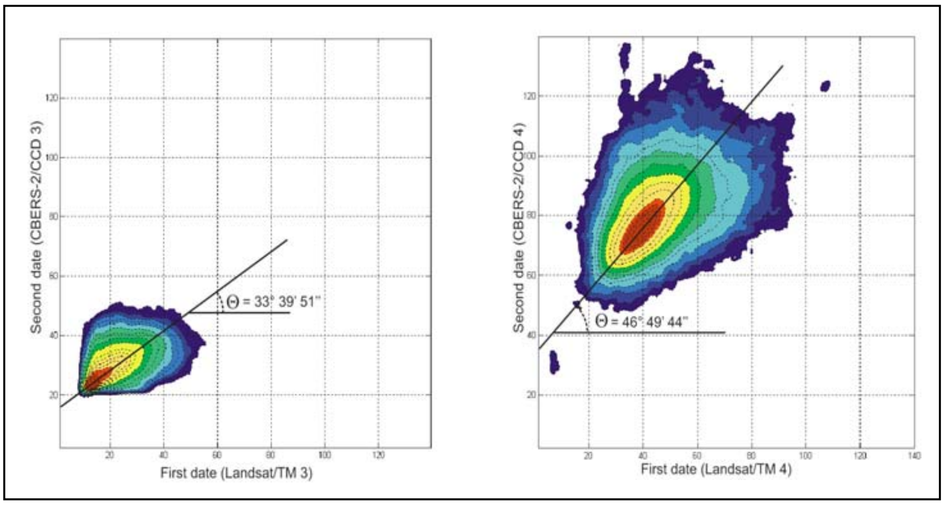

Figure 1. Scatterplots of radiometric values among TM/LANDSAT and CCD/CBERS-2 images and rotation angle for red and NIR bands (θ = 33° 39' 51" and 46° 49' 44", respectively).

Figure 2 shows, the slicing and final labeling of the image detection, based mainly in the form of the frequencies histogram. According to information extracted from the detection image, one observes that for the timeframe of study (August 1999 - 2006), there is an equilibrium at the practice of landscape degradation and recovery of the typical vegetation cover of this region, which is around 10% for each of these two land cover categories. The moderate degradation has been two times higher than the level considered as high degradation. An identical condition is also reflected for the class named "recovery". Sections with homogeneous forest stands with remnants of the Mixed Ombrophilous Forest correspond to 29% of the total area studied (915 km^2). The accuracy of the change detection map, generated from the RCNA multi-spectral technique reach a Overall *Kappa* value of 0.7693 for a comparative analysis with TM/LANDSAT and CBERS data.

The superposition of the plan on thematic variations of land use / land cover (contained at the detection map) with that one of altitude variations from slopes, shows that:

1) the strong and moderate degradation, as well as the recovery process is located predominantly at the hypsometric interval of 775-925 m; those changes of forest landscape, represented by forest conversion to pasture or agricultural areas, considered here as strong degradation sections, occur mainly on areas with slopes till 10° (gentle to moderate rolling relief), where the susceptibility to erosion can be treated with conservationist practices;

2) those land sections directed to forestry activities or that are already integrated in the agricultural and cattle raising production system (timeframe of 1999-2006) did not suffer any change of land use, are located at slopes with < 21°. Approximately 700 km^2 of the region under study are within this condition, of which 7% are on hilly terrain (slope interval of 10.5-21°), depending on intensive control practices to minimize the erosion problem, that occurs when forests are cut and burnt

5. CONCLUSIONS

The RCNA multi-spectral technique allows one to obtain results without complicated radiometric correction pre-processing, minimizing the time of processing. The RCNA technique results can be obtained in a quick and simple form, with any combination of compatible spectral sensors, such as CBERS and LANDSAT, whose data can be applied directly to cartography of recovery and degradation of Mixed Ombrophilous Forest domain and the evaluation of its intensity levels. In conclusion, the RCNA multi-spectral change detection technique should be made available for the community because the offer of satellite information by the Brazilian government opens the doors to the community researchers, who require such methods to fill information gaps.

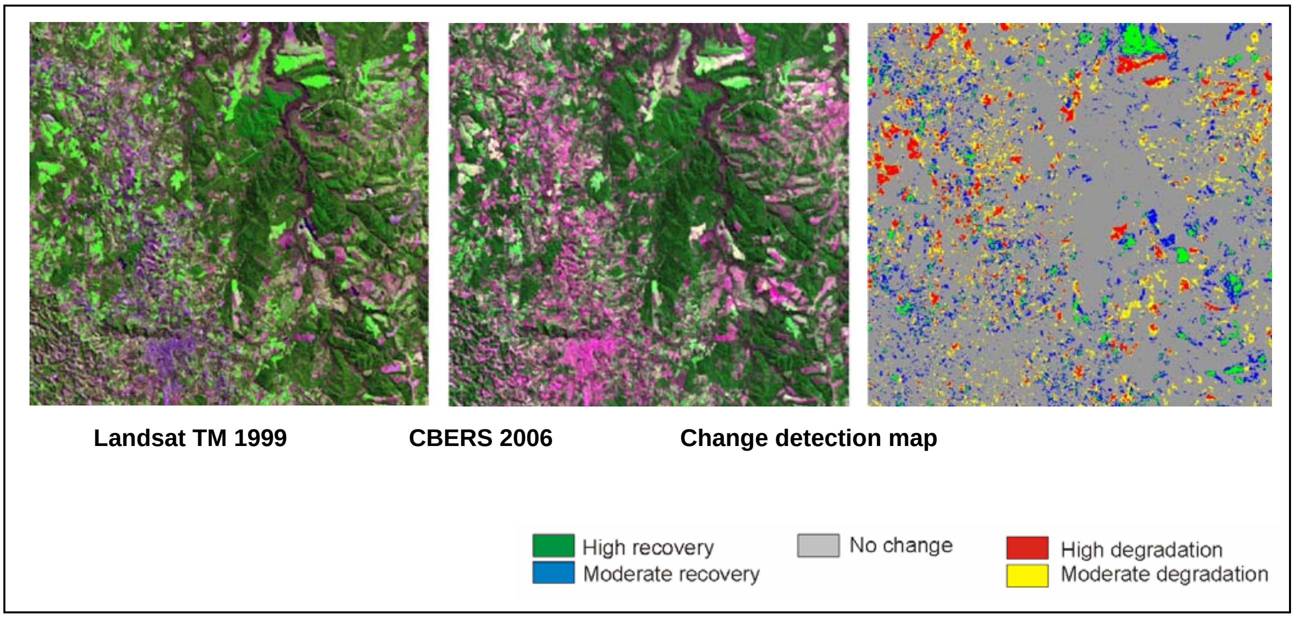

Figure 2. TM/LANDSAT and CCD/CBERS-2 images colour composite with change detection map obtained by RCNA multispectral procedure.

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