DETERMINATION OF THE FOREST CANOPY COVER USING A LOW-COST COMMERCIAL DRONE IN A TURKEY OAK AND DURMAST OAK STAND IN THE ZARAND MOUNTAINS, ROMANIA

T. P. BANU[1], G. F. BORLEA[1], C. BANU[1]

[1] Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timișoara, 119 Calea Aradului 300450, Timișoara, Romania,
e-mail: tibibanu@gmail.com

Abstract . *The vertical projection of the tree crowns that covers the ground area in a stand is defined as the forest canopy cover and it represents a key element in forest inventories. In stands where area is over one hectare, the accurate determination of the vertical projection of crowns can be very expensive in terms of costs, time and labor power. In this study we present the potential of a drone-based method of forest canopy cover determination that could be later implemented in the sustainable management of forests. Aerial images were acquired in a turkey oak and durmast oak stand located in the Zarand Mountains of Romania with the use of a low-cost commercial drone. The tree crowns were delineated based on an orthomosaic that was assembled using the collected images. Further, forest canopy cover percentage was calculated. Current study results were compared with the traditional ground-based field estimation and the advantages of current methodology were discussed in terms of accuracy, labor power and time spent.*

***Key words**: forest canopy cover, drone, UAV, remote sensing*

INTRODUCTION

The vertical projection of the tree crowns that covers the ground area in a stand is defined as the forest canopy cover and it represents a key element in forest inventories.
Multiple studies in hydrology, global change or carbon and nutrient cycling also need accurate estimates of forest canopy and when measuring vertical projection of the tree crowns or the canopy gaps in plots with sizes of over one hectare, the traditional ground-based methods cannot be efficient. An increasing attention has recently been given to the use of unmanned aerial vehicles (UAV) in remote sensing applications, although they are currently in an experimental stage in forestry.

The most efficient method to determine the smallest dimensions of tree crowns or canopy gaps is mapping through drone remote-sensing, especially because the main advantage of using UAV remote sensing is obtaining very high resolution images, provided at low-cost, that can be used to delineate gaps as small as 1 m^2 which can be further used in assessing the understory biodiversity, in improving the sustainable forest management decisions, in spatio-temporal dynamics of forest or gap dynamics.

In this study, the potential of a low-cost commercial drone-based method of forest canopy cover determination combined with free open-source software are presented for a mixed turkey oak (*Quercus cerris*) and durmast oak (*Quercus petraea*) stand.

MATERIAL AND METHODS

Study area

The study area is represented by a mixed turkey and durmast oak stand with a total area of 13,85 hectares (Fig. 1), located in the Zarand Mountains, Arad county, Romania. The stand is administrated by the Royal Forest District of Săvârșin and currently is being under shelterwood cutting process.

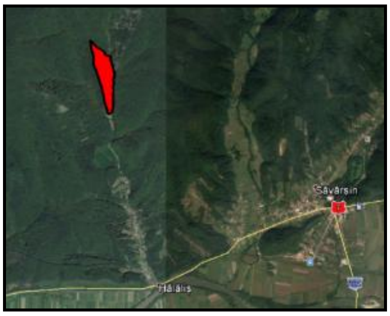

Fig. 1 Mixed Turkey and durmast oak stand, Zarand Mountains, Arad county, Romania (Source: Google Earth)

Drone-based acquisition of aerial images

Images of very high resolution (5,18 cm/pixel) were acquired with a low-cost commercial rotary-wing Unmanned Aerial Vehicle (UAV) - DJI Phantom 3 Professional (Fig. 2) equipped with a FC300X camera with 12 megapixels providing 4000x3000 resolution images. The flights took place in July 2016, noon time (to avoid as much as possible the shading effect), at an altitude of 140 m and a total number of 585 images were acquired. The total flight area included a buffer ranging from 50 up to 200 meters around the study area in order to have good quality images in the vicinity of the stand borders.

Fig. 2 UAV equipment - DJI Phantom 3 Professional

Data processing and calculations

Based on the captured images, an orthomosaic was assembled (Fig. 3a) using a free web-based processing [6] platform and approximately 12 hours were spent in this activity. The orthomosaic was re-projected in the national coordinate system of Romania, Stereographic 1970, and afterwards the stand area of interest was clipped and filtered (Fig. 3b).

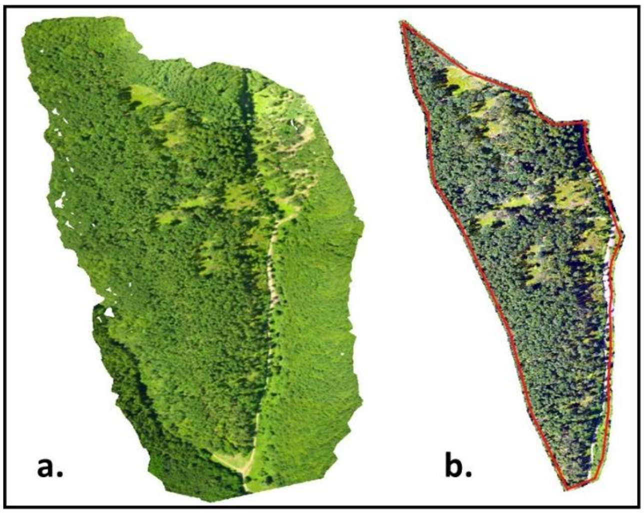

Fig. 3 a. Orthomosaic of the study stand including buffer area
b. Clipped and filtered orthomosaic of the study area

In order to calculate the forest canopy cover area, the tree crowns and the canopy gaps had to be delineated and separated in different classes. For this purpose, a segmentation (Fig. 4a) of the clipped orthomosaic was made using the "*Exact Large-Scale Mean-Shift segmentation*" algorithm implemented in Orfeo Toolbox (Image Analysis) package in QGIS software. It is important to mention that in this stage, the "*minimum region size*" parameter was set to a value of 373 (pixels) which represents the equivalent of one square meter area for the 5,18cm/pixel resolution, considering that a tree crown or a canopy gap should not be smaller than the mentioned size.

Further, a manual classification (Fig. 4b) was made in order to assign each delineated object the corresponding class (tree crown or canopy gap). The classified objects were afterwards dissolved (Fig. 4c) based on the class field and the total area of each class was calculated.

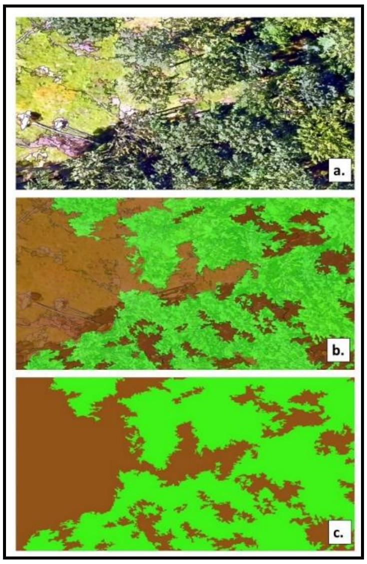

Fig. 4 a. Image segmentation objects resulted with "*Exact Large-Scale Mean-Shift segmentation*" algorithm

b. Objects classified as "Tree crowns" in green color, "canopy gaps" in brown color

c. Objects dissolved based on class field

Ground-based field measurements

The in-situ forest canopy cover estimation was based on the ratio between the current measured standing volume of each species and the volume from forest biometrics in Romania [7] that corresponds to a full canopy cover of that species. The current standing volume of each species was calculated in 18 spatial distributed circle plots of 500 m^2 area each (Fig. 5). In all plots traditional instruments (forestry caliper, Suunto clinometer) were used in order to measure the diameter at breast height (dbh) and tree height for each tree species.

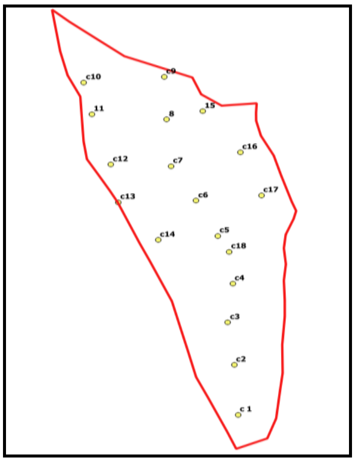

Fig. 5 Points representing the center of the 18 circle plots of 500 m^2 area

RESULTS AND DISCUSSIONS

In the current study area of mixed turkey and durmast oak stand, the in-situ ground-based estimation resulted in an overall 47,00 % forest canopy cover. Through drone-based remote sensing method, an overall area of 66.346 m^2 of canopy cover was detected from the total stand area of 13.8585 m^2, which represents a forest canopy cover percentage of 47,87 % (Fig. 6). The low-cost commercial drone-based forest canopy cover determination method has reliable accuracy, considering that the difference between the results of the two methods is below 1% of canopy cover area.

Fig. 6 Forest canopy cover (47,87%) in green color, canopy gaps in brown color

Regarding the costs and time spent, the drone-based method used a low-cost commercial drone (~1000$) to acquire images (~1-hour field work for 1 person), free web-based processing of the images to assemble the orthomosaic (~12 hours without any labor power) and free open-source software (QGIS, Orfeo Toolbox) for analysis (~5 hours office work for 1 person). Compared to the traditional ground-based method where the time spent for office work is shorter (~2 hours, 1 person) and the total equipment used can cost less (~800$), the time spent in the field is longer (~8 hours field work for 2 persons) and more difficult, especially in inaccessible areas where the drone-based method can have an advantage and the ground-based method can have an overall higher cost.

CONCLUSIONS

Using a low-cost commercial drone in order to determine forest canopy cover of a stand can be a reliable method, especially in large area stands where a high number of plots would be necessary. The time spent for the field work with this method is considerably reduced, another advantage being the possibility to obtain information in low accessible areas.

The overall cost and effort of the ground-based method can be significantly higher based on the labor costs, even though the current drone equipment costs are still higher than those of traditional instruments.

The current study results can be used to estimate the spatio-temporal dynamics of forest, the gap dynamics and even the gap-based assessment of biodiversity in order to improve the future sustainable forest management decisions

BIBLIOGRAPHY

JENNINGS S.B., BROWN N.D., SHEIL D. 1999. "Assessing forest canopies and understory illumination: canopy closure, canopy cover and other measures". Forestry 72(1), p. 59–74.

CHIANUCCI F., DISPERATI L., GUZZI D., BIANCHINI D., NARDINO V., LASTRI C., ET AL. 2016. "Estimation of Canopy Attributes in Beech Forests Using True Colour Digital Images from a Small Fixed-Wing UAV." International Journal of Applied Earth Observation and Geoinformation 47: 60-8.

PROULX R., PARROTT L. 2008. "Measures of structural complexity in digital images for monitoring the ecological signature of an old-growth forest ecosystem". Ecological Indicators, 8(3), p. 270–284.

SHAHBAZI M., THEAU J., MENARD P. 2014. "Recent Applications of Unmanned Aerial Imagery in Natural Resource Management." GIScience and Remote Sensing 51 (4): 339-65.

GETZIN S., NUSKE R.S., WIEGAND K. 2014. "Using Unmanned Aerial Vehicles (UAV) to Quantify Spatial Gap Patterns in Forests". Remote Sens. Journal 2014, 6, p. 6988-7004.

*** Website http://www.dronedeploy.com. Accessed July, 2016.

GIURGIU V., DECEI I., ARMĂȘESCU S. 1972. "Biometria arborilor și arboretelor din România". Editura "Ceres".