Comparative Analysis of Unmanned Aerial Vehicle Land Cover Classification of Two Study Sites in Serbia

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doi: 10.5281/zenodo.11584526

Abstract: In recent decades, using unmanned aerial vehicles (UAVs) for mapping and classifying the Earth's surface has surged. Ecological researchers increasingly rely on UAV imagery due to its centimeter-level resolution and rich information content compared to other remote sensing methods, such as satellite imagery. This study presents a comparative analysis of the land cover classification of orthomosaics in two distinct Serbian study sites using high-resolution imagery captured by different UAVs: the DJI Inspire 1 and DJI Phantom 4 Multispectral. In the study site Topli Do (Eastern Serbia), the DJI Inspire 1 equipped with RGB and NDVI modified cameras was utilized, generating the orthomosaic of six land cover classes. Random forest classification algorithms were employed achieving an overall accuracy of 92.46%. In the study site Glavica (Northern Serbia), aerial images were acquired using the DJI Phantom 4 Multispectral, featuring a multispectral sensor capturing data across blue, green, red, red-edge, NIR, and combined RGB ranges. Applying the random forest, five land cover classes were delineated with an accuracy of 95%. This finding underscores the transformative potential of multispectral cameras in enhancing land cover classification. Using spectral information captured in multiple bands has enabled determining plants up to the species level in heterogeneous vegetation types. Such classification represents a breakthrough in ecological monitoring, allowing scientists to gain insight into ecosystem dynamics, species distribution, and environmental change at the local scale.

Keywords: unmanned aerial vehicles; object-based image analysis; machine learning; land cover classification.

1 Introduction

Unmanned aerial vehicles (UAVs) have emerged as a prevalent method in remote sensing for land cover classification, owing to their capacity to capture very high-resolution (VHR) imagery. Beyond conventional RGB sensors, multispectral and hyperspectral sensors have expanded the potential for detailed land cover classification (Ahmed et al. 2017, Umut et al. 2022). VHR imagery, with its wealth of information, necessitates novel approaches to image analysis. Object-based image analysis (OBIA) has superseded traditional pixel-based classification methods, employing shape, texture, and spatial relationships to categorize pixels (Dronova 2015, Ivošević et al. 2021). Understanding the spatial distribution of land cover classes is imperative for effective land use planning and natural resource management (Verburg et al. 2009). These maps are instrumental in monitoring species distribution and implementing conservation strategies, particularly in ongoing biodiversity campaigns focusing on insects like hoverflies, bees, and butterflies. Integrated into analyses, these maps offer insights into ecological patterns, guiding targeted conservation efforts. Furthermore, beyond ecological studies, this data holds relevance for various machine learning methods, which have the potential to accelerate the classification process. Among these, ensemble learning methods like Random Forest (RF) are acclaimed for their superior accuracy and reliability (Ivošević et al. 2021, Umut et al. 2022).

2 Materials and methods

Materials used in this research are from two study sites in Serbia: Topli Do (Mt. Stara Planina, Eastern Serbia) and Glavica (Fruška Gora, Northern Serbia). Topli Do boasts diverse vegetation classes ranging from forest, shrubs, mowed meadows, roads, water, and rocks. Glavica is covered by forests (90% of the total area), followed by shrubs, mowed meadows, roads, and human-made objects. The UAV equipment used in the study sites is given in Figure 1. Image processing steps including rescaling, layer merging, segmentation, labeling, and classification were executed using QGIS 3.10 with the built-in Orfeo Toolbox, implemented in Python 5.3.

The schematic workflows of all the steps required for the methodology suggested by Ivosević et al. (2021) are shown in Figures 2 and 3 with some differences between the two study sites and UAV equipment used. Topli Do aerial data acquisition at the study site employed a DJI Inspire 1 quadcopter equipped with a Zenmuse X3 gimbal capable of camera interchangeability between RGB and NDVI modalities. Before the flight, placement, and measurement of five Ground Control Points (GCPs) ensured centimeter-level precision, facilitated by the NovAtel SMART6-L GNSS SMART Antenna. A double-grid flight mission yielded two sets of UAV images captured by RGB and NDVI cameras. Image stitching resulted in orthomosaic generation via Pix4Dmapper software. Red, green, blue, and Digital Surface Model (DSM) layers were derived from the RGB orthomosaic, while the NDVI orthomosaic enabled NDVI index map generation. Rescaling layers to a 0–255 bit range preceded the fusion into a five-band orthomosaic. Application of the Large-Scale Mean Shift (LSMS) algorithm enabled image segmentation, followed by manual labeling of training and validation polygons on the vectorized output. The image classification was applied using the RF classifier and land cover classes with percentage coverage were calculated.

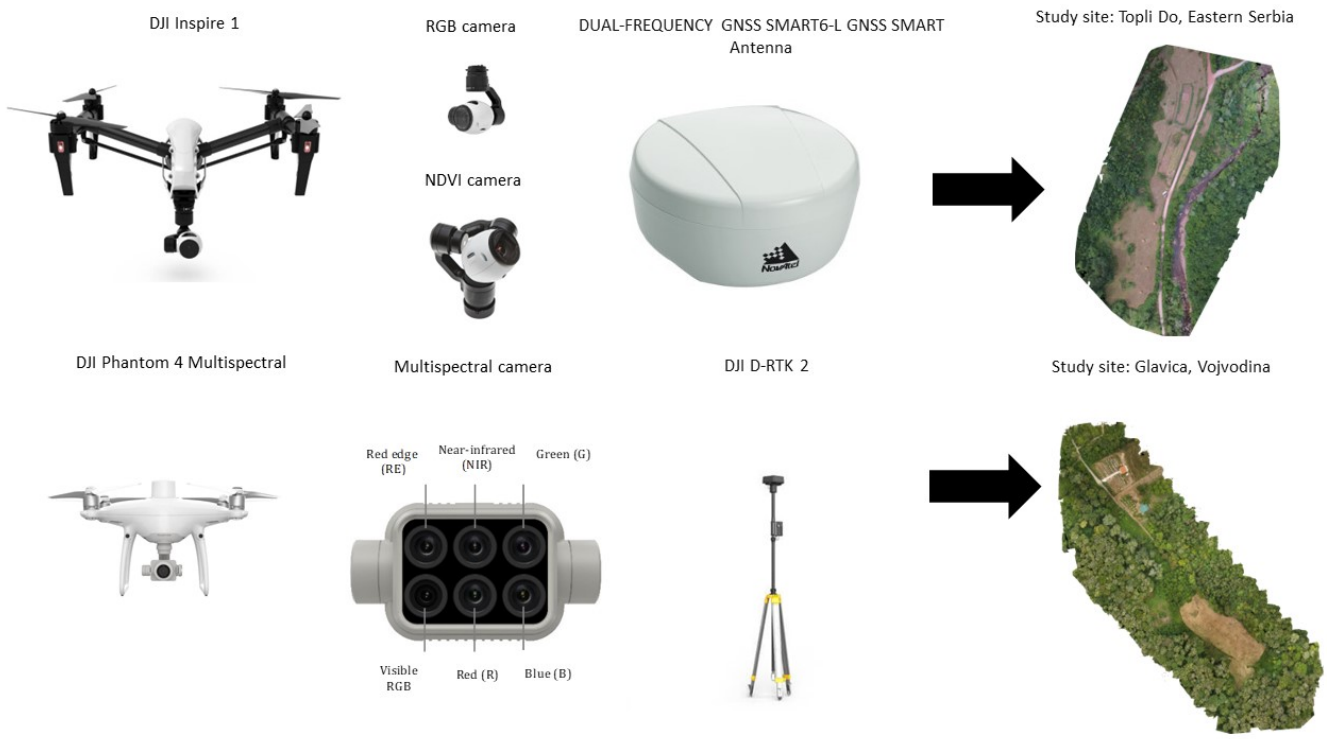

Figure 1. UAV equipment in the study sites.

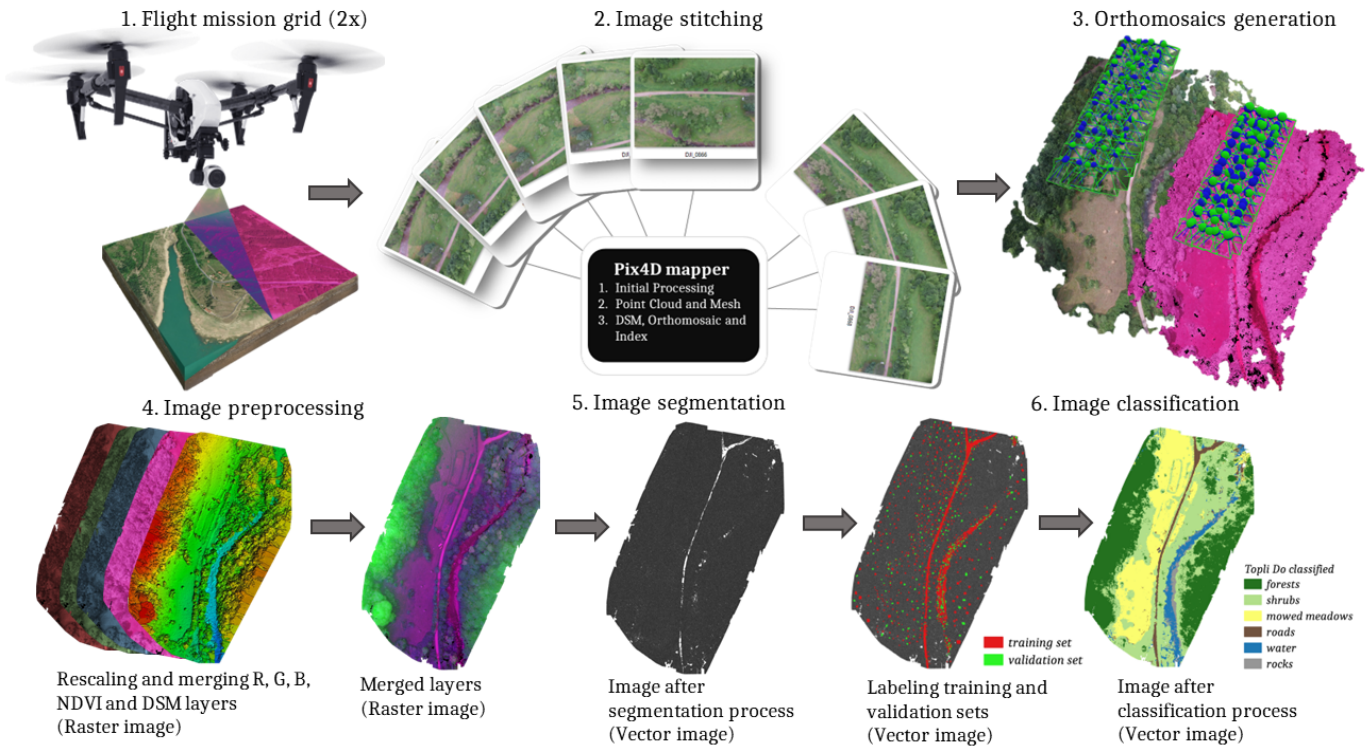

Figure 2. Flowchart for Topli Do.

At the Glavica study site data acquisition employed a UAV DJI P4 Multispectral, equipped with a multispectral sensor capturing data across blue, green, red, red-edge, and NIR spectral ranges, in addition to combined RGB imaging. Utilizing a DJI DRTK-2 mobile station ensured real-time data acquisition with centimetre-level positioning accuracy. Notably, compared to the previous DJI Inspire 1 setup, this configuration featured an expanded flight channel count, enabling simultaneous capture across five channels in a single flight mission. The resulting multiband raster encompassed seven layers: red, green, blue, red-edge, NIR, DSM, and NDVI.

Following image segmentation, vector image labeling extracted polygons for training and validation datasets, essential for the subsequent RF classifier analysis. A common metric utilized to quantify the proportion of accurately classified class values is the overall accuracy (OA) (Equation 1). OA is calculated as the ratio of correctly predicted to total predictions.

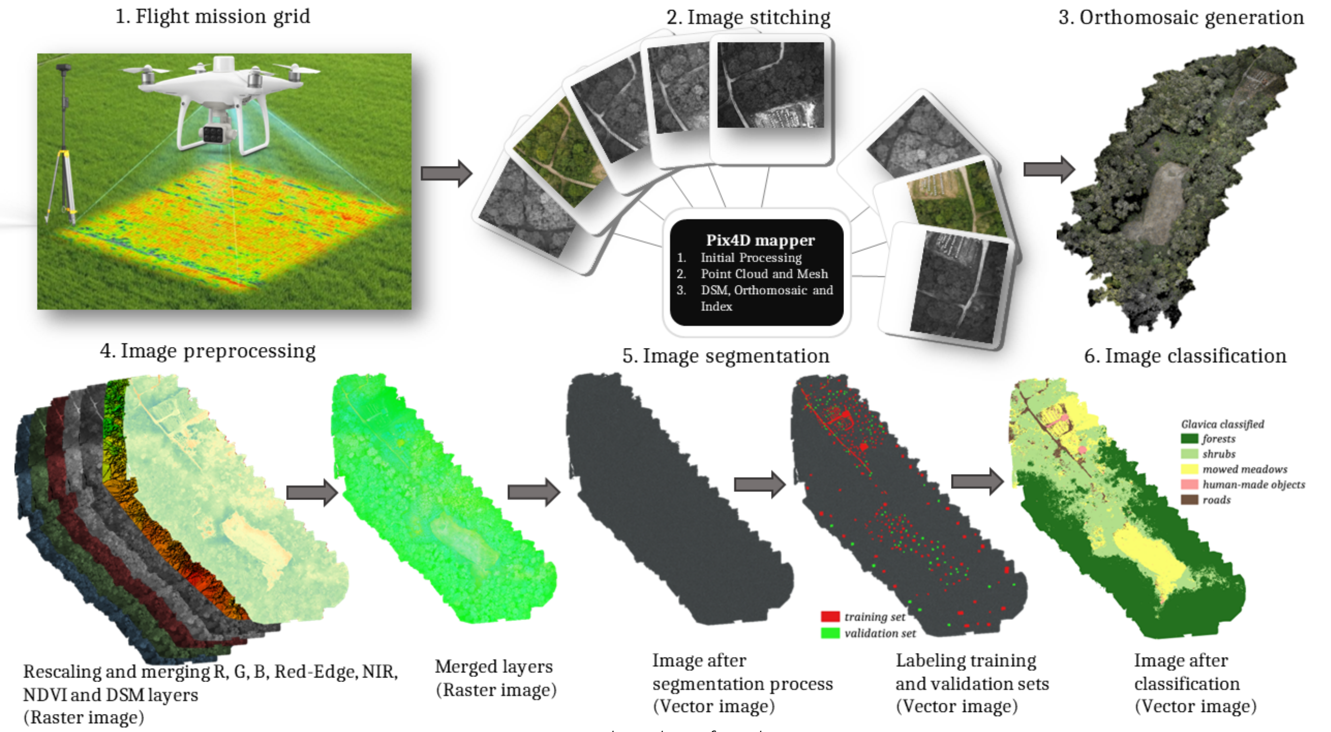

Figure 3. Flowchart for Glavica.

$$OA = \frac{\text{corrected prediction}}{\text{total prediction}} \quad (1)$$

3 Results

The classification for study site Topli Do was performed using six land cover classes: forests, shrubs, mowed meadows, roads, water, and rocks. The achieved accuracy was 92.46%. Based on land cover maps, it is observed that Topli Do is mostly covered by shrubs and forests (34.53%, 34.05%), slightly less by mowed meadows (21.83%), and least by water (4.38%) and rocks (1.80%) (Figure 4).

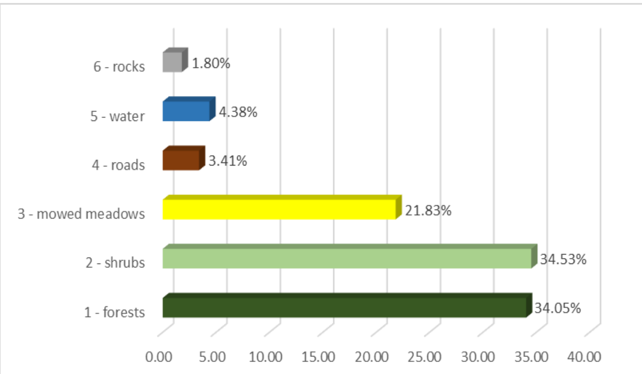

Figure 4. Percentage coverage of each class of study site Topli Do obtained by RF classification algorithm.

In the study site Glavica, the classification was performed using five land cover classes: forests, shrubs, mowed meadows, human-made objects, and roads. The RF classifier achieved an accuracy of 95%. The classification map showed that forests are the most dominant with a percentage coverage of 49.94%, followed by shrubs and mowed meadows (30.28% and 15.76% respectively), while human-made objects and roads are the least prevalent (0.97% and 3.04%) (Figure 5).

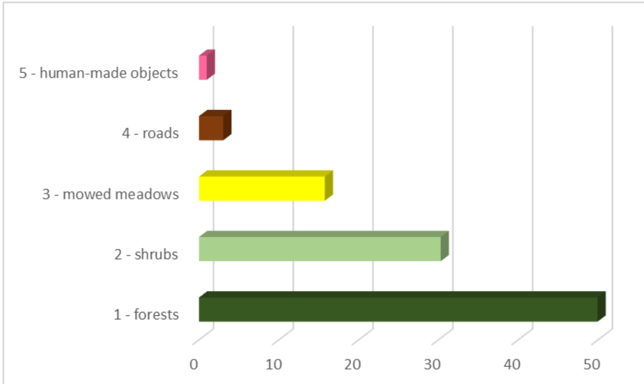

Figure 5. Percentage coverage of each class of study site Glavica obtained by RF classification algorithm.

4 Discussion

The results obtained from the RF analysis in the study sites offer valuable insights into the composition of land cover and the performance of the classification model. The used metrices serve as indicators of classification accuracy. However, initial object segmentation is a prerequisite for accurate classification. The overall accuracy of 92.46% in Topli Do and 95% in Glavica underscore the efficacy of the proposed classification algorithm in accurately categorizing land cover types. These findings align with previous research (Ivošević et al. 2021). In both study areas, forests and shrubs emerged as the dominant land cover types constituting a substantial portion of the landscape. The greatest challenge encountered by the RF classifier in the Topli Do was distinguishing between these two types due to their color, texture, and spatial similarity. This is evidenced by the lower precision values obtained for these classes compared to others: 88.24% for forests and 84.36% for shrubs. However, in the Glavica study site, increased precision values were observed for these two classes: forest – 99.63% and shrubs – 96.71%. This improvement could be attributed to the increased number of features facilitated by multispectral UAV (Vali et al. 2020).

5 Conclusions

This study examines land cover classification using orthomosaics from two distinct study sites in Serbia. Using spectral information captured in multiple bands showcases revolutionary potential in enhancing the quality of land cover maps. Such classification represents a breakthrough in ecological monitoring, allowing scientists to gain insight into ecosystem dynamics, species distribution, and environmental change at the local scale. However, the RF classifier achieves good accuracy with the most errors when classifying between the forest and shrub classes, so the new model should be improved in terms of better precision. In future research, emphasis should be placed on the generalization and robustness of classification models by prioritizing the development of detailed methodologies for feature selection. Additionally, exploring new methods (deep learning, segment anything model) across different study sites can facilitate the evaluation of more generalized models for creating land use maps without manually labeling ground truth data.

Acknowledgments: This work was supported by the European Union's Horizon 2020 research and innovation program (SGA-CSA No. 739570, FPA No. 664387 - ANTARES), as well as funding from the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-66/2024-03/200358). Additionally, the authors acknowledge the support from the Science Fund of the Republic of Serbia's national project SPAS-Serbian Pollinator Advice Strategy (No. 7737504).

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