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Estimation of Stand Canopy Cover by Different Methods on Crown Projections: Sample of Lebanon Cedar Stands of the Yavsan Mountain, Kahramanmaras, Turkey

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Abstract: In this study, the possibilities of estimation of stand canopy cover were investigated by ocular estimation method and graphic methods on computer on the crown projection diagrams with scale. Each of six sample plots selected from Lebanon cedar (*Cedrus libani* A. Rich.) stands of the Yavsan Mountain, Kahramanmaras, southern Turkey, was divided into five parcels of 10×10 m and crown projections of the trees located in these parcels were drawn. Percent canopy covers were tried to be determined by ocular estimation of three different persons (A, B, C) and three different graphic methods (digital square grid, polygon, binary image) on the drawn crown projections. The general mean percent canopy cover (N = 30) was the lowest in the binary image method (0.61), followed by B's ocular estimation (0.62), polygon (0.64), digital square grid (0.65), A's and C's ocular estimation (0.66) methods. The results of one way ANOVA showed that there was no statistically significant difference ($p>0.05$) in terms of the mean percent canopy cover among the methods for all the sample plots. Correlation analysis also revealed that there were very strong positive relationships ($R>0.90$; $p<0.01$) among all the methods. All the methods can be used in the estimation of percent canopy covers on the crown projections. Ocular estimation was a method that was relatively simple and gave fast results, and the digital square grid and polygon methods yielded more stable results than the binary image method.

Key words: Canopy cover, ocular estimation, digital square grid, polygon, binary image

INTRODUCTION

Stand canopy cover is one of the most important structural characteristics of a forest stand. The state of shading of stand soil by the stand canopy is called stand canopy cover (Saatcioglu, 1976). Canopy cover is determined with the percent of a forest area occupied by the vertical projections of tree crowns (Avery and Burkhart, 1994). Canopy cover is strongly related to photosynthetically active radiation and overstory leaf area index (Buckley *et al*., 1999). Stand canopy cover has considerable effects on soil, stem and crown development and natural regeneration (Genc, 2004). In this respect, it is quite important to manage stand canopy cover in a way suitable for the objective in stand tending and natural regeneration activities. On the other hand, canopy cover is a characteristic of which determination is required for describing stand structure. In addition, canopy cover can be used as a variable to predict stand volume from aerial photographs (Eraslan and Sad, 1993; Philip, 1994).

Percent canopy cover can be estimated by ground-based measurements, aerial photographs or satellite images. Determining canopy cover by ground-based measurements is relatively difficult and time-consuming. Therefore, ground-based canopy cover measurements may be preferred when accuracy is an important objective (Fiala *et al*., 2006). Different methods such as ocular estimation (Genc, 2004; Korhonen *et al*., 2006), Cajanus tube, LAI-2000 plant canopy analyzer instrument (Rautiainen *et al*., 2005), line-intercept, spherical densiometer, moosehorn and hemispherical photography (Fiala *et al*., 2006) could be used for determining canopy cover as ground-based. In this respect, by comparing with each other the results obtained by different methods, the selection of the method more suitable to the objective has importance.

One of the methods that can be used in ground based estimations of stand canopy cover is also estimation method by crown projection map with scale (Genc, 2004). In the studies made to determine stand

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structures, stand profiles and crown projections for the sample plots selected from the stands have been drawn (Bozkus, 1987; Ozalp, 1989; Demirci, 1991) and percent canopy covers of these stands have generally been estimated by eye in the office according to the crown projections drawn for the sample plots. However, because graphic methods have also developed with the development of computer programs today, it is also necessary to investigate the usability of graphic methods besides the ocular estimation method in determination of percent canopy covers on the crown projection diagrams with scale.

In this study, the possibilities of estimation of percent canopy cover by different methods on the crown projection diagrams with scale were investigated in the sample of Lebanon cedar (*Cedrus libani* A. Rich.) stands of the Yavsan Mountain, Kahramanmaras. For this, ocular estimation values of different persons and estimation values of different graphic methods were compared with each other; thus, it was aimed to compare the different methods with each other.

MATERIALS AND METHODS

Six sample-plots of 10×50 m each were selected in the direction perpendicular to the contour lines from natural pure and mixed stands of Lebanon cedar at generally pole-thin tree stages in the Yavsan Mountain (1964 m), Kahramanmaras, southern Turkey (Table 1, 2). Each sample plot was divided into five parcels of 10×10 m (100 m^2), the locations of trees, of which heights were ≥5 m, in each parcel were marked on the graph paper as with coordinate and crown widths were measured from four different directions. Crown projections of the trees were drawn on the graph paper with a scale of 1:200 in the office and then were drawn on the tracing paper from this paper. After photocopying the tracing papers, the photocopies were transferred into computer through a scanner, and percent canopy cover of each parcel was tried to be determined from over 1.0 on the obtained digital images (jpeg).

It was benefited from ocular estimation method and three different graphic methods in determining percent canopy covers of the parcels. These methods are explained below:

Ocular estimation method: Percent canopy covers in the parcels were estimated by two experienced persons (A and B) and one less experienced person (C) with a precision of 5% by examining crown projection areas and empty areas in the parcels directly on the photocopy papers (A4).

Table 1: Some site characteristics of the sample plots

Sample plot No.	Stand*	Location	Elevation (m)	Aspect	Slope (%)	Relief
I	S	Yoncali	1455	West	44	Slope
II	S	Catalkaya	1420	Northeast	26	Slope
III	S+G	Yaylacam Tepe	1495	West	60	Slope
IV	S+G	Yaylacam Tepe	1570	Northeast	39	Slope
V	S+Ck+G	Zemzem	1365	Northwest	40	Slope
VI	Ck+G+S	Catalkaya	1565	West	30	Slope

*S: Lebanon cedar (*Cedrus libani*), G: Cilician fir (*Abies cilicica* ssp. *cilicica*), Ck: Crimean pine (*Pinus nigra* ssp. *pallasiana*)

Table 2: Some stand characteristics in the sample plots

Sample plot No.	Mean diameter (cm)	Mean height (m)	Top height (m)	Age interval (year)	Tree number (n ha^{-1})	Basal area (m^2 ha^{-1})
I	16.53	8.87	13.14	40-60	1060	25.700
II	17.40	10.69	16.12	35-58	840	24.076
III	18.37	9.20	14.14	57-79	920	35.688
IV	18.28	12.36	19.62	53-66	1380	42.362
V	17.11	9.91	17.04	46-62	1100	34.262
VI	21.03	10.06	16.90	38-88	700	33.516

Digital square grid method: Crown projection areas in the parcels were filled with black colour through PhotoFiltre (ver. 6.3.2) program on the digital images, then digital square grids were generated on the parcels, and squares belonging to the empty areas in these grids were counted by us. During the counts, half and over empty squares were considered. The number of the total squares of the empty areas was proportioned to the number of the total squares of that parcel, the obtained value was subtracted from 1.0, thus percent canopy cover of that parcel was found.

Polygon method: Polygons were drawn by enclosing the surroundings of empty areas in the parcels with ImageTool (ver. 3.00) program on the digital images and the areas of these polygons were calculated in $pixels^2$ by the program. The total $pixels^2$ value of empty areas in the parcel was proportioned to the total $pixels^2$ value of that parcel, and the obtained value was subtracted from 1.0, thus percent canopy cover of each parcel was determined.

Binary image method: Crown projection areas in the parcels were filled with black colour through PhotoFiltre program on the digital images, then these images were converted to binary image (tif) by using ImageJ (ver. 1.41o) program; in general, crown projection areas were covered with white colour while empty areas were covered with black colour in the binary image. When crown projection areas were less than empty areas, a complete opposite of this coloration occurred. The numbers of black and white pixels in the binary images and their proportions to the total number of pixels in the parcel were calculated by ImageTool program. Thus, the proportion of generally white or sometimes black pixels gave percent canopy cover in the parcels.

After percent canopy covers of five parcels in each sample plot were estimated by the different methods, the mean of five values obtained by each method was calculated and the mean percent canopy covers in the sample plots were found separately according to the methods.

One-way analysis of variance (ANOVA) (Kalipsiz, 1981) was performed to determine whether there was a statistically significant difference in terms of the mean percent canopy cover among the methods for each sample plot, the data were $\arcsin(p)^{1/2}$ transformed before the analyses. In addition, correlation analysis (Kalipsiz, 1981) was applied to determine whether there was a statistically significant relationship in terms of percent canopy cover among the methods. For this, transformed percent canopy cover values of a total of N=30 parcels in six sample plots were used and Pearson correlation coefficients (R) were calculated. In all statistical analyses, a confidence level of $p = 0.05$ was used for statistical significance and the analyses were carried out by using SPSS 16.0 package (SPSS Inc., 2007).

RESULTS

The mean percent canopy covers of the sample plots according to the methods varied between 0.61-0.71 for sample plot I, 0.48-0.54 for sample plot II, 0.66-0.72 for sample plot III, 0.72-0.85 for sample plot IV, 0.59-0.65 for sample plot V and 0.59-0.65 for sample plot VI (Table 3). Thus, there were differences ranging from 6 to 13% according to the methods in the mean percent canopy covers of the sample plots. The highest difference was between the binary image method and C's ocular estimation with 13% in sample plot IV.

The general mean percent canopy cover of all the sample plots varied also between 0.61 (the binary image method) and 0.66 (A's and C's ocular estimation) according to the methods (Table 3). Thus, the highest difference among the general mean percent canopy covers of all the sample plots was between the methods mentioned above with 5%.

According to the general mean values in Table 3, in the ocular estimation method, it is seen that there was a difference up to 4.0% among A's, B's and C's ocular estimation values, A's and C's ocular estimation values were the same with each other, and B's ocular estimation values were relatively lower. There was also a difference up to 4% among the values of the graphic methods, the methods of polygon and digital square grid gave results close to each other, and the binary image method yielded relatively lower values. Furthermore, when comparing the mean of the ocular estimation method (0.65) and the mean of the graphic methods (0.63), 2% higher values were obtained with the ocular estimation method in the general mean.

The results of one-way ANOVA showed that there was no statistically significant difference ($p > 0.05$) in terms of the mean percent canopy cover among the methods for all the sample plots [sample plot I ($F = 0.968$; $p = 0.457$), sample plot II ($F = 0.710$; $p = 0.622$), sample plot III ($F = 0.530$; $p = 0.752$), sample plot IV ($F = 0.879$; $p = 0.510$), sample plot V ($F = 0.155$; $p = 0.977$) and sample plot VI ($F = 0.043$; $p = 0.999$)]. Thus, it is understood that there was also no statistically significant difference in terms of percent canopy cover both among A's, B's and C's ocular estimations and among the graphic methods.

The results of correlation analysis revealed that there were very strong positive relationships ($R>0.90$; $p<0.01$) in terms of percent canopy cover among all the methods (Table 4). Pearson correlation coefficients (R) varied

Table 3: The mean percent canopy covers of the sample plots according to the methods (Mean±standard deviation)

Sample plot No.	A's ocular estimation	B's ocular estimation	C's ocular estimation	Digital square grid	Polygon	Binary image
I	0.71±0.12	0.61±0.11	0.61±0.10	0.63±0.08	0.63±0.08	0.61±0.07
II	0.54±0.10	0.48±0.09	0.54±0.04	0.49±0.07	0.49±0.08	0.48±0.08
III	0.71±0.08	0.66±0.08	0.66±0.11	0.72±0.06	0.69±0.06	0.67±0.05
IV	0.81±0.08	0.79±0.13	0.85±0.08	0.79±0.10	0.78±0.11	0.72±0.09
V	0.61±0.11	0.59±0.14	0.64±0.14	0.65±0.15	0.63±0.15	0.60±0.13
VI	0.60±0.29	0.60±0.24	0.65±0.27	0.63±0.28	0.61±0.27	0.59±0.25
General mean	0.66±0.16	0.62±0.16	0.66±0.16	0.65±0.16	0.64±0.16	0.61±0.14

Table 4: The results of correlation analysis of relationships among the methods

Methods	A's ocular estimation	B's ocular estimation	C's ocular estimation	Digital square grid	Polygon	Binary image
A's ocular estimation	-	0.944**	0.903**	0.942**	0.948**	0.948**
B's ocular estimation	0.944**	-	0.944**	0.963**	0.963**	0.950**
C's ocular estimation	0.903**	0.944**	-	0.934**	0.930**	0.912**
Digital square grid	0.942**	0.963**	0.934**	-	0.996**	0.993**
Polygon	0.948**	0.963**	0.930**	0.996**	-	0.994**
Binary image	0.948**	0.950**	0.912**	0.993**	0.994**	-

**: $p<0.01$

between 0.903 and 0.944 in the relationships among A's,B's and C's ocular estimation; and also varied between 0.993 and 0.996 in the relationships among the methods of digital square grid, polygon and binary image. Thus, it is seen that the relationships among the graphic methods were very stronger and the strongest relationship was between the methods of digital square grid and polygon (R = 0.996).

In the estimation of percent canopy covers in the parcels, the simplest and relatively the fastest method was the ocular estimation method, followed by the methods of binary image, digital square grid and polygon, respectively. While the digital square grid and polygon methods were carried out by using the only one computer program, the binary image method was performed with three different programs by us.

DISCUSSION

While the highest difference determined according to the methods in the mean percent canopy covers of the sample plots was 13% (sample plot IV), the highest difference among the general mean percent canopy covers was found to be 5%. Namely, the differences among percent canopy covers obtained with the methods decreased in the general mean. But, because canopy cover of each sample plot or stand has separately importance, this maximum difference of 13% occurred according to the methods should be taken into account, especially in precision studies. Korhonen *et al.* (2006) also stated that different techniques yielded considerably different canopy cover estimations.

That there was no statistically significant difference ($p>0.05$) in terms of the mean percent canopy cover in the sample plots among the methods indicates that percent canopy cover could be determined on the crown projection diagrams with scale by any of the methods mentioned. In this way, the selection of the method more suitable to the objective from the methods explained gains importance here.

There was no statistically significant difference ($p>0.05$) in terms of percent canopy cover between ocular estimations of the experienced persons (A and B) and less experienced person (C). This situation may result from making the estimations in the office and on the drawn crown projections. Therefore, the obtaining of different results according to the persons could be expected in ocular estimations to be made in the field. Indeed, Korhonen *et al.* (2006) determined that the ocular estimations achieved in the field without proper training might be seriously biased in either direction.

In the study, although the ocular estimation method gave relatively fast results, the estimations in this method were able to be made initially with at least an error of 5%. Similarly, Avsar (1999), Tonguc (2003) and Ayyildiz (2003) estimated stand canopy covers on the crown projections with scale by using the ocular estimation method and with a precision of 10%. In this respect, the error rate in the ocular estimation method could be more than the graphic methods. Moreover, in the present study, 2% higher values were obtained with the ocular estimation method than the graphic methods in the general mean. Korhonen *et al.* (2006) also reported that, in general, labour intensive techniques (the Cajanus tube, line intersect sampling) provide unbiased and more precise estimations, while the estimations provided by fast techniques (digital photographs, ocular estimation) have larger variances and may also be seriously biased.

There was no statistically significant difference ($p>0.05$) in terms of percent canopy cover among the graphic methods as well. However, the polygon method (0.64) and the digital square grid method (0.65) gave results closer to each other than the binary image method (0.61) in the general mean. Avery and Burkhart (1994) also noted that the dot grid estimation technique has the virtue of producing a reasonable degree of consistency among various photo interpreters. On the other hand, in the study, the binary image method was the method in which the general mean percent canopy cover was the lowest. It was determined that this situation resulted from the different perception of the signs showing the center of tree and the pixels in sidelines of the crown projection area in the drawn crown projection diagrams. In order to overcome this, making some additional correction operations is required on the existing digital images.

There were very strong positive relationships ($R>0.90$; $p<0.01$) in terms of percent canopy cover among all the methods. But, the relationships among the graphic methods were very stronger, and the strongest relationship was between the methods of digital square grid and polygon (R = 0.996). This revealed that percent canopy covers obtained by the graphic methods had a very higher linear relationship with each other than those obtained by the ocular estimation method. Rautiainen *et al.* (2005) also determined that the Cajanus tube yielded slightly larger canopy cover values than the LAI-2000 plant canopy analyzer instrument in the field, but the values were nevertheless in good agreement.

In spite of at least an error of 5% at first, the ocular estimation method is a method which is relatively simple and gives fast results. In this respect, if the time is limited, the ocular estimation method can be preferred in determining percent canopy covers on the crown projections with scale. If the time is not limited and more precise results are needed, the methods of digital square grid or polygon from the graphic methods can be suggested. Despite seeming like a complex method and giving lower percent canopy covers, it can be said that the binary image method is an alternative method which is quite fast and to be achieve good results in case of making some additional corrections on the digital images, as well.

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