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COMPARISON BETWEEN PRISTINE PURE-BEECH STAND AND MIXED BEECH-OAK STAND USING AN UNMANNED AERIAL VEHICLE

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Abstract

Percentage Canopy Cover (PCC) has an important role in forest inventories and, as an ecological indicator, can also determine light conditions, habitats or microclimates. Canopy gaps, which are the result of natural causes or anthropogenic activities, have an important influence on the incoming light that controls how regeneration and the understory biota evolve. Unmanned aerial vehicle (UAV) remote-sensing has become an efficient, increasingly used alternative method, with the advantage of spatially-explicit mapping of the smallest canopy gaps. Following endeavors for 'near-natural' silviculture vertical analyses of tree crowns could provide substantial information for a consecutive management. In this paper, UAV-based measurements of canopy cover, tree crowns and canopy gaps are made in a pure-beech pristine forest and a managed old mixed beech with oak stand. Very high resolution images (3-4 cm/pixel) were acquired and assembled into orthomosaics. The canopy gaps and the upper tree crowns were delineated and the PCC, area (A), perimeter (P) and position of each tree crown were determined. For canopy gaps, calculations of: area (A), perimeter (P), perimeter/area (P/A), circularity (C) and gap shape complexity index (GSCI) were made. The results represent the mentioned structural determinations and the spatial distribution of trees and gaps in both study plots, results which are further compared and discussed.

***Key words**: UAV, PCC, canopy gaps, pristine forest.*

INTRODUCTION

Forest canopy cover, also known as the crown cover or Percentage Canopy Cover (PCC) (Pretzsch, 2009) represents the proportion of the ground covered by the projection of the tree crowns (Jennings et al., 1999) and is an important part of forest inventories. Also, canopy cover is useful as an ecological indicator that can show different habitats, microclimates or light conditions (Korhonen et al., 2006).

In forest canopies, gaps have an important role, especially for the regeneration and the understory biota diversity perspectives (Getzin et al, 2014). Canopy gaps are made by natural causes (windthrow, insects, disease etc.) or by humans in the thinning process and have an important influence of the incoming light that controls how the understory layer will evolve (Proulx, Parrott, 2008). The size, the shape complexity and the spatial distribution of the gaps are key elements in the establishment of the future formations (Koukoulas, Blackburn, 2004; Koukoulas, Blackburn, 2005).

Traditional ground-based methods are difficult to manage efficiently when measuring the ground projection of tree crowns and canopy gaps in plots with sizes of over one hectare (Proulx, Parrott, 2008). Furthermore, if there are desired determinations of the smallest dimensions of canopy gaps and tree crowns, then a very efficient method is mapping by drone remote-sensing (Getzin et al., 2014). And since the diversity of the understory species is related to the direct light radiation, it is important to also monitor the smallest gaps (Montgomery, Chazdon, 2002; Moora et al., 2007).

The main strength of using UAV remote sensing represents the very high resolution of the images, provided at low-cost, that can be used to accurately map gaps under one square meter, which can be further used in assessing the understory biodiversity (Getzin et al., 2014).

In this work, measurements of canopy cover, tree crowns and canopy gaps are made with the use of an UAV in an old mixed beech with oak stand for further purposes as: improved forest management decisions; spatio-temporal dynamic of forest; biodiversity assessment; comparison with other unmanaged/managed forests etc.

MATERIALS AND METHODS

Study area

The study area is represented by 2 plots in different stands. First plot is located in the State Forest „Kranzberger Forst", compartment Rehbuckel („Kleiner Spessart"), near Freising, Bavaria, Germany (Figure 1) with a total area of 7.0 ha. The plot is located in a stand dominated by European beech (*Fagus sylvatica* L.; age approx. 140 years) and common oak (*Quercus robur* L.; age around 170 years) on a loamy soil. The stand was managed for decades in a selection system for crop trees (mostly oak) but by the time beech gained space due to stronger competition. At present harvest of mature trees and release for the best individuals takes place. Natural regeneration of beech is wide spread.

Figure 1. Mixed beech and oak stand (red area) - „Kleiner Spessart" (Source: Google)

The second plot is located in „Izvoarele Nerei" Nature Reserve, Caraș-Severin County, SW Romania. The Reserve is included in the Semenic - Cheile Carașului National Park and proposed to be included in UNESCO Biosphere List, representing one of the largest pure beech virgin forest in Europe with an area of over 5000 ha. The stand (Figure 2) has a total area of 3.9 ha and is represented by pure beech trees with an average age of over 300 years.

Figure 2. Pure beech stand (red area) - „Izvoarele Nerei" Reserve (yellow line) (Source: Google)

Aerial images

Images of very high resolution were acquired with a rotary-wing UAV - DJI Phantom 3 Professional (Figure 3). The flights took place at 100 m altitude and were made during noon time (to avoid as much as possible the shading effect). The total flight area included a buffer area used in order to have good quality images in the vicinity of the stand borders. The details of the flights are presented in Table 1.

Table 1. Flight details

Plot	No. of photos (#)	Date of acquisition	Planned overlap of photos (%)	Flying altitude (m)	Ground resolution (cm/pixel)
Kleiner Spessart	437	October 2016	86	100	3
Izvoarele Nerei	286	June 2016	85	100	4

Figure 3. UAV equipment - DJI Phantom 3 Professional

Data processing and calculations

Based on the captured images, orthomosaics were assembled (Figure 4) using Agisoft Photoscan Professional software. The orthomosaics were reprojected into the national coordinate systems (ETRS1989_UTM32_M -

Germany; Stereographic 1970 - Romania). Corrections based on GPS ground control points followed by shifting and filtering of each orthomosaic were made.

The canopy gaps and the upper tree crowns were delineated throughout a manual digitizing process using ArcGIS software in order to create geospatial polygons. Based on resulted polygons, the following: canopy cover, area and perimeter for each tree crown and the positions of the trees (as being the centroid of the crown polygons) were calculated. Regarding the properties of the canopy gaps, determinations of: area (A), perimeter (P), perimeter/area (P/A), circularity ($C = 4\pi A/P^2$) and gap shape complexity index ($GSCI = P/sqrt(4\pi A)$) were made. While the first four are basic measurements, the GSCI is an important index for forest gaps (Koukoulas and Blackburn, 2004) and has significant correlation with species richness (Getzin et al., 2012).

Furthermore, a pattern analysis regarding the spatial distribution of gaps and tree crowns was made.

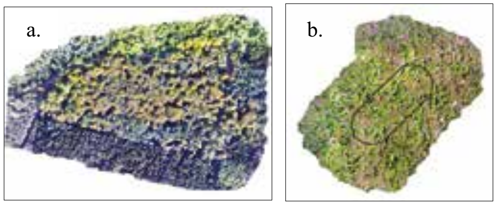

Figure 4. Orthomosaic of the study stand assembled with Agisoft Photoscan Professional software:
a. „Kleiner Spessart" stand; b. „Izvoarele Nerei" stand

RESULTS AND DISCUSSIONS

Structural determinations

In „Kleiner Spessart" stand of mixed beech and oak, a canopy cover of 74.49% (Figure 5) from the total area of 7.0 ha was calculated, a total number of 201 canopy gaps and 675 trees from upper layer (Figure 5) were identified.

In „Izvoarele Nerei" pure beech stand, a canopy cover of 81.57% (Figure 6) from the total area of 3.9 ha was calculated, a total number of 248 canopy gaps and 704 trees from upper layer (Figure 6) were identified.

A summary of the determinations is presented in Table 2.

Table 2. Summary of measurements and determinations

Plot	Type	# per ha	A (m^2)			P (m)			P/A			C			GSCI		
			Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Kleiner Spessart	Gaps	29	1.8	89.5	1457.1	6.1	56.4	696.3	0.30	1.42	4.07	0.03	0.42	0.91	1.05	1.78	5.87
	Upper tree crowns	96	6.4	77.8	274.3	9.6	35.9	78.1	-	-	-	-	-	-	-	-	-
Izvoarele Nerei	Gaps	64	0.2	20.2	388.28	1.7	24.1	256.2	0.55	2.79	8.78	0.07	0.43	0.92	1.04	1.70	3.67
	Upper tree crowns	180	3.4	45.3	149.9	6.9	27.6	62.1	-	-	-	-	-	-	-	-	-

Table 3. Spatial analysis of plots

Plot	Pattern type		Z-score		Observed Mean Distance		Expected Mean Distance		P-value	
	Gaps	Crowns	Gaps	Crowns	Gaps	Crowns	Gaps	Crowns	Gaps	Crowns
Kleiner Spessart	dispersed	dispersed	2.81	13.56	11.65	7.58	10.55	5.96	0.004964	0.000000
Izvoarele Nerei	dispersed	dispersed	7.09	24.33	7.98	5.54	6.46	3.75	0.000000	0.000000

Figure 5. Upper tree crowns and the overall canopy cover of the stand „Kleiner Spessart"

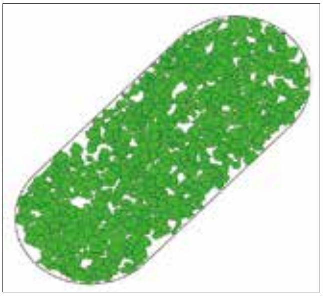

Figure 6. Upper tree crowns and the overall canopy cover of the stand „Izvoarele Nerei"

Spatial analysis

Regarding the spatial analysis, the average nearest neighbour algorithm reported a dispersed pattern for both plots (Table 3) when looking to canopy gaps (Figure 7) and upper layer tree crowns (Figure 8).

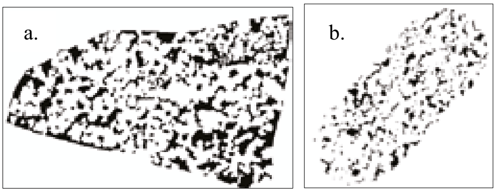

Figure 7. Spatial distribution of the delineated gaps: a. „Kleiner Spessart" plot; b. „Izvoarele Nerei" plot

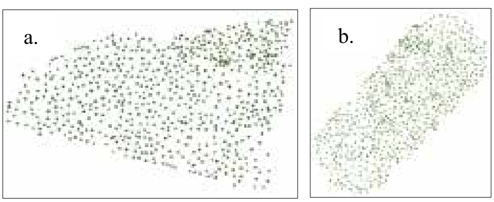

Figure 8. Spatial distribution of the highest trees: a. „Kleiner Spessart" plot; b. „Izvoarele Nerei" plot

CONCLUSIONS

Using UAVs to measure gaps and tree crowns, especially when they have small dimensions (e.g.: 0.2 m^2/gap in this study) can be very effective compared to terrestrial mapping which is a lot more time-consuming or to satellite images that have coarser resolutions (≥50 cm/pixel). In this study, measurements for the canopy cover, tree crowns and canopy gaps with an UAV were successfully accomplished.

Looking at the GSCI values (the value of 1.00 is the minimum one and represents 0% shape complexity - similar to a circle), canopy gaps in the „Kleiner Spessart" plot have values ranging from 5% to 487% in shape complexity and those in „Izvoarele Nere" plot have values ranging from 4% to 267% in shape complexity.

Considering that numbers above 1.732 for GSCI are classified as high complexity (Jenks and Caspall, 1971), 40% of the canopy gaps in the „Kleiner Spessart" plot are in this case. Related to the recent studies where GSCI is significant correlated with the species richness (Getzin et al., 2012) and could be used to assess biodiversity, some of the current outliers and the +78% shape complexity of the mean GSCI value should indicate that species richness level is above normal for the „Kleiner Spessart" plot. The forest management activities in this plot could be the cause of the regularly distributed patterns of canopy gaps and trees.

Further attempts could focus on an evaluation of GSCI to enhance forest management for biodiversity or to find references.

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