

EVALUATION OF FOREST REGENERATION SUCCESS USING MULTISPECTRAL DATA ACQUIRED BY UNMANNED AERIAL VEHICLE

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Objectives

To evaluate the applicability of UAV-based remote sensing methods for monitoring natural regeneration and planted stands at ŠLP Křtiny.

Introduction

Forest ecosystems are crucial for biodiversity conservation, climate regulation, and ecosystem services.

Effective monitoring of forest regeneration is essential for sustainable management.

Traditional field-based methods are time-consuming and costly. UAV-based photogrammetry provides high-resolution, flexible, and cost-effective data for assessing regeneration success.

Location

Location: University Forest Enterprise Masaryk Forest in Křtiny, Czech Republic

Mixed forest stands with natural regeneration and afforestation plots.

Elevation: ~350–500 m a.s.l.; moderate climate.

Typical Central European temperate forest species composition.



Materials and methods

UAV Data acquisition

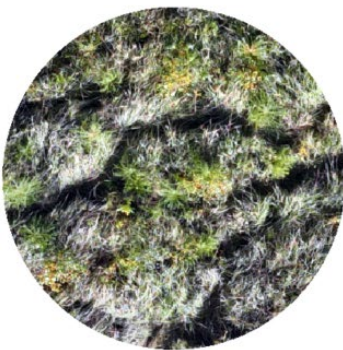
Platforms: RGB and multispectral UAVs operating at very low flight altitude.

High-resolution sensors: RGB camera and Parrot Sequoia+ multispectral camera.

Flight parameters: high overlap ($\geq 80\%$), low altitude (80, 40, and 25 meters).

Data processing

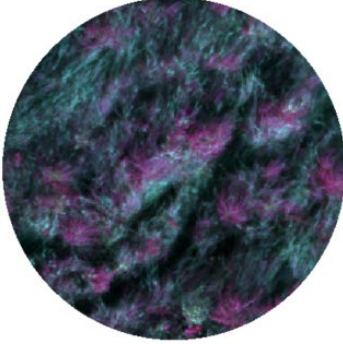
Structure-from-Motion photogrammetry processing to obtain DEM and orthomosaics.



RGB image (1.2 cm resolution)



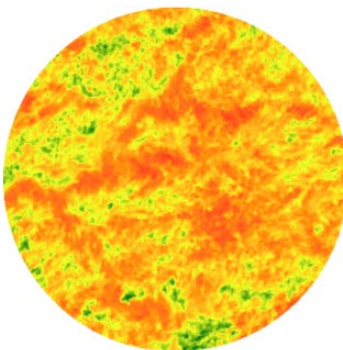
RGB image (2 cm resolution)



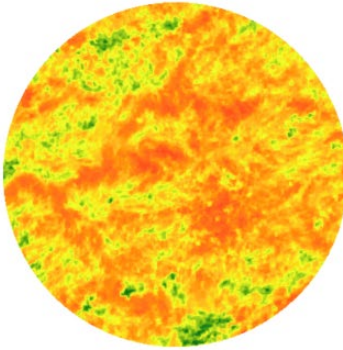
MSP image (2.8 cm resolution)

Vegetation indices

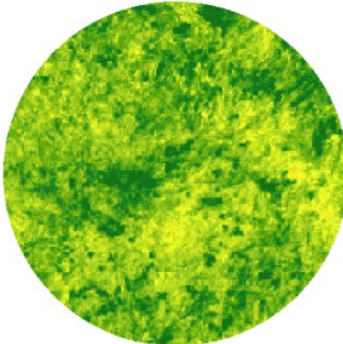
Multiple broadband indices were tested (GNDVI, GRVI, NDRE, NDVI, PSRI, REChI, SR).



GNDVI



NDRE



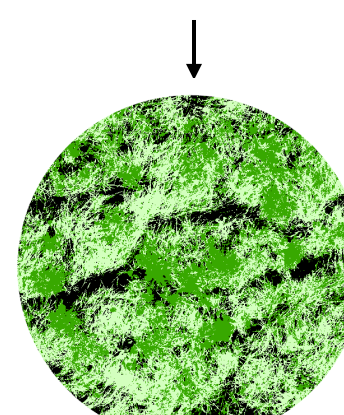
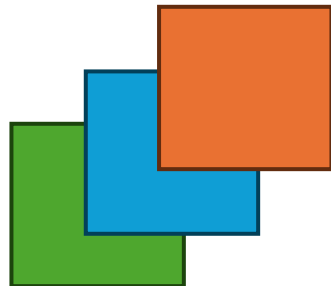
NDVI

Object detection

Supervised classification using the Maximum Likelihood classifier and deep learning testing (YOLOv3).



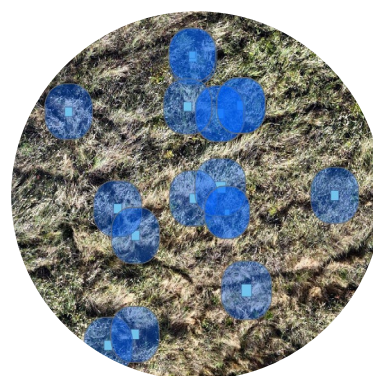
Different light conditions



Saplings
Shadows
Grassland

Field survey and accuracy assessment

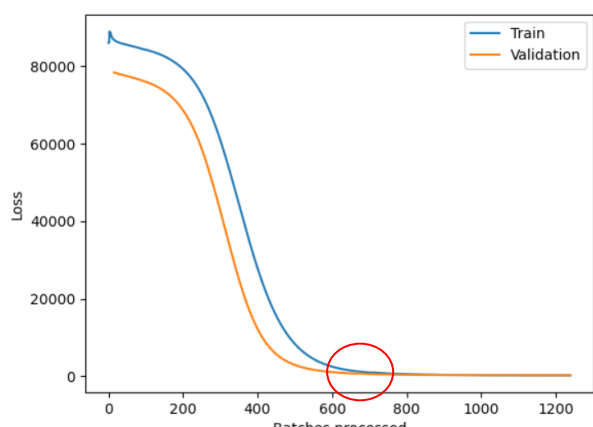
Training samples of saplings were collected using RTK GNSS.



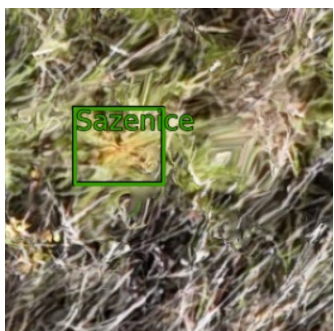
Results

Classification Accuracy

Method	Overall Accuracy	Producers Accuracy	Users Accuracy	Notes
SVM	73 %	42.9 %	51.7 %	Best balanced accuracy
RF	70.6 %	37.1 %	45.2 %	Robust to heterogenous plots
ML	69 %	33 %	46 %	Lowest kappa (0.21)
DL (CNN)	68.3 %	65.7 %	45.1 %	Kappa (0.3)



Ground Truth / Predictions



Vegetation Indices

NDVI and NDRE effectively separated vegetated and non-vegetated areas.

GNDVI and PSRI showed sensitivity to chlorophyll content and seedling stress.

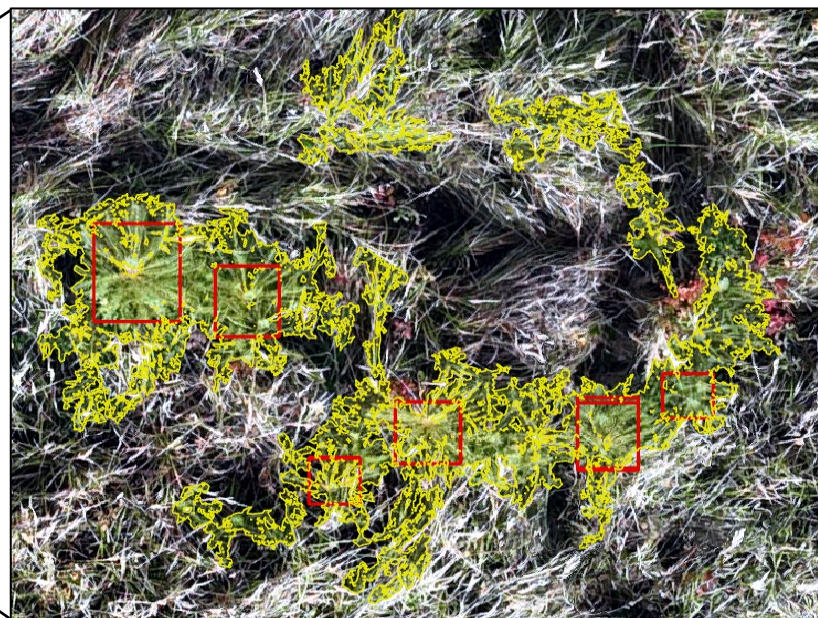
A combination of indices and ML increased the reliability of regeneration detection.

Regeneration Assessment

Automated counting of regeneration individuals corresponded closely to field data.

UAV-based gap detection accurately located missing regeneration spots.

UAV photogrammetry proved suitable for periodic monitoring of regeneration success.



Detected saplings
Detection using vegetation indices
Deep learning model detection

Conclusion

UAV photogrammetry and remote-sensing indices provide an effective tool for forest regeneration monitoring.

The SVM and Random Forest models achieved the best balance between accuracy and robustness.

The workflow is transferable to other Czech forests and supports cost-efficient forest management and planning.