MULTITEMPORAL NOAA/AVHRR DATA TO ANALYSE SEASONAL CHANGES ON VEGETATION AT CONTACT AREAS BETWEEN FOREST AND SAVANNA WOODLAND

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ABSTRACT

This paper analyses seasonal vegetation changes in a transition area between forest and savanna woodland using monthly obtained NOAA/AVHRR Normalized Difference Vegetation Index (NDVI) data in a Global Area Coverage (GAC) format. The study area is located between 14° 00' and 15° 00' S and 58° 30' and 60° 00' W in Southeast Mato Grosso State. The methodological procedure includes the following steps: (1) acquisition and georeferencing of GAC data (January 1990 to May 1991) and generation of a grid (25 x 17 pixels GAC) which was overlaid on a vegetation map derived from TM Landsat images; (2) selection of NOAA/AVHRR pixels representative of semideciduous submontane forest, savanna woodland and wooded savanna units (the homogeneity of the pixels of the first two units ranged from 90% to 100%, and for the wooded savanna, it was above 70%); (3) generation of monthly NDVI histograms and comparison of their changes with agroclimatological data. The results show that the highest NDVI values correspond to forest, with a mean (x) equal to 0.54895 and a standard deviation (s) equal to 7.51%, followed by the savanna woodland (x = 0.44359 and s = 9.71%) and wooded savanna (x = 0.37874 and s = 13.61%). The higher value of s for the wooded savanna is due to the high degree of disturbance as a result of human activity of this land cover, associated to its seasonal characteristics. In general, the highest NDVI values for any specific type of vegetation, are related to the water content of the soil. The savanna woodland is more sensitive to hydric conditions (excess or deficit) than the forest. The NDVI provides a valuable tool for the monitoring of changes in the photosynthesis of the active phytomass.

1. INTRODUCTION

The vegetation responds very fast to the seasonal cycles or to the non-regularity of precipitation. This fact requires a continuous monitoring in a short interval of time that is difficult to achieve with Landsat Thematic Mapper (TM) or SPOT High Resolution Visible (HRV) data, due to the revisiting cycles of 16 and 26 days, respectively, and to the high cost of these products.

So, the Advanced Very High Resolution Radiometer (AVHRR) data from NOAA satellite series is a valuable low cost tool with excellent temporal resolution, and easy access for vegetation monitoring, despite its coarse spatial resolution.

The objective of this paper is to verify the capability of the Normalized Difference Vegetation Index (NDVI), derived from NOAA/AVHRR data, to analyse the seasonal behavior of vegetation in a transition area of forest and savanna woodland.

2. STUDY AREA

The study area is located Southeast of Mato Grosso State between the geographical coordinates of 14° 00' and 15° 00' S and 58° 30' and 60° 00' W, with approximately 17,900 km².

The precipitation in the Brazilian Central-West region presents a gradient from North to South and from West to East. The hydric behavior is typically tropical, with maxima values in the summer (January - March) and minima in the winter time (July - September).

In almost the entire region over 70% of the total rainfall per year occurs from November to March, with the peaks from January to March in the northern region of the State, from December to February in the central, and from November to January, in the southern region of Mato Grosso (IBGE, 1989).

The RADAMBRASIL Project (1982) reports a total precipitation between 1,300 mm and 2,000 mm with annual mean temperature of 24 °C, for the area corresponding to map sheet SD-21 CUIABÁ.

3. MATERIALS AND METHODS

3.1. Materials

3.1.1. NOAA/AVHRR Data. The AVHRR data can be obtained from the NOAA satellite in real time or it can be recorded on board transmitted later to the receiving stations.

The standard products of this sensor are:

- LAC (Local Area Coverage) data with a spatial resolution of 1.1 km at nadir;

- GAC (Global Area Coverage) data with a spatial resolution of approximately 4 km recorded electronically on board of the satellite by sampling the LAC data;

- NDVI (Normalized Difference Vegetation Index) data derived from NOAA/AVHRR, is a ratio according to the following equation:

$$NDVI = \frac{(Band\ 2 - Band\ 1)}{(Band\ 2 + Band\ 1)}$$

The width of the bands is: Band 2 (725 nm - 1,100 nm) and Band 1 (580 nm - 680 nm).

The resulting daily NDVI values obtained are resampled to a spatial resolution of approximately 7 km (Tucker, 1986).

These monthly NDVI images are composed by the highest NDVI values for each pixel recorded during the period analysed, in order to minimize the effects of the atmospher, the cloud cover, and the off-nadir view. Such effects cause low NDVI values (Justice et al., 1986; Santos and Shimabukuro, 1993). In this study, the mean monthly NDVI images were analysed for the time frame January 1990 to May 1991.

3.1.2. Thematic classes in the vegetation map. From the interpretation of Landsat-5 Thematic Mapper images corresponding to the Path/Row 228/070 and 229/070 acquired on February 23, 1991 and November 22, 1990, respectively, Miranda and Duranton (1993) generated a map with vegetation units of the study area, corresponding to the map sheet SD 21-Y-A UIRAPURU, at 1:250,000 scale. The vegetation classes identified were: forest, gallery forest, "várzea" forest, disturbed forest, savanna woodland, disturbed savanna woodland, rocky savana woodland ("cerrado rochoso"), wooded savanna with or without gallery forest, disturbed wooded savanna, natural grassland with and without gallery forest, disturbed natural grassland, natural flooded grassland, and disturbed areas (low, medium and highly disturbed).

3.1.3. Climatological Data. The climatological data utilized were obtained from the "Boletim Agroclimatológico Mensal" edited by the "Instituto Nacional de Meteorologia". Due both to the lack of a climatological station within the area under study and the difficulty to interpolate the data available (mainly from Bolivian stations), the data set analized comes from the Diamantino station (Figure 1).

For the last two months of the period considered, data of the Alcomat station were also obtained. This station is located within the study area, but only two months of data alone do not permit any analysis of the seasonal behavior of the vegetation types considered.

3.2. Methodological Approach

3.2.1. Acquisition and Georeferencing of AVHRR/GAC Data. The data utilized in this work are part of the Global Normalized Difference Vegetation Index archive of Global Inventory Monitoring and Modeling Studies Group (GIMMS/NASA).

3.2.2. Relation between NDVI data and the Vegetation Map. Selection of NOAA/AVHRR pixels representative for each vegetation cover.

To establish the relation between NDVI data and the different units of the vegetation map, a grid in which each cell corresponds to a pixel of AVHRR GAC image was elaborated with a specified monthly NDVI value. So, the study area was divided into 25 by 17 cells.

The next step was to overlay the grid on the map to define the percentage of area occupied by each vegetation type within the AVHRR pixel. Those pixels that presented the highest percentage of the area of a specified vegetation type, were selected to represent pure NDVI values, permitting to establish the relation between these values with the different vegetation cover types.

3.2.3. Generation of monthly NDVI histograms and Comparison with Agroclimatological Data. The monthly NDVI values corresponding to the pixels representative of each vegetation unit were used to obtain the mean monthly NDVI value, which was plotted to obtain the histograms of NDVI.

The following step was to ploted the histograms of NDVI with climatological information to analyse the seasonal behavior of these vegetation types.

4. RESULTS AND DISCUSSION

4.1. General Results

The units represented in the vegetation map (including those in the process of change of land use) do not have a similar behavior when faced to an excess or deficit of water. Analyzing Figures 2 through 4, one can make the following observations:

Figure 2 corresponds to August 1990 and the histogram is shifted to lower NDVI values, that reflects the climatological conditions of significant drought preceded by four months with rain deficit.

For November 1990 (Figure 3), the range of NDVI values was higher, coinciding with a relatively dry month preceded by two months with water excess.

Figure 4 correspond to February 1991, it present the higher NDVI values coinciding with the end of the rainy season, although this February has been considered atypical due to the highly decrease of the precipitation.

4.2. Correlation Between NDVI Values and Map of Vegetation Units

Through superposition of the grid (mentioned at 3.2.2) over the vegetation units map, it was possible to choose those pixels that were considered representative of the vegetation cover types mapped. It is important to mention that NDVI values were not obtained for all vegetation cover, considering that most of them did not present pixels with an adequate homogeneity or belong to any categories of disturbed areas that are not of interest for this study.

The selected pixels corresponded to the following vegetation units: forest, savanna woodland, and wooded savanna. For the forest unit, was considered to include 4 pixels with homogeneity of 100% and 11 pixels with homogeneity between 90% and 100%. For the savanna woodland unit, 18 pixels were selected with at least 90% homogeneity, of which 7 were 100% pure. For the wooded savanna, 4 pixels were selected with homogeneity above 70% but only 1 pixel was 100% pure.

In Table 1 the proportion of the study area covered by each vegetation units is presented. The forest showed the highest coverage (21.55%) followed by disturbed wooded savanna (18.10%), and by savana woodland (17.42%). Note that the words of "small", "medium", and "large" disturbed areas, do not refer to the size of these areas, but to the intensity of the disturbance process.

4.3. Corelation Between NDVI Values and Agroclimatological Data

Figure 5 presents the mean NDVI value of each vegetation unit selected. In general, it is noticed that the three curves show similar behavior of NDVI during the period considered.

The highest NDVI values correpond to the pixels of forest (0.54895), followed by savanna woodland (0.44375), and finally by the wooded savanna with mean value of 0.37874.

These monthly NDVI values present a standard deviation of 7.29% for forest, 9.01% for savanna woodland, and 13.20% for wooded savanna. The lowest value can be explained by the higher homogeneity of forest canopy, whereas the physiognomy of savanna woodland "latu sensu" varies structurally with a arboreal-bush or herbaceous-bush facies.

Analyzing the Figure 5 in detail, it is observed that the highest NDVI values of forest occurs in March 1991 (0.60157) and May 1990 (0.59180) during the rainy season and the lowest values in August and September 1990 (0.46680 and 0.47461, respectively). As for the savanna woodland similar characteristics ocurr with maximum values in May (0.51368 and 0.48828 for 1990 and 1991, respectively) coinciding with the end of rainy season and the lowest value occurs in August 1990 (0.37891) that was the driest month of the studied period. The wooded savanna presents the highest NDVI value (0.46289) in the end of the rainy season, but the lowest value (0.28125) in January, probably due to the influence of bare soil with a certain moisture content, causing a saturation of the pixel for lowest NDVI values.

Comparing the curves of forest and savanna woodland, one can see that savanna woodland responds more rapidly to the changes in the hydric behavior. The savanna woodland has the highest moisture loss due to a more open canopy structure and it is located in very sandy soils.

Another fact is concerned to the low variability (non-significant) of NDVI among the pure pixels of forest and those pixels contaminated partially by other types of vegetation cover.

In the savanna woodland unit, generally the pixels presented homogeneity around 90%, due to the presence of forest facies within the pixel of this vegetation unit.

For the wooded savanna, it was not possible to establish a NDVI pattern, due to the small amount of representative pixels (4) and to the low threshold defined (70%) without taking into acount the influence of the wooded savan composition.

5. CONCLUSIONS AND RECOMMENDATIONS

After the analysis of results obtained, one can conclude that the Normalized Difference Vegetation Index (NDVI) images are a valuable tools to study the seasonal behavior of the vegetation. Considering the large coverage, the periodicity, and the low cost of these images, it is possible to study the variation of the vegetation in a short period and it is ideal for studying very dynamic phenomena.

The authors recommended the installation of a climatological data collection network in the surrounding areas to generate more reliable data for the region considered in this study.

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Forest	3,857.67	21.55
Gallery Forest	415.30	2.32
"Várzea" Forest	368.76	2.06
Disturbed Forest	261.35	1.46
Savanna Woodland	3,118.35	17.42
Disturbed Savanna Woodland	121.73	0.68
Rocky Savana Woodland ("Cerrado Rochoso"),	279.26	1.56
Wooded Savanna	1,353.32	7.56
Wooded Savanna with Gallery Forest	12.53	0.07
Disturbed Wooded Savanna	3,240.08	18.10
Natural Grassland with Gallery Forest	214.81	1.20
Natural Grassland	284.63	1.90
Disturbed Natural Grassland	10.74	0.60
Natural Flooded Grassland	89.50	0.50
Low Disturbed Areas	1,466.09	8.19
Medium Disturbed Areas	1,428.50	7.98
Highly Disturbed Areas	1,378.38	7.70

Table 1. Proportion of the study area covered by each vegetation units

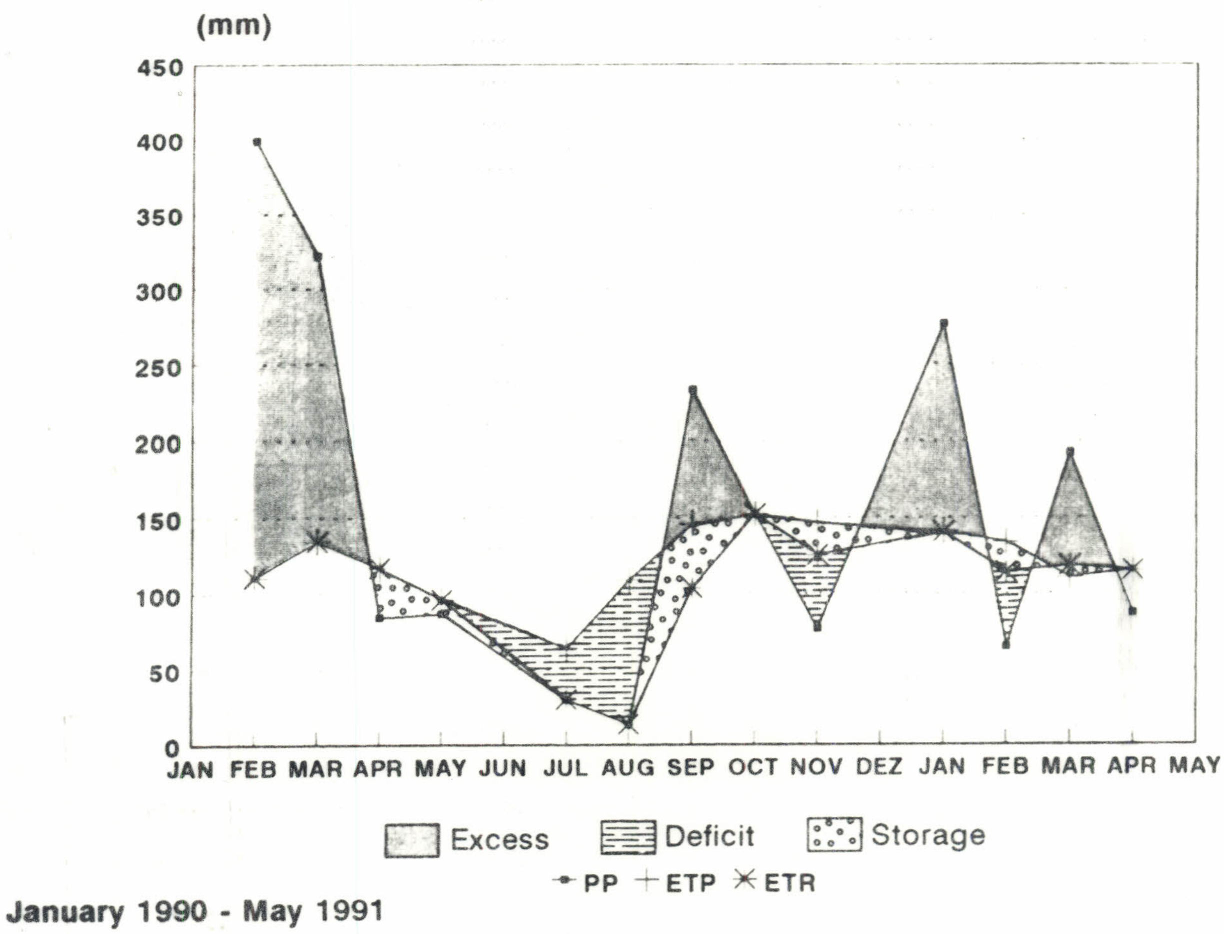

Figure 1. Hydric balance for Diamantino climatological station.

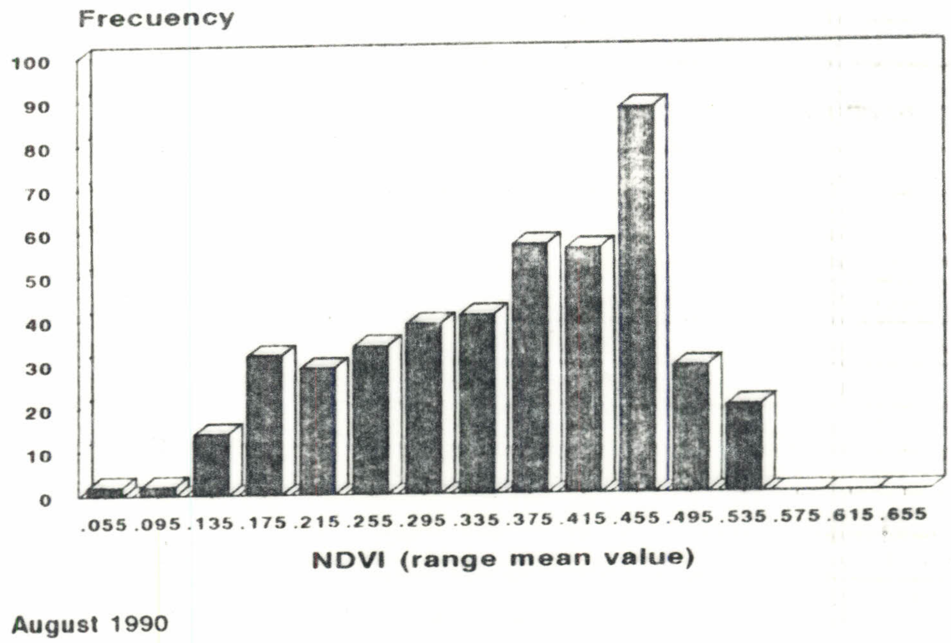

Figure 2. Frecuency histogram of NDVI values derived from NOOA/AVHRR (Period of August 1990).

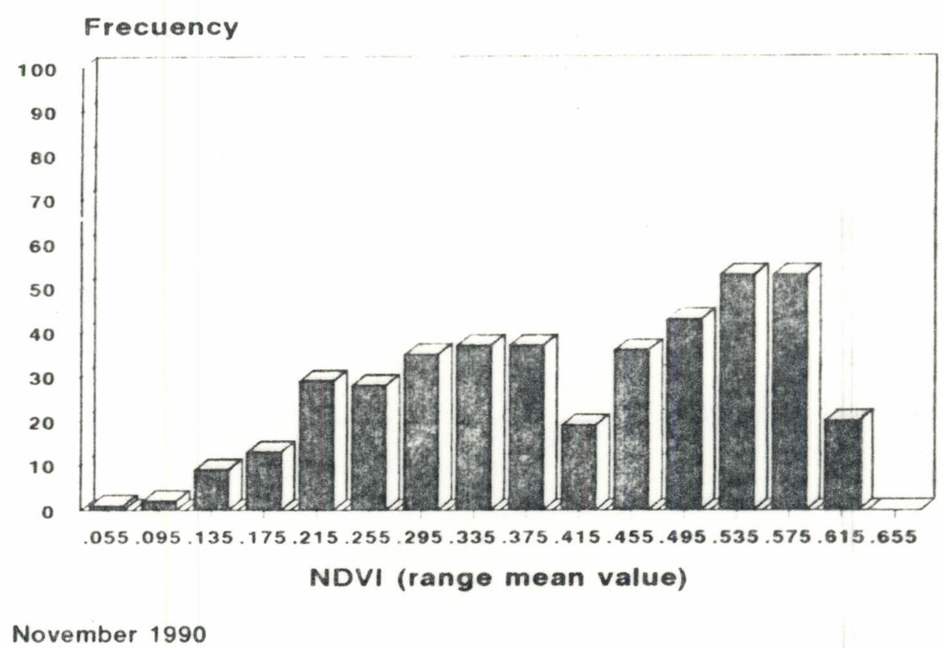

Figure 3. Frecuency histogram of NDVI values derived from NOOA/AVHRR (Period of November 1990).

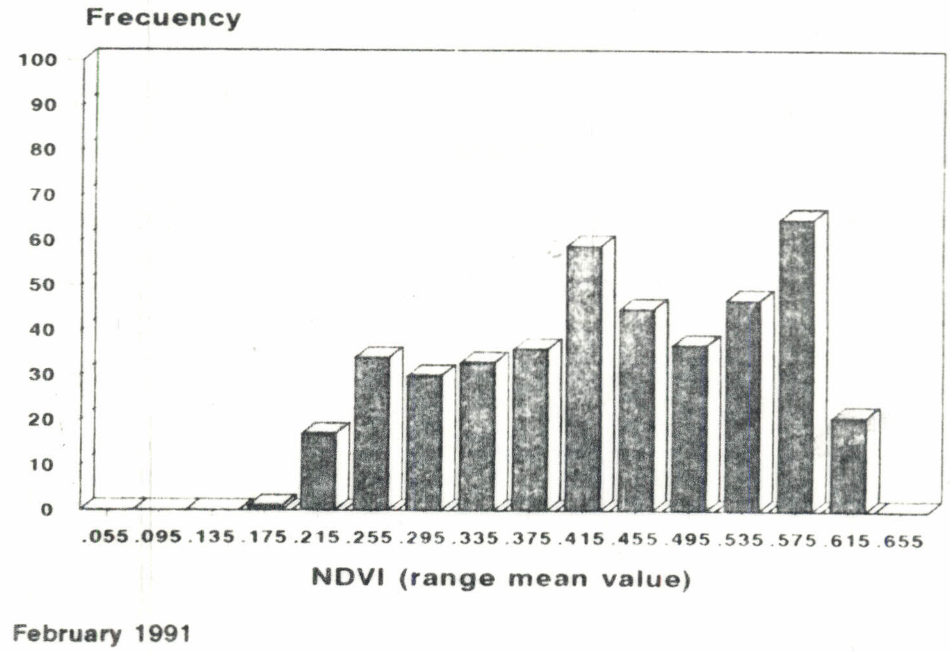

Figure 4. Frecuency histogram of NDVI values derived from NOOA/AVHRR (Period of February 1991).

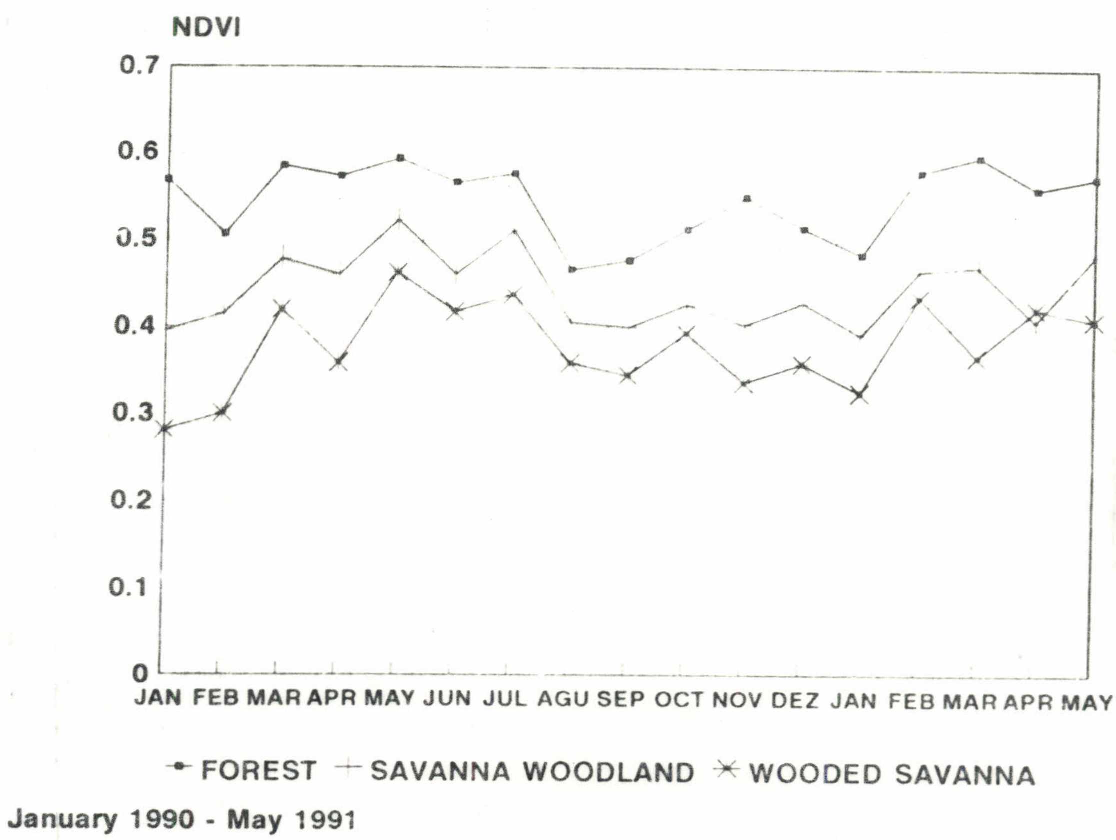

Figure 5. Monthly mean NDVI values of vegetation cover (forest, savanna woodland and wooded savanna).