ASPECTS REGARDING THE USE OF IKONOS IMAGES IN STAND VOLUME ASSESSMENTS

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The place of remote sensing within an intensive silviculture has been discussed over the years in relation to the precision of biometrical measurements. In the past decade, the use of high resolution satellite images, such as IKONOS, QUICKBIRD, Kompsat2, has allowed the development of interactive models of photo interpreting biometrical parameters of stands and trees. The advantage of high resolution satellite data is given on one hand by its precision (especially in the case of high incidence angle >70^0) and, on the other hand, by the multispectral characteristic of the images (the images are taken in four different spectral channels, some of them highly sensitive to vegetation parameters). The statistical model used for comparing the ground data, included the use of biometrical parameters measurable both by forest inventory: diameter at breast height, height, crown diameter, canopy closure index, number of trees within a plot, and remote sensing means: crown diameter, density, number of trees on a hectare. The method was studied on relatively even aged stands of silver fir and Norway spruce, with homogeneous characteristics. Taking into consideration the possible use of such methods (stand volume assessments on very large areas with high efficiency), the possibilities of computing stand volume by remote sensing means has been analyzed on a large scale, within 73 sample plots of 1000 m^2, based on the average values of parameters. The results show that the average tree volume is highly correlated to the number of trees/plot and the average crown diameter. The total volume for each plot tend to be correlated with the number of trees, the canopy closure index and the spectral response (pixel value) in the panchromatic and near infrared spectral channels. The multiple correlation coefficient for the multi parametric regression is 0.525, very significant for the data sets used.

Key words: IKONOS; Stand volume; Biometric parameters.

INTRODUCTION

Stand volume is a parameter with implications in the large scale management of forest areas. It is important to know not only the value of the wood volume within a given area, but also the structural parameters that characterize it: stand volume distribution related to the specie, age, trees quality and average volume. The usual methods for stand volume measurements involve the statistical inventory, with certain intensity, of each stand, related to the precision of determination. Remote sensing methods have been used, in other countries, within the forest inventory methods on large scale territories, offering a lower precision but having the advantage of a lower cost, high productivity and a unitary perspective on a large area at the time the images were taken. The advantages have become obvious with the use of high spatial resolution satellite images (IKONOS, Quickbird), comparable with aerial image from this point of view, but having also a multispectral character and a higher precision, especially in the case of high incidence angle (>70^0) [3].

The present paper intends to compare ground data regarding the stand volume with the values obtained by remote sensing, by means of: measurements of crown diameter, number of trees per hectare, density index and pixel value within each spectral channel.

MATERIAL AND METHODS

The study area is located on the East side of Stănişoarei Mountains, in Agapia Production Unit III, Varatec Forest District. The characteristic proportion of species in the area involves a high percentage of silver fir, in mixed stands with Norway spruce and beech. The research method is represented by the systematic sampling using 1000 m^2 sample plots, installed in mixed stands of silver fir and Norway spruce with ages between 100 and 120 years. The stands are homogenous from the biometrical characteristics point of view (density, species proportion) and can be analyzed unitary.

The field works included inventory of 73 sample plots of 1000 m^2, with variable radius according to terrain slope, used for determining a parametrical computing model for stand volume. The sample plots have been installed using a rectangular network with the distance of approximately 80 m between the plots, taking into account all values of the interest parameters. In each plot we measured the parameters needed for stand volume computing (specie, diameter at breast height, height) and the parameters that are to be measured on the IKONOS image of the area (crown diameter on two directions, density index). The comparability of the ground data with the satellite images has been done by overlaying the sample plots as a *shape file* on the geo-referenced and orthorectified satellite image.

The measurements on the satellite images have been done within the sample plots, using specific features of image processing programs. The crown diameter has been measured on two directions, as well as in the field; the number of trees per hectare has been determined by counting the trees within each sample plot. In the case of trees located on the limit of the plot, the criteria for deciding on including the tree was the proportion of trees crown inside the plot (if the tree had more than half of the crown inside, was included). The density index (crown closure index) has been measured by overlaying a rectangular network of 100 points on the plot area and counting the points on the crown areas. We also measured, for each plot, the average pixel value within each spectral channel of the IKONOS image with specific tools of *Arcview* GIS.

For the ground data volume calculus we used the double logarithmic regression equation applied for each tree in the sample plots, with different coefficients for silver fir and Norway spruce resulting the average volume of one tree and the total volume for one plot. After a statistical analyze of the values of crown diameter, number of trees/plot and density index obtained from the field and from measurements on the images, the relation between average tree volume, stand volume, biometrical parameters and average pixel values has been studied by means of correlation and multiple regression analysis.

RESULTS

The sample plots of 1000 m^2 are large enough to characterize the immediate neighborhood from the measured characteristics point of view and compensate for eventual errors of sample positioning and trees included in plots. Given the fact that the proposed model uses average values of the characteristics, the representativity of the data is higher and could be relatively easy extrapolated to stand scale by integrating the data from all plots (Fig. 1).

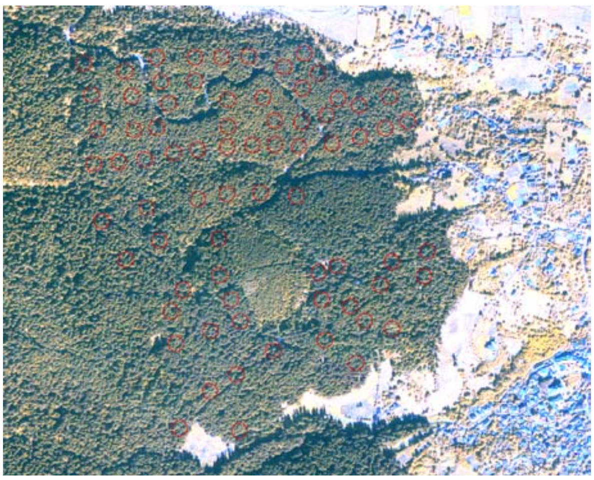

Fig. 1. The sample plots in Production Unit III, Văratec Forest District.

After computing the plot volume, the model of volume calculus was tested using the crown diameter, canopy closure and the number of trees, all determined by terrestrial means. All three parameters are significantly correlated to plot volume (r = 0.4 – 0.7***) and can be used for determining a multiparametric regression equation:

$$v = 2.684 + 1.5084 \cdot n + 7.4559 \cdot k + 2.5811 \cdot d_c$$

where: v represents total plot volume;
n the number of trees / plot;
k canopy closure index;
d_c average diameter for each plot.

The significance of the equation is characterized by the determination coefficient and the multiple correlation coefficient[5]. In this case, the value of the determination coefficient is R^2= 0.492 and the multiple correlation coefficient r = 0.702***. The two parameters besides the crown diameter tend to replace satisfactory the contribution of height in this equation, given the fact that the measurements of heights on satellite images are not representatives for the variation of this parameter within the stand (heights can be measured on satellite and aerial images only in open areas, holes in the canopy)[2]. Because of the fact that these areas are characterized by lower competition intensity, the average height is significantly lower than within the stand. In other cases, the stands don't show any open spaces and it is impossible to measure the height of any tree.

The statistical analyze of the difference between the values determined on the IKONOS images in the combination *RGB – Near Infrared Panchromatic Red* and ground data showed no significant differences between the two sets (the couple method of significance testing for difference, returned lower experimental Student test values than the theoretical ones for 5% transgression probability). In this case, the model can be extended on the values extracted from the satellite images by metrical measurements (crown diameter, number of trees/plot, canopy closure index) or by reflectance measurements in the spectral channels of IKONOS images.

In order to determine the parameters with the outmost influence on plot volume, we computed the correlation matrix (Table 1) for the elements mentioned before.

One can notice in the table above very significant correlation coefficients between the average tree volumes on one hand and the number of trees and crown diameter on the other hand. This can be explained physiologically through the competition process, which affects the form and dimension of the trees[9, 10]. In cases of high density stands, the trees tend to have smaller crown diameters and lower individual volumes. In the opposite cases, in lower density areas, the trees tend to neglect the height growth and intensify the growth in diameter (at breast height) as a result of larger crowns, receiving light on the sides[7]. The total volume within one sample plot is very significantly correlated with the number of trees and canopy closure index, but is also significantly correlated with the spectral response within the channels near infrared and panchromatic.

Table 1

Correlation matrix between the parameters measured on IKONOS images, pixel values within spectral channels, average and total volume

	Blue	Green	Near infrared	Panchromatic	Red	n	k	d_c	Average tree volume [m^3]	Total volume [m^3]
Blue	1									
Green	0,875***	1								
Near infrared	0,219	0,594***	1							
Panchromatic	0,350**	0,698***	0,982***	1						
Red	0,856***	0,976***	0,594***	0,692***	1					
n	-0,018	0,22	0,474***	0,460***	0,202	1				
k	-0,334**	-0,159	0,299	0,255*	-0,195	0,275	1			
d_c	0,205	0,120	-0,07	-0,019	0,111	-0,446***	-0,174	1		
Average tree volume (m^3)	0,212	0,105	-0,046	-0,024	0,094	-0,465***	-0,017	0,414***	1	
Total volume (m^3)	-0,012	0,128	0,282*	0,248*	0,089	0,459***	0,333**	-0,191	0,095	1

The two correlation coefficients obtained in the case of NIR a panchromatic, are affected also by autocorrelation (the correlation coefficient between them is 0.982***). Because of that, there are no different implications of these two factors (they have effect on volume in the same way) and must be taken into account only once.

We can approach the problem of stand volume computing in two ways. The first method would involve the statistical determination by the regression equation of the tree average volume, using the characteristic significantly related to it: the pixel value in the *blue* band, the number of trees and the average diameter of the crown. The average tree volume, multiplied by the number of trees, will result in an estimation of plot volume. The regression equation used in this case for average tree volume estimation is presented below and is characterized by a multiple correlation coefficient of 0.520***.

$$\bar{v} = -3.0545 + 0.0040 \cdot b + 0.0219 \cdot n + 0.1438 \cdot d_c$$

where: $\bar{v}$ represents total plot volume;
b – the pixel value in the blue spectral channel of the IKONOS image;
n – the number of trees / plot;
d_c – average diameter for each plot.

A second approach to this matter means using all characteristics for determining directly total stand volume; the regression equation obtained is characterized by a multiple correlation coefficient of 0.578***, higher than the one obtained above. The advantage of using this method is given not only by the higher correlation coefficient, but also by the fact that it directly offers the total volume of the plot. Thus, we do not have to multiply the value obtained with the number of trees, number which is affected by errors (for the method to be efficient, all characteristics should be measured on the satellite image). The second regression equation was used for computing the total volume of the plot, represented against ground data (Fig. 2).

$$v = -227.4194 + 0.2143 \cdot b + 3.1591 \cdot g + 0.9462 \cdot \cdot NIR - 2.5461 \cdot p - 1.7251 \cdot r + 0.8457 \cdot n + 49.2448 \cdot \cdot k + 1.2234 \cdot d_c$$

where: v represents total plot volume;
n – the number of trees / plot;
k – the canopy closure index;
d_c – the average crown diameter for each plot.

The correlation and determination coefficients are relatively low, due to the high variability of the biometric parameters used; taking into account the very high significance of these coefficients, we could count on a correlative relation between the total volume of the stand and the other characteristics[2, 4, 5]. Other authors[1, 7] have used for computing the total volume per hectare only the spectral response in certain channels and obtained relatively high correlation coefficients (0.7–0.75); that can be explained by the fact they used for model calibration stands with different volumes

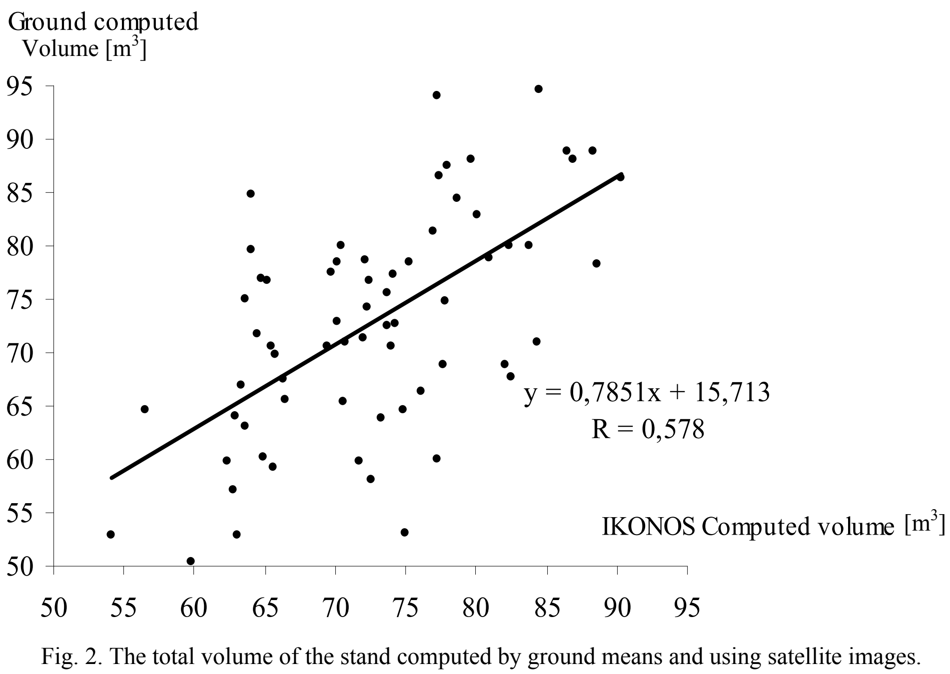

Fig. 2. The total volume of the stand computed by ground means and using satellite images.

per hectare and different ages, so the difference between the spectral reflectance is influenced by the age difference.

DISCUSSION AND CONCLUSIONS

The remote sensing methods for stand volume computing are used in other countries for estimating the size and the approximate structure of the forest fund on large areas. The method used for estimating stand volume takes into account the biometric parameters measurable on IKONOS satellite images: crown diameter, canopy closure index and the number of trees per plot. The model has been tested using the ground measured values of the parameters, in which case we obtained a multiple correlation coefficient of 0.702***. This coefficient shows that between these parameters we can notice a very significant correlative relation and can be used for stand volume estimation. The IKONOS images offer also the possibility of determining the spectral response of each plot within the spectral channels of the IKONOS images. Using the correlation matrix of all characteristics mentioned before (crown diameter, canopy closure index, the number of trees per plot, the spectral response of each plot, the average tree volume per plot and the total volume of each plot), we noticed significant correlations between the average tree volume, the crown diameter and number of trees. The total volume of each plot is highly correlated with the number of trees per plot, the canopy closure index and the spectral response within the near infrared and panchromatic channels.

The possibility of stand volume computing has been analyzed using two hypotheses: one involves the determination of average tree volume for each plot (the total volume of the plot results by multiplying the average volume and the number of trees) and the other is based on a multiple regression of the total plot volume in relation with the characteristic measurable on the IKONOS images. The multiple correlation coefficients are comparable in both situations (0.520*** and 0.578*** in the second case). In spite of these similar correlation coefficients, the second method is more precise due to the direct approach to total stand volume, while in the first case it results by multiplying the average tree volume with the number of trees per plot measured on the IKONOS image and affected by errors.

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