FORESTRY VARIABLES ASSESSMENT USING LANDSAT TM DATA*

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ABSTRACT

Considering time and costs decrease inherent to informations obtainment process, a methodology was developed associating forestry productivity with site potential and these with spectral response measured from TM/Landsat-5. The dendrometric variables were measured in **Araucaria angustifolia** areas in the National Forest of Passo Fundo (southern Brazil), being calculated the means of each site in each stand. The prognosis model, in a first level, was obtained connecting volume as a dependent variable and TM digital number of band 4 as a independent one. Preliminary results show the influence of site potential in productivity and an improvement of estimatives, when compared with those obtained by others approaches.

1. INTRODUCTION

The Brazilian forestry field have presented an expressive participation in national economy. The incentives policy to this sector was established in 60's, with the main purpose to increase the forestry activity. Once reached the initial goal of expansion of implanted forest areas to supply raw material and energy became necessary to obtain inherent informations to forests, like growth and productivity.

Remote sensing data have been used to evaluate dendrometric variables by several researchers, specially in 80's. Can be mentioned studies of relationship between dendrometric variables and spectral response (Franklin (1986); Peterson et al. (1986); Butera (1986); Danson (1987) and Shimabukuro et al. (1989)).

The advances verified in last years in digital image processing and geographical information systems opened new

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perspectives to forestry stand analysis, giving suport to dendrometric variables quantification through models which describe the interaction between radiation and canopy.

The natural site productivity has a deep effect in wood production (Schneider, 1986). Thus, the natural site inventory, dendrometric variables and orbital data association can derive a new approach to production planning. The purpose if this preliminary approach is to verify this point of view and establish a methodology to obtain forest volume by using a mathmatical model, which input is a digital number of a certain pixel.

2. LITERATURE REVIEW

The increasing wood cleam have carried forestry researchers to study and to develop new methods to qualify and to quantify the forestry production. The obtainment of these informations is fundamental to forestry management: the planning is particularly important due to the large periods of time involved and to the difficulties in to promove rough changes in a forest management (Schneider, 1986).

Site is a fundamental concept in silviculture and forestry management, and can be defined as a spatial unit where the ambiental factors are similar, providing a similar production. Site classification is important to volume prediction. In a certain site, a stand can reach a maximum level of occupation, until find soil and air space restrictions. This level includes the maximum biomass physicaly possible, expressed by the site potential. The factors that define the site classification are represented in maps developed to facilitate planning tasks, defining the units (sites) which have similar properties and productions (Andrae, 1978).

Pioneer works related to leaves optical properties were developed by Gates (1965) and others. In these works were established the importancy of pigments, leave water content and internal scatter as the basis of leaves reflectance and transmitance properties.

Basically, there are two approches to estimate dendrometric variables using remote sensing data, i.e., statistical and phisycal approaches. In the statistical one, used in this case, the objective is to establish a statistic correlation between the spectral data and dendrometric variables, using statistic methods.

The usual methodologies of forest survey involve considerable time and costs in characterization and data raising. To optimize the informations obtainment, the literature presents some papers involving site determinations through orbital data, like Tom and Miller (1979) and Hame (1984). Related to dendrometric variables, can be mentioned Mukai and Takeuchi (1979), Franklin et al. (1986), Butera (1986), Peterson et al. (1986), Shimabukuro et al. (1989).

3. MATERIAL

The National Forest of Passo Fundo is located in Passo Fundo (Rio Grande do Sul state) in southern Brazil, between the geografic coordinates 28^{o} 16' and 28^{o} 20'S and 52^{o} 09' and 52^{o} 13'W (Figure 1).

The study was done in 391.767 ha (1 ha = 10,000 m^2) of **Araucaria angustifolia** (Brazilian pine). The area has a mean altitude of 600 meters and mean slope of 10 degrees. According to Koppen classification, the climate of this region is included at subtropical **Cfa** class. The annual mean precipitation is 1659 mm, moderately distributed.

In geological terms, the study area belongs to Serra Geral formation, characterized by basaltic rocks. The soil is framed in the Passo Fundo Mapping Unit, classified as a distrofic dark red latossoil. This unit presents 80% of the soils with 2.5 to 3.0 meters of depth, latossolic B horizon, well drained, without stonies. The texture is argillaceous with more than 40% of clay along the whole profile. Beside this characteristic and dominat soil type, there are hidromorfic and litossolic soils.

To the development of this paper was selected a TM/Landsat image, band 4, corresponding to orbit-point 222/80, North quandrant, dated of 06/27/1987. This passage coincides with data field colect, to assert more veracity to results. The image was analised in the Images Treatment System (SITIM), developed by National Institute for Space Research (INPE).

4. METHODS

The natural site delimitation used the Andrae methodology described in Andrae (1978), where the sites are defined according to secundary factors (soil and vegetation) by the mutual correlation between them and the possibility of its alteration in less time.

Defined the location of study points, soil and vegetation data were colected. The existence of a different type of site in relation to the precedent one determined the search of the transition line (in line or between the study lines). When it was finished the sounding, the areas with similar properties and informations were joined to elaborate a natural site map. This work was done sistematicaly in all stands and then was elabotared a 1:10,000 scale map.

The forestry inventory was continue type (measured periodically) with stratified sampling and proportional allocation. The sampling frame defined five strata in volume, according to the five natural sites mapped in the forest. In this preliminary paper, only three sites were evaluated: 07 samples in site 1, 02 in site 2 and 11 in site 3 (total of 20 samples, in 4 stands).

Considering works developed in this area, the sampling intensity was calculated admiting an maximum sampling error of 10% of the stratified mean, with 95% of probability. The amostral unit used was rectangular, with 20x30 meters and the colected data folowed the standard methodology of the Forestry Research Center (CEPEF/UFSM), presented by Schneider et al. (1988).

The TM/Landsat-5 image (512x472 pixels) was transfered to the Images Treatment System (SITIM) and a window of 2x2 pixel was disposed over the sample area, using the natural site map. With "LEPIXEL" subroutine of SITIM, the digital values were extracted. One window was generated to each sample, in form to correlate its mean value with volume measured at field.

5. PRELIMINARY RESULTS

Finished the sounding of natural sites, the mapping of implanted forest areas shown the occurrence of five different natural sites presented in Table1.

In Table 2 the forestry inventory results are presented. Are also presented the statistic analysis and estimatives accuracy.

Table 3 shows the differences between volume in the different sites in percentual terms. For example, site 3 produces 8.28% more than site 4, and this produces 37.30% more than site 2.

The statistical analysis of the TM4 band image results in digital numbers values between 01 and 98, and an average of 48.94. Table 4 shows the 20 volume/digital number sampled.

Another researchers approaches used a aleatory sampling, in the place of use stratified sampling, as in this case. The stratified sampling approach can produce more accurate results. Table 5 shows the mean volume of each stand considering both approaches, to demonstrate the differences bewteen them.

The differences between the two statistical methods results are low. In the Table 6 it was reorganized the data set, been calculated the volume and digital number by site by stand, according to the stratification purpose. Using the data set of Table 4, the simple linear regression results in

$$V= -33.78897 + 6.40913\ ND$$

where V is the volume and ND is the digital number of each sample. The correlation coefficient is 0.65335 and the standard error 31,88m^3/ha. Using the data set of Table 6, the expression obtained is

$$V= -170.40753 + 9.17807\ ND$$

The correlation coefficient increases to 0.85123 and the standard error decreases to 23.67 m^3/ha. In this way, considering the correlation coefficient and the standard error, the second expression is statisticly more accurate.

6. FINAL CONSIDERATIONS

The papers on forestry production quantification based on remote sensing data are scarces, existing only one in Brazil. Thus, the development of a methodology to quantify dendrometric variables aimed to our reality and conditions is necessary.

The preliminary results obtained, stratifying productivity by sites, agree with the literature informations, confirming the soil type influence in forestry stands productivity. The improvement in the volume/TM4 correlation confirm the validity of site/productivity/spectral response association.

It is expected that the correlation between volume or others dendrometric variables and spectral response from orbital sensors can provide a mathmatical model which estimates these dendrometric variables with time and cost decreases, in a initial level. Improving this study with a great number of samples (229 were colected at field resulting in 137 final data set), better estimatives are expected.

Considering the Brazilian forestry reality, the existence of an operational methodology in these terms would be used to forestry planning, conciliating the necessity of informations obtainment with low costs and time, in comparation with usual methods.

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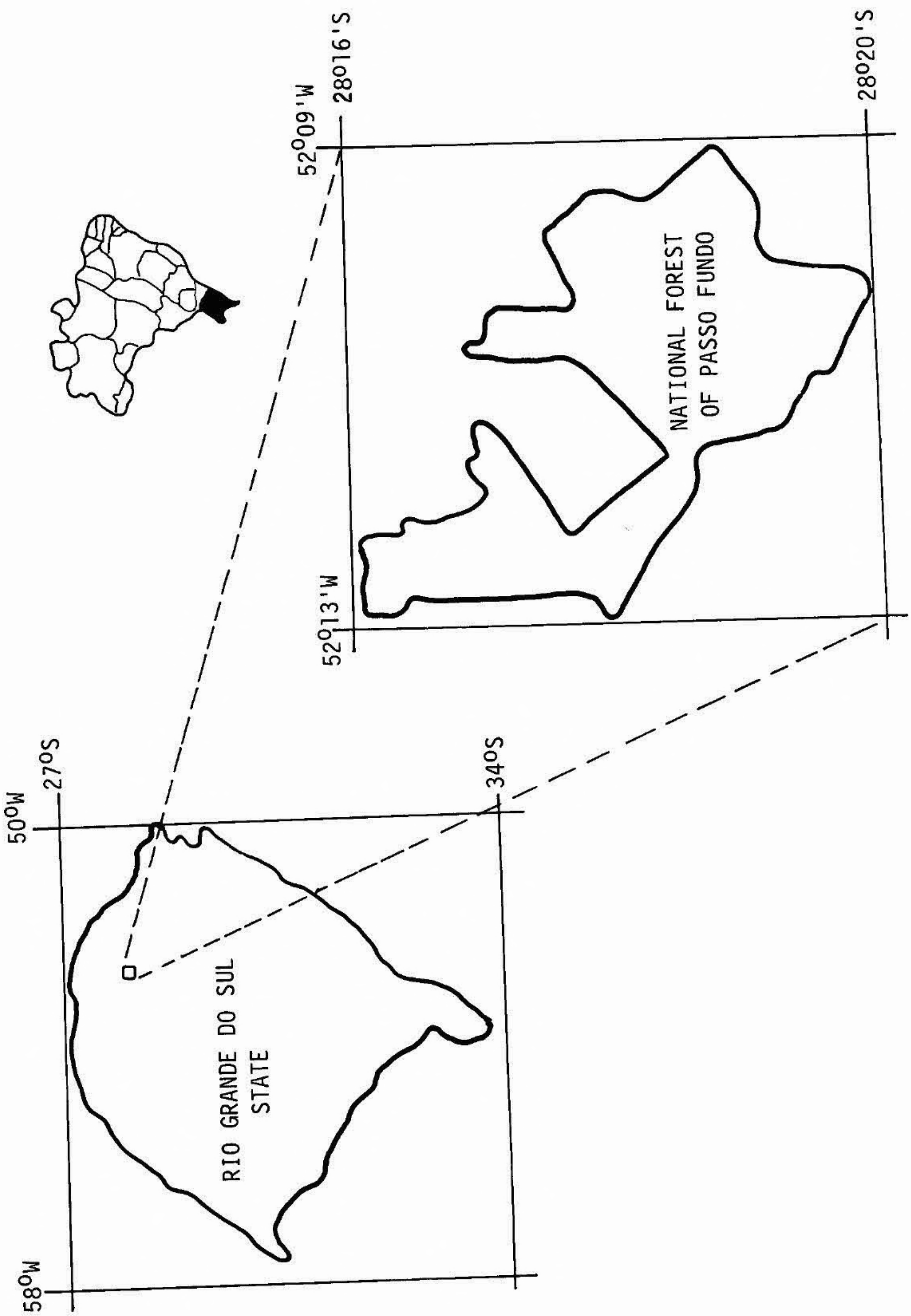

Figure 1. Study area location.

Table 1. Forestry Sites Characterization.

SITE	AREA	MAIN CHARACTERISTIC
Site 1	35.10%	deep latossoil
Site 2	11.21%	hidromorfic soil
Site 3	30.82%	litossoil
Site 4	19.26%	compacted latossoil
Site 5	3.61%	highly compacted latossoil

Table 2. Forestry Inventory Results.
(significance level of 95%)

Parameter	Value
Stratified mean (m^3/ha)	292.37
Stratified variance (m^3/ha)	4,028.32
Variation coefficient (%)	21.71
Stratified mean variance (m^3/ha)	28.55
Standard error (m^3/ha)	5.34
Sampling error (%)	3.60
Total estimative (m^3)	109,294
Least estimative (m^3)	106,000

Table 3. Percentual Difference in Volume Between the Natural Sites.

	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
SITE 1	0				
SITE 2	-37.24%	0			
SITE 3	-20.26%	+27.07%	0		
SITE 4	-13.64%	+37.60%	+ 8.28%	0	
SITE 5	-21.32%	+25.37%	- 1.33%	- 8.88%	0

Table 4. Volume and Digital Number of Data Set.

SAMPLE	STAND	SITE	VOLUME (m^3)	DIGITAL NUMBER
01	01	01	215	45
02	01	03	270	47
03	01	03	280	47
04	01	03	260	46
05	01	01	230	45
06	02	03	280	51
07	02	02	360	55
08	02	02	340	56
09	02	01	240	48
10	02	03	310	53
11	03	01	225	47
12	03	03	315	49
13	03	03	275	49
14	03	03	260	50
15	03	01	235	39
16	04	01	230	48
17	04	03	320	45
18	04	03	280	50
19	04	03	290	43
20	04	01	230	42

Table 5. Mean Volume According Aleatory and Stratified Methods.

STAND	Aleatory sampling	Stratified sampling
01	251.00 m^3	240.31 m^3
02	306.00 m^3	308.75 m^3
03	262.00 m^3	256.65 m^3
04	270.00 m^3	271.62 m^3

Table 6. Reorganized data.

STAND	SITE	V (m3)	DN
01	01	222.50	45.00
01	03	270.00	46.66
02	01	240.00	48.00
02	02	350.00	55.50
02	03	295.00	52.00
03	01	230.00	43.00
03	03	283.33	49.33
04	01	230.00	45.00
04	03	296.66	46.00