Monitoring the spread of invasive and native plant species by advanced remote sensing methods: implications for management

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Introduction

Efficient **management of alien plants** in protected areas requires **precise and up-to-date data** on their distribution, which is costly and time-consuming to collect. The early detection of newly arriving alien species is crucial, but challenging in rugged, mountainous terrain that is difficult to access. Furthermore, species management should be **prioritised according to their impact** on native communities. Therefore, we have **developed automated technology to monitor** the spread of selected invasive and native plant species in areas under different management regimes, and to **assess their impact** on co-occurring plants.

Methods

We acquired **multispectral UAV data** and **botanical ground-truth** data to calibrate and validate species detection within the UAV imagery. Botanical surveys were conducted four times in 2024 and three times in 2025 at 14 localities with different management (mowing, grazing, mulching and herbicide application) in two protected areas, **Krkonoše** and **Orlické hory Mts.** in **the Czech Republic.**
The spread of most problematic species, three invasive (***Rumex alpinus***, ***Telekia speciosa***, ***Lupinus polyphyllus***) and two native species (***Veratrum album***, ***Senecio nemorensis* agg.**) have been tested by using **convolutional neural network detection** in ArcGIS Pro. The **impact** of dominant species on **plant community composition** was tested using multivariate methods (PERMANOVA and RDA), which accounted for spatial pseudoreplication (i.e. locality). This was done using 50 5×5 m plots at the 14 localities, with species cover serving as the response variable.

Veratrum album, a tall, native perennial, is recently spreading in the mountains. It is problematic because it competes with smaller native plant species.

Aerial images taken by a DJI Mavic 3 multispectral drone were processed to create an orthomosaic with a ground sampling distance of 1 cm.

Sheep grazing led to the complete eradication of *Lupinus polyphyllus* (left), while it remained abundant in mown meadow (right).

Hand pulling was not effective in *Lupinus polyphyllus* due to the intensity of the labour required (~700 seedlings per 25m²) and the fragility of the roots.

Results – detection and impact

- ✓ Accuracy of the species occurrence detection ranged between 90% and 96%, with the highest accuracy was recorded for *Rumex alpinus*. Some species are best detected during flowering (*Lupinus polyphyllus*, *Telekia speciosa* and *Senecio nemorensis* agg.), while others can be well detected in spring due to different leaf appearance and fast growth, e.g. *Veratrum album*, *Rumex alpinus*, *Lupinus polyphyllus* in managed meadows (**Fig. 1**).
- ✓ Dominants differed in in the co-occurring plant community composition, indicating distinct niches of study species (**Fig. 2**).
- ✓ The community composition of the co-occurring plant species changed significantly with the dominant cover (*Lupinus polyphyllus, Rumex alpinus, Telekia speciosa, Veratrum album*), indicating an increase of native, nutrient demanding species in communities that are typically nutrient-poor (**Fig. 3**).
- ✓ When testing each species separately, *Lupinus polyphyllus* and *Rumex alpinus* significantly changed the co-occurring plant community composition, while *Telekia speciosa* and *Veratrum album* had no significant effect (**Table 1**).

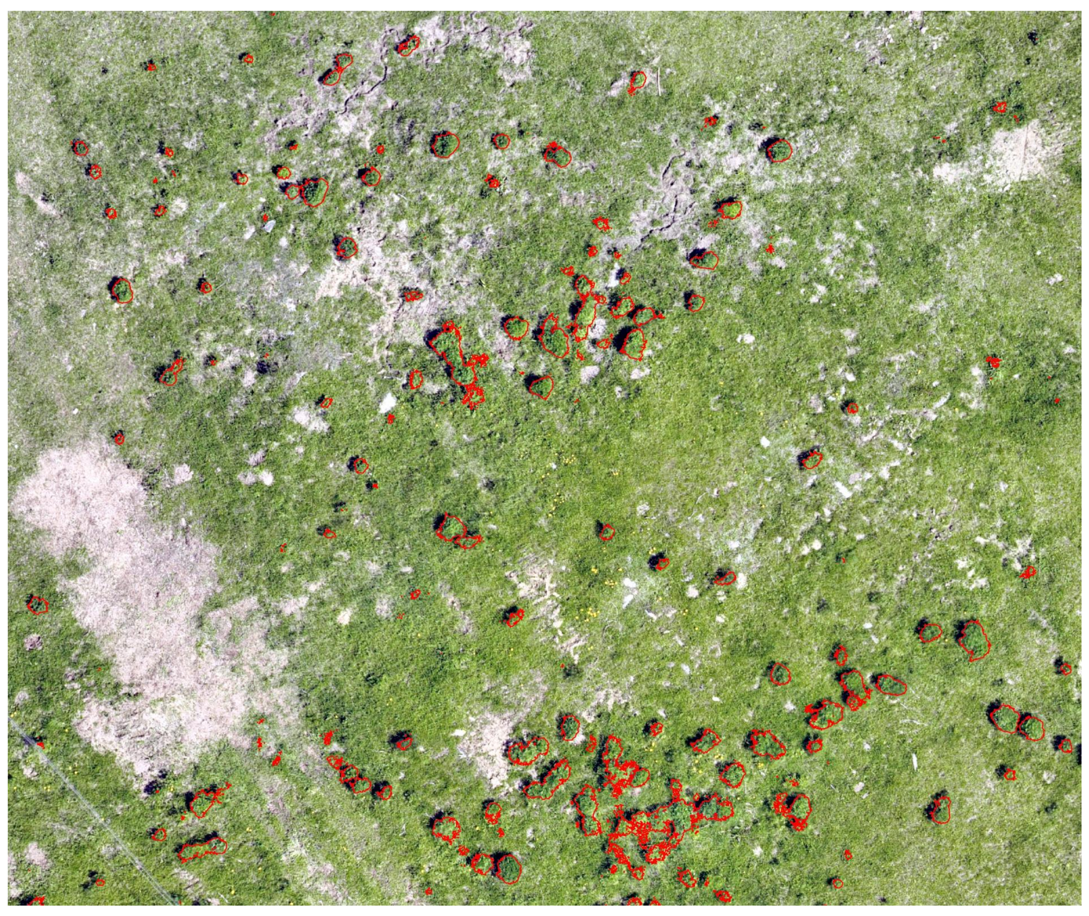

Fig. 1. Detection (in red) of invasive *Lupinus polyphyllus* on a meadow grazed by cattle in Krkonoše Mts. Detection by a U-Net convolutional neural network with a ResNet-34 backbone and customised data augmentation. Species detectability was 90%. Photo taken in May 2025.

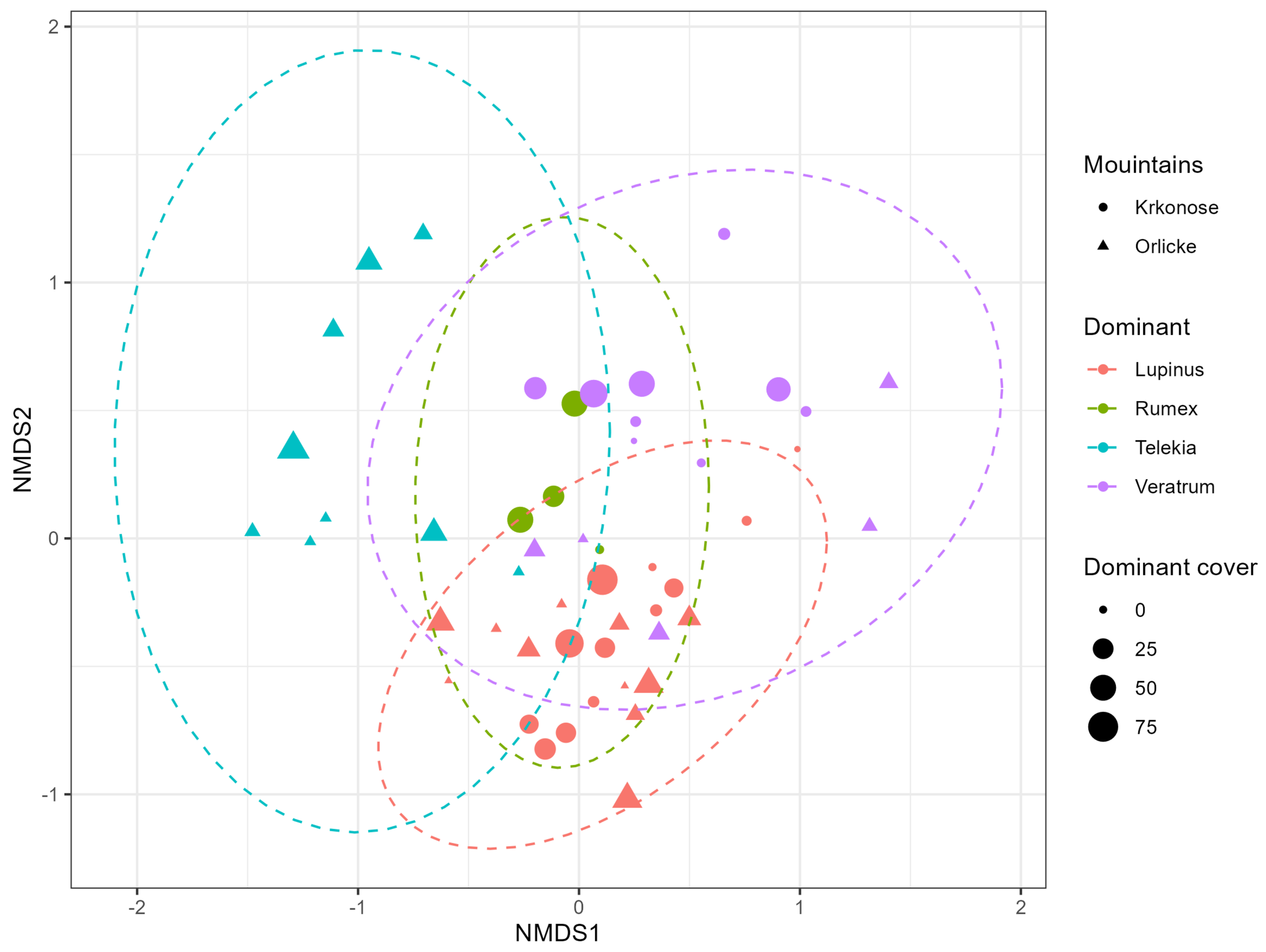

Fig. 2. NMDS ordination shows the differences in community composition of co-occurring species among native (*Veratrum album*) and invasive *(Lupinus polyphyllus, Rumex alpinus and Telekia speciosa)* dominants. The similar species composition across localities and mountains indicates distinct niches of each study species. Stress = 0.182, Bray-Curtis dissimilarity index was used to calculate the distances between samples.

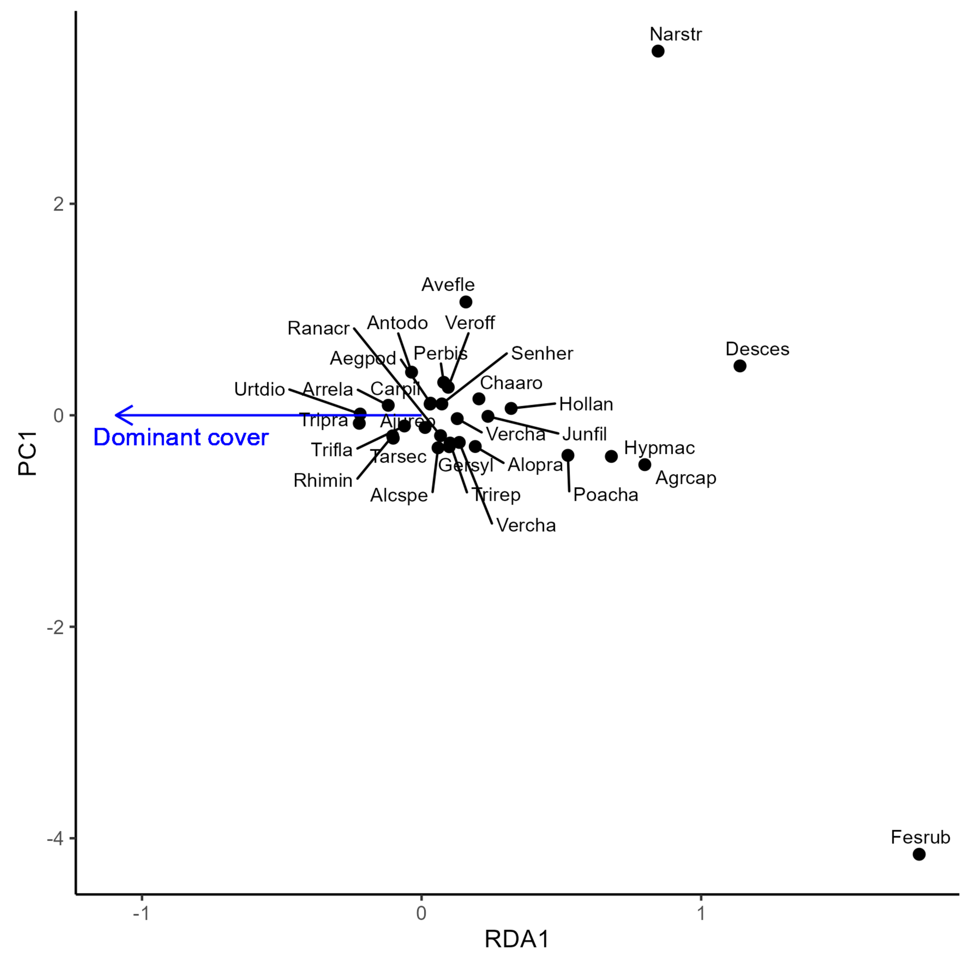

Fig. 3. RDA ordination shows the effect of dominant cover on the composition of co-occurring plant species. Native grasses, such as *Festuca rubra* or *Deschampsia cespitosa* (on the right), are being replaced by the four dominant study species. Invasion led to community ruderalization. Locality was set as a block-defining covariate. P = 0.003, dominant cover R^2 = 2.6%, locality R^2 = 57.3%.

	Df	R^2	P
Lupinus polyphyllus	1	3.4%	**0.041**
Rumex alpinus	1	2.7%	**0.020**
Veratrum album	1	-	0.904
Telekia speciosa	1	-	0.137
Residual	45	81.6%	
Total	49	100.0%	

Table 1. PERMANOVA results, permutations (999) of species abundances was restricted within localities. Plant community composition significanty changed with abundance of *Lupinus polyphyllus* and *Rumex alpinus*.

Conclusions

- ❖ **Species detectability** varies. **Well-detectable species** include ***Rumex alpinus*** **(96%)**, characterized by large fleshy leaves and extensive homogeneous stands, and ***Veratrum album*** **(95%)**, which has large leaves with prominent parallel veins contrasting with the surrounding predominantly grassy vegetation.
- ❖ Those that are more **difficult** to detect include ***Lupinus polyphyllus*** **(90%)** with compound leaves that are similar to the surrounding vegetation. However, the distinct flowers and clumps in spring, thanks to faster growth, make it easier to detect. Another difficult species is ***Telekia speciosa*** **(93%)**, which occurs in tall herb fringes.
- ❖ *Lupinus polyphyllus* and *Rumex alpinus* have **significantly changed plant community composition**. In general, dominants are replacing nutrient-undemanding grasses, and their spread led to ruderalization of native communities.
- ❖ Management has had a strong influence on the abundance of ***Lupinus polyphyllus***: it **was completely eradicated in one enclosure with sheep** but was hardly affected by cattle. **Mulching reduces abundance** but does not appear to kill the plant. Hand pulling is labour demanding and inefficient.

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