RELATIONSHIP BETWEEN SAVI AND BIOMASS DATA OF FOREST AND SAVANNA CONTACT ZONE IN THE BRAZILIAN AMAZONIA

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ABSTRACT

The Brazilian Amazonia presented the important dynamic changes in land use/land cover in the last two decades, mainly at the forest and savanna transition zones, due to human activities related to selective logging, cattle raising farms, and agricultural settlements. The general objective of this study is to verify the potential application of Soil Adjusted Vegetation Index (SAVI) derived from Thematic Mapper (TM)/Landsat data to relate with biomass values of forest and savanna formations. The thematic classification of synthetic SAVI image by the Iterated Conditional Mode (ICM) algorithm was used to show the spatial distribution of vegetation cover and its biomass. The results of this study are an important task to support a program for monitoring Amazonia region using remote sensing data.

1 INTRODUCTION

The burning procedure has been used in tropical areas as an easy and economical procedure for cleaning the terrain surfaces for agricultural or cattle raising activities. This extensive practice, when performed in forested areas, contributes for the climatic unbalance in a regional and global level, loss of soil potentiality in a medium term, and also loss of local biodiversity. Forest fires, starting in the savanna areas (as occurred in the state of Roraima, northern Brazil) and advancing in the direction of open and dense tropical forest, have evidenced the need for monitoring the existing biomass in this transition vegetation zones. Satellite data, provided by optical and microwave sensors (Santos et al., 1999; Araujo et al, 1999) with the optimization of the information extraction procedures, has been utilized as a tool for forest inventory.

Inside this context, the present work has the objective to evaluate the synthetic image, generated by the SAVI (Soil Adjusted Vegetation Index) model using TM Landsat data, for estimating biomass of forest and savanna formations. Linear regression analysis was utilized to verify the relationship between SAVI and biomass variables. The spatial distribution of vegetation types associated with biomass values was generated.

2 STUDY AREA

The study site is located at central-north of Roraima State (Brazilian Amazonia), with geographical coordinates 2° 30" to 2° 50" N and 61° 00" to 61° 30" W, representing a zone of abrupt contact zone between forest and savanna physiognomic formations (Figure 1).

The climate of this region is Awi type, according to Köppen, presenting a tropical rain dominance and a well-defined dry season, with an average yearly rainfall of 1,800 mm.

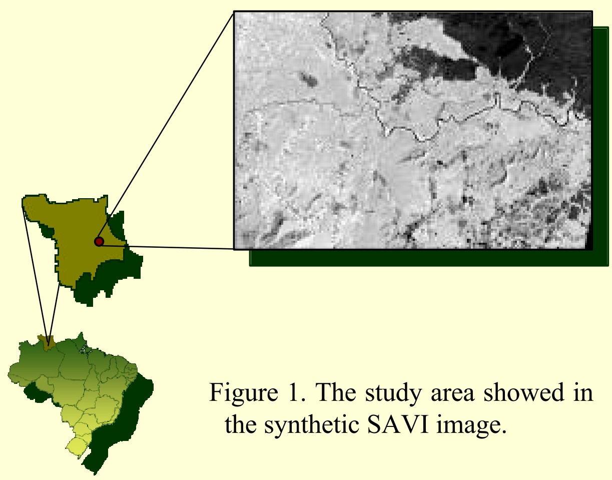

Figure 1. The study area showed in the synthetic SAVI image.

3 DATA ACQUISITION AND METHODS

The TM Landsat, path / row 232/058, acquired on January 17, 1996, was used in this study. The digital processing of this TM image (bands 3, 4, and 5) was performed using SPRING software (INPE, 1999). Initially, the TM image was geometrically corrected using the topographic chart 'Maloca do Sucuba', MI-53, scale 1:100,000 of DSG (Diretoria de Serviço Geográfico).

The TM digital numbers were converted to reflectance values according to Markham and Barker (1986) before generating the synthetic SAVI image (Huete, 1988). This synthetic image has the purpose to minimize the influence of soil in the spectral characterization of the canopy cover, and is expressed by the following equation:

$$SAVI = [(TM4 - TM3) / (TM4 + TM3 + L)] \cdot (1 + L)$$

where,

TM4 = Reflectance value of band 4 (near infrared) of TM sensor;
TM3 = Reflectance value of band 3 (red) of TM sensor; and
L = constant.

The L value is a function of the level of surface coverage in the different facies, varying from 0 (close canopy cover) to 1 (open canopy cover). To characterize the different facies, it was generated SAVI images using L values of 0.25, 0.5, and 0.75. Following this procedure, the integration of spectrum textural of synthetic image (vegetation index values) with the biomass values was performed. The vegetation index values extracted from the synthetic images have the same geographic location of the stands where the biomass values were measured on the field. Since the analysis of the relationship between satellite data and field measurement was done, it was performed a supervised classification utilizing ICM (Iterated Conditional Modes) algorithm of ENVI software, including a series of sample tests to evaluate the resulting map including vegetation cover types associated with class intervals of biomass values. The results found in the classification process were evaluated using Kappa statistics analysis (Landis and Kock, 1977).

In a summary description of field work, besides an analysis of landscape, it was performed a forest inventory, acquiring DBH and height (H) measurements, in a 250 m x 10 m transects for primary forest (9 transects) and 100 m x 10 m transects in areas of secondary succession (10 transects), as detailed by Araujo (1999). From these DBH and height values, utilizing the specific allometric equations (Brown et al., 1989; Uhl et al., 1988), the biomass values were calculated. In the savanna areas (32 transects), a clear cut and weighting all individuals of arboreal and/or shrub for biomass estimation were done in a 50 m x 5 m sample units. The contribution of herbaceous stratum for the biomass estimation was also obtained by clear cut in 5 plots of 1 m^2 each, for each one of the sample units. This herbaceous materials was weighted and dried in a estufa, in order to determine the dry weight.

4 RESULTS

Visually, the synthetic images generated by SAVI model, distinguish the forested and non-forested areas. It was observed no significant difference among the SAVI images generated using three different L values, which showed a certain similarity in the correlation of this vegetation index with biomass, either for forest and savanna. From this analysis, the value 0.5 for the constant L was adopted to generate the synthetic SAVI image, comprising the different densities of vegetation cover in this transition zone. In this image, it is noted low SAVI values (0.13) for park savanna and grass/shrub savanna areas, due to: low foliage cover (with higher exposition of soil), the condition of leaf material, with higher percent of non-photosynthetic capacity, and consequently, low biomass (mean values varying from 7.4 and 4.5 ton/ha, respectively). The areas in forest regeneration process, which canopy cover is more homogeneous, with pioneer species in a plenty development stage, i.e., photosynthetically more active, present value of 0.47 of SAVI (mean values of biomass = 43.8 ton/ha). From a determined growth stage, the SAVI values tend to decrease again. This can be observed when the values for primary forest are analyzed, with SAVI = 0.36, a little lower than of the secondary succession, in spite of having higher biomass (130.6 ton/ha) and have a structural characteristic more complex, composed by several stratum and a higher diversity of species. As observed by Bernardes (1998) in forested areas, after certain level, there is a decreasing of SAVI value with increasing biomass.

All this behavior (Figure 2) may be explained by higher proportion of shade in the primary forest area, due to the structural variation of the canopy, causing lower spectral response in relation to the areas in the secondary succession process, specifically in band 4 of TM (near infrared portion). A different photosynthetic capacity among several individuals, which compose the several stratum of primary forest, has different effects in the spectral response in band 3 (red portion) of TM, when compared to secondary vegetation cover.

Concerning to savanna areas, it is observed that is impossible to distinguish intra-classes, with standard deviation values occupying the same attributes space, either for grass/shrub savanna and park savanna. The characteristic of park savanna is composed by few arboreal individuals sparsely distributed over a grass stratum, which causes a certain similarity in the spectral response with the grass/shrub savanna, in this kind of synthetic image.

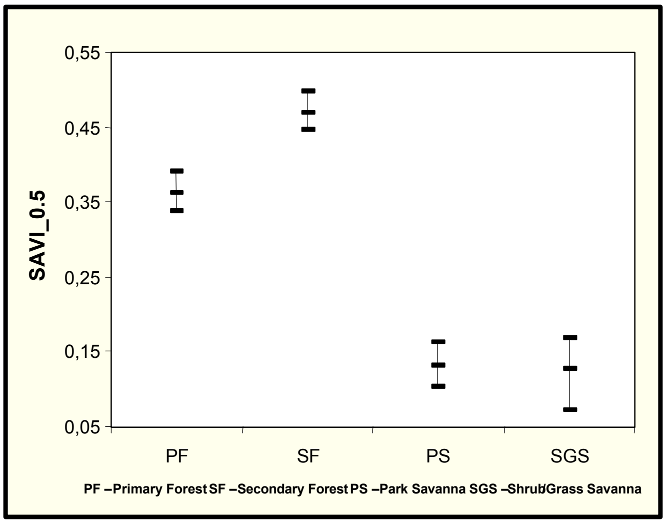

Figure 2. Mean digital values and standard deviation extracted from SAVI_0.5 image according to the vegetation cover types.

The construction of simple regression model, with a linear function, permitted to observe the high relationship of SAVI values with biomass of forest formation, which model is expressed as: Biomass = 419.64 - 797.27 (SAVI). It is important register that the presented model represents the condition of undisturbed primary forest, as well as with some degradation, identified in the samples inventoried in the fieldwork. In these forested areas (Figure 3 a), the significant correlation coefficient (r^2 = 0.80) demonstrates that the most part of biomass variable can be explained by the SAVI values, on the contrary of savanna formation (Figure 3 b) with low correlation coefficient (r^2 = 0.16), represented by a following expression: Biomass = 0.2531 + 38.8 (SAVI).

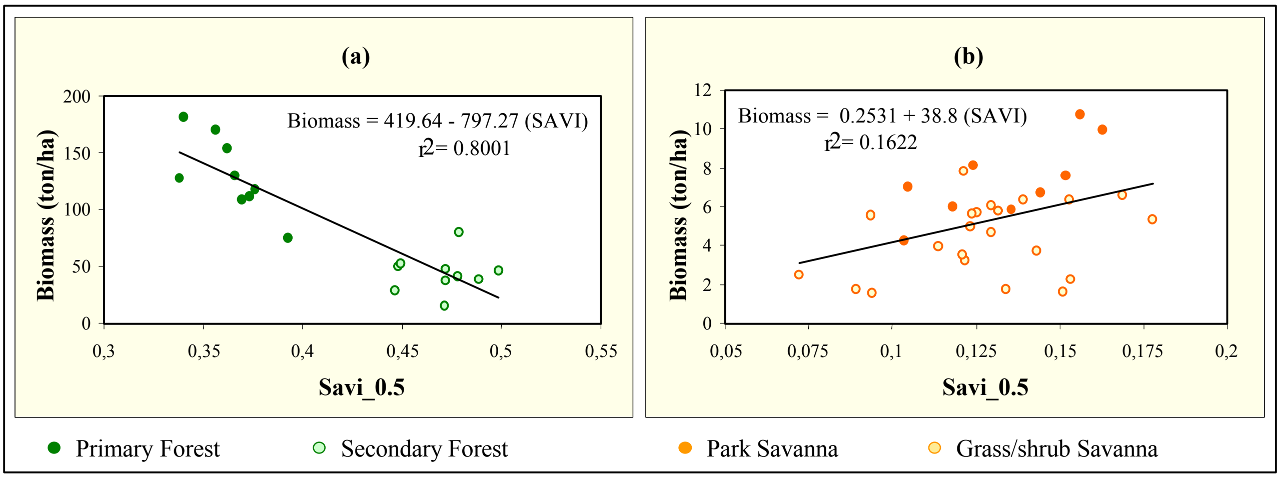

Figure 3. Scatterplot relating SAVI values with: (a) forest biomass and (b) savanna biomass.

The analysis of the confusion matrix corresponding to the classification of SAVI (L = 0.5) image demonstrates that there is a more difficulty for discriminating between classes of savanna. For instance, 33% of the classified areas as grass/shrub savanna occupy in the synthetic image, the same attributes space of park savanna. The primary and secondary forest areas are better discriminated, presenting a classification error no greater than 8%. The analysis of classification performance was performed using 30 test samples, spatially distributed in the several vegetation cover types found within the study area. Firstly, with the identification of all 8 thematic classes (primary forest, regrowth, park savanna, grass/shrub savanna, pasture, bare soil, water, and unclassified) a kappa coefficient of 0.74 was found for the thematic classification of the study area. The *kappa* coefficient increased to 0.88 due to the combination of both park savanna and grass/shrub savanna in just one class (Figure 4)

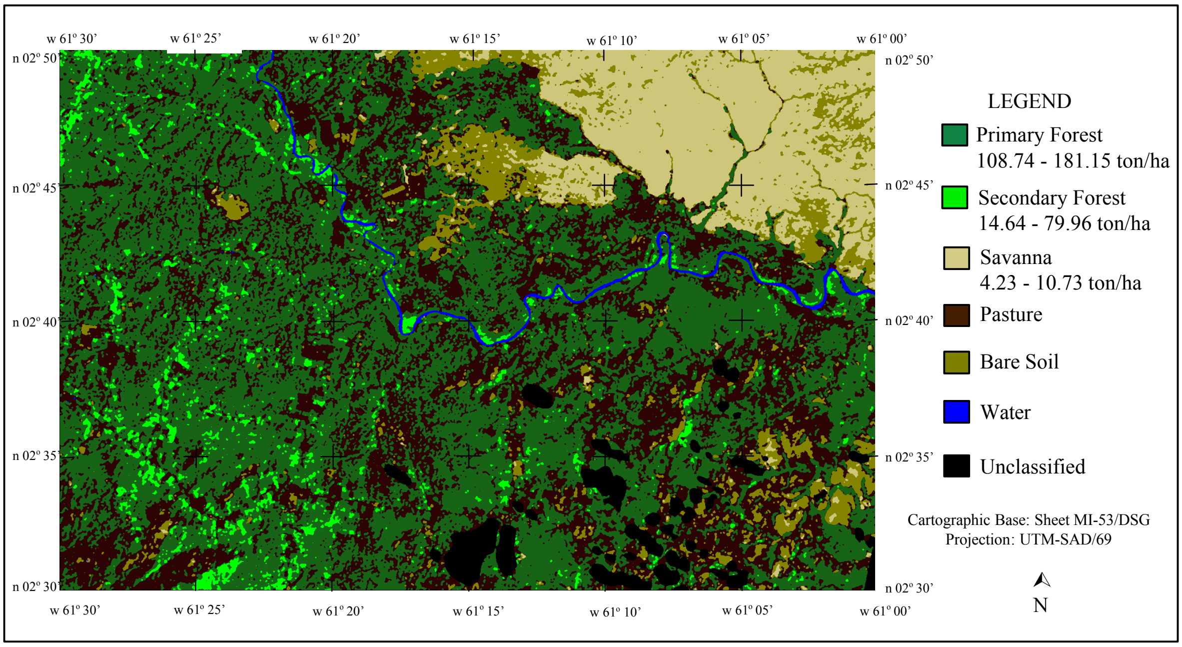

Figure 4. Distribution of vegetation cover in the forest and savanna contact zone derived from synthetic SAVI image obtained by the ICM classifier algorithm.

5 CONCLUSIONS

The SAVI model presents a reasonable performance in the characterization of forested and non-forested areas. However, this performance is not significant in the intra-class analysis, with a similarity in the space of spectral attributes, mentioning for example, the park savanna and grass/shrub savanna. Taking into account that there is an increase on density of forest cover, with greater structural and biomass complexity, the characterization of intra-classes using synthetic SAVI image is also difficult. This may be explained by the saturation limit of this vegetation index for a certain level of forest canopy closure, where due to the roughness of canopy, there is a higher shade proportion, which influences in the intra-pixel response. Actually, it is confirmed that in the relationship between biomass and SAVI values, there is not a direct linear behavior with the increase of values from one of these variables, after a certain limit.

In a synoptic view, the synthetic SAVI image can be accepted for a initially approach in the spatial distribution of vegetation cover types and their corresponding biomass, in this region of forest and savanna contact zone. However, new digital processing techniques must be searched especially for identifying new parameters to constitute the vegetation indices, in order to make the optical image an effective tool for forest inventory in tropical regions.

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