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Assessing agricultural landscape diversity between 2022 and 2023 using rectangular and hexagonal grid frameworks

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Abstract:

Regular grids are widely used across scientific, technical, and even artistic disciplines. Although grids with square elements have been a historically dominant approach, non-square grids, particularly hexagonal grids, are now a growing trend across multiple domains (Magillo 2025). In landscape ecology, it is crucial to choose the appropriate visualization method, particularly when conducting experiments and simulations. The aim of this study is to compare and evaluate rectangular and hexagonal grid visualization methods in terms of capturing agricultural landscape changes over two years using Geospatial Aid Application System (GSAA) data obtained from the Integrated Administration and Control System (IACS) of the European Commission. Since systems for data collection are implemented nationwide and the focus of this study was to assess changes within Slovakia, the entire territory of the Slovak Republic was selected as the study area (Fig. 1).

The primary dataset used in this study was a vector polygon layer representing agricultural parcels declared by farmers within the GSAA, defined by Art. 68 of Regulation 1306/2013. This dataset is derived from the Land Parcel Identification System (LPIS), which characterizes all agricultural land eligible for subsidies in Slovakia. Both systems form part of the IACS implemented across the European Union, with their respective datasets updated annually to reflect current land-use practices. The time period of 2022-2023 was selected in relation to the Common Agricultural Policy (CAP) reform introduced in 2022, which implemented measures promoting increased crop diversity and the inclusion of non-productive areas on agricultural land. These changes provide a context for assessing their potential impact on landscape fragmentation.

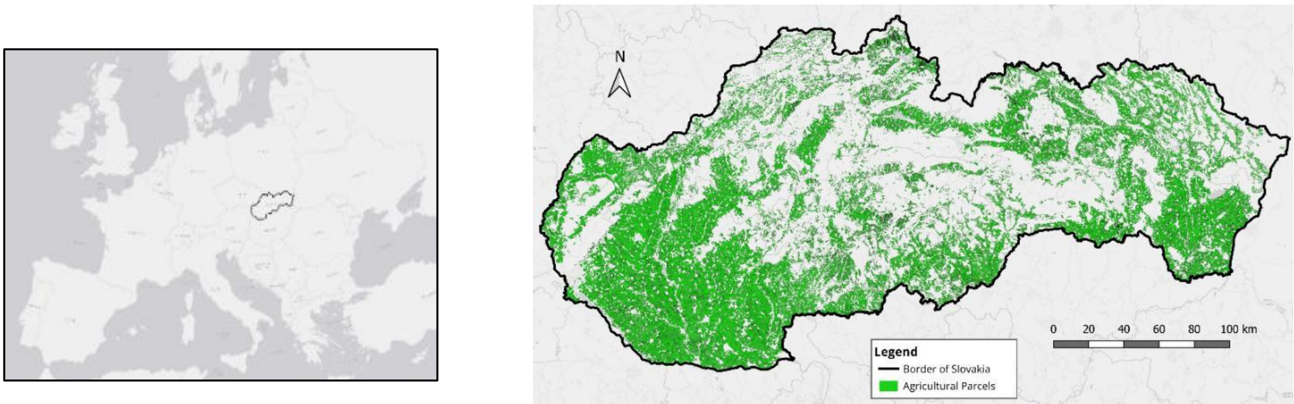

Figure 1. Agricultural parcels eligible for subsidies in Slovakia in 2023 based on GSAA data.

We hypothesize that the 2023-2027 Common Agriculture Policy reform increased the landscape fragmentation, with this change being more pronounced in Slovakia's agriculturally active areas. To spatially quantify this fragmentation change between 2022 and 2023, a regular hexagonal grid with 5 km vertical spacing and a regular rectangular grid with the same vertical spacing were generated in QGIS and clipped to the boundaries of the Slovak Republic. Each grid cell was then intersected with the GSAA agricultural parcels, and all parcels overlapping a given cell were assigned to it. The Effective mesh size (m) metric (Jaeger 2000) was then calculated for each cell of the chosen grid, where the area of each hexagonal cell represented the total landscape area (A_t), patches were represented by GSAA agricultural parcels, and the area of each patch was calculated separately (A_i).

$$m = \frac{1}{A_t} \sum_{i=1}^{n} A_i^2$$

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Effective mesh size was calculated for each year and for both types of regular grids using a Python script in JupyterLab. Subsequently, differences between the two years were computed at the grid-cell level and exported as a new regular grid layer. All spatial datasets were processed and visualized in QGIS using the S-JTSK / Krovak East North projection (EPSG: 5514).

The visual comparison of both representations reveals a notable difference between rectangular and hexagonal grids (Fig. 2). The rectangular grid exhibits stronger directional bias, particularly along the horizontal and vertical axes. In contrast, the hexagonal grid reduces orientation-related bias due to its more uniform spatial configuration and equal edge adjacency. Furthermore, the hexagonal grid produces smoother and more spatially consistent patterns, whereas the rectangular grid tends to emphasize local extremes in both positive and negative values. These findings highlight the influence of the Modifiable Areal Unit Problem (MAUP), in which the same underlying individual-level data, when enumerated by different boundaries, may lead to different findings derived from the map (Kraak et al. 2020), with hexagonal grids generally offering a more stable depiction of landscape structure.

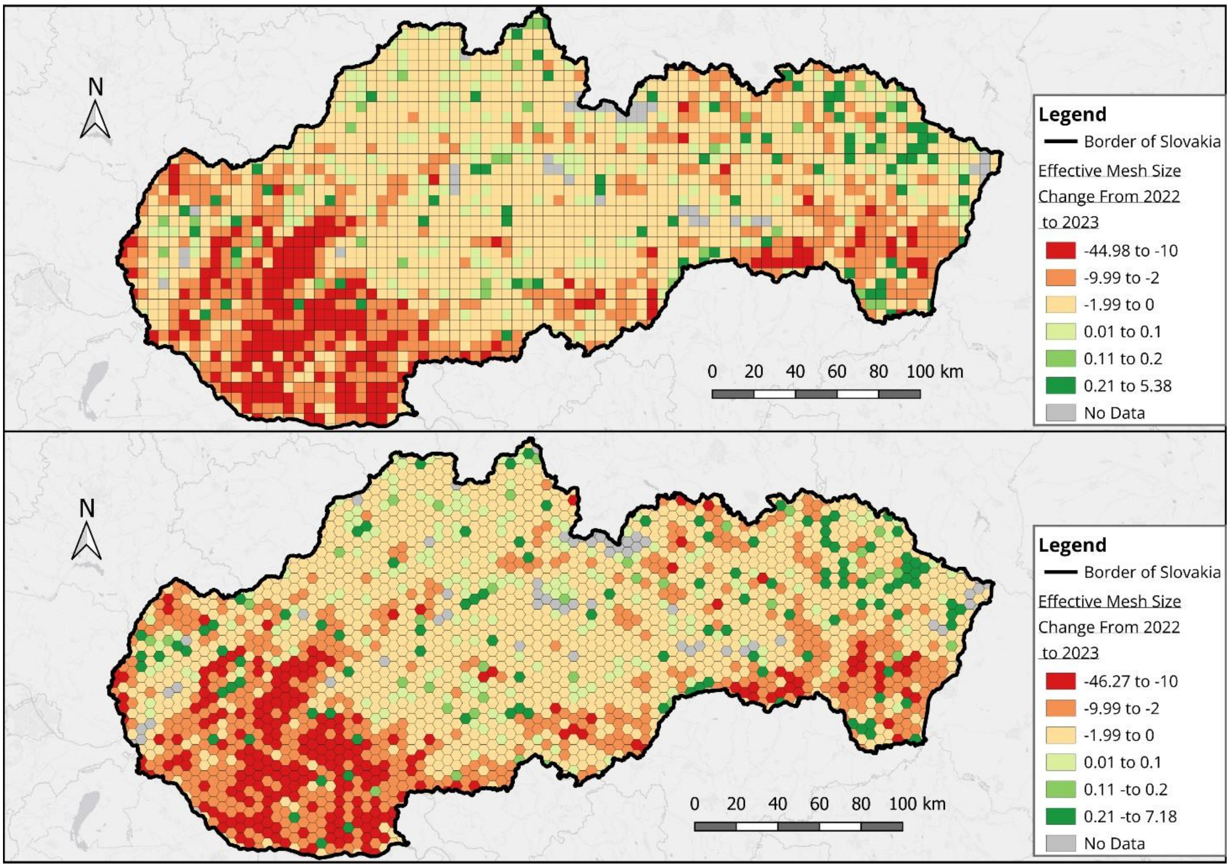

Figure 2. Change in Effective Mesh Size after 2023-2027 Common Agricultural Policy Reform on two different boundaries of (a) square grid cell, (b) hexagonal grid cell, both at 5km resolution

Acknowledgements

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