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REMOTE SENSING APPLICATION IN FOREST ASSESSMENT

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Abstract: *In this research the relationship between structural variables of pine and spectral data of Landsat 5 TM sensor were evaluated in an area of Durango, Mexico. To determine such relationship multivariate techniques were applied. Using information of the evaluated sites, a prediction model was generated with Landsat TM bands; the better relationships were found for the sensor's spectral data with the variable ERT (m^3/ha) were found with the band 4, with $R^2 = 0.72$ and with the band 3, with $R^2 = 0.66$.*

Key words: *Remote sensing, modeling, Landsat 5 TM, spectral data.*

1. Introduction

In the last decade, the development of new technologies, satellite imagery and use of tools designed to support Geographic Information Systems (GIS) have strongly influenced the field of applied research in forest inventories and natural resource monitoring. While GIS was originally adopted almost exclusively by the disciplines related to geography, over time other sciences have found applications in such a powerful tool.

One of the most important applications of the use of satellite images in the study of the environment is the possibility to follow up dynamic processes. The growing emphasis on forestry applications is underlined by the importance of the temporal dimension, as is to prevent and assess a wide variety of phenomena as a key for monitoring their dynamics [4].

In this context the following research carried out at the venue "The Encinal" near the City of Durango, Mexico, was aimed at analyzing dasometrics variables of a pine forest, using satellite data from Landsat 5 TM.

Remote sensors provide a tool to facilitate the measurement and monitoring of those variables. Remote sensing systems can provide extensive and also detailed spatial resolution of forest structures, allowing the mapping and monitoring of large areas of forest cover [10].

Remote sensing techniques provide an alternative to acquire quickly and cost effectively, assessment procedures for inventory, monitoring and forest mapping. Recently, multispectral satellite imagery such as broad spectral resolution satellite IKONOS and Quick-Bird allow observations realizing in the visible and near infrared (450-900 nm); the spatial resolution of these satellites provide a new opportunity for a more accurate assessment of forestry resources [6], [2], [9].

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Vegetation detection and evaluation using remote sensors of very high spatial resolution is an issue that arouses great interest in obtaining information of the forest. The algorithms used to delineate forest structural attributes require the analysis of image pixels, which can be delineated using the method of “pixel seed” getting a segmentation of the image spectral patterns.

Remote sensors have emerged as a useful tool to estimate and evaluate productivity in mountain vegetation and the growth media. The NDVI (Normalized Difference Vegetation Index) provides a means for monitoring the distribution of vegetation types and their condition and state [3].

Information evaluation regarding distribution and dynamics of ecosystems production potential, has a special meaning for scientific research and for the use and integrated management of natural resources. If through sensors it is possible to identify different levels of forest productivity, this represents reduction in effort and cost in comparison with traditional field measurements [8]. However, the current results are still not satisfactory to obtain good estimates of forest volume [1], especially when specific classes of volume in the field are not associated with spectral classes (bands) detected by the image [7].

2. Materials and Methods

2.1. Location of the study area

This research work was developed on the ejido "El Encinal", municipality of Durango. The study area is located by the following geographic coordinates: 105°06' west longitude and 23º40' north latitude; the municipality in which the studied area is located, is bordered on the south by the municipality of Pueblo Nuevo, southeast and west Mezquital and San Dimas, which are municipalities with strong forestry (see Figure 1).

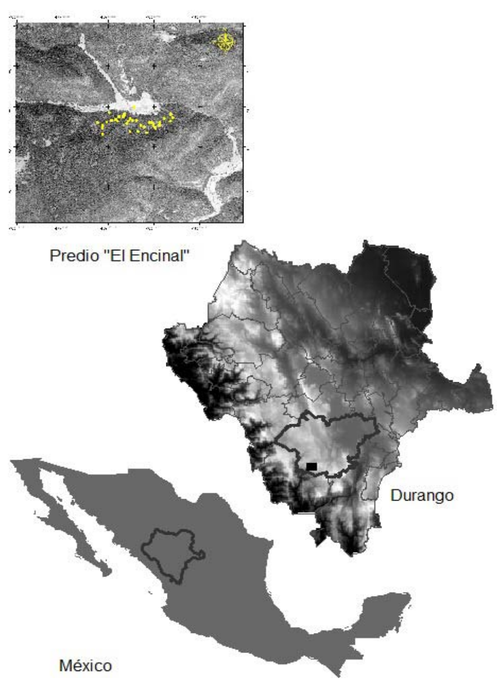

Fig. 1. *Location of the study area*

2.2. Methods

Data Sources

To carry out this study a Landsat 5 TM image 2003 was used, and 1:50,000 scale orthophoto maps generated by INEGI, as a reference and support for location details. The programs used for the process and analysis of data were: KILIMAJARO IDRISI and ArcGIS.

Landsat-TM processing

Once recorded the scene, the radiometric analysis procedures applied were suggested by [4], in order to mitigate possible noise due to intrinsic effects of the sensor.

Analysis of Variables

Dasometric variables considered in this study were the normal diameter (DN), height (HT), total standing timber volume (ERT/ha) and normal basal area (AB). Field data were collected following the methodology used by the National Forest Inventory (CONAFOR, 2005) using techniques in the plot of fixed size changed Tena (2005).

For the prediction map of ERT/ha classes, the ERT/ha data obtained in the sampling site were related to spectral data of the bands used as independent variables in the regression equation, which were generated by scanning techniques. The simple linear regression model was:

$$Y = \beta_0 + \beta_1 X_1 + \varepsilon, \quad (1)$$

where: Y = ERT/ha (m^3rta); β_0 = intercept; β_1 = slope; X_1 = band 4 and 3; ε - experimental error.

3. Results and Discussion

3.1. Modeling dasometrics variables

To determine the relationship of the sensor data with the variables of the forest, both data were analyzed using multivariate linear regression techniques.

3.2. Description of the forest variables

A correlation analysis was performed to observe the degree of relationship between variables; this relationship was found to be significant among the variables of normal diameter (explains 93% of the variation in timber volume), the height of the trees (explains 56% of the same volume variation) (Table 1).

Parameters' significance for Table 4 is the following: DN = Normal diameter, Vol = Volume of trees, ALT = Height of trees, ERT = Total standing timber volume, N_AH^{-1} = Number of trees per hectare.

3.3. Regression analysis of spectral data of the sensor

The relationships between field variables and the Landsat 5 TM reflectance data were analyzed by linear regression techniques, considering such relationships as random or response (independent) variable to the

Table 1

Correlation matrix of the forest structural variables

	DN	ALT	N_AH^{-1}	VOL	ERT
DN	1.000				
ALT	0.558	1.000			
N_AH^{-1}	0.623	0.303	1.000		
VOL	0.932	0.561	-0.342	1.000	
ERT	0.293	0.046	-0.296	0.264	1.000

forest structural data, which are related to another variable (not necessarily random) called "predictive" or associated with the reflectance data registered by the already mentioned studied sensor. Departing from the evaluated sites, a prediction model was determined using all the Landsat 5 TM bands.

Table 2 shows the best of relations generated by the sensor. The relations of the spectral data of the band 4 of Landsat TM data presented the highest ERT determination coefficient (R^2 = 0.72), while band 3 showed a comparatively low value (R^2 = 0.66).

Description for the parameters presented in tabe no. 5 is the following: L4 y L3 = Landsat Sensor bands, ERT = Total standing timber volume, *N* = sample size (number of sites).

Table 2

Prediction equations derived from the relationship of ERT [m^3/ha] *with Landsat 5 TM spectral data*

Equations	**Bands**	***N***	R^2	**Bands**	**N. probe**
ERT=214 – 3.07	L4	34	0.72	L4	0.000
ERT=147 – 1.13	L3	34	0.66	L3	0.000

A previous study [5], reported strong relationships between forest structural variables such as height, diameter at breast height, basal area, age and density of trees in a plantation of spruce (*Picea sitchensis* Bong. Carr), with reflectance data from Landsat TM and SPOT sensors in HRVIR, at the United Kingdom. Using a linear model the best relationships were found for height of trees, with a R^2 = 0.85 (Landsat TM, bands 4 and 5) and R^2 = 0.74 (SPOT HRVIR, Band 4).

3.4. Prediction equations of timber volume (ERT)

The ERT variable predicted with the Landsat TM band 4 is represented by the fitted line, which explains a portion of the variability of the dependent variable (ERT); the rest of the variability is explained by residuals (Figure 2).

The most relevant information is to determine if the residuals are normally distributed, with zero mean and constant variance. The easiest way to check this is by getting a visual impression.

4. Conclusions

The results show that it is important to consider Landsat TM remote sensing as an important data source in forestry studies. With an appropriate radiometric and geometric correction reliable predictive models can be obtained. Besides, the scenes are not expensive and each one of them covers a large tract of land.

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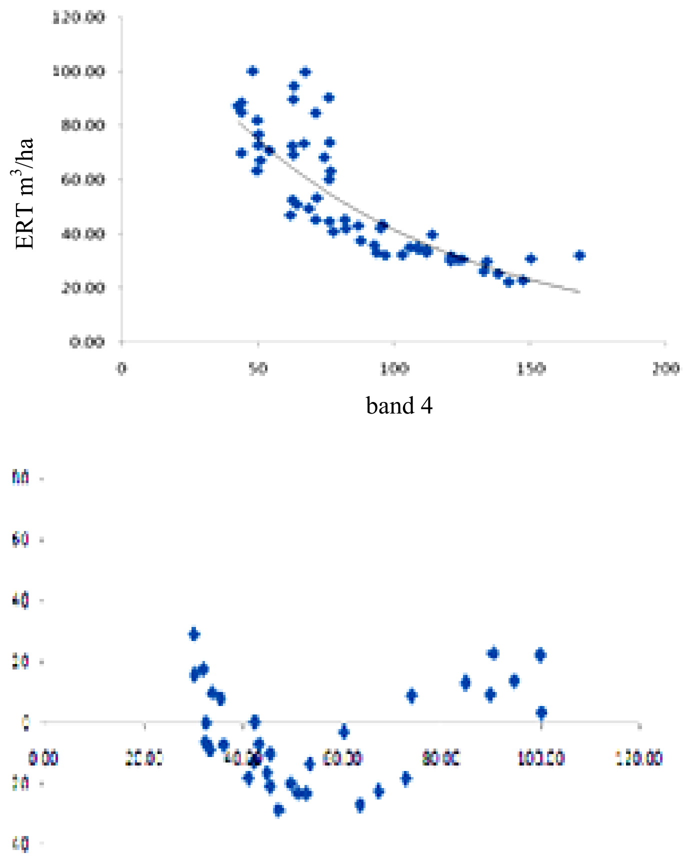

Fig. 2. *Regression and residuals analysis of the predictions made with band 4 of Landsat TM sensor, versus the total real stock variable (ERT)*

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