

## Long-term trends of landscape changes in marginal areas: the example of Central Europe (Šahy, Slovakia)

### Trendy v dlhodobých zmenách využívania krajiny marginálneho územia na príklade zo strednej Európy (Šahy – Slovensko)

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Received: October 16, 2024; accepted: March 21, 2025

#### ABSTRACT

The article presents changes in land use in the marginalized area of Šahy town on the Slovak-Hungarian border in relation to socio-economic changes. The aim of the research was to outline future development trends and propose management measures for the future in terms of the optimal functioning of this area. The assessment of the historical development of the landscape is based on the natural potential of the landscape, to which relevant socio-economic characteristics are added. These create and characterize the theoretical basis of the processed issue and the methodological concept for further processing. Analyses of the development and use of the landscape in the context of the real development of the landscape according to historical time horizons from the first military mapping (1769 - 1784) to the present state are conditioned by field research. Changes in land use are observed through the analysis of elements of the secondary landscape structure (SLS) and further processed methods of geographic information systems (GIS) and statistical evaluation of data. The evaluated changes are typical for the entire territory of the post-communist countries of Central Europe. They include peripheral regions in terms of environmental preservation depending on urban infrastructure. One of the conclusions of the research is the proposals for management measures for the Šahy town in connection with its strategic planning and strategic documents. The measures are divided into 3 areas - economic, social and environmental. We have determined positive or low in relation to the development of the country in the future.

**Keywords:** land use, landscape development, trends in the development of the territory, socio-economic processes, Geographical information system, Slovakia

## ABSTRAKT

V článku sú prezentované zmeny využívania krajiny v marginalizovanom území mesta Šahy na slovensko-maďarskej hranici vo vzťahu k socio-ekonomickým zmenám. Cieľom výskumu bolo načrtnutie budúcich trendov vývoja a návrh manažmentových opatrení do budúcnosti z hľadiska optimálneho fungovania tohto územia. Hodnotenie historického vývoja krajiny vychádza z prírodného potenciálu krajiny, ku ktorému sa pridáva relevantná socio-ekonomická charakteristika. Tieto vytvárajú a charakterizujú teoretické východiská spracováanej problematiky a metodickú koncepciu pre ďalšie spracovanie. Analýzy vývoja a využitia krajiny v kontexte reálneho vývoja krajiny podľa historických časových horizontov od prvého vojenského mapovania (1769 – 1784) k súčasnému stavu sú podmienené terénnym výskumom. Zmeny využívania krajiny sú pozorované prostredníctvom analýzy prvkov sekundárnej krajinnej štruktúry a ďalej spracované využitím metód geografických informačných systémov (GIS) a štatistickým hodnotením dát. Vyhodnotené zmeny sú typické pre cele územie post komunistických krajín strednej Európy. Zahŕňajú periferálne regióny v zmysle zachovania životného prostredia v závislosti od mestskej infraštruktúry. Jedným zo záverov výskumu sú návrhy manažmentových opatrení pre mesto Šahy s nadväznosťou na jeho strategické plánovanie a strategické dokumenty. Opatrenia sú rozdelené na 3 oblasti – hospodárske, sociálne a environmentálne. Určili sme 20 lokalít pozitívnych alebo negatívnych vo vzťahu k vývoju krajiny do budúcnosti.

**Kľúčové slová:** zmeny krajiny, vývoj krajiny, trendy vývoja územia, socio-ekonomické procesy, geografické informačné systémy, Slovensko

## INTRODUCTION

The understanding of landscape structure is a complex process that is a combination of approaches and information from multiple fields of environmental science. The ability to distinguish analyses of vertical relationships on the same surface and horizontal relationships where the area distribution and the relative position of ecological factors are analysed is essential (Feranec and Otaheľ, 2001). Methodological approaches in landscape structure research are based on the works of prominent landscape ecologists such as Forman and Godron (1993), Miklós et al. (2020) and others. Landscape change assessment is an important topic in the European and global context (Boltižiar and Olah, 2013; Feranec and Otaheľ, 2001; Janus et al., 2023; Izakovičová et al., 2019; Pucherová et al., 2021; Žoncová et al., 2020 and others). Historical mapping, aerial imagery, and satellite data are used to assess long-term landscape evolution. For the territory of Slovakia, works depicting different spatial scales from national to local have been produced at different scales (Mojšes and Petrovič, 2013; Kanianska et al., 2014; Súľovský et al., 2017; Nozdrovická et al., 2020 and others).

Currently, Slovakia is planning to build more motorway sections as part of the infrastructure construction,

which is causing changes to the landscape use and the overall landscape image. Keken and Kušta (2010) state that analysing the construction and operation of linear structures such as motorways and expressways, and their direct impact on the landscape or the whole ecosystem is a complex process. The area of interest of the town of Šahy is affected by the planning of the new R3 road connecting Slovakia and Hungary (Figure 1), and the R7, which has been approved to connect Šahy with Bratislava (the capital city).

The study area was part of Hungary before 1918, it became part of the border region after World War I and the establishment of the Czechoslovak Republic, and is currently a marginal territory of Slovakia. Plans to build new infrastructure, which are socio-economic in nature, can completely change the appearance of the landscape and the overall use of the landscape. The Central Poiplie region, of which the town of Šahy is a part, is also interesting from the point of view of the biodiversity of the area. It is bordered to the south by the river Danube and to the west by the river Ipel', forming important biocorridors. The rivers also form a natural border with Hungary. Historically, the region was characterised by agriculture, viticulture, and fruit-growing, but today

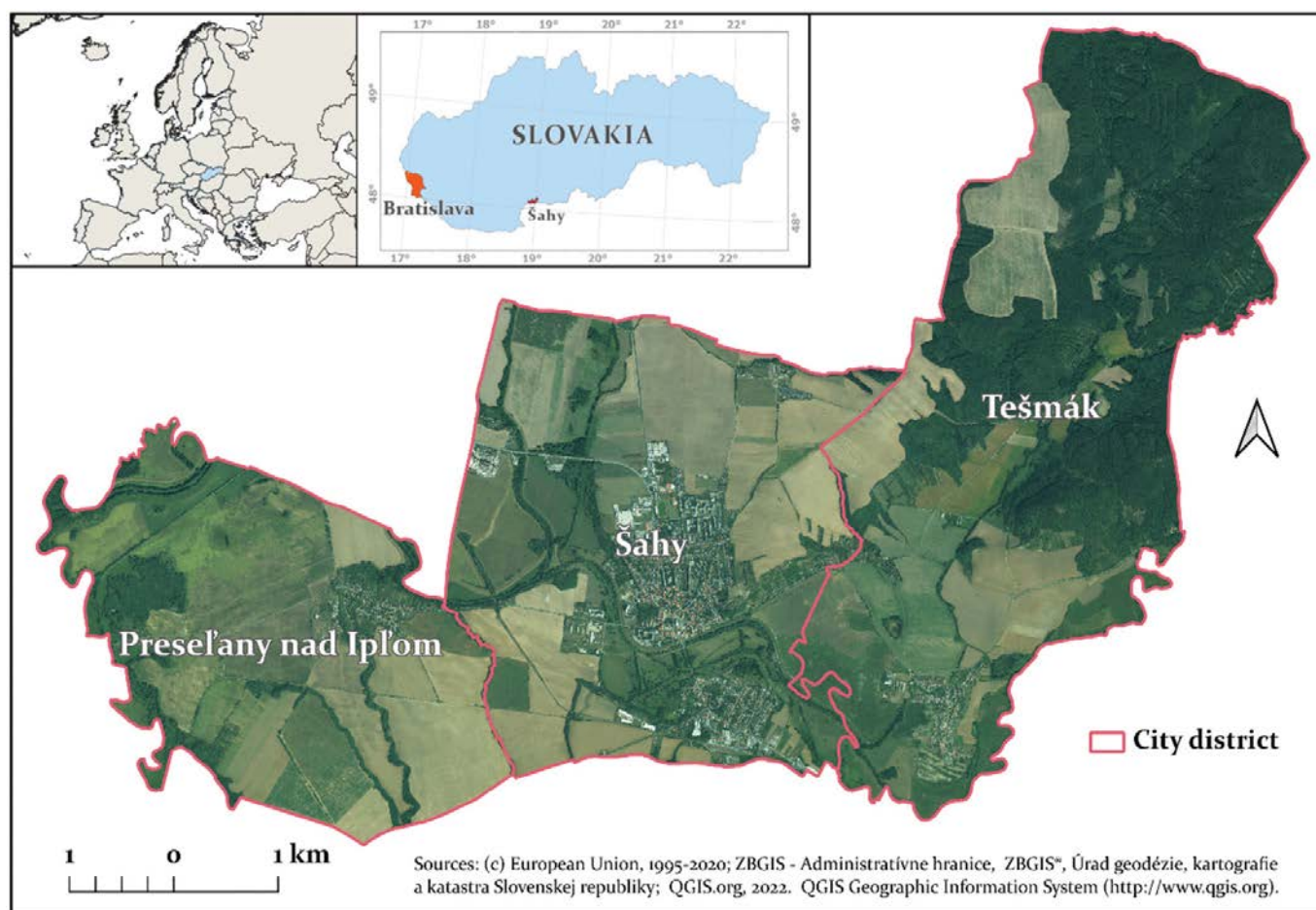


Figure 1. The case study location

tourism, fishing, and hunting dominate here (<http://www.poiplie.sk>), which underlines the relevance of research on changes to land-use in relation to socio-economic change. However, Belčáková (2003, 2016) notes that the study of landscape and its use is becoming a very challenging issue characterised by knowledge of natural, historical, economic, but also social patterns in a given space and time. The use of Geographical Information Systems (GIS) environments and their statistical analyses is of great importance in capturing these relationships more accurately.

Our research aims to analyse the historical development of the landscape and to outline the future trends of landscape changes in relation to the ongoing socio-economic processes. It also includes the proposal of management measures for the future from the point of view of the most optimal functioning of the marginal

landscape of the cadastral areas (cadastral districts) administratively belonging to the town of Šahy, which is included in the region of the Central Poiplje.

## MATERIALS AND METHODS

### Study Area

The town of Šahy is located in the southwestern part of Slovakia. The territory of the town consists of 3 urban districts with an area of 42.73 km<sup>2</sup> and a population of 6,992 inhabitants (31 December 2023).

The subject of our study are 3 cadastral territories (c.t.) in 2 urban districts of the town of Šahy, namely Šahy and Tešmák, and cadastral area Preseľany nad Ipľom (Figure 1). The c.a. of the town of Šahy itself is dominated by agricultural land (more than 761 ha) and built-up areas (more than 218 ha). The smallest area in the c.t. of the

town of Šahy does not include forests, but vineyards and orchards. The situation is different in the structure of land use distribution (land groups) in the rural parts of the region (i.e. in the c.a. of Preseľany nad Ipľom and Tešmák). Tešmák is a heavily forested area, where the area of forests prevails (almost 792 ha) and alternates with areas of agricultural land (over 645 ha). Forests represent important local and regional biocentres.

The territory of the town of Šahy also includes the territory of the original proposed Landscape protected area (LPA) Poiplie. Currently, the region of Central Poiplje also extends into the Special Protection Area (SPA) Poiplie.

There are several strategic planning documents prepared by the Šahy municipality. For example, the Programme of Economic and Social Development (PESD) for the period 2014 – 2020, the Preliminary Project Plans of Šahy for the years 2016 – 2023 and the Zoning Plan of Šahy with amendments and supplements from 2001 proposing changes in the boundary of the built-up area of the town in connection with the expansion of the areas of storage, technical spaces, and parking places.

### **Data and Methodology**

The process of monitoring qualitative and quantitative changes and development trends leads to an understanding of the forces causing these changes (Múcher, 2009). The basic methodological procedure in determining the functional aspect of the landscape is the compilation of a set of thematic maps, allowing the comparison of the results of basic monitoring, which provides information on the state of the landscape, the functioning of the landscape, its optimisation and the structure of land use through the design of management measures. This information in a GIS environment can then be integrated into temporal and spatial data on the functioning of the landscape structure as a whole system (Bodlák et al. 2008).

Geographic and cartographic methods are those used, including the interpretation of Earth's remote sensing data, which are applied to the environment of

geographic information systems. Satellite imagery and aerial orthophoto imagery have been the main sources of data over the last half-century. Topographic base maps of the I. and II. Austro-Hungarian mapping at a scale of 1:28,880 from the Military Archives in Vienna serve as the oldest basis for the analysis. Other sources are aerial photographs from 1949, provided by the Topographic Institute in Banská Bystrica, and base topographic maps at a scale of 1:25,000 from the period 1957-1960.

The next period is characterised by aerial orthophotos from 2003, before Slovakia accedes to the European Union. The last period is interpreted from available imagery from 2021. Trpáková (2009) argues that a basic prerequisite for the ecological analysis of the historical evolution of landscapes is the use of a holistic view of nature and society, which introduces the time element into the understanding of landscapes, which 'is the content of causes.

Petrovič et al. (2009) divided the basic landscape elements into 6 main groups: 1. Tree and shrub vegetation, 2. Grassland vegetation, 3. Agricultural crops, 4. Bedrock outcrops and raw soils, 5. Surface water and wetlands 6. Settlements and built-up areas. These are further subdivided into 4 hierarchical levels into lower groups.

This mapping requires refinement of the mapped units in the field. This is closely related to the implementation of the actual mapping at a scale of 1:10,000 with the use of orthophoto images at a scale of 1:5,000 in the processing of documents for the analysis of the landscape structure in the context of socio-economic changes in the defined area. It is the basis for updating the data obtained from the processing of maps from different time horizons. The work includes the compression of data from the already implemented research in the Ipel' river basin, compiled by Miklós et al. (2011), as well as Jakubcová et al. (2014). Field mapping has been conducted in Šahy since 2019, but intensively in 2020-2021.

The creation of maps is carried out in the computer GIS environment, in the QGIS and ArcGIS software environment (QGIS 3.x, ArcGIS 10.2) and in accordance with the methodological procedures of the authors



Boltžiar and Chrastina (2018), Mojses and Boltžiar (2011), Oláhová et al (2013), and Grežo et al. (2020) includes the following operations:

- identification of individual landscape structure elements by means of interpretation of aerial photographs and map documents,
- digitisation of spatial data using the “on screen” method (based on analogue visual interpretation of orthophoto images) – the creation of a thematic map of the landscape structure, digitisation was carried out at a scale of 1:5,000, as aerial images provide very high resolution, the resulting map of the landscape structure is at a scale of 1:10,000, the minimum size of one polygon exceeds 0.5 ha of area,
- the creation of a flexible database system in which all relevant information is stored and which will allow all other operations to be carried out,
- cartographic representation of the information layers in analogue output form - landscape structure maps.

In the preparation of this step, the works of Boltžiar and Olah (2009), Ořáhel et al. (2019), Vaishar et al. (2021), and Vavrouchová et al. (2022) were used. Map documents from Arcanum Maps (n.d.) - first and second military mapping, Historical orthophoto map GEODIS SLOVAKIA, s.r.o, Historical LMS, Topographic Institute Banská Bystrica, Orthophotomap EUROSENSE, s.r.o. and GEODIS SLOVAKIA, s.r.o., TU Zvolen (year 1949) (Historical orthophoto map of Slovakia (n.d.) – year 1949, Eurosense (n.d.) - year 2003, images from Seznam.cz, EUROSENSE, DigitalGlobe (year 2021) were used.

According to the methodology of mapping and evaluation of secondary landscape structure according to Petrovič et al. (2009), the division into 6 main groups of landscape elements was applied:

- (1) tree and shrub vegetation,
- (2) grassland vegetation,
- (3) agricultural crops,
- (4) bedrock outcrops and raw soils,
- (5) surface water and wetlands,
- (6) settlements and built-up areas.

In the defined area (the c.a. of the town of Šahy) the available map documents in the environment of geographic information systems were analysed and were elaborated in terms of the above methodology and individual time horizons. Subsequently, the historical and contemporary maps were digitised and georeferenced in the above-mentioned GIS environment. The landscape structure maps were processed in ArcGIS, version 10.2 combined with the QGIS 3.0.3 Girona environment, included free plugins that improved the visualisation and some of the graphical and statistical map processing functions. The first two historical landscape structure maps are related to the Josephinian Land survey (military mapping).

This is followed by a map of the historical landscape structure of the post-war period in 1949-1950, and then 2 maps of the current landscape structure, the most recent of which is from the latest available layers from 2021, the older one from 2003.

The results of the acreage of landscape features were exported. Their determination, and trends of landscape changes were distinguished by colour, into MS Excel. The outputs were first processed at high resolution and then, for the purposes of exporting these results. The outputs were generalised to a smaller scale at adequate resolution. The MS Excel tables show separately the area sizes by feature and the lengths of the lines and linear landscape features in the other tables. The output maps exported for the printing of this article are positionally referenced, as are the vectorised data and the styles used in the maps. The present landscape structure has been processed in detail. More than 4,800 polygons were identified in the map, to which geomension checking was performed without major errors. A 4-digit secondary landscape structure (SLS) code was used for mapping according to orthophotomaps from Mapy.cz [www.mapy.cz](http://www.mapy.cz). The base legend is the legend according to Petrovič et al. (2009), with a total of about 287 entries, including groups, subgroups, sub-subgroups, and features (there are 193 of these). Finally, the SLS output legend was reduced to the map of the current landscape structure (Figures 2 and 3) to 84 visible landscape elements. The occurrence of the others was null or negligible.

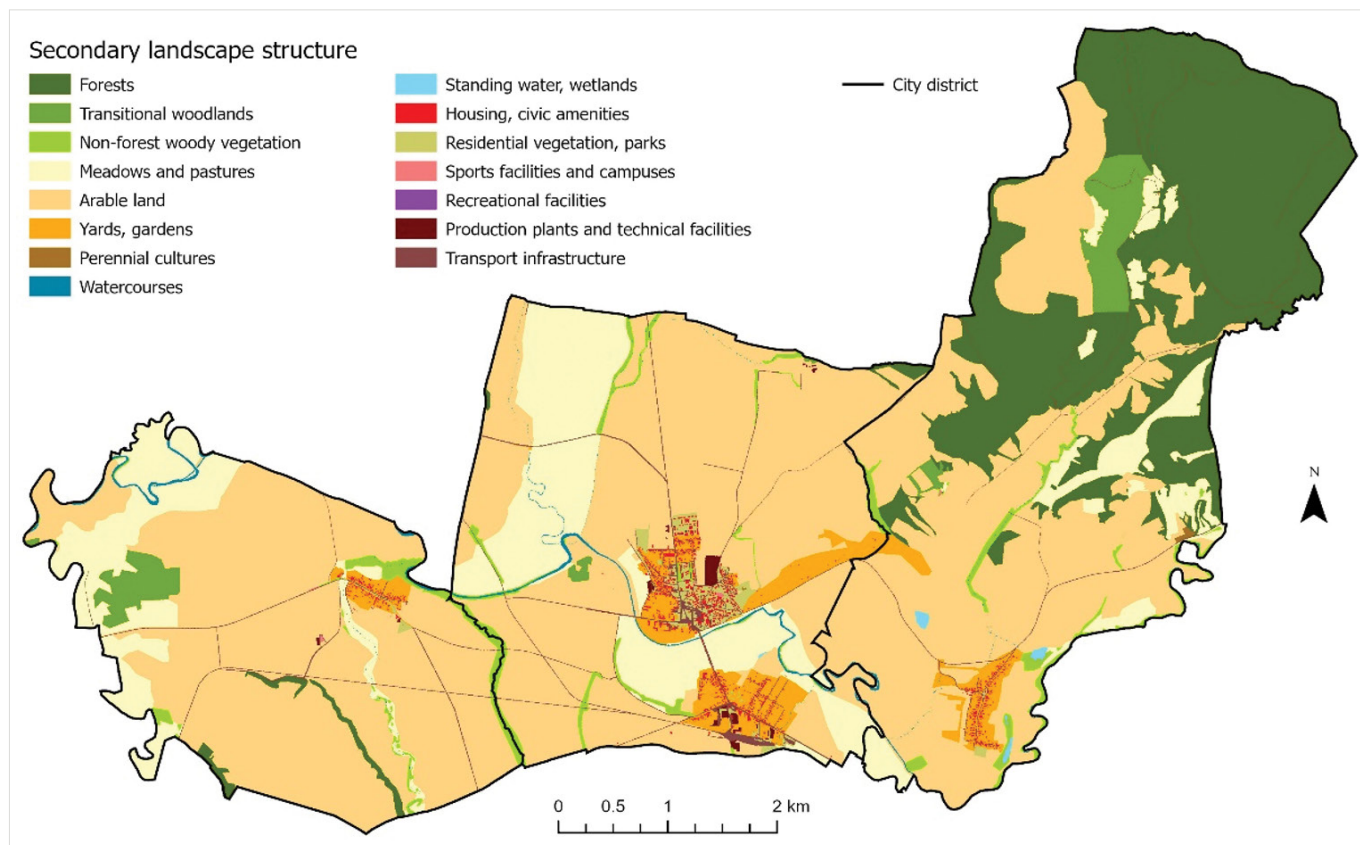


Figure 2. Secondary landscape structure year 1949

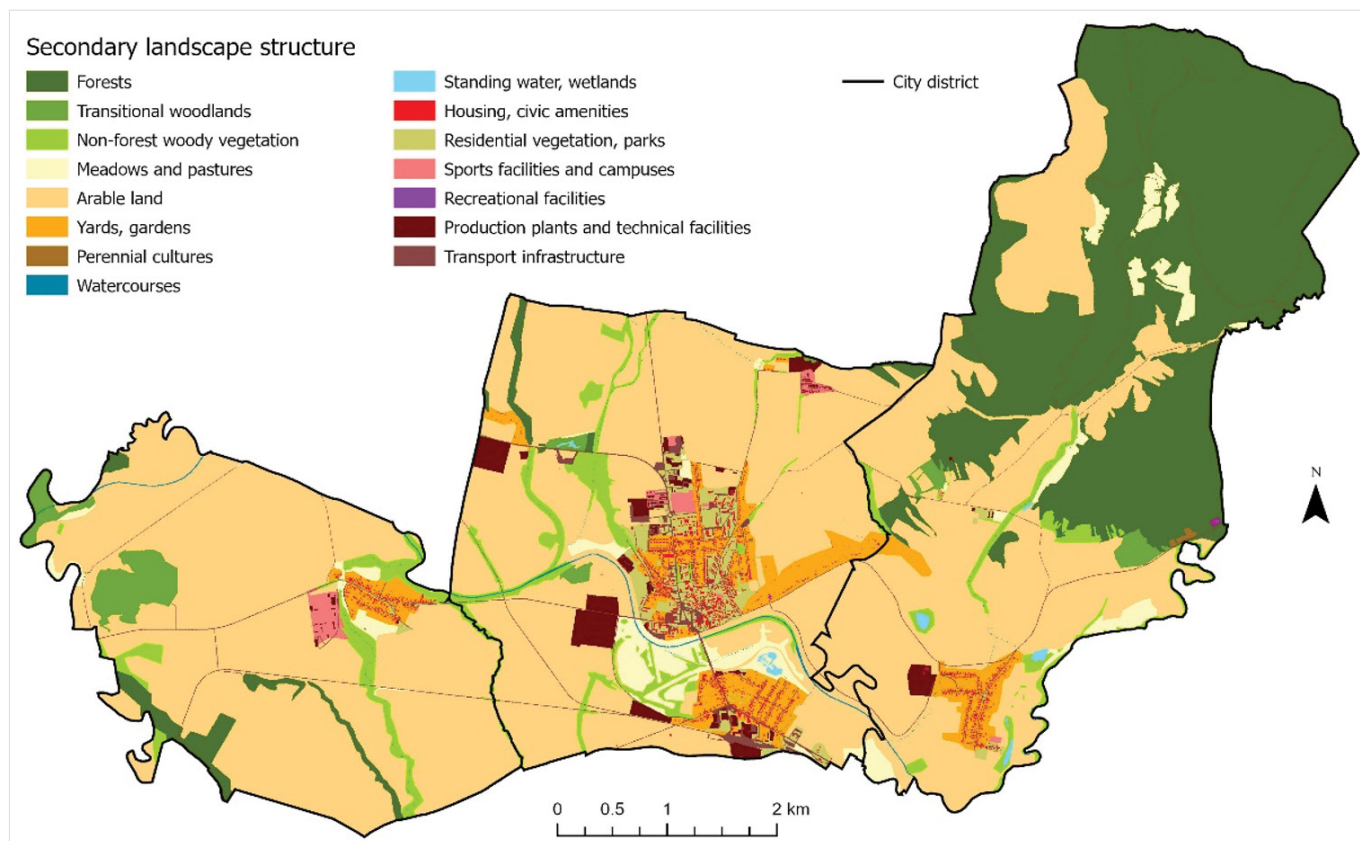


Figure 3. Secondary landscape structure – year 2021

Based on an analysis of trends in landscape structure change, which reflects the apparent changes in the landscape over the timeframe, the following key trends were defined:

- (1) urbanisation,
- (2) industrialisation and technologisation,
- (3) remediation (reclamation),
- (4) afforestation,
- (5) deforestation,
- (6) intensification of agriculture,
- (7) extensification of agriculture,
- (8) waterlogging,
- (9) drainage,
- (10) industrialisation (except for point 2),
- (11) remediation (except point 3),
- (12) no changes.

## RESULTS

Current developments in geoinformation technologies, which include GIS, represent some of the most progressive opportunities for mapping secondary landscape structure and its changes at a variety of scales, from global to local (Feranec et al., 1997).

### *Changes in the landscape structure of Šahy between the first and second military mapping (1769 - 1869)*

After overlaying the processed map outputs of the first military mapping (1769-1784) and the second military mapping (1869) and identifying the identical or different areas of landscape features, the analysis of landscape structure changes was processed (the detail of the maps did not allow interpretation of the 4-digit code). A 3-digit code was used to analyse trends of change as part of the data generalisation.

The changes and trends were compiled, where the transition between landscape elements in the compared historical periods is shown. The final change in landscape feature areas with the area (m<sup>2</sup>) converted to trend types from the first military mapping to the second military mapping. The colours in the map represent trend types that are in the legend. These were visualised spatially, but

somewhere two trend types overlap in one area, hence the colours are of different depths. The coloured cells contain the area in m<sup>2</sup> of the given trend type. However, e.g. remediation and waterlogging of an area can also be in one cell - this is e.g. a change from code urban area to natural watercourses (that is why the cell is highlighted in blue, but it could also be marked as remediation), then we have focused on the dominant trend in the area.

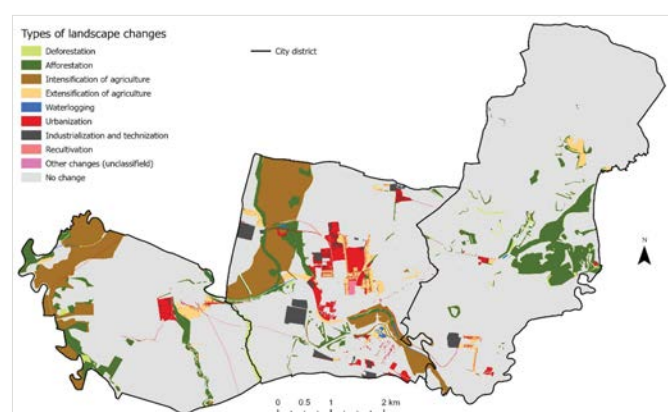
In terms of area or size, the most extensive trends of change in the period include the intensification and extensification of agriculture and its spatial changes. Extensification took place mainly on the boundary areas of the parcels, which gradually expanded the area of agricultural land on forest boundaries, borders, linear stands, and meadows towards the wider area. Intensification was observed, on the contrary, in the northern and north-eastern corners of the territory of Šahy, where there were qualitative changes in the settlement and spatial activity of the population. More detailed parcellation of land and changes of ownership in connection with intensive human activity in this area influenced these changes of intensification. The second most significant spatial change is afforestation, which spatially accompanies the areas alongside and near the sites intensified by agriculture. Afforestation increased during and after the second military mapping; this trend persists roughly to the present day. It corresponds to a gradual increase or, at present, stagnation of the area of forests in the c.a. of Tešmák, which passes into the Krupinská planina mountain range and its southern part into the floodplain forests within the Ipeľ basin. Already in this period, the trend of gradual afforestation of the geomorphological unit Krupinská planina can be observed from the southwest, which was caused by leaving the self-development of the forests of this unit without obvious interference from human activity. The remaining southern and south-western part of the territory is part of the Podunajská pahorkatina and is therefore intensively used, especially agriculturally, which is reflected in the long-term monitoring of the secondary landscape structure. Environmentally, in terms of territorial nature protection, this included the establishment of the LPA Poiplie and the Poiplie Ramsar site in Tešmák.



An important qualitative change, although smaller in area, is the waterlogging, or the increase of waterlogged areas, which occurred due to flooding and at that time the flooding of the Ipeľ river and its branches. This was, and still is, linked to remediation and drainage measures, which subsequently increased the area of the territory over time as a result of this trend. In the period between the military mappings, there is already a clear, although not so marked, trend of a gradual increase in area by urbanisation and related activities, especially in the vicinity of the hub (the centre of the Šahy area). This trend will be even more prevalent in the next stages. In this period, it is still worth mentioning that a large part of the c.a. of Šahy town and adjacent territories is without identified changes, which are caused by the slower progress of significant human activity and the degree of detail of mapping, or the methods of its processing.

#### ***Changes in the landscape structure of Šahy town between the post-war period and the current landscape structure (1949 - 2021)***

After processing the historical landscape structure from the post-war period in 1949, it was compared with the current landscape structure in 2021 (Figures 2, 3 and 4).



**Figure 4.** Landscape changes in the period of 1949-2021

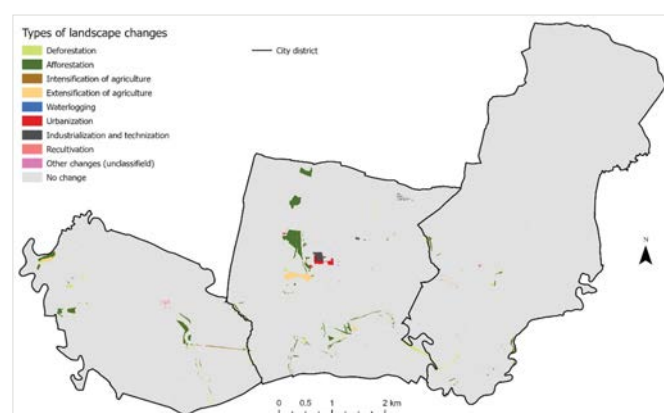
The fundamental changes and subsequent trends in the development of the defined area in the period 1949-2021 include the intensification of agriculture, which caused the establishment of large-block fields at the expense of meadows, pastures, and small-area fields. This

is a consequence of economic and social changes resulting from changes in the political system. The proportion of forests has been increasing, especially in the area of the Krupinská planina in the c.a. of Tešmak, but also in the c.a. of Preseľany nad Ipľom.

Other changes have also occurred between these periods, e.g. stream alteration and its regulation, also the disappearance of meanders. Urbanisation took place in all three parts of the c.a. of Šahy, the establishment of industrial and technical complexes, agricultural objects, expansion of roads, etc. All the above changes can be observed in detail in Tables 1 and 2.

#### ***Changes in the landscape structure of Šahy town between the period before EU accession and the current landscape structure (2003 - 2021)***

The monitoring of trends of landscape structure changes in this period, i.e. between 2003 and 2021, was included due to the accession of Slovakia to the European Union. After 2003, there were significant changes in the legislation of Slovakia in the field of regional development and landscape formation. The new legislation was to bring changes in the integration of EU regulations into Slovak legislation. It was expected that the change in legislation would also bring changes in the landscape, even if it was only for a 12-year period. Trends of landscape structure in the cadastral areas of Šahy town in the period 2003-2021 are presented in Figure 5.



**Figure 5.** Landscape changes in the period 2003-2021



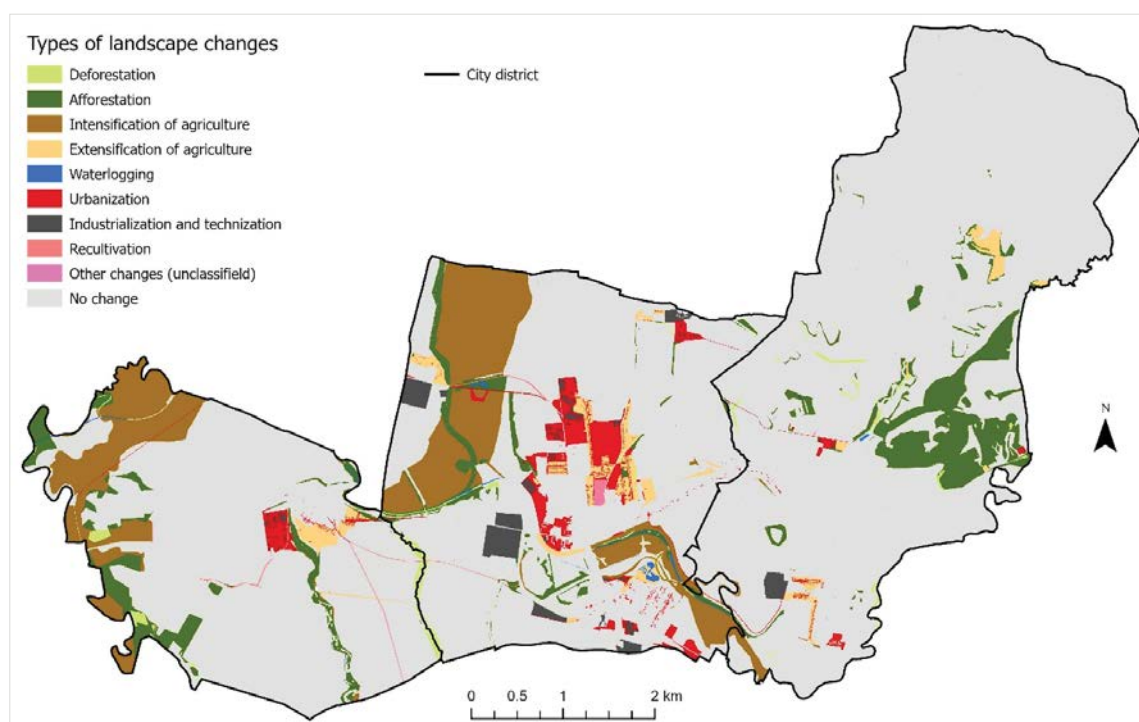
SLS code	SLS group	1949 area (ha)	%	1949 - 2003 change (ha)	% of changed area between 1949 - 2003	2003 area (ha)	%	2003 - 2021 change (ha)	% of changed area between 2003 - 2021	2021 area (ha)	%
11	Forests	778.96	18.23	+201.53	+4.72	980.49	22.95	+0.04	+0.00	980.53	22.95
12	Transitional woodlands	93.37	2.19	-24.54	-0.57	68.83	1.61	+3.71	+0.09	72.54	1.70
13	Non-forest woody vegetation	89.42	2.09	+68.15	+1.59	157.56	3.69	+22.22	+0.52	179.78	4.21
21	Meadows and pastures	615.86	14.41	-480.46	-11.25	135.40	3.17	+2.96	+0.07	138.36	3.24
31	Arable land	2,413.89	56.50	+75.41	+1.76	2,489.30	58.26	-34.15	-0.80	2,455.15	57.46
32	Yards, gardens	138.12	3.23	+30.97	+0.72	169.09	3.96	+0.48	+0.01	169.57	3.97
33	Perennial cultures	1.20	0.03	+0.45	+0.01	1.65	0.04	+0.00	+0.00	1.65	0.04
51	Watercourses	25.29	0.59	-11.95	-0.28	13.34	0.31	-0.03	+0.00	13.31	0.31
52	Standing water, wetlands	4.17	0.10	+2.50	+0.06	6.68	0.16	0.00	+0.00	6.68	0.16
61	Housing, civic amenities	21.51	0.50	+10.14	+0.24	31.64	0.74	+0.08	+0.00	31.72	0.74
62	Residential vegetation, parks	31.95	0.75	+42.09	+0.99	74.04	1.73	+0.51	+0.01	74.55	1.74
63	Sports facilities and campuses	0.64	0.01	+21.32	+0.50	21.96	0.51	-0.19	+0.00	21.77	0.51
64	Recreational facilities	0.10	0.00	+1.19	+0.03	1.29	0.03	-0.18	+0.00	1.11	0.03
65	Production plants and technical facilities	7.21	0.17	+46.75	+1.09	53.96	1.26	+2.74	+0.06	56.70	1.33
66	Transport infrastructure	50.99	1.19	+16.46	+0.39	67.44	1.58	+1.81	+0.04	69.26	1.62
	Sum	4,272.68	100.00	1,033.92	24.20	4,272.68	100.00	69.10	1.62	4,272.68	100.00

**Table 2.** Landscape trends research area in 1949-2021

Landscape trends	Trends 1949-2003 (ha)	Trends 1949-2003 (%)	Trends 2003-2021 (ha)	Trends 2003-2021 (%)	Trends 1949-2021 (ha)	Trends 1949-2021 (%)
No change	3,369.04	78.85	4,210.50	98.54	3350.91	78.43
Deforestation	25.63	0.60	9.81	0.23	23.24	0.54
Afforestation	265.56	6.22	0.03	0.00	289.19	6.77
Intensification of agriculture	378.19	8.85	35.62	0.83	365.38	8.55
Waterlogging	6.47	0.15	1.24	0.03	6.43	0.15
Urbanisation	92.30	2.16	2.81	0.07	94.29	2.21
Industrialisation and technisation	50.16	1.17	7.63	0.18	52.88	1.24
Extensification of agriculture	76.83	1.80	3.55	0.08	82.00	1.92
Recultivation	7.01	0.16	0.23	0.01	6.88	0.16
Other changes (unclassified)	1.49	0.03	1.26	0.03	1.48	0.03
Together	4,272.68	100.00	4,272.68	100.00	4,272.68	100.00

The hypothesis that EU accession will bring significant changes in landscape structure was not confirmed, as Figures 3, 5, and 6 show. The change trends showed significant interventions only in areas that are not very

significant in terms of size. These include mostly scattered small areas, which means in real scale increase of areas, e.g. due to urbanisation and settlement activities, agricultural and industrial activities.

**Figure 6.** Landscape changes in the period 1949-2003

The most significant trend of this period is the change in usage of some of the original agricultural cooperatives, or some of the old sheds that were brought back into use, some were demolished, or new ones were built on the same sites. To the north, the dominant change includes the area of the new photovoltaic power plant and several smaller areas were added directly in the town (Šahy town area). Construction interventions were minimal, e.g. the petrol station was extended. Individual housing construction was also suspended, or the progress of changes was minimal. An interesting change is that some arable land was taken in favour of development, the cemetery area was extended, and the meadows were gradually becoming more overgrown with trees, especially those that have grown spontaneously around water bodies. In places around the industrial areas, concreted areas were added for parking and for open storage areas. The woodland broadly held its extension, and some allotments appeared to be less well-maintained and therefore overgrown.

#### ***Significant changes in the landscape structure of Šahy town in key historical periods***

The processed data and the most significant long-term trends in the development of the landscape, including afforestation, were analysed, especially in the Krupinská planina area (c.a. of Tešmák) in the north-eastern part of the territory. Meadows and pastures, which have been shrinking in favour of agricultural land, have shown the opposite trend. In some parts of the territory (mainly in c.a. of Preseľany nad Ipľom) deforestation has occurred, but overall, mainly in the lowland and upland parts of the territory. Fields were ploughed at the expense of borders and meadows. The vineyards, which were widespread in the map of the I. military mapping, gradually disappeared, and one part near the town's urban area was preserved, which was also documented by field research. The riparian vegetation originally included meadows, which are now overgrown with linear woody riparian forest vegetation.

Watercourses that were not regulated are now regulated, dead branches have disappeared, the flow has been modified and straightened, the channel is narrowed, and thus the water runoff from the basins is accelerated.

Urbanisation and the increase in the area of the settlement structure have been carried out mainly at the expense of the fields; the extension of the built-up area is evident both to the north and to the south in the defined area. Industrialisation (new halls, agricultural cooperatives, power stations, etc.) is also an important factor. The identification of the loss of domestic gardens to residential areas is significant.

#### ***Trends of changes resulting from the mapping and the forecast of the development of Šahy town***

Based on the tables that identified the changes in landscape elements and landscape element groups, the graphical outputs for better interpretation were created. In group deciduous forests, as already indicated, there has been afforestation and an increase in the proportion of this element. After 1949, the emergence of transitional woodlands, clearings, forest nurseries, and non-forest woody vegetation was observed. The opposite trend occurred in the case of meadows, where there was a short-term increase (1769 - 1869) and then a decline, mainly from 1949 to the present. Generalisation caused the data on large-block (typical of socialist management) and small-block fields (privately owned) to disappear. The largest change in the sub-category was recorded in the period from 1949 to 2021. However, since the first mapping, acreages have decreased, with family house gardens gradually increasing as opposed to vineyards, which have been disappearing. The radical decline is evident towards 1949, and the trend is maintained until 2021.

There have been changes in the group of surface streams and wetlands. There has been a modification of watercourses and their regulation in natural watercourses, with a similar trend in still waters and wetlands.

In settlements and built-up areas, changes have occurred mainly due to urbanisation, political and social changes. The urban area has been modified, and a decrease in the historical landscape structure and the current one can be seen. In 1949, an increase was recorded again. Since 1949, an increase in park vegetation and urban green ruderal vegetation has been recorded.

As for the amenities, sports facilities, and complexes, recreational facilities were built mainly after 1949. The creation of industrial and technical objects, production halls and warehouses, agricultural objects, and complexes is recorded mainly from 1949 until the present, also with a change between 2003 - 2021. At the same time, railway lines and roads were built.

After analysing the changes and trends, management measures for the c.a. of the town of Šahy similar to the Action Plan of Šahy (currently for 2021) were prepared and divided into 3 areas, which are related to the trends of development and changes in future periods:

Economic area - we recommend continuing with the investment plans of the municipality with the use of structural funds and funds of cross-border cooperation, to continue with the repairs of buildings (reconstruction of the municipal office building, building barrier-free entrances to public buildings, to continue the repair of the museum building), to repair the surface of sidewalks and local roads and to build parking spaces in the streets where there are no available garages. At the same time, the management measure focused on the construction of cycle routes and the connection to the cycle route Dudince - Šahy and the continuation in the direction of Hungary (Interreg SK - HU programme) can be considered positively, although the local self-government is dealing with the settlement of land under the planned cycle routes and the involvement of several entities. The planning of a regional information centre and activities related to increasing the tourist attractiveness of the area (rafting on the Ipel' river) is considered positive. A negative trend is the postponement of some planned activities in the future (cycle routes, tourist paths, repair of the main square, regional information centre, and renovation of the health complex due to the non-cooperation of the current owner). In this area, the arrival of investors such as ZF Slovakia, a.s., or the construction of a photovoltaic power plant on a brownfield or grey field is considered positive. The use of these areas can be considered crucial in relation to the preservation of green areas in the cultural landscape. The planning of expressways in the area is also positive as it can help to move trucks away

from the city centre and the square and can bring in more investors in terms of building infrastructure and jobs.

Social measures also include the use of structural funds and cross-border cooperation, mainly measures to maintain social service (now implemented through the support of the Ministry of Labour, Social Affairs and Family), the reconstruction of the hospital building, repairs to improve the quality of primary school premises, playgrounds and sports grounds, the repair of the primary art school, repairs to the local public radio and the extension of the CCTV system. On the negative side, projects and plans such as the construction of a citizens' facility, a day-care centre, construction of a new multifunctional sports hall, and, above all, the construction of rental flats and low-standard flats have been postponed or delayed. These plans are recommended to be implemented because of the decreasing population of the c.a. of the town of Šahy. The restoration of rail transport is also a positive social measure that can provide transport links for the citizens of the region in the direction of Zvolen city.

The environmental area in terms of management measures includes recommendations for the continued reduction of energy intensity. A negative phenomenon is the lack of use of the sewerage system in the whole c.a. of the town of Šahy (gradual connection of end-points), only partial gasification, and delays in the removal of illegal waste dumps. The measures aimed at the separation of municipal waste (equipment of technicians and containers) or the improvement of the inner blocks in housing estates are assessed positively.

The strategic documents that the town of Šahy has prepared are considered to be sufficient. In the case of observance of all system measures, planned action plans, and strategic documents, the prognosis for the development of the town of Šahy is positive.

On the basis of detailed field research based on strategic documents and GIS mapping, several locations in the territory were identified where the important trends or the need for changes based on the management measures that we provide for the given trend were analysed:



Use of brown and grey fields from the premises of the Agricultural Cooperative of Šahy (location towards Preseľany nad Ipľom), which so far had partially dilapidated and only old buildings, and at the same time, a large prefabricated hall is built next to them. The premises of the agricultural cooperative in Tešmák are currently for sale; agricultural machinery was located on the premises, but the buildings looked unused. The site has potential for brownfield and greyfield uses.

Establishment of new industrial and warehouse areas at the entrance to Šahy in the direction of Hokovce. However, the old halls, which we classify as brown and grey fields, are deteriorating here. This phenomenon is considered negative from an environmental point of view. This is the Westmetal SK, s.r.o. plant located pursuant to the zoning plan in an industrial area. As already stated, there is potential for unused brown and grey fields near the plant of this company.

The establishment of ZF Slovakia, a.s. plant in the urban area of Šahy (in the Pod vrškom area) and its expansion of production, is a positive and at the same time a negative trend in the landscape. In comparison with the zoning plan of the town of Šahy, we found that it is in the proposed industrial site. At the same time, it was approved by the decision of the District Office Levice, Department of Environmental Protection. However, it is located in the town's urban area, near the town cemetery and Lidl store, and looking at the landscape, it could have been located in the so-called brown or grey fields. Its construction was observed during field mapping. A positive trend in relation to employment and social areas can be seen. In the past, people had to commute to Hungary for work; a company in Šahy created 400 jobs.

Individual housing construction is minimal despite the data in the PHSR and spatial planning documents. Newer housing units have been located at the exit from Šahy to Preseľany nad Ipľom. The trend of minimal construction is considered to be negative from a social point of view.

Floods are another negative threat to the c.a. of the town of Šahy. During our mapping and research, there were no floods, but in the past, the town faced floods several times (1999, 2010, 2013, etc.). This phenomenon is considered to be serious and is referred to as a negative phenomenon in relation to the development in the defined area.

The floods and inundation of the Ipľ river are considered to be important factors that influence further development of the c.a. of the town of Šahy. In the area of interception, measures such as changing the species diversity of forest crops, increasing the depth and density of the root system of grasslands, reducing the number and size of places without vegetation cover, reducing large blocks of monocultures in the landscape or building irrigation systems are included.

## DISCUSSION

Landscape and landscape structure research is a broad issue of understanding the evolution of the landscape based on the existing features and characteristics of the landscape with different uses, human impact, and the changes that these activities have caused and influenced. Landscape use change can involve conversion (categorical change, e.g. building on arable land) or modification (gradual transition, e.g. meadow becoming forested) of one type of the area to another (Coppin et al., 2004). At the same time, the change of landscape can affect the quality of life of the inhabitants (Petrovič and Murgaš 2020, 2021, Petrovič and Maturkanič 2022, Murgaš et al. 2023, Petrikovičová et al. 2022, Maturkanič et al. 2022).

The mapping land cover change at the level of landscape features can lead to a large amount of analytical evidence that does not produce comprehensible results without systematic synthesis. For the assessment of territorial changes over time, it is essential to follow the changes of landscape elements in a chronological sequence, in relation to territorial specificities.

The relevance of addressing the issue in relation to landscape changes and further development is confirmed by authors such as Muchová and Petrovič (2010), Petrovič et al. (2017), Kolejka et al. (2020), Pazúr et al.

(2020), Šťastná and Vaishar (2020), Skokanová et al. (2016, 2021), Havlíček et al. (2018), Burgi et al. (2022), Tuan (2022), Fayet et al. (2022), Lieskovský et al. (2024) and others.

However, there are different approaches and methodologies of different authors to landscape research. The methodology of Petrovič et al. (2009) in our research of our study territory is followed. This approach provides more detailed results at a local scale than using the databases and methodological procedures of the CORINE Land Cover project, with outputs at a scale of 1:100,000, suitable for comparing trends of larger regions. This approach is based on the concept of identification of landscape structure elements mappable on the territory of Slovakia, based on the analysis of maps and aerial photographs with a logical classification of secondary landscape structure elements. The landscape structure elements represent the basic database of information and knowledge about the studied territory, and by loading the layers and their classification, they were transformed into layers with informative value. These layers have created new knowledge about the nature of changes in the defined area of the c.a. of Šahy. Their subsequent interpretation and comparison of trends in development provided knowledge about qualitative and quantitative changes in the landscape, with the possibility of outlining management measures for future periods in the sense of sustainable development of the territory.

Changes in the secondary landscape structure came gradually, from the historical mapping (first and second military mapping - 1769 - 1869) through the post-war period (1949), to the period before the accession to the EU (2003) and the present day (2021). Reger et al. (2007) consider the changes in the spatial structure of the European landscape since 1950 to be significant. The general trend in marginal regions is the abandonment of arable land and the gradual increase of grassland or forest cover. In former socialist countries, 40 years after collectivisation and the subsequent change of the political system, land abandonment also occurred outside the borderland areas (Lipský, 1995). Bičík and Jeleček (2009) state that the most significant drivers in the area of groups

of agricultural cultures and settlements and built-up areas came after land reforms, changes in the political and social system, massive industrialisation, nationalisation and collectivisation of agriculture. The same conclusions can be drawn when considering the c.a. of Šahy and its development. After 1989, restitution and renting of agricultural land took place, which caused stagnation of agriculture, although the area of fields in the study area did not decrease significantly after that year. The biggest changes were, as the authors stated, after 1949, due to the change in the political and social system. Agricultural intensification dominated, with large-block arable land being dominant. Evidence of this is also the decline in the grassland group from 14.26% (1949) to 3.24% (2021).

The whole district belongs to the most suitable area for agricultural production within the territory of Slovakia in terms of natural conditions, in terms of trends within the district in the last 30 years, due to the location away from the major centres of sales, together with the decline of local consumption to a reduction in the production capacity of livestock production, the area of agricultural land in the district has decreased by almost 1%. Due to its location near the border, it is now difficult to shift to more sophisticated sectors of the economy (Blažík et al., 2011). The cultivated arable land within the Šahy area of interest currently occupies 58.43% of the territory, which is, however, the smallest share when examining the development according to individual mapping. Agricultural land had the largest share during the first military mapping (61.14%). From an ecological point of view, the intensification of agriculture is a negative trend, as this process destroys the borders and copses, monocultures are cultivated, thus significantly reducing the biodiversity of the territory, and the use of pesticides and fertilizers is increasing, causing land degradation. However, from an economic point of view, this process has a relatively positive impact, as it increases agricultural production and thus industrial production in the food sector. In the vicinity of Šahy, there was a significant decrease in the area of vineyards and a decline in viticulture production. Although the decrease in wine-growing areas after joining the EU occurred in the entire territory of

Slovakia, the decrease was not so significant in the Lesser Carpathian wine-growing region. For example, 72,7 % of vineyards are still used in the town of Modra (Karlík et al., 2017). However, construction wasn't only observed in green areas and arable land of the given territory. The investments that came in the last period (2003-2021) were in accordance with the strategic documents, and there were no special changes in the spatial planning documentation, and these were areas designated for industrial production. However, the focus of companies on the mainly automotive industry remains an issue.

Based on a land-use study of southern Germany, Meyer and Früh-Müller (2020) point out that the agricultural landscape is changing mainly through processes of afforestation and urbanisation. The change to built-up areas is mainly driven by socio-demographic factors and afforestation by environmental drivers. A better understanding of land use changes contributes to a more efficient use of ecosystem services. Among European regions, the abandonment of agricultural land is particularly important in Eastern Europe, Southern Scandinavia and mountainous regions (Estel et al., 2015).

Changes and trends in land use based on the analysis of secondary landscape structure elements from the first mapping to the present, according to our findings, correspond to trends that are generally known for the territory of Slovakia. Similar conclusions were reached by Petrovič (2006), Petrovič and Petrikovičová (2021), who state that the development of rural peripheral regions in the sense of the quality of preservation of their environment depends on the amenities of the villages with the existing infrastructure and the ability to meet the specific requirements of agro-tourists. In recent years, it has been possible to see changes in the development trends of these areas, partly towards certain rural tourism activities. One of the prevailing features is the transition from mass tourism to individual forms of tourism in traditional landscapes, preserving their natural, folklore, cultural and historical features. Jakubcová et al. (2014) add that the proposal of zonation and routing, including proposals for new scientific research sites and monitoring

areas, would be possible in the future in the study area in the form of small-scale projects in the territory, possibly through a larger cross-border Hungarian-Slovak cooperation project. Similar projects have already been implemented in the c.a. of Šahy in the field of cycling or hiking. This enables access to and exploration of the area, but it is also essential to direct the movement of visitors where it is appropriate for the landscape. This would combine classical nature conservation with the sustainability of the region by increasing its attractiveness. However, the results of research by Petrovič (2006) and Petrovič and Petrikovičová (2021) should also be taken into account, as he states that if the potential of such areas should only lie in the impulses and in innovative practices of tourism development in the territory, it is necessary to be aware of the fact that not all rural marginal areas are potentially suitable for this, and that this alternative of development is only one of its possibilities.

## CONCLUSIONS

Detailed analyses of the long-term landscape development of marginal regions have an important place in landscape-ecological and geographical research. They can help not only in determining landscape development trends but also in designing management measures and international cooperation within neighbouring countries.

The territory of the town of Šahy was chosen because of the proximity of our current operation, but also because of the cooperation in the pre-mapping of the territory of Ipel' from the point of view of sustainable development. However, also because of the marginality of this town in the Levice district in the direction of Hungary, the development of the town of Šahy interested us in the context of the planned preparation of the R3 expressway, since the M2 expressway is being built in Hungary. The added value of this territory is primarily the river Ipel'.

Our analysis found that the area had 23.12% deciduous forests in 2021. The smallest part consisted of forests during the II. military mapping (12.22%). This trend is also positive in terms of rural tourism potential. The biggest modifications of the flow of the Ipel' river came after 1949,

which is also related to changes in agriculture. As we have already mentioned, floods also occurred in the c.a. of Šahy. The reduction of waterlogged areas was mainly related to collectivisation in the 1950s. It is interesting that despite the marginality of the territory, the arable land does not overgrow as in other marginal regions within the Slovak Republic with less fertile mountain soils, where extensification of meadows and pastures is manifested. On the other hand, measures taken upon entry into the EU also led to a significant reduction in the area of vineyards.

The development of urbanisation and expansion of housing and technical infrastructure is evident mainly in the town of Šahy, but also in Tešmák and Preselany nad Ipľom. An important change came in the form of the development of road infrastructure and the establishment of manufacturing and industrial enterprises. However, after 1989, there was a decline, and the recovery is only now taking place with the arrival of new foreign companies, who partly use the buildings after the industrialisation in the 70-90s of the 20<sup>th</sup> century. On the negative side, new halls and warehouses are being built on greenfield sites.

The results of the presented work - identified changes in landscape structure and outlined future development trends with management measures- can be the basis for further spatial planning documentation of the town, but can also help create other strategic documents. We are of the opinion that the conducted research can be supplemented in the future in terms of issues of sustainable development, flood threats, and also use statistical methods used in landscape-ecological research.

## ACKNOWLEDGMENTS

This work was supported by the grant VEGA 1/0578/24 and VEGA 1/0217/23 of the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of Slovakia and the Slovak Academy of Sciences.

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