Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 4 (53) No. 1 - 2011

ASSESSMENT OF SOME STRUCTURAL CHARACTERISTICS OF THE FOREST STANDS USING SATELLITE RECORDS

Gh. CHIȚEA[1] E. IORDACHE[2]
R. DERCZENI[2] M. MIHĂILĂ[1]

Abstract: *In this paper there are presented aspects regarding the usage of satellite images with very high spatial resolution in determining the characteristics of forest stands. The focus was mainly on the number of trees per unit area and medium diameter of the crowns. Determinations were made by special processing - reception programs followed by the processing of statistical methods.*

Key words: *satellite image, number of trees per unit area, medium diameter of the crown.*

1. Introduction

The researches carried out had as objectives to establish the possibilities to use the satellite records, with very high spatial definition (IKONOS 2) in the forest economy sectors and especially for finding out and characterizing the horizontal and vertical structure of the stands structure [1]. The practical purpose of the researches consists in emphasizing the modality of satellite records with high spatial definition usage and establishing the elements that can be deducted from these registrations.

The satellite records, considered as metrical and objective registrations taken with a defined scale, in a precise wavelength or from a different zone of the electromagnetic specter could be used to determine the quantitative and qualitative characteristics necessary to be used in the management and production works, both in silviculture and forest logging sectors [2], [3].

The measurements could be made on the satellite records, both in a direct and indirect correlative way. For the first category we could mention the measurements regarding the horizontal and vertical characteristic of the stands and trees. In the second category there could be mentioned: the basis diameter at 1.30 m, the stand volume, the class quality, the age class. The measurements and the determinations could be made both on singular or successive pair records taken over one after the other, respectively on the digital model of the field and also on the optical model of the stand that is used for adequate records [2].

The scale of the records has an important role in the metrical determinations, because this has much interference in the calculus relations of the elements of stand characteristics. Also, there has to be considered that the scale of registration is

[1] Dept. of Forest Management, *Transilvania* University of Braşov.
[2] Dept. of Forest Engineering, *Transilvania* University of Braşov.

medium and for fragmented fields with high level differences considerable variations could occur. In this context, special attention should be given to the working area where the measurements have been made, because the precision of the processed data is influenced by the field shapes.

In accordance with the IKONOS 2 records, the next aims were followed:

- application of direct and indirect interpretation criteria on the satellite records with high spatial resolution;
- determination of some characteristics of the trees (crowns diameter, the height of trees);
- determination of the stands (number of trees on the surface unit, the medium diameter of the crowns, the medium height of the trees);
- establishing the stands density and their composition;
- determination of the surface on stand categories;
- estimating the volume of the stands.

2. Place of the Researches

The researches were made in stands located in five different Management Units with production and protection functions from the Braşov mountainous area.

Generally, there were chosen for study pure beech stands, spruce stands or mixed beech - spruce stands.

The existence of more records taken at different dates helps to carry out some comparative researches based on statistical analyses and processing [2].

The sampling areas placed on the field and on the record has different surfaces, starting from 1000 m^2 and till 5000 m^2, being located in compartments no. 1B, 2B, 3A, 4A, 20, 21, 65, 68A (No. V Management Unit "Fața Pietrei Craiului), 43 (No. V Management Unit "Noua"), 53C, 53E, 53F (No. V Management Unit "Tesla"). Generally, the shape of these compartments was square, and their placement, especially on the records, is aimed to catch the representative areas from these stands. The position of each sampling area, both on field and on satellite records (images) was established using the corner coordinates of these records.

Generally, there were placed and studied more sampling areas, taking into account the proposed objectives (determination of the trees number, stand density, surface a.s.o.) but there was also taken into account the statistical coverage to achieve the level of precision.

3. Materials and Study Methods

Materials used in the paper are based on high spatial resolution satellite records such as IKONOS2, whole or frames of those records, georeferenced in the UTM system and/or in the "stereograph 70" system, panchromatic or multispectral registrations, covering all or part of the territory taken in the study (Figure 1).

In addition with satellite records, there have been used for study air photogramms, at 1:8000 and 1:5000 medium scale, taken with the photogrammetric camera WILD RC9 (f = 88.46).

For the areas where the samplings were located, data from the forest managements were available. There were also used the base plans and photogrammetrics returned at 1:5000 scales, plans supplemented with appropriate topography. Satellite records processing was carried out, mainly with Erdas Image program (version 8.6). The methods used in researches are those of observation, comparison, analysis, visual interpretation and correlative method.

4. Results

Processing and interpretation of satellite records have been carried out mainly with

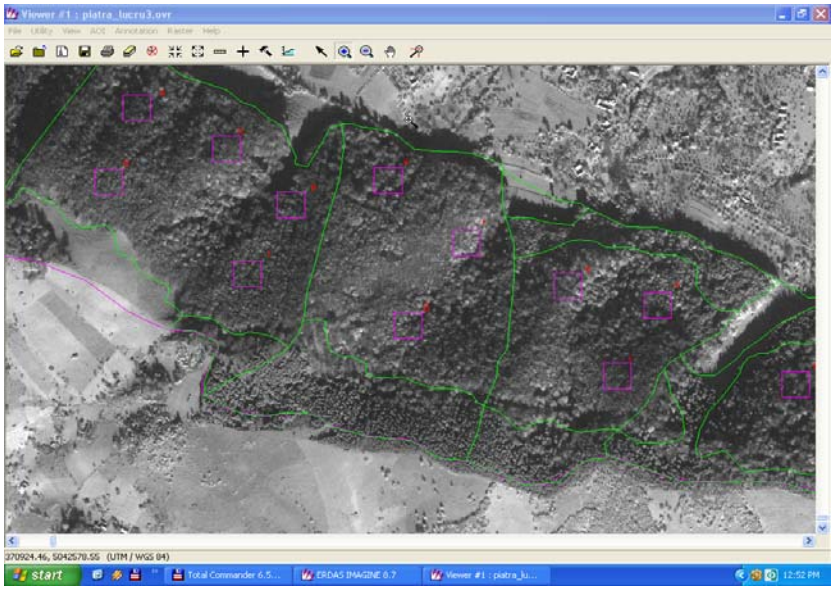

Fig. 1. *Study area*

the following software: Erdas Image version 8.6, ENVI, ArcInfo and Global Mapper. The software used represents specialized GIS programs for multispectral image processing with the main module for image correction, image processing and classification of records. Also, this software provides an easy handling of both types of records as raster and vector formats type in order to achieve and view the digital model of the terrain.

Viewing records and gathering useful information for further processing was done with the viewers Geomatica Free View v. 8.2, ER Viewer - ER Mapper, ERDAS Viewfinder, MrSID GeoViewer and MrSID Viewer.

4.1. Determinations on Forest Stands

Number of trees per unit area [m/ha] deduced from the satellite records with high definition, was performed on the stereo model (3D), when trees in these stands are viewed/individualized better than on individual records.

To define the *x* and *y* planimetric positions there has been used the ERDAS program for IKONOS satellite image with high spatial definition. To perform the comparison between the results obtained from the sampling area placed on the stereoscopic model and the one from the terrain, there have been used data from the forest managements plans and from the production tables (for the determinations made in Forest District Zărneşti and Forest District Săcele). To check the results, the studied sampling areas have been vertically and horizontally surveyed, starting from points with known coordinates which have been determined using GPS and the respective details have been surveyed using the combined traversing method with raying. The surveys were made with Trimble and Leica total stations. The survey consists in raying of all the existing trees in the studied compartments.

For determinations and comparisons between the satellites records there have been used different variants of the records with a scale between 1:3000 and 1:5000, using the same sampling areas.

The comparison between the results for different scale of value was performed using analysis of dispersion considering as graduation factor the scale of the records viewed on the display (Table 1).

The analysis of data shows the following:

- the differences are insignificant for scales of visualization having values between 1:2500 and 1:3500;
- the differences are significant for 1:4000 scale of visualization;
- distinct significant differences were determined between the measurements made on 1:5000 scale of visualization and 1:7000;
- for values of scales of visualization higher than 1:2500 or for some records at 1:3000 scale there could not be determined individual trees because of the pixel size which is greater than the crown diameter.

From the researches there was determined the number of the trees established on the basis of the satellite records with high spatial definition. In most of the situations the value is underestimated especially in the case of uneven - aged stands, because there have been taken into account only the dominant trees and a part of the co-dominant trees, which appear with the peak in the higher ceiling. The best results are obtained in case of pure mono - storied stands, aged over 40 years for coniferous and broad leaves over 60 years. The decrease of the trees number is lower in relative horizontal terrains and higher on steep terrains (Figure 2).

Following the researches, it was found that the precision of determination on satellite records is influenced by the following factors:

- processing scale of the satellite records;
- stand composition and their age; for coniferous and light broad leaves with very well individualized crowns, even in case of middle ages there could be obtained close results with the situation on the field;
- the stands structure which influences the determinations precision; these are superior in pure even - aged stands (mono-storied) in comparison with the uneven - aged or mixed stands (Table 2);
- band of registration in which the determinations were made.

Between sampling areas with 5000 m^2 and 1000 m^2, respectively 4000 m^2 and 1000 m^2, differences regarding the number of trees per hectare are significantly distinct and between sampling areas with 3000 m^2 and 1000 m^2 differences regarding the number of trees per unit area are significant.

Medium diameter of the crowns. Using satellite records with high spatial resolution, the medium diameter of the crown (D_{mc}) is established as an average measurement of individual crowns made through the coordinates x and y, values determined by ERDAS software in each sampling area.

Another process that was envisaged in the researches conducted on satellite records with high resolution was to set the medium diameter of the crowns (D_{mc}) on the relationship between canopy area (Sc) and number of trees (n) also based on the records:

$$D_{mc} = \sqrt{\frac{4 \cdot Sc}{n \cdot \pi}}. \quad (1)$$

Surface area of the canopy was deducted from the stand surface, established after digitization through the function "Measurement Tools" in the software ERDAS, its value resulting directly after closing the polygon. The value obtained was reduced using the coverage index (I_a), in most cases when the stands did not have a full consistency.

Results from this procedure are presented in Table 2.

In order to compare the two processes the analysis of differences by couples method was used (Table 3).

After applying the statistical test it was concluded that between the two determining

Table 1

Determination of trees number
Analysis of variance for the sampling areas in compartment 1B (105 years)

Compartment	Size of sampling area	Number of trees, x_{ij}			Number of observed values, n	$\sum T_i = \sum (x_{ij})$	Average	$\frac{T_i^2}{n}$
T/1B	1000	9	10	9	3	27	9	243.00
	2000	7	11	8	3	26	8.67	225.33
	3000	7	8	7	3	22	7.33	161.33
	4000	6	7	5	3	18	6	108
	5000	6	7	5	3	18	6	108
Total					**15**	**111**	**7.4**	**845.66**

Source of variance	Sum of the partial deviations, Q	Number of degrees of freedom, f_1	Dispersion	F	
between groups	$Q_T = 24.26$	$f_T = 8$	3.03	1.383561644	
within groups	$Q_E = 15.34$	$f_E = 7$	2.19	2.55	for 5%
Total	$Q = 39.6$	$f = 14$	2.83	3.71	for 1%

Group	n_i	$\sum (x_i^2) - \left(\sum \frac{(x_i^2)}{n_i} \right)$	Number of degrees of freedom, f_1	S_i^2	Calculus
1000	3	2.00	2	1	$H_{exp} = 12.94$ $H_{0.05\%\ theoretical} = 202$ homogeneous surface
2000	3	8.67	2	4.335	
3000	3	0.67	2	0.335	
4000	3	2.00	2	1	
5000	3	2.00	2	1	
Total	**15**	**15.34**	**10**	**-**	

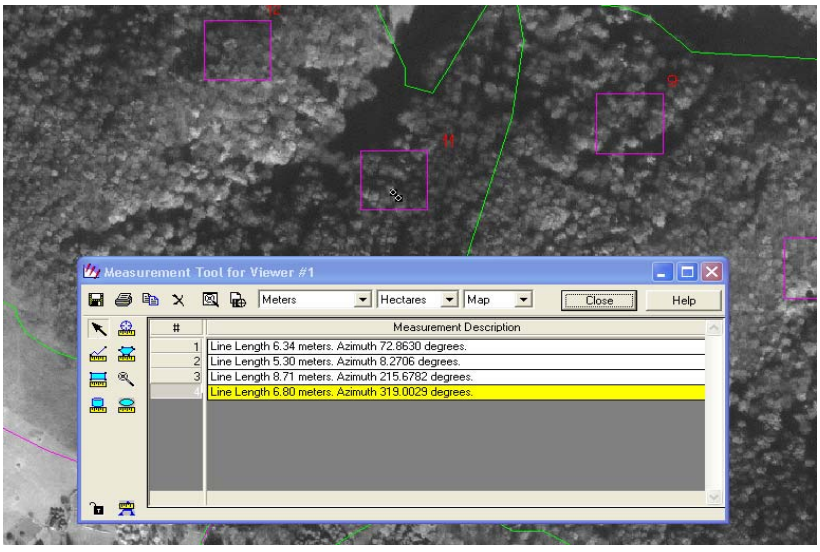

Fig. 2. *Measuring the diameter using the "measure" command in ERDAS software*

Analysis of variance - number of trees per hectare depending on the size of the sampling areas Table 2

Group	x_{ij}						**n**	**T**	$\bar{x}_i$	**H test**
5000	60	110	82	85	101	130	6	568	94.67	$H_{exp.} = 3.25$
4000	59	98	73	86	107	133	6	556	92.67	$H_{teor.} = 3.25$
3000	68	111	73	93	122	130	6	597	99.5	Resulting homogeneous system
2000	86	140	81	102	118	155	6	682	113.67	
1000	90	177	97	158	195	195	6	889	148.17	
Total							30	3292	109.73	$c = 361242.13$

Source of variation	**Sum of squares of deviations**	***f***	s^2	**F test**	s_E = **17.81**			
between groups	$Q_T = 12693.662$	4	$s_T^2 = 3173.4168$	$F_{exp} = 3.33$ $F_{teor} = 2.76$ significant differences	α	5%	1%	0.1%
within groups	$Q_E = 25790.203$	25	$s_e^2 = 3173.4168$		*t*	2.06	2.787	3.725
Total	$Q_t = 36483.87$	29			s_d	36.69	49.64	66.34

Group	**Average**	**5000**	**4000**	**3000**	**2000**	**1000**	**Observations**
5000	94.67	-	2	4.82	18.95	53.5*	*distinct significant difference **significant difference
4000	92.67	-	-	6.83	21.10	55.5**	
3000	99.50	-	-	-	14.17	48.67*	
2000	113.62	-	-	-	-	34.5	
1000	148.17	-	-	-	-	-	

Analyze of differences - couples method Table 3

5000					
No.	**Method x_1**	**Used x_2**	$d_i = x_1 - x_2$	d_i^2	**Calculus**
1	9.14	9.11	0.03	0.0009	$\bar{d} = 0.1183333$, $s_d^2 = \frac{0.0913 - 0.0840166}{5} = 0.00145648$, $t_{exp} = \frac{\bar{x}_1 - \bar{x}_2}{s_d}\sqrt{N}$, $t_{exp} = \frac{8.325 - 8.225}{0.0381654} \cdot 2.4494832 = 6.41$, $t_{teor} = 2.77$. $t_{teor} < t_{exp}$ - significant difference
2	8.05	7.80	0.25	0.0625	
3	9.22	9.09	0.18	0.0324	
4	8.61	8.52	0.09	0.0081	
5	7.50	7.37	0.13	0.0165	
6	7.43	7.46	0.03	0.0009	
			0.71	0.0913	
4000					
No.	**Method x_1**	**Used x_2**	$d_i = x_1 - x_2$	d_i^2	**Calculus**
1	8.92	8.67	0.25	0.0625	$\bar{d} = 0.18$, $s_d^2 = \frac{0.7231 - 0.1944}{5} = 0.10574$, $s_d = 0.3231768$, $t_{exp} = 1.3359028$. $t_{teor} > t_{exp}$ - insignificant difference
2	4.48	4.25	0.23	0.0529	
3	9.58	9.27	0.31	0.0961	
4	9.22	9.11	0.11	0.0121	
5	7.71	7.56	0.15	0.0225	
6	8.04	8.01	0.03	0.0009	
			1.08	0.7231	

3000					
No.	**Method x_1**	**Used x_2**	$d_i = x_1 - x_2$	d_i^2	**Calculus**
1	9.13	9.11	0.02	0.0004	$\overline{d} = 0.175$, $s_d^2 = \frac{0.6484 - 0.18375}{5} = 0.61165$, $s_d = 0.782$, $t_{\exp} = 0.5481594$. $t_{teor} < t_{\exp}$ - significant difference
2	8.10	8.03	0.07	0.0049	
3	8.66	8.45	0.21	0.0441	
4	7.68	7.42	0.26	0.0676	
5	8.87	8.54	0.33	0.1089	
6	9.28	9.12	0.16	0.0256	
			1.95	0.6484	
2000					
No.	**Method x_1**	**Used x_2**	$d_i = x_1 - x_2$	d_i^2	**Calculus**
1	8.73	8.73	0.07	0.0049	$\overline{d} = 0.1733$, $s_d^2 = \frac{0.25201 - 0.1802666}{5} = 0.0143486$, $s_d = 0.1197859$, $t_{\exp} = 3.543794$. $t_{teor} < t_{\exp}$ - significant difference
2	7.75	7.64	0.11	0.0121	
3	8.05	7.96	0.09	0.0081	
4	7.76	7.35	0.41	0.168	
5	6.66	6.43	0.23	0.529	
6	9.14	9.01	0.13	0.0169	
			1.04	0.25201	
1000					
No.	**Method x_1**	**Used x_2**	$d_i = x_1 - x_2$	d_i^2	**Calculus**
1	9.42	9.26	0.16	0.0256	$\overline{d} = 0.10166$, $s_d^2 = \frac{0.1788 - 0.0620166}{5} = 0.0233566$, $s_d = 0.1528286$, $t_{\exp} = 1.63$. $t_{teor} > t_{\exp}$ - insignificant difference
2	5.11	5.03	0.08	0.0064	
3	6.01	5.97	0.04	0.0016	
4	6.07	5.96	0.11	0.0121	
5	6.23	6.12	0.11	0.0121	
6	8.54	8.43	0.11	0.0121	
			0.61	0.1788	

methods for the medium diameter of the crown there are differences, the first being more accurate, outlining that the goals of the stand and canopy is quite relative, especially when we have mixed stand or uneven stand (bi-storied).

To highlight the accuracy of these two methods the study considered to determine the medium diameter of the crownThere were considered esults obtained in the five variants, with surfaces between 1000 m^2 and 5000 m^2, resulting the following:

- significant difference appears between these two methods in samplings of 5000 m^2, 3000 m^2 and 2000 m^2;
- the differences are insignificant in samplings of 4000 m^2 and 1000 m^2.

To determine the optimal size of the sampling areas for determining the value of medium diameter of the crown, simple analysis of variance was applied to sampling areas located compartments 1B, 2B, 3A, 4A, 68A, 65A, Management Unit No. V Piatra Craiului, Forest District Zărneşti, resulting the following (Table 2).

5. Conclusions

Regarding the measurements performed on these satellite recordings with high spatial resolution by means of processing such data (GIS), e.g. specialized software ERDAS Image type, the following considerations can be drawn:

- with these programs measurements can be made both on single records, but especially on records taken in succession which can be achieved in stereoscopic model. In the last case, records are more secure because in stereoscopic view the crowns of trees are defined more clearly, are better outlined and other criteria could be taken into account;
- determinations are safer in pure stands of coniferous, because the crowns of the trees have more regular forms, well defined in comparisson with the broadleaves;
- in both types of stands, the precision of determinations increase as forest stands grow older. In this case, measurements (determinations) may be made only when the individualization of the crown of each tree is carried out;
- the accuracy of results is conditioned by the value of the working resolution the results of determinations increasing in precision with the increase of the spatial resolution. Over a certain amount of resolution size, both in the softwood and hardwood the power recognition of each tree is lost because the pixel size is increased and the image on the screen becomes scattered. Thus, is no longer allows the individualization of each tree from the above ceiling of the stand. It was generally found that an increase in scale over 1:3000 (in certain situations 1:2500) in panchromatic and 1:4000 in multispectral, leads to a blurred image of the pixel which does not allow the measurements. This is in correlation with stand age;
- IKONOS 2 satellite records can be used to establish the characteristics of the structure of forest stands such as: number of trees per unit surface, determining the diameter of the crown which using regression relations can determine the amount of medium diameter at 1.30 m.

In conclusion, the use and especially the exploitation of satellite records with very high spatial resolution in making numeric and metric determinations are an important source of data to complement and improve the processes that are carried out in a terrestrial way.

References

1. Chitea, Gh.: *Biostatistică* (*Biostatistics*). Braşov. Editura Universităţii *Transilvania*, 2001.
2. Chiţea, Gh., Kiss, A., Vorovencii, I.: *Fotogrametrie şi teledetecţie* (*Photogrammetry and Teledetection*). Braşov. Editura Universităţii *Transilvania*, 2001.
3. Vorovencii, I.: *Cercetări privind posibilităţile de utilizare a imaginilor satelitare în lucrările de amenajarea pădurilor* (*Researches Regarding the Possibilities to use the Satellite Images in Forest Management*). In: Ph.D. Thesis, *Transilvania* University of Braşov, Braşov, Romania, 2005.