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# Monitoring and interactive mapping of illegal environmental activities on the example of Slovakia

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**Abstract:**

Human activities profoundly impact the landscape, often leading to categorical shifts in land use known as land use/land cover changes (LU/LCC). These changes involve transitions from one type of landscape to another, such as converting meadows into housing developments. Because these alterations can significantly influence the state of the landscape, it's crucial to understand where and to what extent they occur. Legal LU/LCC interventions are typically planned and documented in various official records, including land registries, agricultural plans, forestry documents, and water management plans. However, despite these efforts, the landscape is increasingly vulnerable to unauthorized human encroachment. Such an attack poses challenges for competent authorities to detect, and address caused activities, particularly in remote areas with limited communication accessibility.

Various methods are currently employed for monitoring (which involve the planned, systematic, and continuous collection of representative characteristics about landscape objects) LU/LCC changes. Among these methods, those utilizing remote sensing data, including optical and radar imagery, environmental databases, and field survey data are particularly progressive. This approach proves suitable for identifying LU/LCCs, including changes resulting from the three most common illegal human activities: the devastation of protected grasslands, removal of non-forest woody vegetation, and enlargement of closed and rehabilitated dump sites by illegal operation.

This paper aims to present the process of monitoring the three types of illegal activities in the country and present the results through interactive maps. Through data analysis, we identified spatial and temporal changes in protected grasslands, non-forest woody vegetation, and closed landfills caused by illegal activities such as ploughing, tree removal, and expansion of closed landfills. We achieved this using Sentinel-1 interferometric coherence and PlanetScope optical imagery analysis. The research focused on specific areas delineated by datasets containing masks of protected grasslands, non-forest woody vegetation, and closed and reclaimed landfills. These datasets were complemented by information on illegal activities in the landscape provided by a stakeholder, the Slovak Environmental Inspectorate (SEI).

For satellite data, we utilized PlanetScope imagery from Planet Labs, accessible through a research license. These images offer daily global coverage with a resolution of approximately 3 meters per pixel and are available in four multispectral bands: red, green, blue, and near infrared. To construct the time series, we initially filtered the PlanetScope images based on the locations provided by the SEI. Subsequently, we defined an offset time window centred on the identification date of the illegal activity to capture the landscape state before and after the illegal activity. Additionally, we employed the Sentinel-1 radar mission within the Sentinel Application Platform toolbox to compute coherence. Coherence calculations were performed using the Sentinel-1 Interferometric Wide mode, specifically focusing on the VV polarization. This analysis was conducted over a temporal range with a time step of 6 days, resulting in a spatial resolution of 20 meters.

The analysis of coherence changes determined from radar images demonstrated its suitability and advantages, thanks to its regularity and independence from the time and conditions of imaging. However, it also revealed the limitations of using medium-resolution Sentinel-1 images for detecting very small changes due to illegal activity. In such cases, utilising data with high spatial resolution would be more appropriate (min. 3 m in the direction of azimuth and range or better). It


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would also be more appropriate to use data from satellites using the X band (wavelength approximately 3 cm), e.g., TerraSAR-X. The analysis of the relationship between Sentinel-1 interferometric coherence and optical PlanetScope images through Normalized Difference Vegetation Index (NDVI) will bring closer the possibilities of the potential complementarity of these data in the context of identifying changes in illegal activities in the landscape using satellite data.

The verification of results was conducted through several methods. Firstly, in-situ visual verification was performed, where field visits allowed direct observation and confirmation of the detected changes. Additionally, geodetic surveys were utilized to determine new boundaries following illegal activities, providing precise spatial data for comparison. In cases involving illegal activities on stockpiles/ closed landfills, drone surveys were deployed to assess changes in volume or mass, offering detailed insights into alterations over time.

We visualized the results of changes in the three types of land cover caused by illegal activities (Fig. 1) through an interactive cloud-based hosted web map. The interactive map incorporates various base maps, including those of the Slovak Republic cadastral maps, as well as orthophotos, both current and historical. Furthermore, it can be enriched with tabular data and photographs depicting areas where illegal activities have been identified. Access to the interactive map will be provided to SEI staff based on defined access levels. Additionally, the map will be made available to the public either as a web application or through open data initiatives, ensuring transparency and accessibility of the information.

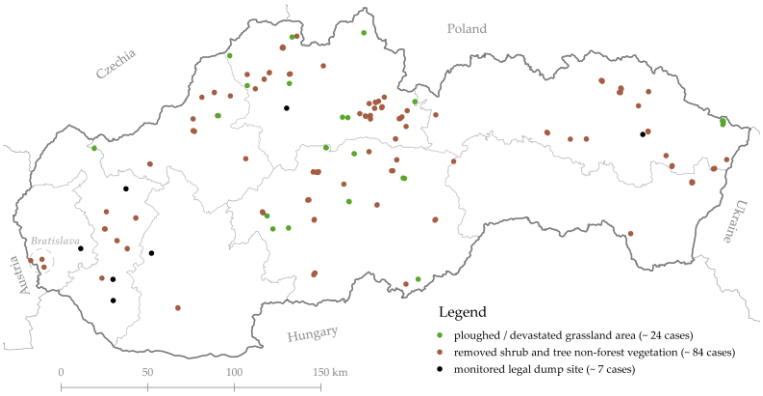


Figure 1. Map of illegal activities in the landscape (valid for April 2024).

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