EVALUATION OF THE CONVERSION FROM FOREST TO PASTURE USING REMOTE SENSING FOR SOIL FERTILILY ANALYSIS

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ABSTRACT

This study shows a application of remote sensing techniques for the evaluation of conversion from forest to pasture in the State of Rondonia, Brazil. The main objective of this study was to establish a pasture chronossequence for the analysis of the soil fertility dynamic by using multitemporal Landsat Thematic Mapper data over the State of Rondônia, in order to optimize the study site sampling in the field. The multitemporal classificaton of shade fraction image derived from spectral mixture analysiswas employed to identify the age of pasture. Using this approach, land cover change between 1987 and 1997 was divided into six age classes , including forest as a control for analysis of the dynamic of the soil fertility.

1 INTRODUCTION

The impact of the conversion of primary forest into pasture in the Amazon region has been discussed by many authors (Fernanside, 1983; Buschbacher, 1986). The continuous and rapid expansion of this kind of exploitation has been attributedto the short pasture caused by the rapid decay of soil fertility with time (Fernandes, 1980; Serrão et al., 1982;Falesi & Veiga, 1987). The level of soil fertility in pastures varies greatly according to the age of the pasture settlement, besides soil type and management system (Serrão et al., 1982), as shown in Figure 1. To characterize the pattern of the degradation of pasture soil fertility and propose a better management procedure, for a sustainable development in this region, we require an better understanding of theof the dynamics of the soil fertility in the pasture chronossequence. Remote Sensing is a tool to render representative sampling for different stages of pasture..

Multitemporal remote sensing analysis has been used to characterize the process and the pattern of the land cover change (Alves & Skole, 1996). This approach can also describe the history of the land use and cover change and then the identification of the age of the certain land cover types (Adams et al., 1995; Lucas et al, 1996; Foddy et al. 1996; Roberts et al., 1998).

For most of the studies on soil nutrient dynamics, the choice of sampling sites is based on interviews with ranch managers and owners (Uhl et al., 1988), or carried out in experimental fields (Teixeira & Bastos, 1989; Leônidas, 1998). Remote sensing techniques could be used to expedite and develop a strategy for optimizing field sampling design at different scales, from local to basin-wide (LBA, 1996).

This study presents a remote sensing approach for evaluating the conversion of forest into pasture, in the Amazon region, in order to optimize plans for soil sampling in the field. The approach was used to establish pasture chronossequences since the conversion of the forest to pasture, going from a recent conversion to more than 10 year-old pasture, using multitemporal Landsat TM data.

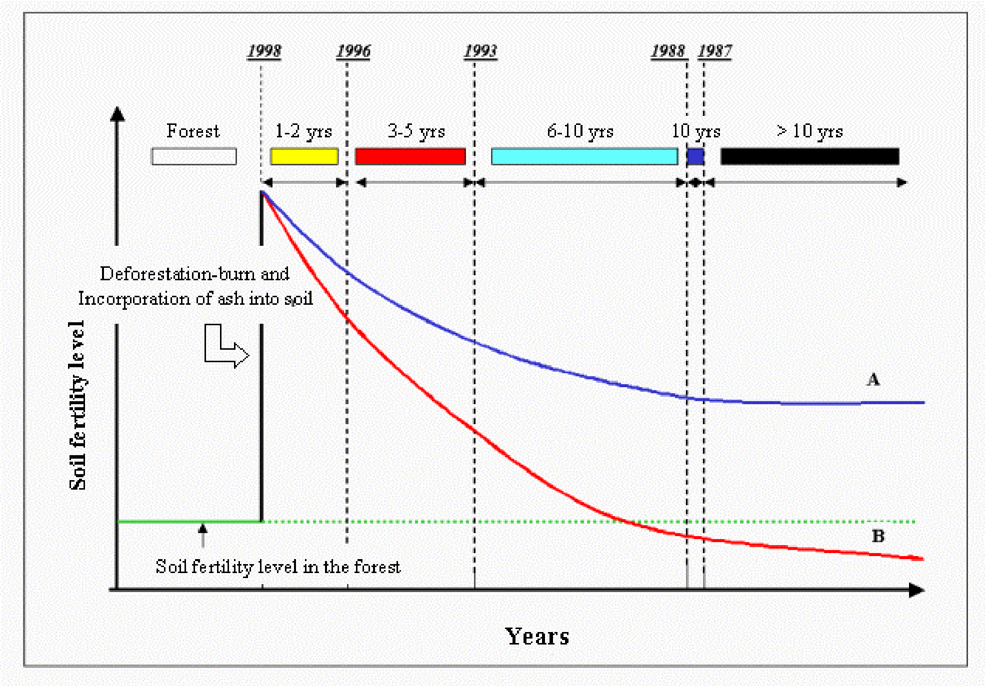


Figure 1. Conception of the dynamic of the soil fertility in pasture after the conversion of forest

STUDY AREA

The study area is located in the southeast part of the State of Rondônia, Brazil, Ariquemes, Cacaulândia, Jaru and Theobroma counties. This area is well known as one of the most exploited areas by human activities in Amazon, showing typical colonial development structure known as “fish bone”.

The conversion of primary forest to pasture has been the main form of land exploitation in the past decades. This kind of land cover occupies relatively extensive areas that can reach up to 2000 ha. Other land use practices occur onl small or medium properties (<100ha), in which some annual and perennial crops, such as rice, beans, coffee and banana, in addition to grassland. Some second growth forest can be observed as a result of the pasture/crops abandonment or in areas that were intensively used cocoa and rubber production in past decades.

3. METHODOLOGY

Temporal sequences of Landsat TM images (path/row 231/067, bands 3, 4 and 5) were used for the classification of pasture ages (since forest/pasture conversion). The time series consisted of 5 scenes acquired as follows: 12/jul/1987, 30/jul/1988, 28/jul/1993, 08/03/ 1995, 04/jul/1996 and 07/jul/1997. Initially these images were geometrically registered to the image 1995, previously georeferenced by using grand control points obtained through GPS (Alves. 1998), using the nearest neighbor interpolation algorithm. After image registration, images were to 3,000 by 3,900 subset pixel, corresponding to an area of 10.530 km^2. As stated above, the main goal of this study was to establish the pasture chronossequence by categorizing the pasture into different ages in order to choose sampling sites for analysis of soil fertility dynamic. To achieve that purpose, the following procedure was developed.

3.1 Shade fraction image

Since the shade image derived from spectral mixture analysis can provide a high degree of separability between mature forest area and non-forest area (or land use area), it can be useful to detect the conversion of forest to land use area in a given period (Shimabukuro, 1997). The spectral mixture model was applied to all images with the constrained least squares method (Shimabukuro and Smith, 1991). A pure spectra for component “vegetation”, “soil” and “shade” were acquired directly from each image consisted with bands 3, 4 and 5, by analyzing spectra signature on band 4 and band 5 scatter plot.

3.2 Classification

Multitemporal shade images 1997 were divided in two sets of false color composition (FCC) (figure 2). The first one consisted of the images 1987, 1988 and 1993, attributing each of these to bands blue, green and red, respectively. The colors resulting from this combination allow us to identify the time frame of the deforestation and to infer the time frame of the land cover change. Combined with second set of FCC, consisting of the shade images 1993, 1996 and 1997, all age classes of pasture related to land cover changes occurred in the period in study are represented. These FCC sets were used to extract training area for each age class and then the supervised classification (MAXVER classifier) was run so that all pasture ages information could be gathered in a single image.

Land cover changes were divided in five classes: 1-2 years old, 3-5 years old, 6-10 years old, 10 years old and >10 years old. The class "forest" was included as a control to indicate the natural soil fertility. These classes were chosen to represent most of the pasture chronossequence phases and associated soil fertility dynamics shown in Figure 1. However, one must recognize that this procedure also detects the time frame of land cover change that also include other uses than pasture that also shows up with low shade fraction. In this case other criteria are needed to identify pasture, such as size and form of the area. With that in mind, fieldwork was designed and the pre-selected sites were verified for future sampling. The area extent of 10 year old class turned out to be too small, so it was eliminated from the soil fertility decay study. To evaluate the results of the classification, a reference map of the deforested areas of the region was elaborated by analyzing visually each image of time series images used in this study. (for details, see Numata , 1999).

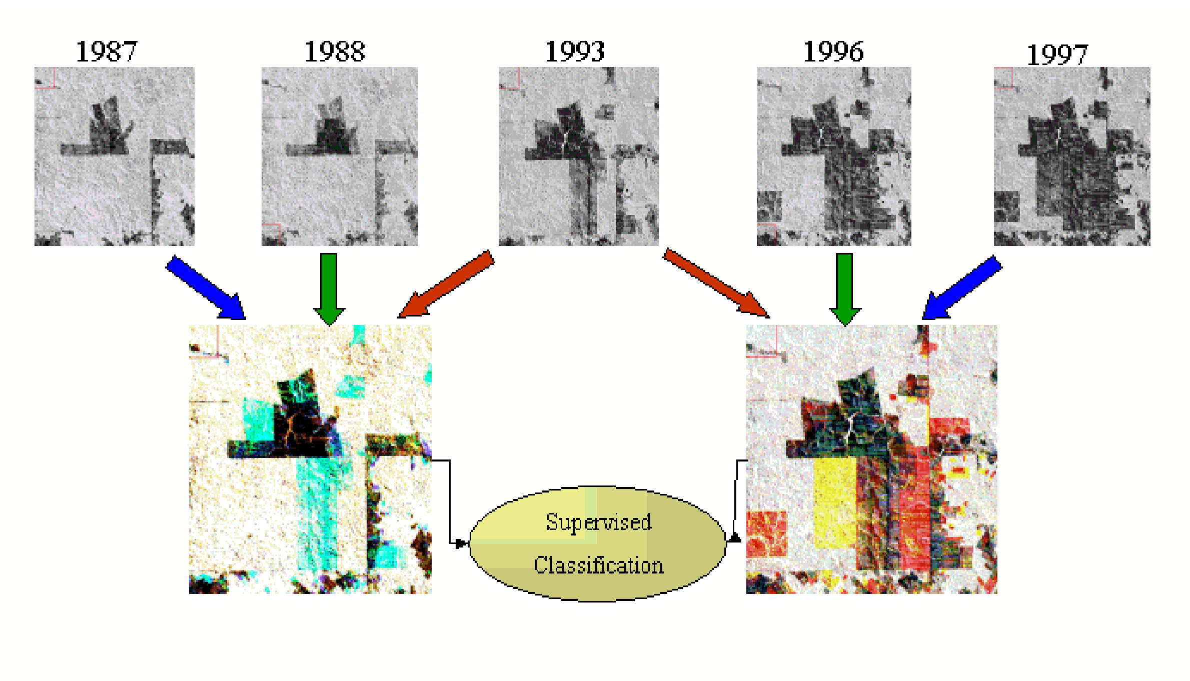


Figure 2. The classification procedure by using the multetemporal shade fraction image 1987-1997

Class	87 – B	88 – G	93 – R	Resultant color
Forest				
6-10 yrs			X	
10 yrs		X	X	
>10yrs	X	X	X	

Class	93 – R	96 - G	97 – B	Resultant color
Forest				
1-2 yrs			X	
3-5 yrs		X	X	
>6 yrs	X	X	X	

Figure 3. The color composition associated with the periods of the land use

4. DISCUSSION:

A sub region of the 1997 Landsat TM image with different cover classes and the corresponding classified image from the multitemporal shade images covering 1987 through 1997 are shown in Figure 4. This example shows how one can readily summarize the spatial and temporal dynamics of land cover change over the more than a decade time frame. In the field, it was verified by interviewing farm owners that some of the stands in the class > 10 years of –use (non forest) selected as candidates for pasture, did not really follow "forest to pasture" conversion history, but followed either "forest-cropping-pasture" or "forest-cocoa-pasture".

There was some misclassification, as shown by comparing the classified image with the reference map obtained using ground trusting, associated with the characters of the shade fraction image as illustrated in Figure 6. Figures *a*-1 and *a*-2 show the reference map and the classified image, respectively. The error area indicated by the arrow in *a*-2 results from converted area (*b*-1) with high shade fraction, as verified in the correspondent shade fraction image *b*-2. This misclassification can be associated with insufficient training for the classification, since the training area acquired for characterize the class 10 year-old was very small. Beside that, there are some possible factors that can produce a high shade fraction such as dark soil and clay texture; pasture recently burnt. Other causes of errors can be the confusion of primary forest with older second growth forest, and with deforested area where shades are due to topography.

Considering the spectral confusion associated with physical characteristic of land cover types, it would be required more sophisticated spectral analysis to improve the classification, including other spectral fraction images beside the shade. As verified by Roberts et al (1998), pasture can be highly dominated by nonphotosynthetic vegetation fraction (NPV) and soil fraction. Physical characteristics of pasture such as a amount of glass plant and soil types, mixuture betweem pasture and second growth, can be interpreted based on NPV and Soil fractions, what is very difficult to do using only the shade image.

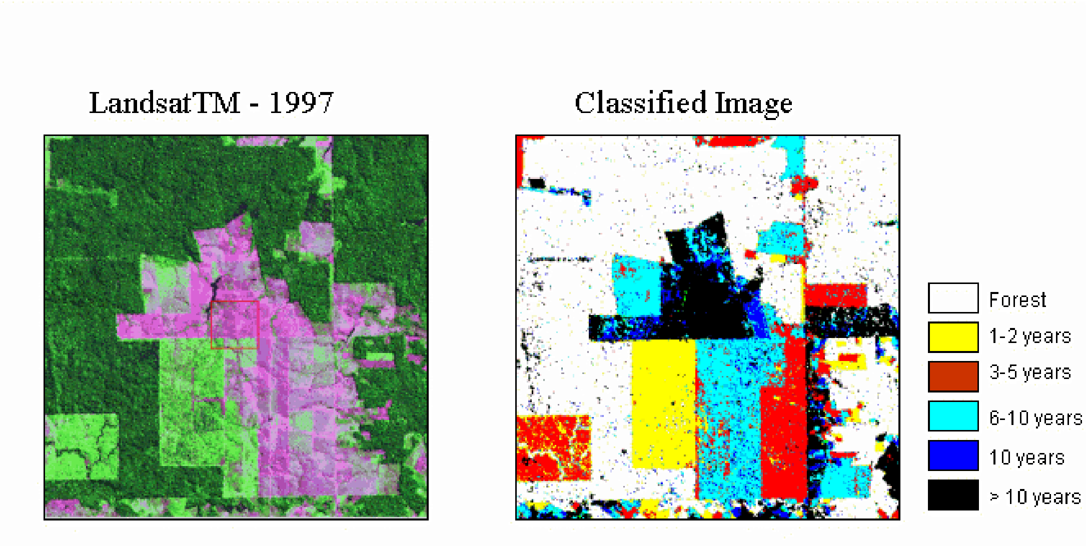


Figure 5. Left: Landsat TM FCC R5G4B3. Right: the classified image

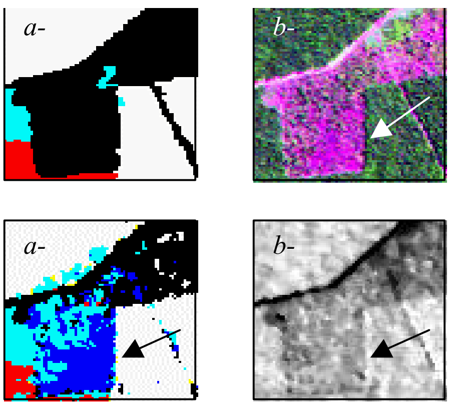
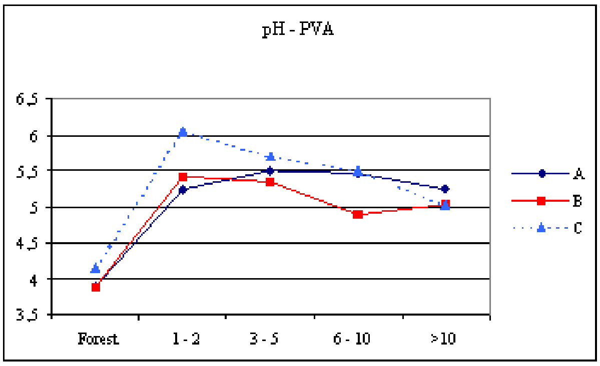


Fig 6. the misclassification and some factors of error . *a*-1) reference map; *a*-1) classified image; *b*-1): landsat/TM1987; *b*-2) shade image fraction data derived from Landsat/TM1987



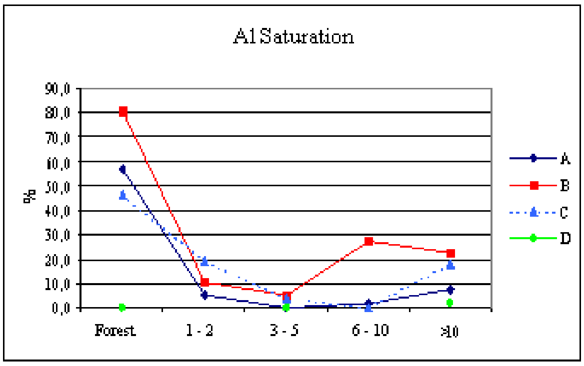


Figure 7. The result of the pH (left) and Aluminum saturation (right) in the pasture chronosequence.

As a pre-selection procedure for pasture land implementation chronossequence sites, this method seems promissory as for minimizing the fieldwork. With this logic, four study sites were selected for soil sampling representing pasture settling chronossequence. The dynamics of soil fertility (increase and decay over time) in pasture chronossequence (also including the primary forest as a control) is illustrated in the Figure 7.

The dynamics of the soil fertility in the pasture chronossequence such as pH, aluminum saturation and phosphorus observed in this study were similar to the results of the other studies like Serrão et al. (1982), Teixeira & Bastos, (1989). For more detail about soil fertility analysis, see Numata (1999).

5 CONCLUSIONS

The remote sensing method presented in this study was useful for the identification of pasture chronossequence, by allowing the visualization of the spatial and temporal changes in land cover, in a simple and readily available manner, leading to the optimization of fieldwork. The temporal information obtained from remote sensing corresponded to the dynamics of soil fertility in the pasture chronossequence. To improve the classification, it is important to include other spectral fraction images, such as NPV and soil, characterizing better the land covers type. In term of the soil fertility In term of the impact of the conversion of forest into pasture in soil fertility in Amazon, it is recommended to analyze the relationship between soil fertility dynamics and pasture productivity in the pasture chronossequence, characterizing pasture biomass dynamics measured through some remote sensing parameter.

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