POSSIBILITIES TO ESTABLISH THE STANDS VOLUME USING GIS AND SATELLITE RECORDINGS

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***Abstract**: In the paper are presented aspects regarding the possibilities to use GIS and satellite recordings with high resolution to determine some stand characteristics and especially their volume. For this purpose were placed sampling areas in mixed spruce, fir and beech stands with ages between 70 and 120 years. In the paper are presented also aspects regarding the errors that could occur at the determination of stand volume using the elements took over from the satellite recordings.*

***Keywords:** stand volume, satellite recordings, recognition.*

1. Introduction

The researches that were made had as objectives to establish the possibilities to use the satellite records, with very high spatial definition (IKONOS 2) in the different fields of forest economy sectors for a rational and sustainable management of the forest stands. Besides the scientific objectives, the practical purpose of researches is to highlight of the use of satellite records with high resolution and determining what items may be deducted directly from these records through specialized programs such as ERDAS and NVI.

One of the basic problems of sustainable management of the forest is the stands inventory, in order to establish the timber volume which is used for determining the annual growth of each stand and respectively for determining the possibility of primary and secondary annual products.

Stands inventory using satellite recordings with high spatial resolution can be made using various methods for assessing different statistical dendrometric characteristics (medium crown diameter, medium stand height which is determined using the parallax measurements, coverage index a.s.o.), measurements which are made on representative samples from contents and depending on which is made the extrapolation to the entire stand.

Stands volume evaluation by means of remote sensing is not a recent problem and is always present in all forest economy types, as is evidenced by the numerous specialized papers that have appeared and appear in this field [1], [3], [4].

2. Place of researches. Methodology

Volume assessment using means of remote sensing involves in some cases combined determination both on recordings with specialized programs and on land measurements, or in some cases, only measurements made on the spatial model of stand done through recordings.

In both cases are required tests by sampling works in the studied stands. In this way are confirmed the results of determinations [2].

Of course, using a combined method or a pure remote sensing method is conditioned primarily by the degree of precision what is expected to be touched by these evaluations, the homogeneity of the stands, the quality of the available records, the means with which the determinations are made or the effective of effort.

In order to evaluate the stands volume using satellite records, it has been working during the following stages, differentiated after cases, as follows:

- grouping stands in homogeneous areas with low variability in horizontal and vertical structure of elements that have been taken into account in determining the volume, the number of sample surfaces and the number of specimens of each sample surface, so it will be met the condition of statistical assurance for a specific tolerance or a level of precision that should be achieved; the operation has been done in good conditions because viewing satellite record using specialized remote sensing programs offer information regarding the structure and the condition of stand that have been studied;
- determining the dendrometric factors that underlying inventory processes of stands. From these structural elements, some or all can be measured directly from satellite recording (singular record or in stereo mode) using the component menus of software such as: crown diameter, height, number of trees and consistency. Other structural features are derived indirectly based on correlations established both on measurements made on field and on measurements that are made on satellite records. Correlations determined by analysis and statistical tests refer to: diameter measured at 1.3 m, coefficient of form, age class, production class, origin, species, composition, etc.
- calculation of stand volume on sampling surfaces on basis of elements took over from the record and extrapolate the values throughout the entire stand;
- spot - checks carried out on the ground, after which you can make comparisons between values obtained using satellite records with high spatial resolution and the results obtained using classical methods.

All methods for determining the stand volume are underlying from the elements that are based on the individual tree volume determining, which is gave by the relationship:

$$V = \frac{\pi \cdot d^2}{4} \cdot h \cdot f \qquad (1)$$

where:

d – basis diameter at 1.3m;

h – tree height;

f – coefficient of form of the tree.

Based on this relationship, the problem of estimating and defining these dendrometric characteristics occur, depending on measurable or deductible elements from satellite record.

For each area that was taken in the study, in which was follow to determine the volume using satellite records with high spatial resolution, values of coefficient of regression equations were determined based on the concrete situation from the field. For this purpose, were placed on the land sampling areas where the volumes were determined directly - by classic full inventory - in order to obtain the reference values of the volume (V); the values h, n, and i were determined on the same areas on satellite recordings.

In order to achieve a more concrete corresponding between sampling areas located both on land and on satellite recording was done the following:

- locating the sample areas on the digital model and positioning the surface in coordinates using the menu "Stereo" in the ERDAS program;

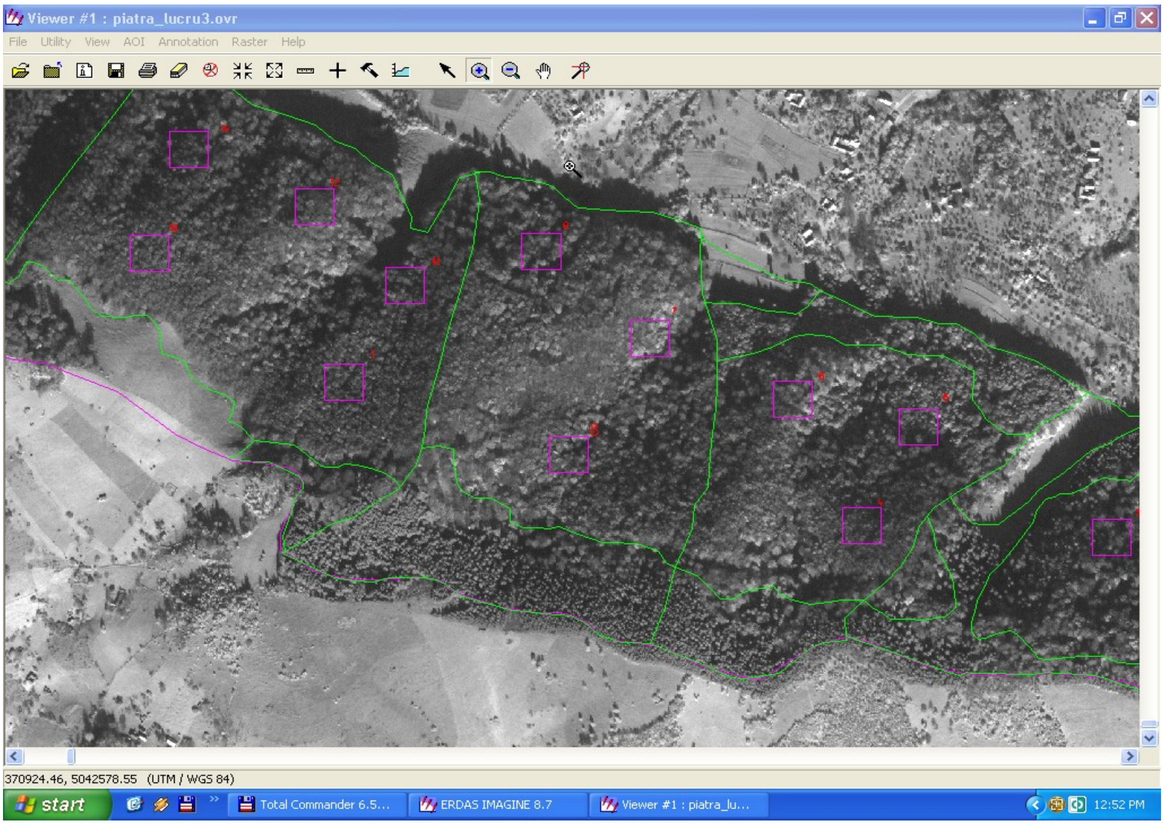

Fig. 1. Sampling area

- locating on the field the position of sampling surfaces according with the coordinates determined with Leika GPS in simple frequency;
- after determining the sampling surface, these areas were survived with the positioning of every tree in that area (ua. 43 - Management Unit No. V "Noua").

3. Results

Measurements regarding the stand volume performed on satellite recordings with high spatial resolution watched to determine trees height depending on the parallax difference establish using the stereoscopic model, made with the mentioned menu. Also, on the same stereoscopic model, it was established the number of trees per unit area.

Height was calculated according to the following elements:

$$h = c \cdot \Delta p - \frac{h^2}{H} \tag{2}$$

where:

c - constant specific of recording;
Δp - parallax difference;
H – height of recording.

In order to determine the volume using satellite record with high spatial resolution, in this particular case we worked with the following relationship:

$$V = b_0 + b_1 \cdot h + b_2 \cdot n \quad (3)$$

where:

b_0, b_1, b_2 - coefficients which define the relationship between measured elements on the spatial model of the record and volume determined on the basis of elements from sampling areas;

h – medium height of stand, value establish on basis of parallax volume;

n – number of trees on unit area establish also on the spatial model (stereoscopic);

V - volume per hectare resulted from the full inventory on field in the sampling areas;

Values used to obtain the unknown coefficients b_0, b_1 and b_2 are shown in Table 1.

Table 1. Volume determination on sampling areas on basis of data by conventional measurements and after the data from records.

Sampling area	Surface (ha)	Composition	Number of trees/hectare	Volume per hectare (m^3)	D_m (cm)	H_m (m)	Values from recording		Differences (record and field)	
							H_m (m)	number of trees/ha	number of trees/ha	H_m (m)
1	1,21	9,5Mo+0,4Br+0,1Fa	670	765,1	33,7	30,1	30,8	530	-140	+0,7
2	2,22	9,7Mo+0,2Br+0,1Fa	410	661,1	40,8	31,3	31,7	338	-72	+0,4
3	1,11	9,0Mo+0,9Br+0,1Fa	525	852,5	44,7	32,3	33,6	454	-71	+1,3
4	1,63	8,9Mo+0,9Br+0,2Fa	503	934,6	46,5	33,9	34,7	496	-7	+0,8
5	1,84	9,8Mo+0,2Fa	406	678,0	30,8	31,4	32,1	362	-44	+0,7

The values contained in this table shows that there are systematic differences between values obtained from satellite records and values obtained by conventional determinations (number of trees per unit area is underestimated, and the height is overestimated).

In order to obtain the most probable values of unknown coefficients (b_0, b_1, b_2) from the regression relationship of the data set and also to test the significance of the correlation between variables and volume, in these relationships was used in the method of least squares using the minimum condition on sum of squares. For this aim, after squaring, derivatives in accordance with the three unknown - variable b_0, b_1, b_2 were matched with zero, resulting the following values:

$b_0 = -1271{,}06$; $b_1 = 52{,}16$; $b_2 = 0{,}76$.

Recalculating the volumes for verification and control using the coefficients led to the following amounts of volumes:

$V_1 = 755{,}8$; $V_2 = 650{,}5$; $V_3 = 850{,}03$; $V_4 = 932{,}3$; $V_5 = 690{,}4$.

Following the researches, it was found that when is working with sampling areas smaller than 2500m^2, the results are weaker. However, regarding the volume, outcomes obtained through satellite records can meet the needs of knowledge, in a first evaluation, of the volume stands (Table 2).

The analysis of significance of differences using couples method shows that the differences between the two processes are insignificant for a 5% probability of transgression. Regarding the determination of the stands volume, results that the used relations, namely the relationship between volume, height and number of trees is relatively close (table 2).

The accuracy of results is directly conditional by the accuracy of height measurement and by the accuracy of establishing the number of trees through stereoscopic model of the registrations.

Table 2. Testing the significance of differences using the couples method.

Sampling area	Volume per hectare classical inventory (m^3)	Volume per hectare resulted from regression relationship (m^3)	Differences		Significance of differences	
			Absolute	Relative	d^2	
1	756,1	755,8	-0,3	99,96	0,99	$\bar{d} = 0{,}49$
2	661,1	650,5	-1,06	98,4	112,36	$s_d^2 = 66{,}2025$
3	852,4	850,03	-1,37	99,72	1,8769	$s_d = 8{,}136$
4	934,6	932,3	-2,3	99,75	5,29	$t_{exp} = 0{,}677$
5	678,3	690,4	+12,1	101,78	146,41	$t_{teor} = 2{,}57$
Total			2,47		299,03	$t_{teor} < t_{exp}$

Regarding the measurement errors on stereoscopic model of satellite registration using the ERDAS software, respectively the accuracy in determining the volume value per hectare, should be taken into the question the accuracy of trees height measurement and also the precision of counting the trees. Starting from the relationship of spreading of the random errors in indirect measurements, result the following:

$$e_V = \pm\sqrt{\left(\frac{\partial v}{\partial h}\cdot e_h\right)^2 + \left(\frac{\partial v}{\partial n}\cdot e_n\right)^2} = \sqrt{(52{,}2\cdot e_h)^2 + (0{,}79\cdot e_n)^2} \quad (4)$$

The error e_h of heights measurement is conditioned by the error of parallaxes measurement (± 0.028 mm). This multiplied with constant c, result an error for heights e_h = 1,56. Thus, result that error for volume varies between 9.7% at 1:8000 scale and 12.5% at 1:10000 scale.

4. Conclusions

It should be noted that setting the volume from satellite records with high spatial precision is a first step in approximating the production found without claiming to achieve the results which are achieved by traditional methods. Usage of such registration can be made for an approximate evaluation of stands volume on large areas and also for a quick estimation.

5. References

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