

# Applications of unmanned aerial vehicle and 3D modelling in forestry

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**Abstract** The fast development of the UAV devices has led to an extended use in a variety of fields of study, both scientific and applicative. The present study will exemplify and bring arguments in favour of the use of UAV techniques in forestry (landscaping and arboriculture) through the use of a surface model (Digital Surface Model-DSM) for the USAMV Cluj Napoca university campus and a model for the identification of the dominant tree species using the spectral answer of tree crowns. The PHANTOM 3 ADVANCED drone was used for this purpose, with a HD camera which took 178 photographs during a previously defined flight, so that the degree of photography overlay was 90%. These photographs were eventually used in specialised geoinformatic software in order to create a highly precise surface model (the final resolution of the model being 2.32 cm/pixel). Taking into consideration the high degree of details, the results were used to identify the tree species which are present in the university campus by identifying their spectral characteristics, as well as to indirectly monitor the health of the trees by using a cloud of 8639052 points. The use of these modern means of forestry monitoring leads to the creation of detailed models for the analysed areas, in considerable less time and with a lower cost and use of resources in comparison to traditional methods, being suitable for different forestry activities which will be detailed in the article.

## Key words

U.A.V., 3D modelling, forestry monitoring, drone, point cloud, mesh

U.A.V. devices (*Unmanned Automated Vehicle*) include aerial vehicles without a pilot or flying vehicles which are remotely flown in order to obtain spatial and visual information about a territory, by remotely operating the device or in an automated mode, on a predefined flying track. The drones which are currently available on the market differ according to size, number of engines, flight autonomy, transport capacity, photo and video camera, specific teledetection and topometric sensors etc. In Romania, in order to use drones for scientific purposes, one needs to register the device at the Romanian Civil Authority for Aeronautics, and in order to fly, one needs to receive a written flight authorisation 30 days before the flight inside the built-up area and a telephonic confirmation from the same authority in the case of flights taken outside the built-up area, together with the proof of a specific flying course undertaken by the drone's possessor and the existence of the drone's assurance (HG nr. 912/2010).

The drones which can be found on the market have an incorporated GPS system and also highly precise digital cameras (RGB, thermal cameras,

multispectral and hyperspectral cameras) which can lead to the acquisition of highly precise and accurate information in the identification of tree species (1,2).

In the present study a series of general objectives have been followed: the testing of the drone in the 3D modelling of the U.S.A.M.V. campus, the execution of the flight for taking images as georeferenced raster databases, the processing of the information, generation and interpretation of results (Digital Surface Model-DSM, Mesh, Ortomozaic, Point Clouds), the identification of tree species from the U.S.A.M.V. Cluj-Napoca campus, the evaluation of the initial tree health state and last, but not least, the analysis of the applicability of U.A.V. techniques in forestry.

The choice of the study area, represented by the campus of the University of Agricultural Sciences and Veterinary Medicine (U.S.A.M.V.) from Cluj Napoca, Romania, is motivated by the large diversity of tree species from this campus. This aspect has also made the research more difficult, due to the different colours present in the tree crowns, a specific habitus for each individual species and a large number of infrastructure

elements which are present in the campus.

The methodology presented in this study follows the necessary stages when monitoring a certain territory with various tree species. In this case a green area was selected in the campus of the University of Agricultural Sciences and Veterinary Medicine (U.S.A.M.V.), but the same stages can be applied when flying over a group of trees or a forest area with a different content.

## Materials and Method

The whole methodological process is based on a logical scheme which highlights four main stages (database acquisition, database analysis, analysis of results and validation of results), each stage being subdivided in the main components, represented by actions and procedures (Fig. 1).

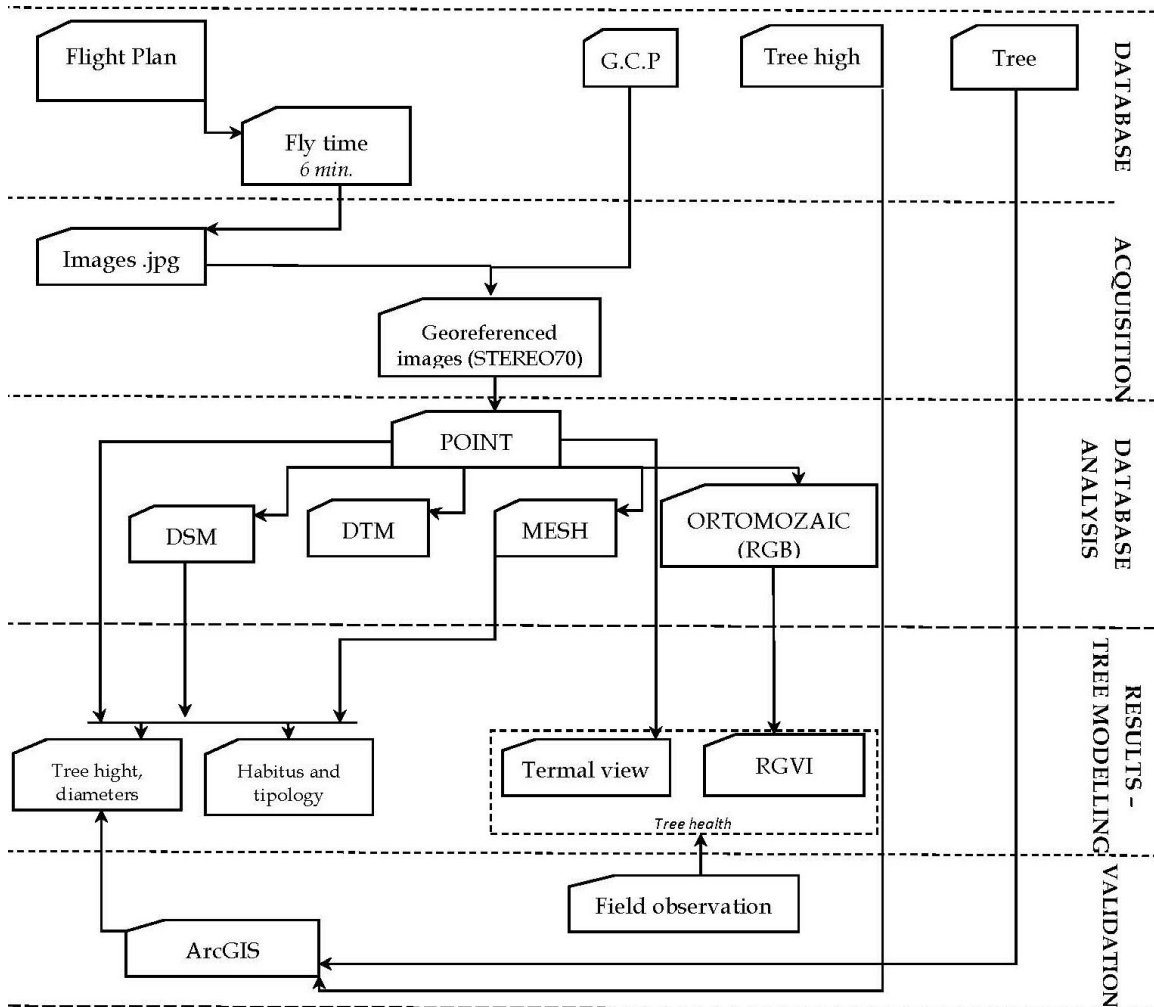


Fig. 1 Methodological stages

The whole scientific process is structured as a spatial analysis model which fulfils all the conditions of structure, starting from database acquisition, analysis and recommendations and solutions, but not before the validation of results. The latter was performed on two different methodological directions: the direct comparison of measurements made in the field with the values measured using modelling databases, as a result of the model implementation, and the identification of correspondence degree between the species identified by analysing and 3D visualising of the point cloud, resulted from analysing the aerial images, and the reality

in the field. The same technique was used in order to validate the health degree of the trees, by directly comparing results and reality.

In order to attain the objectives of the study, the drone PHANTOM 3 ADVANCED was used, which is equipped with a camera having a resolution of 12 Megapixels, which allows the acquisition of aerial photographs with a medium to high accuracy. This aspect will influence the resolution of the derived databases. The acquisition of the georeferenced images was performed following a predefined flight plan, which was designed during the desk stage (Fig. 2), with

specific settings which allow a high degree of overlap for the consecutive and adjacent images, namely 80%. In order for the automatic georeferencing precision, based on the GPS information, to have a high value, during the presetting stage of the flight parameters, an average flight speed of the drone was selected during the flight, thus the whole flight plan was finalised in 6.46 minutes. The flight height influences the quality of the databases obtained through data management and analysis, the higher the flight, the lower the quality of the point cloud and, thus, the lower the resolution of the raster generated as a digital surface model by image processing. The flight was performed at 50 m during a double flight mission, based on the application Pix4Dcapture which was used on an Android system. In order to generate 3D maps using aerial photogrammetry, it is necessary to position the camera perpendicularly to the land surface and if the photogrammetry is to be used for creating 3D models of monuments or statues, the camera must be positioned horizontally in relationship to them. The choice of these flight parameters will influence the quality of the data acquired, as well as the quality of the eventually derived and modelled data (3).



Fig. 2 Flight characteristics of the mission (11 April, 2017)

The flight was performed during the spring of 2017 when the trees were starting their vegetation process. This time period was chosen to better highlight the use of the U.A.V. technology in measuring the average diameter or the height of the monitored trees. Of course this process is no longer possible in the areas with a high tree density where their crowns intertwine and where the dominant species are no longer visible. In order to calibrate and georeference the images acquired with the drone, 4 control points were marked on the ground (Ground Control Points), their position being

identified with the differential GPS GeoMax Zenith 35 Pro, in a Stereographic 1970 coordinate system.

The use of the specialised software Agisoft PhotoScan allows the generation of the point cloud, the digital surface model and the digital terrain model, these databases being eventually processed with the help of the ArcMap 10.1 software, to inventory the specific tree diameters and heights, as well as to identify the clues that point to the health state of the trees.

## Results

By performing the flight, 178 aerial photographs were generated, which were eventually used in specialised geoinformational softwares in order to obtain a surface model with high accuracy and precision, as well as the orthophotoplan of the overflown area (Fig.3) (final resolution being 2.32 cm/pixel). This resolution is superior to that of satellite images (of a few tens of meters), which lie at the base of monitoring studies of forested areas on various surfaces. These databases allow the visualisation of the analysed territory both as an overview and at the level of a study case, being the basis for the measurements of the surface occupied by forest vegetation and the identification of tree density etc.

The point cloud, whose quality is dependent on texture, sharpness, as well as on the correct calibration of the camera (4, 5), includes 8639052 points. The possibility to visualise the results in three dimensions, in RGB colours and from different horizontal and vertical angles enables the identification of the tree types to be performed with a higher accuracy, due to the fact that the observer can analyse at the same time more characteristics which stand at the basis of the identification process (tree crown, trunk, branch-trunk angle etc.) (Fig. 5). By using the remote sensing indices implemented on RGB images, the surfaces covered with vegetation were identified and the degree of vegetation coverage was calculated at the same time for the analysed territory. The macroscale analysis based on supervised classification has highlighted areas with tree vegetation of a specific type. These analyses lie at the basis of generating the databases which are needed in studying the degree of tree vegetation coverage, as well as for the visual and quantitative interpretation of the elements from the study area, using the products of the softwares which process the UAV images: Mesh, Orthophotoplan, Digital Surface Model (Fig. 4).



Fig. 3 Visualisation on ortophotoplan

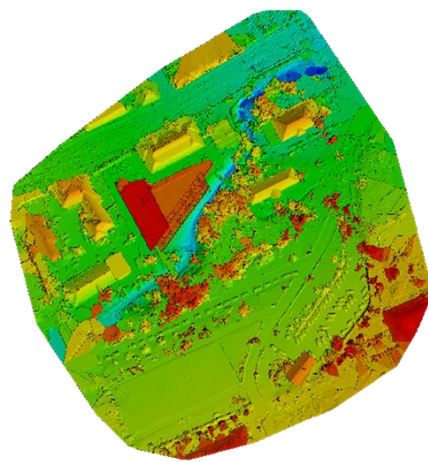


Fig. 4 Digital surface model



Fig. 5 Cloud point obtained for the U.S.A.M.V. campus

Specialised softwares also allow the visualisation in thermal spectre (Fig. 6). The analysis in thermal spectre of the databases obtained by exploiting the information

given by the point cloud highlights the health state of the vegetation according to the different thermal responses of each species.

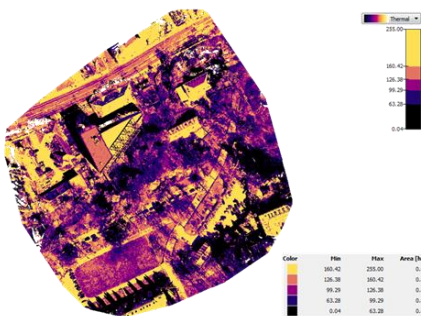


Fig. 6 Thermal visualisation of the USAMV campus

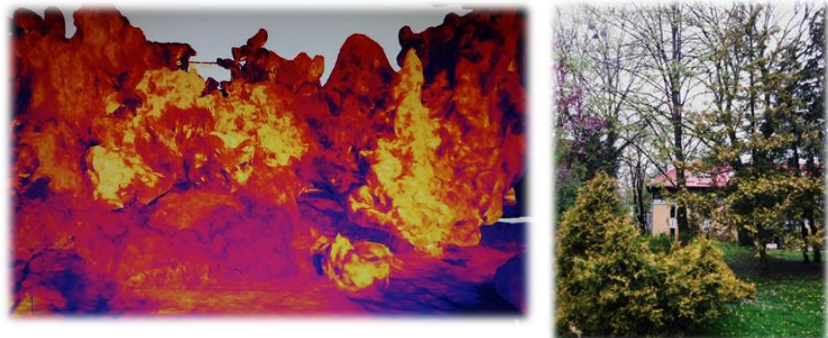
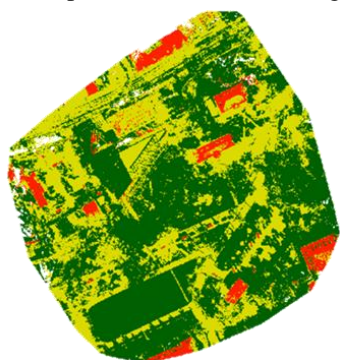


Fig. 7 Preliminary analysis of the vegetation health state

After obtaining the point cloud, one can calculate vegetation indices by processing the bands from the visible spectre resulted from the decomposition of the RGB image.



In this case the Green-Red Vegetation Index was calculated:

RGVI =  
 $(\text{Green} - \text{Red}) / (\text{Green} + \text{Red})$ ,  
 Green > Red: Wooden vegetation (coniferous, deciduous);  
 Green < Red: Areas without

Fig. 8 Indicele RGVI calculate la nivelul campusului U.S.A.M.V.

vegetation, soil;  
 Green=Red: Water, snow.

Considering the fact that for this study a RGB camera was used and the time period when the flight took place was before the vegetation maximum, one can notice the validity of this index in such studies (the lack of leaves as well as leaf discoloration can be easily identified). To exemplify this, the image of the species *Thuja occidentalis var. aurifera* was used, its crown hues allowing the testing of this method for evaluating the health of forest vegetation.

The decomposition of the R, G, B bands

enables the preliminary analysis of the tree health state (Fig.7), both directly and through models.

By image analysis, the surfaces with grass and tree vegetation are highlighted (pixels in green hues), as well as the building and transport infrastructure elements (in red hues). This indicator can represent the basis for calculating the surface of each land cover class.

The individual estimation of tree height was performed using remote sensing in regional and detailed studies, their prediction degree being dependent on the used resources. Thus, the best results were obtained using U.A.V. devices with LiDAR sensors (6,7,8), and the more general results were obtained by using the spatial resolution of satellite images (9,10).

As it made possible the estimation of tree height and tree diameter, which through allometric equations can lead to the estimation of the basis diameter (DBH), and thus of the tree volume, the U.A.V. technology has gained ground among the methods and techniques of forest inventory on different surfaces and with results which depend in accuracy on the quality of the devices used (11,12,13).

Using the point cloud obtained by processing the photographs taken with the drone, one can generate virtual tree models and, thus, measure some morphometric indices of the tree trunk, tree crown, or the tree as a whole.

Special care must be given when measuring the height of the trunk at its basis because the interpolation can lead to underestimated values when there is thick grass vegetation or dense brushwood (14, 15,16).



Fig. 9 The estimation of tree height using the point cloud and validation with telemeter and forestry caliper

With the purpose of validating the virtual trees, four samples were selected after modelling. For these virtual trees, specific measurements were performed, such as the diameter at 1.3 m and the tree height, both in situ and

in the point cloud. As a result, there was an underestimation of the basis diameter value and an overestimation of the tree height for the virtual trees (Table 1).

Table 1

### Comparative measurements on field and on virtual tree

Sample tree	Field	Virtual Tree
Diameter (cm)	48	45
	40	37
	68	67
	76	74.5
High (m)	Field	Virtual Tree
	21	21.6
	12	11.2
	18	19
	20	21

Due to the high detail level of the results (DSM, DTM, Mesh etc.), one can identify using the colour and the shape of the tree crown the specific habitus of each tree species.



Fig. 10 Identification of tree species from the campus of the University of Agricultural Sciences and Veterinary Medicine from Cluj Napoca, based on tree habitus and on morphological and morphometric tree characteristics.

It is clear that a high density and diversity, thus a large number of species mixed together, can make the mission more difficult. Previous studies show that good results were obtained when identifying coniferous species (17).

This study also highlights with the help of Mesh the coniferous species present: *huja occidentalis*, *Picea Abies*, *Abies alba*, *Pinus nigra* (Fig.10). These stand out in the study area through height, different colour and their conical and fusiform habitus (Fig. 10). Species such as *Corylus columnna*, *Quercus rubra* or *Tillia tomentosa* are also easily identifiable due to their specific habitus and their large dimensions, being located along the access ways and at a distance of a few metres from the rest of the trees, which gives a better precision to their corresponding point cloud.

## Conclusions

The use of these modern means of forestry monitoring leads to the development of detailed models for the analysed areas and reduces the necessary amount of time, cost and resources in comparison to traditional methods. As a result, these modern methods can be used in various forestry activities.

The low initial cost and the low maintenance cost of drones and the possibility to equip them with various cameras enable the capture of spatial and temporal images through repeated flights in a specific time interval.

Some negative aspects associated with the use of U.A.V. in forestry are represented by the limitation imposed by legislation, the necessity of initially training the operator of the drone and the person that processes the images, the logistical requirements and the dependency on meteorological conditions during flights.

The results of this study can be used in the stage of scientific research as well as in activities of identification and monitoring of forest vegetation inside the USAMV campus.

The identification of tree species from the USAMV campus can be easily performed by using the habitus as classification criterion: pyramidal shapes (conic, fusiform, columnar), ovoid and globular shapes.

In order to identify the exact position of the individual trees from different species in the field, a series of control points were used, their location being established with the help of a differential GPS. These marks were used in the process of georeferencing the images resulting from the processing of the images taken with the camera installed on the drone.

The results related to the computation of dendrometric indices, the evaluation of tree health and the identification of tree species using indirect methods (three dimensional modelling of tree species using georeferenced images obtained with UAV techniques) highlight the successful use of the method and recommend its use in the process of tree species evaluation for detailed analyses and at a large

representation scale. The relatively short time which is necessary for applying this method proves the utility of implementing it in reference to the management of time and personal resources. This is valid in study areas with good accessibility, but especially in areas which are less or hardly accessible, where the person used as a specialised evaluator cannot make a direct tree inventory based on classical methods.

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