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Validation of surveillance applications and low-cost drone for mapping and exploitation of forest areas in urban environment

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Abstract The municipalities of big cities utilize public green areas within the urban fabric, in order to create a small-scale natural environment for the community. The methods and the instruments for surveying and implementing topographic projects differ in quality, accuracy, time and cost. The purpose of the present research is to compare three different surveying methods according to these factors, and to test the adequacy of the results for highlighting best available techniques in forest urban areas. The results of measurements derived from a total station and unmanned aircraft were compared. Measurement errors were combined with the time required to complete the survey and the cost of each instrument and associated software for data processing. Based on the results, the time and cost of each application has shown that low-cost methods give sufficient results that can be used for the design and implementation of forest urbanization studies. The prospects for utilizing these methods of measuring and surveying urban forested areas are multiple and constantly improving with the development of technology.

Keywords: Surveying, Low-cost methods, Forest Urban Environment, spatial planning, UAV

1. Introduction

Topographical maps are a key element for landscape design or formation of public green areas. Different surveying methods and applications are being used in order to produce them. UAV remote sensing surveying, surveying with total station, image processing, the research of mosaic method and the field application of remote sensing technology are studied by researchers in order to optimize the production of topographical maps.

The total station was introduced in 1971 and for the first-time distance and angle measurements could be recorded by a single instrument (Stergiadis, 1984). The total station is a transit integrated with an electronic distance meter (EDM), , which can read slope distances from the instrument to a particular point of land (Hoffman 2013).

A drone survey refers to the use of a drone, or unmanned aerial vehicle (UAV), to capture aerial data with downward-facing sensors, such as RGB or multispectral cameras, and LIDAR payloads. UAV aerial photogrammetry is widely used, and mainly depends on the characteristics of UAV aerial photogrammetry technology such as aerodynamics, resolution and positioning systems. (Hong, 2017; Dibao, 2018).

A low-cost method to survey public green areas require an accuracy, persistence and high-resolution results (Stergiadou et all, 2016). The urban green is limited in parks or in rows on both sides of major roads, while the suburban green spaces have also declined dramatically with the continuous expansion of the building (mainly arbitrary) (Kassios, 2003).

The purpose of the present research is to highlight the use of UAVs in the field of producing topographical maps and calculating the vegetation's crown area of green areas. Topographic measurements of green areas are more tolerable in terms of accuracy compared to those which are used in fields such as the cadastre and real estate. Thus, the factors of the cost and the time of measurements are more important. This research compares a classical topographic method with UAVs photogrammetry in order to produce topographical maps of green areas.

2. Methodology

2.1. Research area

The forest-botanical garden of the university campus of the Faculty of Forestry and Natural Environmental Sciences of the Aristotle University of Thessaloniki was selected as a research area The study site is located in the area of Foinikas in the western suburbs of Thessaloniki. The university complex houses the department's laboratories, the administration's offices, as well as ancillary facilities for education and research with a total area of approximately 50.000 m^2.

The forest-botanical garden of the university is located inside the area. It has the typical characteristics of a forest area within an urban environment and contains various forest species of all forms (herbs, shrubs and trees). Initially, for the precise delimitation of the survey area, a topographic survey took place. During the survey, the fence in the east, south and west side and the inner road in the north side of the area were recorded. Finally, in the measured perimeter of the area, a buffer of 2m was applied, to ensure that trees' whole crowns are included. Finally, the size of the research area, as depicted in Figures 1,2 and 3 is 28.101,31m^2.

2.2. Materials and Methods

The extent of the crown of the vegetation of the study area was measured by the use of three methods. The aim was to calculate proportion of the vegetation in relation to the bare area.

The first approach was implemented with regular topographic methods. A total station, was established in five different points inside the area in order to have line of sight of the whole area. The dependence of the survey was made by exploiting already installed points with known coordinates in the Greek Geodetic Reference System (GGRS ΄87) by the Hellenic Military Geographic Reference System. The measurements were conducted by 3 researchers. The first was the operator of the total station, the second of the reflector and the third was responsible for the coordination of the works and the production of an initial hand-made topographic chart. For the measurement of the crown of individual trees and shrubs a single point was recorded in the center of the trunk, and diameter of the plant was recorded with a tape measure. The purpose was to create a circle as close as possible to the observed area of the crown of the plant. On the other hand, for measuring the crown of the plants found in clusters, the measurement was made with points around the cluster which formed a polygon. In total, 102 points were recorded. After the completion of the measurements, the data were transferred in CAD software, and a topographic chart was produced. In total, the time cost which needed in order to complete the implementation of the method was 32 hours (3 researchers worked for 8 hours for the field measurements plus 1 researcher worked for 8 for processing the measurements and extract the results).

The second and the third approaches were implemented, based on the usage of an Unmanned Aircraft System (drone). Specifically, a DJI Phantom 4 UAS was used, which is characterized as a low-cost device with satisfactory performance. The drone executed one flight for approximately 25 minutes and took 50 photographs in total. The photos were stitched in an appropriate software and by the end of procedure, an ortho-photograph plus a digital elevation model (DEM) as well as Digital Surface Model (DSM) of the area were extracted. In addition, to ensure the accuracy of the ortho-photograph and of the rest derived products, during the flight, specified fixed points were highlighted. These points called Ground Control Points (GCPs) are necessary for the accurate dereferencing of the produced ortho-photograph. In total, 6 GCPs were used with known coordinates in GGRS'87.

For executing the second methodology, the ortho-photo was introduced in a GIS software and a detailed digitalization of the vegetation of the area took place. The digitalization was done by creating polygons in the orthophoto, in the areas which the user distinguished vegetation. According to this technique, the proportion of vegetation in relation to the total area was measured (Tselepis, 2021).

Finally, the proportion of the area covered by vegetation was estimated by a third methodology, using an automated object-based image classification algorithm with the contribution of the Support Vector Machine classifier (Hearst et al., 1998). In more detail, the third methodology is consistent of three (3) steps.

The first step is to produce the Normalized Digital Surface Model. As a result, the true values of the study area objects' heights are calculated by implementing the following equation (Hiscock et al., 2021):

nDSM = DSM - DEM

- The second step includes the transformation of the RGB orthophoto with the aid of 3 vegetation indices:Excess Red (ExR): (1.4*R-B) (Dong et al., 2020)
- Excess Green – Excess Red (ExGR: ((2*G-R-B)-(1.4*R-B)) (Dong et al., 2020)
- Visible-band Difference Vegetation Index (VDVI): ((2*G)-R-B)/((2*G)+R+B) (Wang et al., 2015)

Then, a composite image is created which consists of the 3 previous transformed images.

The third step includes the segmentation of the composite image with the Mean Shift Algorithm (Fukunaga & Hostetler, 1975), the selection of the training samples representing 5% of vegetated and non-vegetated area of the image and finally the training of the SVM classifier with the integration of the nDSM raster, leading to the creation of a classification model. Afterwards, the model was applied on the segmented composite image, resulting to the final classified image. The total accuracy of the classification was 89.5%.

The time cost for the second and the third method was 12 hours (2 researchers worked for 2 hours for preparing and executing the flight with UAV and 1 researcher worked for 8 for processing the measurements and extract the results).

2. Results

Based on the used methodology, there were produced 1) maps with Total Station measurements, 2) vegetation polygons in the study area created by digitalization in ortho-photo, 3) vegetation polygons in the study area created by OBIA Classification method. The Figures produced by measuring and relating vegetation with the total area inform us about the variety of measurements.

Table 1 summarises total area of vegetation that was measured as well as the proportion of the vegetation related to total area. In addition, the time spent in order to implement each method is depicted, as a key factor to estimate the cost of each method. The time presented is the sum of the time of the field measurements plus the time required to process the measurements and extract the results.

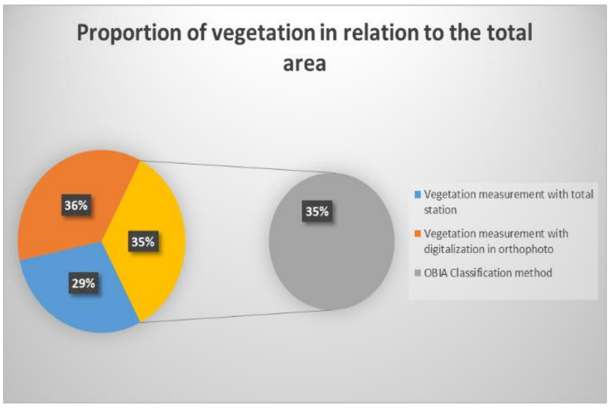
Figure 1. Vegetation polygons in the study area created with Total Station measurements

Figure 2. Vegetation polygons in the study area created by digitalization in orthophoto

Figure 3. Vegetation polygons in the study area created by OBIA Classification method

Table 1. Comparison of methods

Methodology	Total area of Vegetation Measured (m^2)	Proportion of vegetation in relation to the total area	Time Spent (hours)
Vegetation measurement with total station	7253.97	25.81 %	32
Vegetation measurement with digitalization in orthophoto	8889.79	31.62 %	12
OBIA Classification method	8527.82	30.35 %	12



3. Conclusion - Discussion

The OBIA method, seems to produce results similar to the manual digitization of the vegetation in the study area. The total difference of the manual digitization and of the OBIA method was 1.27%. The manual digitization of the research area includes user related accuracy errors, since the delineation is performed by visual interpretation. Furthermore, another type of user error is the faults due to his/her digitization actions when drawing the polygons.

As a result, OBIA delineation of the vegetated area is far more accurate than the method exploiting a Total Station Instrument. However, misclassification issues occur due to the fact that the nDSM is not very accurate because of photogrammetric errors. This is caused probably by the quality of the UAS's hardware and especially of the Imaging Sensor. This error leads to misclassification of vegetation with sparse crowns. This observation is in consistency with the derived results since OBIA method is underestimating (even by a small percentage of 1.27%) the vegetation area.

Nevertheless, the results for groundcover estimation in urban green areas with the OBIA methods are found to be accurate enough, while the occurring misclassification errors can be characterized as insignificant. Furthermore, the OBIA classification method is not time consuming, can handle large datasets and can easily be used in large areas. However, the combination of methods is probably leading to the best results, because the total station can accurately extract the tree stems, while the OBIA method through the UAS image can accurately extract the tree crowns.

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