# Relationships between thematic mapper radiance and tree community characteristics in the mayan biosphere reserve, Guatemala 

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#### Abstract

RESUMEN Este artículo describe las relaciones existentes entre la topografía composición y riqueza de las comunidades de árboles y la densidad y altura foliares, medidas en el campo, y los valores de radianza de cuatro bandas del Thematic Mapper a lo largo de un transecto de 750 m . localizado en los bosques tropicales estacionases de la Reserva de la Biosfera Maya (Guatemala). Se distinguen cuatro unidades forestales en función de sus características medidas en el campo y las radianzas de las bandas TM3, TM4, TM5 y TM7. La posición topográfico estaba negativamente correlacionada con las radianzas de las bandas TM3, TM5 y TM7. La composición de las comunidades de árboles estaba negativamente correlacionada con las radiancias de estas tres bandas, y positivamente correlacionada con la radianza de la banda TM4. La riqueza de especies de árboles y la altura foliar estaban negativamente correlacionadas con la radianza de la banda TM3. La mayor parte de las relaciones observadas son consistentes con un estudio de teledetección a escala regional realizado anteriormente en la misma área.


PALABRAS CLAVE: árboles, composición, follaje, riqueza de especies, topografía.

## INTRODUCCIÓN

Remote sensing techniques are becoming essential for the understanding of ecological patterns and its applications, such as vegetation mapping, land use planning (e.g. nature reserve design) and natural resource monitoring (Roughgarden et al. 1991, Roy et al. 1991, Saxon \& Dudzinsky 1984, Westman et al. 1989). This paper contributes to highlight the relationships between ecological data from a seasonal tropical forest measured in the field and Landsat Thematic Mapper (TM) radiance.
For the same area and imagery considered here, Rey Benayas \& Pope (1995) published a regional, larger area study of landscape ecology and diversity patterns. Based upon TM spectral radiances, they distinguished 6 land coyer types corresponding to distinct forest units. Now we focuss on a smaller area (community level) and the compari-


#### Abstract

This paper describes the relationships between topography, tree community composition and richness, foliage height and density measured in the field, and Thematic Mapper radiance values for a 750-m transect located in the seasonal tropical forests of the Mayan Biosphere Reserve, Guatemala. Four forest units differed according to their characteristics as measured in the field and TM3, TM4, TMS, and TM7 radiances. Topographic position was negatively correlated with TM3, TM5, and TM7 radiance. The community composition was negatively correlated with TM3, TM5, and TM7 radiance, and positively correlated with TM4 radiance. Tree richness and foliage height were negatively correlated with TM3 radiance. Most of the observed relationships are consistent with a larger, landscape remote sensing study in the area.


KEY WORDS: composition, foliage, species richness, topography, trees.
son of the results with the results obtained for the landscape study.

## MATERIAL AND METHODS

The data were collected within the Mayan Biosphere Reserve in El Peten, Guatemala (coordinates are $17^{\circ} 40^{\prime} \mathrm{N}$ and $89^{\circ} 35^{\prime} \mathrm{W}$ ) (Figure I)in April 1992 (dry season). The geomorphology of the El Peten is typical of tropical karst regions with conical hills, closed depressions, and falls within the subtropical moist Life 7 -one of Holdridge et al. (1971).The imagery analysed corresponded to TM path 20, row 48, April 27, 1988.
To describe the relationships between TM radiances (bands 3, 4, 5, and 7) and tree community characteristics, we sampled a 750 m -transect of the forest for tree communities (composition and species richness), canopy height and canopy density, upwards following the topographic relief. Me
altitudinal difference between the extreme points in the transect was of 100 m , This transect extended from lowland swamp forest to upland semievergreen forest, but did not include the highest upland forest nor the lowest lowland swamp as identified by Rey Benayas \& Pope (1995). Trees 10 cm dbh within 2010 m -diameter plots and 2.5 cm dbh within 20 concentric 2 m -diameter plots were accounted for. The smallest distance between adyacent plots was 20 m . Five plots per forest unit were sampled. The forest units were distinguished in the field by their physiognomic features. Canopy height and canopy density (number of times that a calibrated pole intersected branches with leaves) were recorded every 5 m along the transect.
To spatially coregister field samples to the pixels in the TM image, the exact position of the transect was determined in the field with a GPS. For statistical analyse (see below), we averaged the closest 9 pixels to the field measures to minimize adverse effects of locational errors inherent in the GPS readings. The compiled tree-by-plot matrix was ordinate using a Correspondence Analysis. The first multivariate axis loadings of every plot were used as a measure of tree community composition. TM imagery was analysed with MIPS (Skrdla 1992). 'Re relationships between field measures and TM radiances were highlighted by correlation analyses. The forest units were compared by means of ANOVAs. All statistical analyses were done with SAS (1989).

## RESULTS AND DISCUSSION

We found 57 tree species within the 1571 m 2 sampled (mean number of tree species per plot was 7.9 , ranging from 4 to 12 ), a result that once more points out the enormous diversity of this biome (Flenley 1993). The first axis of the Correspondence Analysis performed on the tree matrix reveals that the major source of composition variation was related to the topographic gradient (correlation between plot loadings and their relative position in the transect was $\mathrm{r}=0.90, \mathrm{P}, \mathrm{n}=20$ ). The species with the smallest (most negative) loadings for this axis are characteristic of low seasonal swamp forests (Haematoxylon campechianum, Coccoloba spicata), whereas the greatest loadings correspond to the more upland species (Simaruba glauca, Proteum copal. Species with intermediate loadings either occupy intermediate topographic positions (Laethia damnea, Sabal morricina) or are represented throughout the entire transect (Pouteria reticulata). The position in the topographic gradient is also correlated with foliage height ( $\mathrm{r}=0.77, \mathrm{P}, \mathrm{n}=26$ ) and foliage density ( $\mathrm{r}=0.74, \mathrm{P}, \mathrm{n}=26$ ). These patterns have also been describes by Rey Benayas \& Pope (1995) and by Pope et al. (1994) in adjacent areas of Belize using AIRSAR radar biophysical indices.

Tree community richness and composition are positively related, but this relationship is not statistically significant. This lack of significant correlation may he due to the fact that the extreme vegetation units, both in their topographic position and


Figure 1. Map of the study area in northern El Petén, Guatemala. Shown are the boundary of the Mayo Biosphere Reserve (region above the dotted lino, which includes the buffer zone), the location of the Landsat TM quarter scene used In the analysis (large box), and the three test sites (small boxes) studied by Rey Banayas \& Pope (1995). The transect analyzed in the study la within the area A.
tree richness, have not been included in the study. The positive relationship between tree richness and the relative position of the forest community along the topographic gradient in the region has been suggested by Bartiett (1936) and Lundell (1937), and our data confirm it. Similar relationships are reported from lowland tropical forests in Costa Rica (Lieberman et al. 1985).

| Rank | -0.58 | NS | -0.52 | -0.47 |
| :--- | :---: | :---: | :---: | :---: |
| $(\mathrm{n}=26)$ | $(0.002)$ |  | $(0.006)$ | $(0.01)$ |
| Tree composition | -0.60 | 0.56 | -0.55 | -0.64 |
| $(\mathrm{n}=20)$ | $(0.005)$ | $(0.009)$ | $(0.01)$ | $(0.002)$ |
| Tree ríchness <br> $(\mathrm{n}=20)$ | -0.52 | NS | NS | NS |
| Folíage heíght <br> $(\mathrm{n}=26)$ | $-0.02)$ |  |  |  |
| Foliage density <br> $(\mathrm{n}=26)$ | NS | NS | NS | NS |
|  |  |  |  |  |

Table 1. Correlation coefficients and p-values (In parenthesis) between various forest characteristics measured in the field and TM radiances. Rank repreeents relative position along transect from lowest to highest elevation. NS means not significant at a $\mathrm{P} \leq 0.05$ level

Table 1 summarizes the pair-wise correlations between the forest characteristics measured in the field and TM band radiances The position in the topographic gradient is correlated with ali bands except TM4. Tree richness is negatively correlated with TM3 radiance, and previously TM3 radiance has been shown to be related to productivity (e.g. Cook et al. 1989). This result can be interpreted as the positive relationship between species richness
and green leaf biomass or productivity describes by various studies (Scheiner \& Rey Benayas 1994, Smith \& Huston 1989). At the landscape scale the same relationship was found. Tree community composition is the only variable measured in the field correlated with all bands. Foliage height was correlated with TM3 radiance, but despite of the high correlation between this variable and foliage density ( $\mathrm{r}=074, \underline{\mathrm{P}}, \mathrm{n}=20$ ), significant correlations for foliage density and TM radiances were not found, in contrast to the studies by Horber (1986), Spanner (1990) and others.

The comparisons (ANOVAS) among the four forest units resulted in significant differences for tree community composition ( $\mathrm{F}=37.05, \underline{\mathrm{P}} 0.0001$ ), foliage height ( $\mathrm{F}=6.12, \mathrm{r}$ ) and all TM bands (I'M3: $\mathrm{F}=17.56, \underline{\mathrm{P}} ; \mathrm{TM} 4: \mathrm{F}=4.37, \underline{\mathrm{P}} 0.02 ; \mathrm{TM} 5 . \mathrm{F}=13.0$, P0.0001; TM7: $\mathrm{F}=15.58$, P 0.0001 ). Thus, differences in ecological characteristics as measured in the field are represented by differences in TM radiances. Red and middle infrared bands account for more TM variability among the forest units than does the near infrared TM4. This result is consistent with the analysis of sources of TM variability at a landscape scale (Rey Benayas \& Pope 1995), since this source was related to middle infrared in the lowlands and near infrared in the uplands, and the transect under study includes more lowland than upland forests.

Overall, various forest characteristics as measured in the field present significant relationships with TM radiance values. These relationships are in general consistent with the relationships established at a landscape scale. The only discrepancy is the lack of significance for the correlations between tree richness and the position in the topographic gradient with TM4 radiance. Foliage density was also little related to TM radiances. The TM sensor has been shown to provide an accurate estimate of various ecological properties at a landscape scale with a high degree of confidence, but the reliability of single pixel estimates are poor (Cook et al. 1989). Our results indicate that the spatial resolution and information provided by the TM sensor can be used to describe ecological characteristics at a plant community level, mostly vegetation composition, in the seasonal tropical forests of the region, and thus extrapolate relationships that may aid land use planning and monitoring.

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