A CHANGE VECTOR ANALYSIS TECHNIQUE TO MONITOR LAND USE/LAND COVER IN SW BRAZILIAN AMAZON: ACRE STATE

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Abstract

The Brazilian Amazon is an area where extensive tropical rainforest areas are being destined to agriculture and cattle raising activities, contributing to the environmental and landscape change of this large region. In this context, the main objective of this paper is to present and test a technique for change detection called Change Vector Analysis (CVA) to analyze the variability of land use/land cover dynamics in the region of Peixoto, Acre State, using multitemporal analysis of multispectral TM-Landsat data. The results demonstrate the capacity of the CVA technique to stratify different types of change related to land use/land cover dynamics in this region.

1. Introduction

In the Brazilian Amazon, the annual deforestation rate has been around 16,000 Km^2 , due to agricultural and specially cattle raising activities. The use of remote sensing and GIS techniques has been an important tool for environmental monitoring, specially in areas where information is lacking and demand is greater for faster natural resource management processes, such as in Acre State. The main objective of this study is to analyze the CVA technique as a tool for studying land use/land cover dynamics, using TM-Landsat data from years 1990, 1997 and 1999.

2. Study Area Location

The study area was of 3,744 Km^2 and is located between coordinates 9° 38’ S, 10° 26’ S and 66° 41’ W, 67° 30’ W , in western Acre State(Figure 1). The main settlement of this area is Acrelândia, which is crossed by the east-west highway BR-364 that connects Rio Branco (AC) to Porto Velho (RO).

3. Material and Methods

This study was done using three TM-Landsat-5 scenes, bands 1 to 5 and 7, for the years 1990, 1997 and 1999. Topographic maps from DSG (Brazilian Army) were used as a cartographic support to the information obtained from TM images, as well as the following thematic maps from Projeto RADAMBRASIL: Geology, Geomorphology, Soils and Vegetation. The digital images were processed using the software packages EASI/PACE-PCI and SPRING, version 3.4 developed by INPE.

3.1 Pre-processing

Pre-processing techniques are used to attenuate geometric and radiometric variations in orbital images. In order to get a cartographic uniformity of the different scenes used, a geometric correction technique was applied based on control points from a pre-registered image. As consequence of the multi-temporal character of this study, all satellite images were radiometrically corrected, in order to normalize the reflectance values of each pixel to those pixel values of the reference image. This process included the conversion of digital values to reflectance values, using the relationships proposed by Markham and Barker (1987) and the radiometric rectification according to a methodology proposed by Hall et al. (1991).

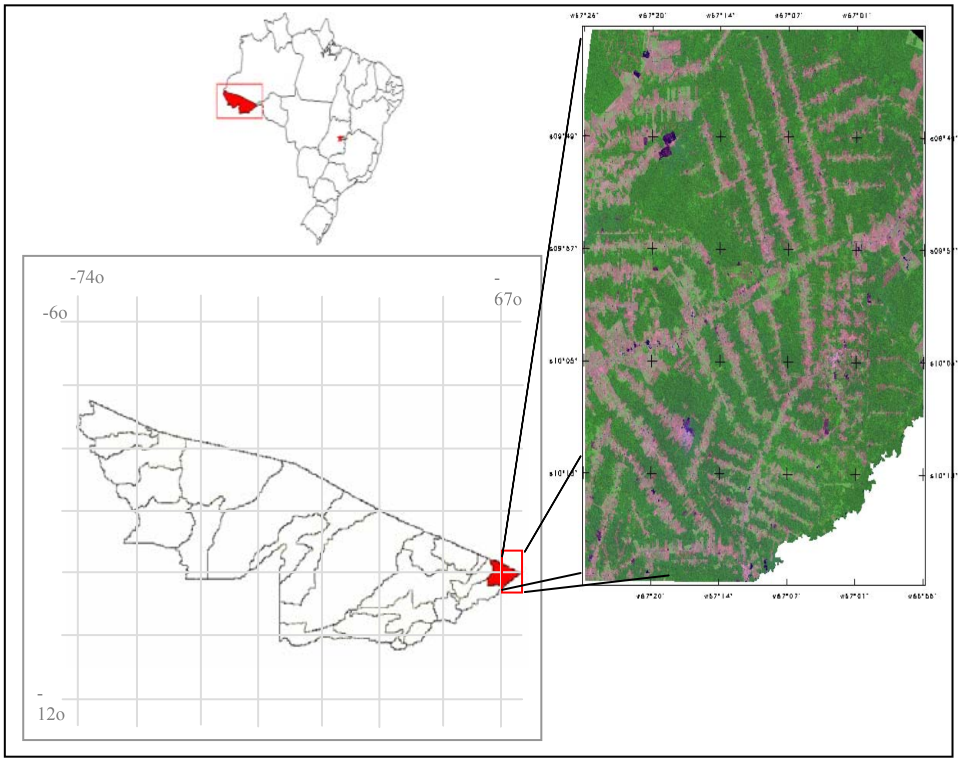

Figure 1 – Area under study

3.2 Analysis by Change Vector

The first step of the CVA method was to apply a Tasseled Cap transform (Kauth & Thomas, 1976), which generates the components Greenness and Brightness, in order to reduce the amount of redundant information of orbital images to be analyzed. This transform can be understood as defining a new coordinate system, where data from different bands occupy a new system of coordinates, where data from the different bands occupy new axes associated with biophysical properties of targets. In this case, such axes are Greenness, associated with the amount and vigor of vegetation, and Brightness, associated with variations of soil reflectance. The position variation of the same pixel during different data-takes within the space formed by these two axes (Fig. 2), determines the magnitude and direction of the spectral change vectors.

The next step in the band transformation process into new coordinates axes was to calculate the magnitude of variation among spectral change vectors between the images pairs 1990/1997 and 1997/1999.

The magnitude of vectors was calculated from the Euclidean Distance between the difference in positions of the same pixel from different data-takes within the space generated by the axes Greenness and Brightness, as follows:

$$R = \sqrt{(yb - ya)^2 + (xb - xa)^2}$$

Where: R = Euclidean Distance
ya = DN values of Greenness from date 2
yb = DN values of Greenness from date 1
xa = DN values of Brightness from date 1
xb = DN values of Brightness from date 2

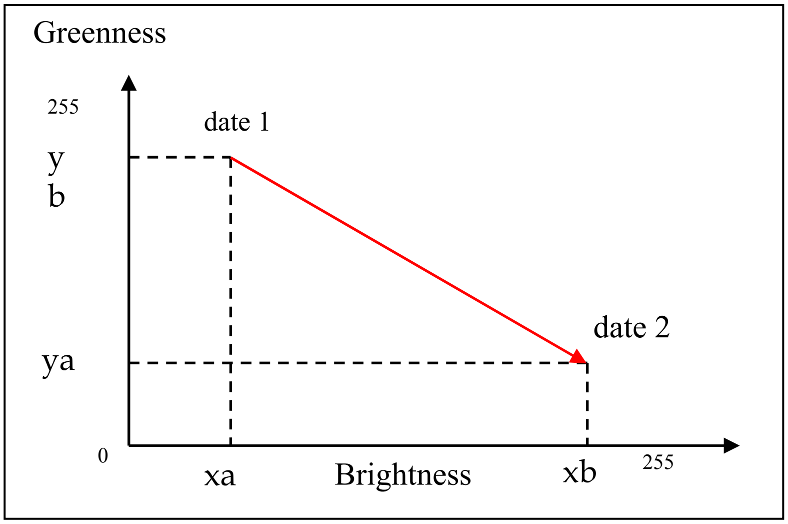

Figure 2 – Change Vector obtained from the position variation of the same pixel in different data-takes.

The angle of the vectors, which indicates the type of change that occurred, varies according to the number of components used (Table 1). In other words, each vector is a function of the combination of positive or negative changes through channels or spectral bands, which allows to distinguishing 2^n types of changes. Since only components Greenness and Brightness were used in this study, only four classes of change were possible.

Class	Brightness	Greenness	Themes
	-	+	Regrowth
	+	-	Deforestation
	+	+	Biomass Loss
	-	-	Burning or Water

Table 1 – Possible change classes from both input components and related types of change.

Class 1, which indicates increase in Greenness and decrease in Brightness, represents a direction of the vector that is mainly related to the growth of vegetation biomass, while Class 2, indicating decrease in Greenness and increase in Brightness, is strongly related to great losses of vegetation biomass as a result of the clear-cut of tropical forest. Class 3, indicating increase in Greenness and Brightness, is mainly related to smaller losses of biomass, such as transformation of sections with regrowth or cultures, as large as bushes, to pasture. Examples of change classes are shown in Figure 3.

A threshold of final magnitude was defined for each one of the change classes through an interactive adjustment (Table 2). The final result of the CVA technique is an image of vector change, where the main function of the threshold was to filter out the valueless spectral information, preserving just those information that are related to each of the Classes of Change.

Classes of Change	Thresholds 1990/1997	Thresholds 1997/1999
Class 1	10	10
Class 2	20	17
Class 3	22	7
Class4	40	40

Table 2 - Magnitude thresholds of change for each class during each data-take analyzed.

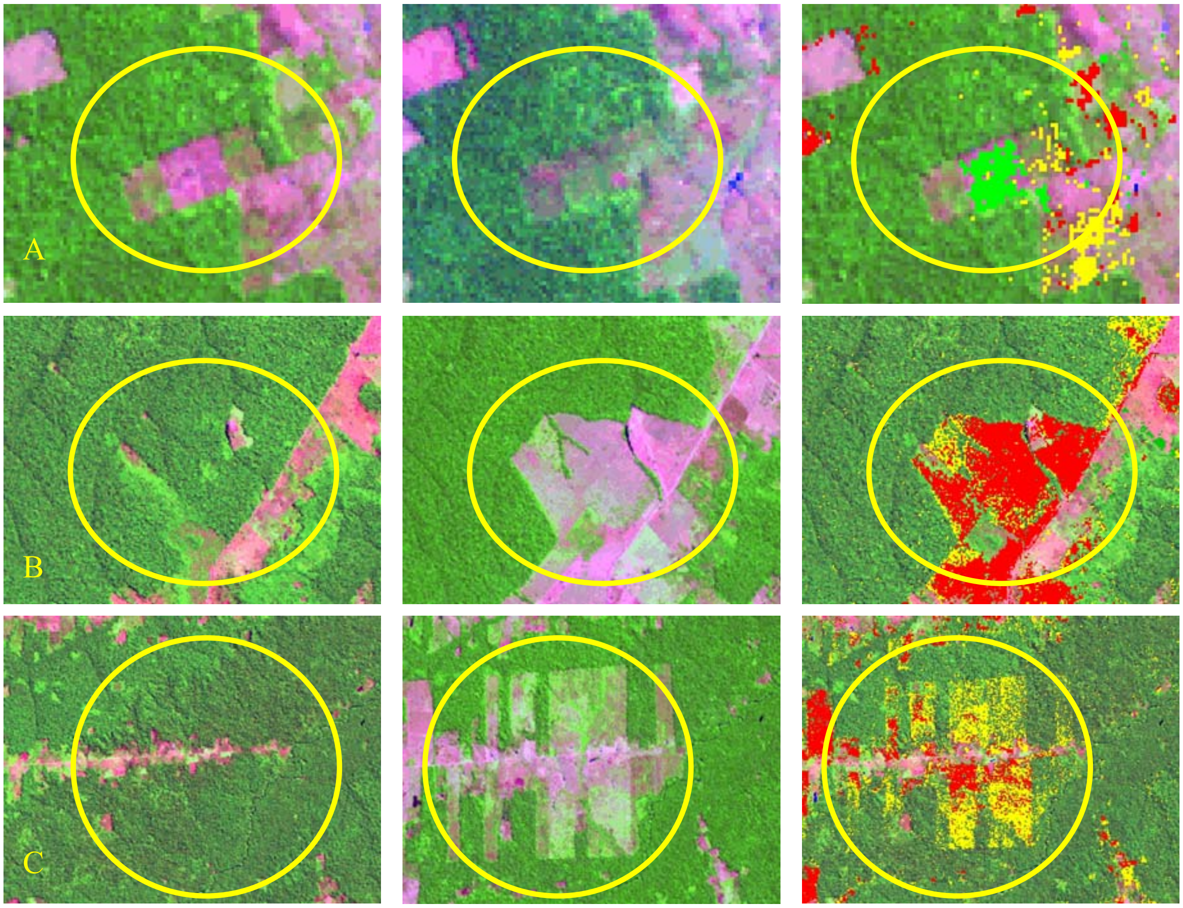

Figure 3 – Examples of thematic changes: (A) Class of change 1 = biomass growth; (B) Class of change 2 = deforestation; (C) Class of change 3 = low biomass loss.

The final product generated using this technique, namely a mask related to 4 possible Classes of Change, was obtained by crossing a grid containing the magnitude values of Vector Changes with the four possible Classes of Change, following the threshold procedure previously described. It was further defined that Class 1, which represents biomass growth, would be represented by green; Class 2, that represents deforestation, by red; Class 3, that represents, among other things, biomass loss derived not from primary forest to bare soil or pasture (lower biomass loss), would be represented by yellow. Class 4, which refers either to the increase in water body coverage area or to areas burned during the second data-take, would be represented by blue.

4 Results and Discussion

The change detection technique called CVA generated results from the investigation of two pairs of images from different dates: 1990 with 1997 scenes and 1997 with 1999 scenes. A field survey was done, including forest inventories (15 plots) and the application of questionnaires to farmers (68 questionnaires). Also, field observations with 130 GPS points, additional thematic analysis, and results of the CVA technique (Lorena, 2001), were included in the analysis.

4.1 Analysis of the change image 1990/1997

The change image referring to the years 1990 and 1997 (Figure 4) shows an intensive dynamics related to the clear-cut of primary vegetation, in a period characterized by the advancement of land occupation activities (agriculture and cattle raising) in the region.

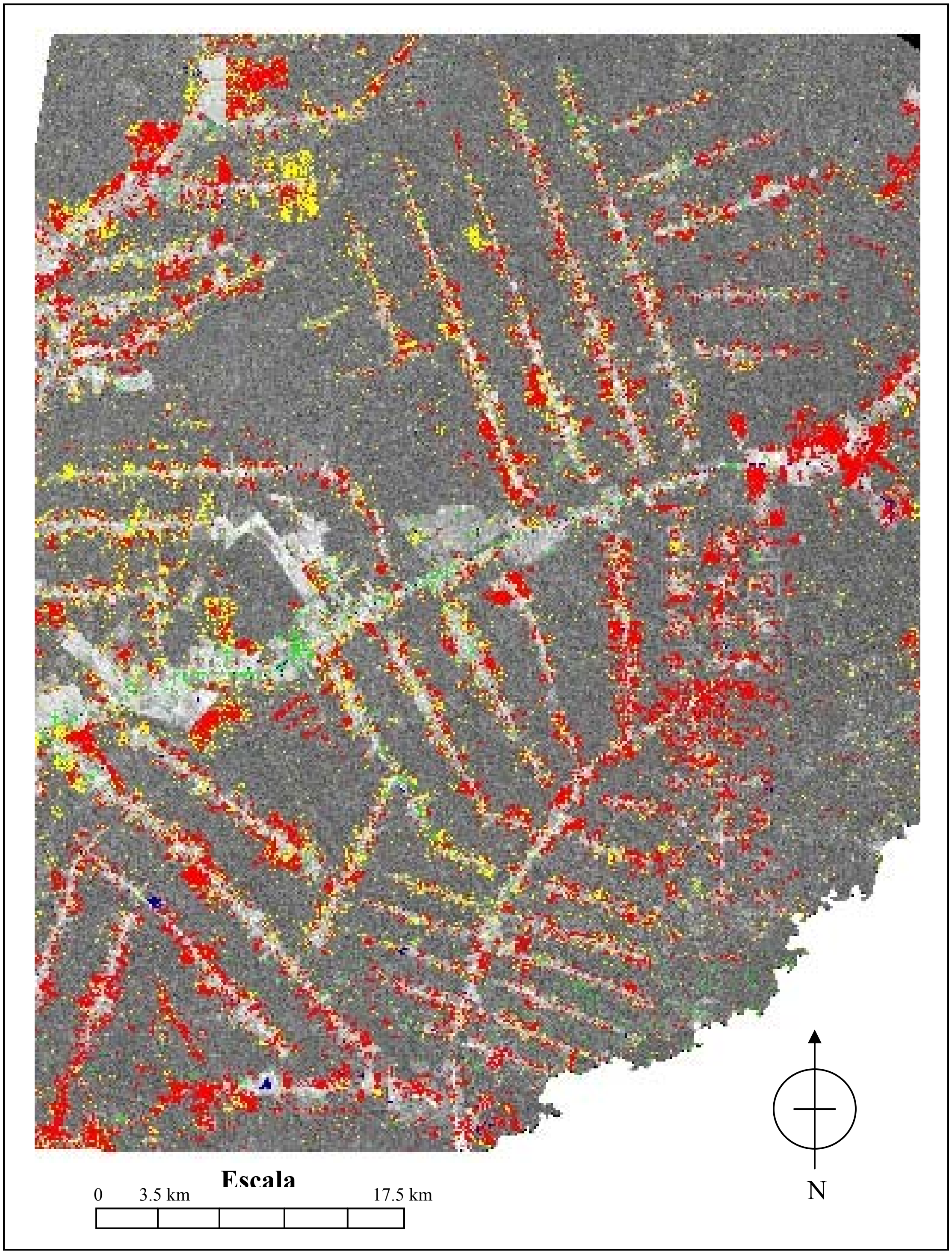

Figure. 4 - Change Vector image 1990-1997 (background scene: Brightness image 1990).

Two classes (2 and 3) show this type of change specifically, with the increase in Brightness values indicating biomass loss (i.e. deforestation). A more detailed analysis of the associated color code suggests that each of these classes represents information related to more specific losses: Class 2 related to clear cut of primary forest and Class 3 characterized mainly by subtle losses of biomass (i.e. losses caused by the reuse of former areas under regrowth). Class 1, related to the growth of biomass, initially appears to have low significance, because this first occupation phase is typically dominated by deforestation in the region, leading mainly to cultures and pasture development instead of processes of secondary succession.

During the period 1990-1997, there is an intensive pressure for land occupation, because this region is relatively close to Rio Branco, the Acre State capital, and because it is part of a former "*Seringal*" (an area licensed for rubber tapping of *Hevea Brasiliensis*), with some infrastructure in place such as small settlements, and access trails, and roads. These indicators eased the penetration of humans into the forest, as well as the transformation of small lots to subsistence agriculture or the grouping of several lots for the extensive cattle raising.

The Class of Change 4 (blue), defined by the decrease in gray levels of "Greenness" and "Brightness" is related to either water bodies /or burnings. The few burned down areas identified during this period are the result of the "slash and burn technique" applied on the primary forest for the expansion of family based, small scale, productive system. It is also observed that few water reservoirs were built in the region, which are normally associated with irrigation and water supply of the settlements during the dry season.

4.2 Analysis of the change image 1997/1999

The Change Image referring to the period 1997/1999 (Figure 5), presents those elements which indicate an evolution on the land use/land cover processes. Classes 2 and 3, referring to the loss of biomass, appear now with less intensity. They are more punctually related to the opening of small clearances in already occupied lots for subsistence agriculture of colonists. After 3 to 4 years of annual cultures on these lots, a new "frontier" for plantations is opened at the cost of primary forest.

Due to slash-and-burn activity over forested areas, and the "cleaning" consequence of such procedure, these sectors become temporarily "enriched", providing a better performance of harvesting in the first years of cultivation. Class 1 now presents a higher significance, showing small regeneration lots or the growth of crops. Class 4, which in the earlier period represented changes related mainly to water bodies, represents now, in this image, changes related to burnings. This is due to the fact that drought at this time of the year allows this kind of land use practice.

During this second period, the area presents landscapes with higher complexity, because of the consolidation phase of rural properties and settlements, such as: different cultures in several stages of growth, diversified pastures, and regrowth sections at variable ages. Within this thematic diversification, the first areas of secondary succession, which were clear cut during the period, can be better discriminated on the images. One can also perceive that, due to government incentives some lots get three to four cultivation cycles.

5 Conclusions

The results obtained by the application of the Change Vector Analysis technique demonstrate the capacity to detect and stratify different types of changes in terms of biomass gain and loss. The Change Vector image of the two periods studied allowed to verify that the deforested area was 850 Km^2 in the 1990-99 period. The annual rate deforestation is 86 Km^2 /year for the period between 1990 and 1997, increasing to 165 Km^2 /year between 1997 to 1999. In future studies we intend to test the components from other types of linear transformations, such as those components derived from processes such as Spectral Mixture Linear Model and Principal Components. Taking into account that the CVA procedures were derived from the Tasseled Cap analysis (Greenness and Brightness components), in temperat and sub-tropical regions, these techniques must be further analyzed and adapted to be used in tropical regions.

Changes introduced in the the study area by human activity and their relationship with primary and secondary vegetation were evaluated by the information obtained from field survey about present and past land use/land cover characteristics. These data were saved on a database that along with the results obtained from satellite data analysis could facilitate the understanding of the changes that took place in the landscape.

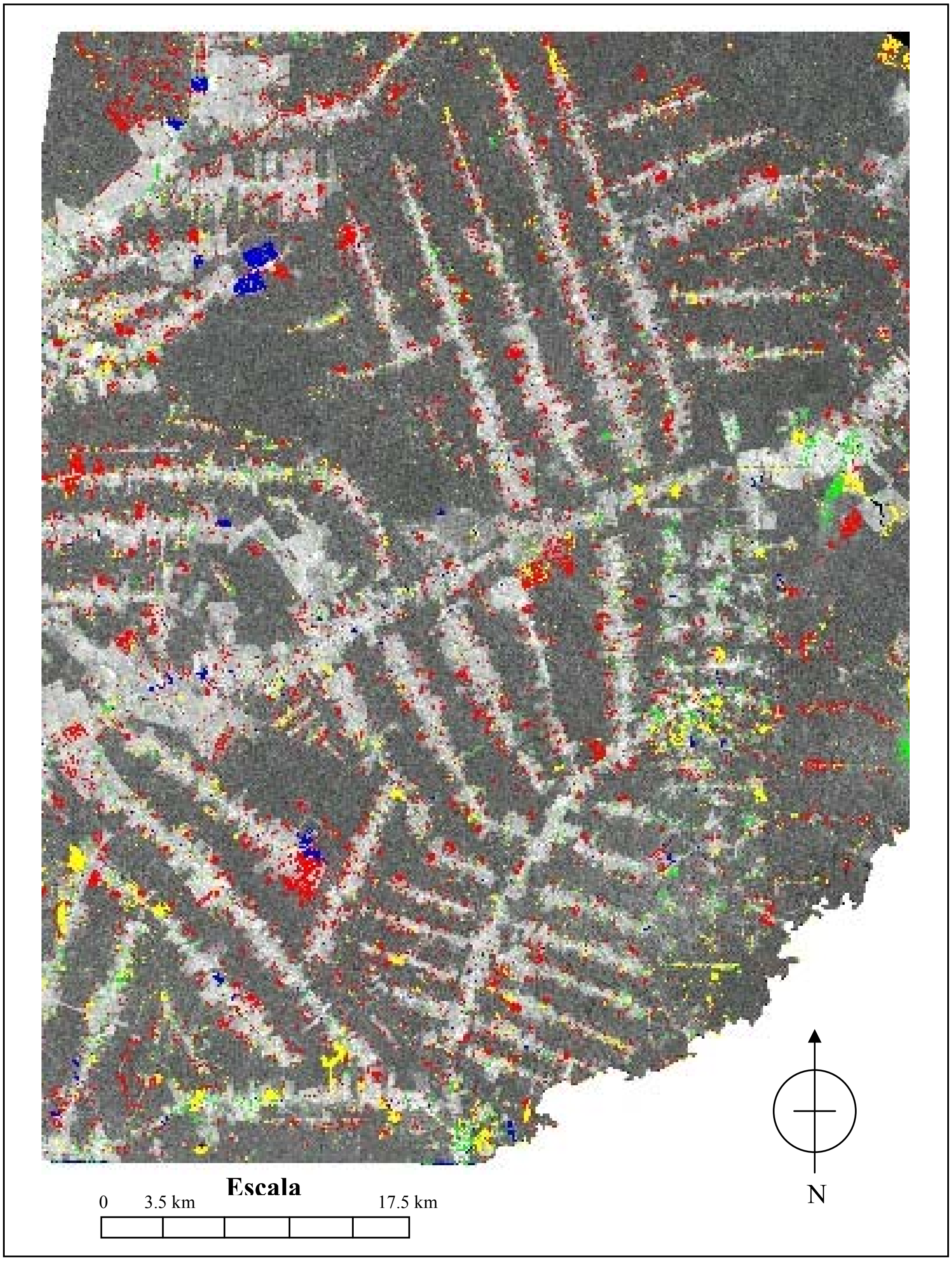

Figure 5 - Change Vector image 1997-1999 (background scene: Brightness image 1997).

Using CVA to study thematic transformations in Acre State is a pioneer study in the use of such technique and can be used as a model for future studies in the Amazon region, specially those that use satellite images to evaluate the spatial dynamics of settlement pattern changes and timber exploitation practices.

6 References

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