VISUAL EXPOSURE OF ROCK OUTCROPS AND SURROUNDING FOREST STANDS DEVELOPMENT IN ŽĎÁRSKÉ VRCHY IN VIEW OF REMOTE SENSING AND OTHER MATERIAL

Balková Marie[1], Bajer Aleš[1], Mikita Tomáš[2], Patočka Zdeněk[2]

[1]Department of Geology and Pedology, Mendel University, Brno, 613 00, Czech Republic

[2]Department of Forest Management and Applied Geoinformatics, Mendel University, Brno, 613 00, Czech Republic

Correspondence to: Balková Marie[1] (balkova.marie@mendelu.cz)

Abstract

This research is focused on the study of visual exposure evolution on the locality of Drátenická skála Nature Monument and surrounding forest complex in history and modelling further possible stands development. Local forests went through conversion from natural fir-beech composition to intensive spruce monoculture growing with few insect pests or windbreak events to actual bark beetle infestation. Historic maps, landscape paintings, photographs and orthophoto served as a basic material for illustration of the past situation. Further development was modelled using orthophoto and point cloud captured by unmanned aerial vehicle (UAV) as the stand models were based on orthophoto and NDVI image classification. As an example, the possible situation after bark beetle calamity, when all coniferous spruce trees could die, was modelled. Other choice and practical use of such pre-processed data is for example model of opening and transformation of the stands around the rock as one of the ongoing outcrop management trends in Protected Landscape Area (PLA) Žďárské vrchy.

Keywords: canopy, image classification, orthophoto, historic maps, UAV, NDVI, digital terrain model, digital surface model

INTRODUCTION

Vegetation cover in localities with protruding rock outcrops could be the key factor of life conditions for animal and plants species, specifically occurring in this environment. They represent specific micro ecosystems, they are biodiversity hotspots that has been facing with threats and impacts of ongoing climate change (Cartwright 2019, Peñaloza-Bojacá et al. 2018). They dispose quite unfavourable edafic, nutrient, temperature and other climatic conditions, one the other hand together with topographic heterogeneity, they serve as suitable habitats for endemic species requiring specific environment (do Carmo and Jacobi 2016).

This paper is primarily focused on the study of visual exposure evolution on the locality of Drátenická skála Nature Monument and surrounding forest complex in history and modelling both current state and further possible development of this habitat and the view of the landscape after bark beetle calamity. Another motivation of the study rises from the management plans of several rock outcrops Nature Monuments in PLA Žďárské vrchy. These plans count with loosening and rebuilding the surrounding stands to approach their original natural state and suitable environmental conditions for endangered habitat-bound species.

METHODOLOGY

Drátenická skála is situated in central Czech Republic, Vysočina region in PLA Žďárské vrchy, that is well known for its specific landscape character created by typical geomorphological forms, rock formations, deep forests, scattered vegetation, stone pastures, flowery meadows, river systems and preserved natural. All these phenomena were and are endangered by human expansion and misuse of the entrusted nature wealth (Kirchner 2016, AOPK ČR 2019). Majority of original mixed forests were replaced by spruce monocultures. Around this rock, there are both fragments of mixed stands of spruce (*Picea abies* Mill.) and beech (*Fagus* *sylvatica* L.) and spruce monocultures. In the last few years, there exist an effort to manage stands around the outcrops in the way described in previous paragraph.

With the aim to compare the situation with the past, old maps, orthophoto, landscape paintings and photographs were collected. Then, UAV model senseFly eBee Plus equipped by multispectral camera Parrot Sequoia (SenseFly 2019) was used to take data for modelling current and future state. UAV flight mission was carried out at the height of 150 m with 90% image overlap. Orthophoto and digital surface model (DSM) were created in Agisoft software and digital terrain model (DTM) was gained from Lidar data provided by Czech State Administration of Land Surveying and Cadastre (ČÚZK). The image position coordinates error taken by UAV was 0.018 m for XY and 0.022 m for Z. The error after data optimisation and aligning was 0.005 m.

Subtracting DTM and DSM models, the vegetation height was determined by canopy height model (CHM). By inverse watershed segmentation method (Edson 2011), particular tree crowns were identified automatically as well as the top and height of each tree. During this process, own neighbourhood circle radius for CHM smoothing by Focal Statistics must be experimentally estimated. The best results were achieved using 1.7 m radius.

To determine coniferous and deciduous trees, we used two raster images – true orthophoto and Normalized Difference Vegetation Index (NDVI) of the stands around the rock. There are other indices, which could be created from Sequoia+ camera and which are useful for tree species determination, e.g. Normalized Differenced Red Edge Index (NDRE), Enhanced Vegetation Index (EVI) or Soil-adjusted Vegetation Index (SAVI). NDVI is vegetation index, that is able to quantify photosynthesis capacity of the biomass, as the chlorophyll strongly absorbs visible light (0.4–0.7 μm) during the photosynthesis and on the other hand specific plant cell arrangement strongly reflects near-infrared light spectrum (0.7–1.1 μm). Based on this fact, NDVI was calculated using red and near-infrared bands (Weir and Herring 2019):

$$NDVI = (\rho NIR - \rho red)/(\rho NIR + \rho red) \tag{1}$$

Because this locality was not large (about 20 ha), Iso Cluster Unsupervised Image Classification for the tree determination was used. Before the classification, terrain and shades were erased. Both raster images were distributed into 20 classes, that were sorted into two classes representing rather deciduous or coniferous trees based on the fact, that each tree type dispose of specific reflectance.

RESULTS

In the Tab. 1 and Fig. 1a–d, there are shown the results of orthophoto and NDVI classifications in comparison with stands distribution declared in the Forest Management Plan (FMP) and with the real visual situation as anybody can perceive. The results of both classifications are very similar. This can be explained by two facts – UAV flight was taken in September, when the differences between coniferous and deciduous are evident well (especially when we mainly distinguish spruce and beech with various leaves green hue; also the chlorophyll content in deciduous leaves decreases during the autumn).Then, this is crucial to make as accurate classification as possible. Also, a landscape painting is added to attend the study with an example of historic material depicting stands development. Using Iso Cluster Unsupervised Image Classification, model of current stands was made as well as model of the situation after potential bark beetle infestation, when all spruce trees were erased (Fig. 2e–h). This study can contribute to effectivity in management planning specifically in outcrops localities which are being rebuilt with the aim to protect life microclimatic conditions for endangered species that are dependent to these specific habitats. In PLA Žďárské vrchy this procedure consists in returning the stands to their original space and wood species composition. However, it must be counted with changes caused by bark beetle infestation. Based on this actual problem, this study can also be helpful during any tree species disease threatening the stands by death.

Table 1. Orthophoto and NDVI image stand classification into deciduous and coniferous trees

	Number of trees	Area (m²)	Density (trees/1000 m²)	Part of whole area (%)	Part of stands area (%)	Average height (m)
Orthophoto classification						
Deciduous stand	1 277	55 936	22.8	28.5	38.4	16.5
Coniferous stand	2 479	89 572	27.7	45.6	61.6	25.8
NDVI classification						
Deciduous stand	1 255	55 817	22.5	28.4	38.4	16.8
Coniferous stand	2 501	89 691	27.9	45.7	61.6	25.4
Whole stand	-	145 508	25.8	74.1	100.0	22.2
Other area	-	50 842	-	25.9	-	-
Whole area	3 756	196 350	-	100.0	-	-

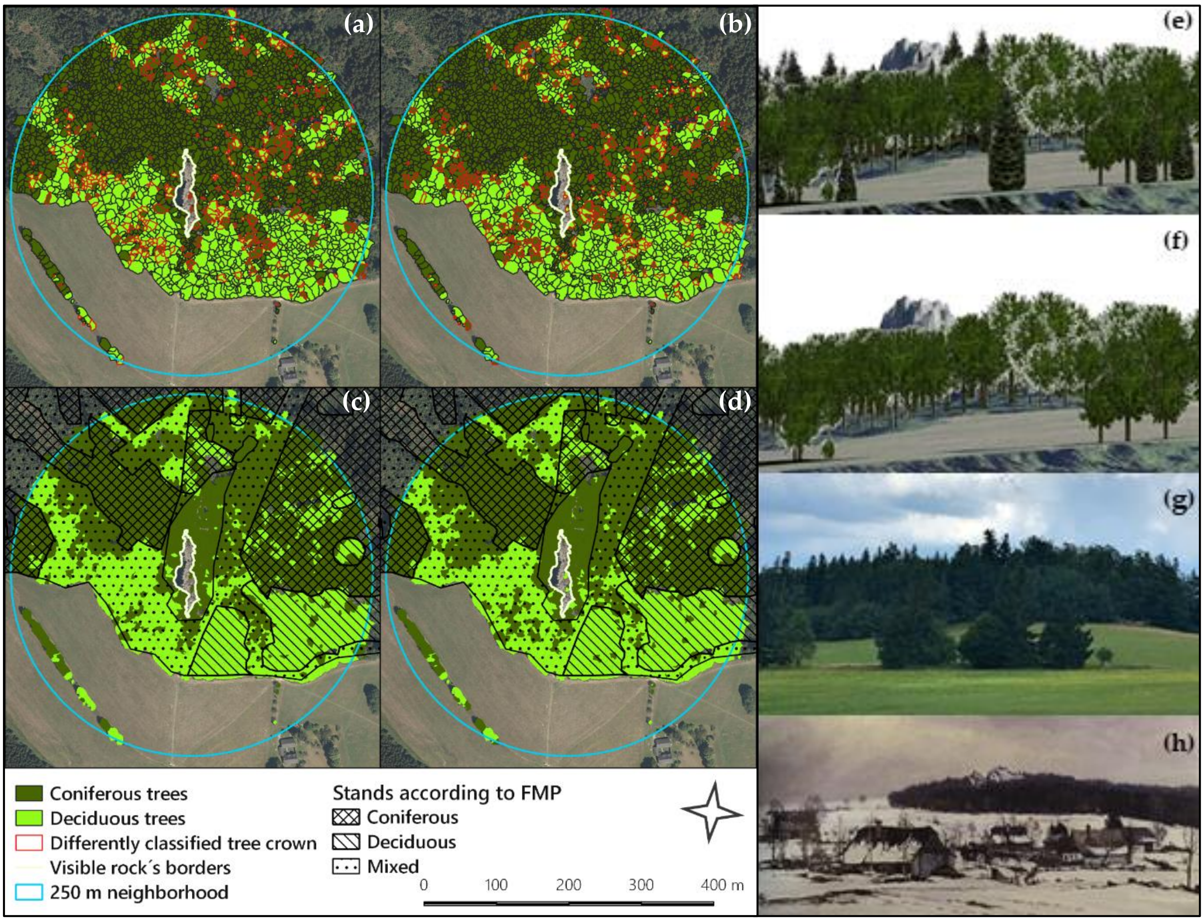

Fig. 1. (a) the results of orthophotoclassification; (c) and comparison with the simplified forest stand map (LČR 2019); (b) NDVI image classification; (d) and comparison with the simplified forest stand map; (e) 3D model of current stands using NDVI classification; (f) 3D model of stands with all spruces erased; (g) current photo of the rock and stands; (h) landscape painting „Zima pod Drátníkovou skálou“, Josef Jambor, 1954

REFERENCES

Cartwright, J. (2019) Ecological islands: conserving biodiversity hotspots in a changing climate. Frontiers in Ecology and the Environment, 17(6), pp. 331– 340, doi: 10.1002/fee.2058.

Peñaloza-Bojacá, G.F., de Oliviera, A.B., Teixeira Araújo, C.A, Fantecelle, B.L., dos Santos, D.N., Maciel-Silva, A. (2018) Bryophytes on Brazilian ironstone outcrops: Diversity, environmental filtering, and conservation implications. Flora, 238, pp. 162–174, ISSN 0367-2530, doi: 10.1016/j.flora.2017.06.012.

do Carmo, F.F., Jacobi, C.M. (2016) Diversity and plant trait-soil relationships among rock outcrops in the Brazilian Atlantic rainforest. Plant and Soil, 403(7), pp. 7–20, doi: 10.1007/s11104-015-2735-7.

Kirchner, K. (2016) Žďárské Vrchy Highland – Geomorphological Landscape in the Top Part of the Bohemian-Moravian Highland with the Unique Crystalline Rocks Forms. In Pánek, T., Hradecký, J., Eds. Landscapes and Landforms of the Czech Republic. Cham: Springer; pp 221–231. ISBN 978-3-319-27536-9. doi: 10.1007/978-3-319-27537-6_18.

Rozbory Chráněné krajinné oblasti Žďárské vrchy (Analyzes of the Žďárské vrchy Protected Landscape Area), Agentura ochrany přírody a krajiny České republiky. (Nature Conservation Agency of the Czech Republic). Available online: https://drusop.nature.cz/ost/archiv/plany_pece/index.php?frame&ID=23662 (accessed on 5th August 2019).

SenseFly Parrot Group. Available online: https://www.sensefly.com/expand/ (accessed on the 16th August 2019).

Edson, C.B. (2011) Light detection and ranging (LiDAR): What we can and cannot see in the forest for the trees. Dissertation Thesis, UMI Dissertation Publishing: Oregon State University, Proquest, Corvallis, pp. 277.

Weir, J., Herring, D. Measuring Vegetation (NDVI and EVI). NASA Earth Observatory, Washington DC. Available online: https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php (accessed on 10th August 2019).

Geoportal. Lesy České republiky (Forests of the Czech Republic, State-owned company). Available online: https://geoportal.lesycr.cz/itc/?serverconf=default&wmcid=882 (accessed on 22th August 2019).