Assessment of landscape changes and processes along selected hydric biocoridors

Jana RUŽIČKOVÁ, Blanka LEHOTSKÁ

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Abstract: *The aim of the study is to determine land use changes and processes in relation to hydric biocorridors. The study area is situated in the contact zone of the Malé Karpaty Mts. and the Podunajská nížina lowland in the western part of Slovakia. The trend of landscape changes in the territory (cadastral areas) of 28 municipalities along Stoličný potok and Gidra streams with their tributaries was investigated. For the analyses of lots development in the period 2006 – 2016, data from the database Aggregate Areas of Land Types (UHDP) were used. The dynamics of landscape processes was evaluated using the following indices: the index of total landscape change, the index of dominant processes, the index of landscape-ecologically significant processes, and the coefficient of ecological quality. The most significant decrease was recorded for the area of arable land; on the contrary, a substantial increase in built-up and other areas was evident. The total change index in the period of 2006 – 2016, ranged between 0 and 15%. Changes over 5% were observed in four cadastral areas. Based on the index of dominant processes, the urbanization process takes place in eleven cadastral areas (39%). The landscape-ecologically significant processes were of a medium intensity in four cadastral areas, in conformity with the dominant processes of forestation and agricultural development.*

Keywords: *Podunajská nížina lowland, Malé Karpaty Mts., indexes, land types, urbanisation, territorial planning*

Introduction

At present, the most frequent phenomenon that can be observed in the surroundings of Bratislava is the development of residential and recreational housing and transport structures.

The aim of the research was to determine which processes prevailed within the study area and if they were moving towards the improvement or deterioration of the ecological quality of the spatial structure of land in relation to the selected hydric biocorridors.

The study area is situated in the western part of Slovakia, in the districts of Pezinok, Senec and Galanta, at the interface of the Bratislava and Trnava self-governing regions. Its area was reduced from 46,654 ha in 2006 to 46,642 ha in 2016 due to administrative changes. The area of interest is situated in three geomorphological units – the Malé Karpaty Mts., the Podunajská pahorkatina upland (specifically its part the Trnavská pahorkatina upland) and the Podunajská rovina lowland (cf. Mazúr and Lukniš 1986). The hydric biocorridors are connected to watercourses: the Stoličný potok and Gidra streams with their tributaries, which spring from the Malé Karpaty mountain range, flow through the Trnavská pahorkatina upland up to the Podunajská rovina lowland where the Stoličný potok influxes into the Čierna voda stream and the Gidra influxes into the Dudváh river. We defined the study area by the borderlines of the cadastral areas running along the studied biocorridors (28 cadastral areas in total, Fig. 1).

The Stoličný potok and Gidra streams were first identified as regional biocorridors in the following documents of the State Nature Conservancy of Slovak Republic: Regional Territorial System of Ecological Stability (RTSES) – ecological network of the former district of Bratislava-vidiek (Staníková et al. 1993) and the RTSES of the district of Trnava (Jančurová et al. 1993, Izakovičová et al. 2002). Stoličný potok was also classified as a regional biocorridor in the RTSES of the district of Galanta (SAŽP 1994). The aforementioned RTSES became the source of documents of the territorial plans of Bratislava and Trnava self-governing regions (Hrdina et al. 2013, Chudík and Hledíková et al. 2014). The obligatory parts of these territorial planning documents include the principles for the creation and maintaining of ecological stability as well as the principles and regulations in relation to the RTSES elements, which call for the acknowledgement and consideration of the defined elements of ecological networks at supra-regional and regional levels. The Stoličný potok and Gidra are also classified as biocorridors of regional importance in the territorial planning documents of municipalities within the study area (Ružičková et al. 2015).

In the past, several water-storage reservoirs were built within the basins of the Stoličný potok and Gidra, and a majority of them act as hydric biocentres. The terrestrial biocentres of supra-regional importance – the Martinský les, Šenkvický háj and Lindava forests, are also situated in the vicinity (Hrnčiarová et al. 2001, Sabo et al. 2002, Ružičková et al. 2011).

Approximately half of the study area is protected. The north-western section of the area stretches to the Malé Karpaty Protected Landscape Area (PLA) and the Special Protection Area (SPA) with the same name (SKCHVU014, Fig. 2, No. 1). Úľanská mokraď wetland (SKCHVU023, Fig. 2, No. 2) is another SPA which stretches to the southern and south-eastern sections of the territory. There are five Special Areas of Conservation (SACs) within the observed area (Fig. 2) – SKUEV0276 Kuchynská hornatina (No. 3), SKUEV0267 Biele hory (No. 4), SKUEV0503 Predhorie (No. 5), SKUEV0174 Lindava (No. 6), SKUEV0089 Martinský les (No. 7). The high proportion of the protected areas within the defined territory should have been manifested in the land use changes as well as in an increase of the share of ecologically significant elements in the landscape.

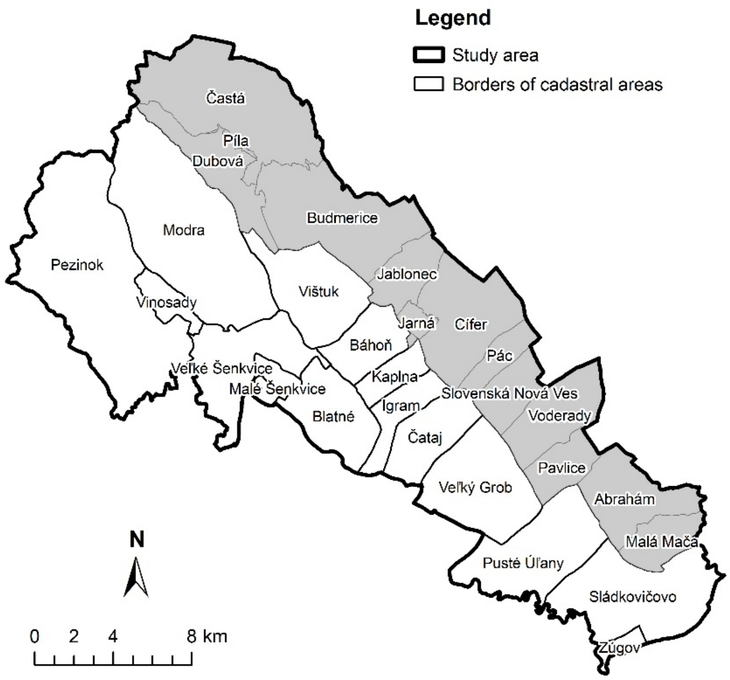

***Fig. 1**. The study area defined by the borderlines of cadastral areas along the selected hydric biocoridors. White colour – along Stoličný potok stream with tributaries, grey colour – along Gidra stream; Source: Authors' elaboration*

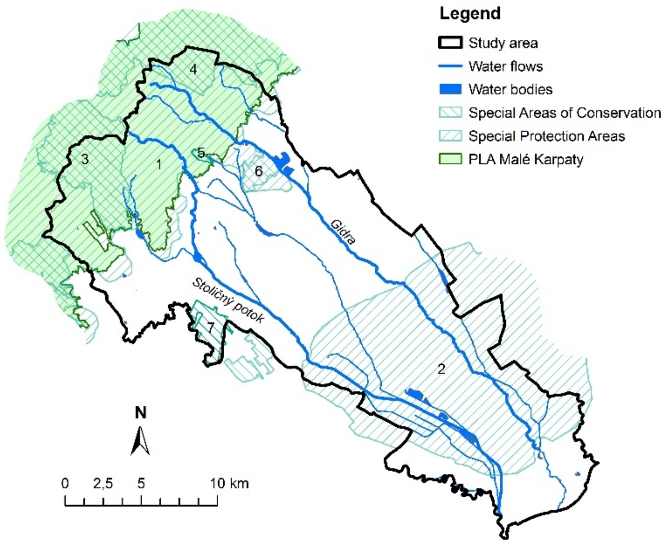

***Fig. 2**. The water flows of Stoličný potok and Gidra and nature protected areas within the study area: SPAs: 1. Malé Karpaty, 2. Úľanská mokraď; SACs: 3. Kuchynská hornatina, 4. Biele hory, 5. Predhorie, 6. Lindava, 7. Martinský les; Source: Authors' elaboration*

Theoretical background

Regarding landscapes strongly influenced by anthropogenic effects, the success of nature protection significantly depends on the land use pattern of the wider surroundings (Csorba and Szabó 2012). According to Lausch and Herzog (2002) in most parts of the world, land-use/land cover can be considered an interface between natural conditions and anthropogenic influence. Indicators are being sought which reflect landscape conditions, pressures and related societal responses.

The changes in the area of individual elements of landscape structure are an appropriate indicator of landscape development. This is evidenced by many publications and studies in which authors applied changes in land use and various indexes of landscape change as an indicator for the development of land cover and land use at the level of states and regions (e.g., Gabrovec et al. 2001, Bičík et al. 2001, 2015, Feranec et al. 2004, Petrovič 2006, Riezner 2007, Łowicki 2008, Šveda and Vigašová 2010, Blažík et al. 2011, Kopecká et al. 2012, Tarasovičová et al. 2013, Munteanu et al. 2014), large cities (e.g., Bičík and Kupková 2006, Šveda 2010, Vavrouchová and Lepková 2013), river basins (e.g., Bičík and Kupková 2003, Atutova 2015) and cadastral areas (e.g., Kochanová and Pauditšová 2005, Moravčíková 2008, Aimbetová and Ružičková 2011, Erlebach 2014, Supuka 2014, Súľovský and Falťan 2015, Ivan and Chebeňová 2015).

In a comprehensive evaluation of changes in landscape structure, Gabrovec et al. (2001) and Bičík and Kupková (2006) applied the method of dominant processes in types of land use. Šveda and Vigašová (2010) used input data from the database of the Aggregated Areas of Land Types (ÚGKK SR 2016) when evaluating the changes in the cadastral areas within functional urban regions of the ten largest Slovak cities.

Interventions and changes in land use in the immediate and more distant vicinity of watercourses have a positive or negative impact on the status, quality and functionality of hydric biocorridors. Changes in land use influence drainage conditions in the watercourses catchment areas as well, which is used for modelling runoff process in various catchments (Hlavčová et al. 2005, 2007, Bulantová et al. 2011, Uhrová and Zárubová 2016).

Data and methods

The trend of land use changes in 15 cadastral areas through which the Stoličný potok stream flows and in 13 cadastral areas through which the Gidra flows was evaluated (Fig. 1, 2). In the studied area, the development of nine land types (arable land, vineyards, gardens, orchards, permanent grasslands, forests, water bodies, built-up areas and other areas) was analysed.

The data analysed cadastral areas for 2006 and 2010 were provided by the Land Registry departments of the District Authorities of Bratislava, Pezinok, Senec, Galanta and Trnava. The data for 2014 and 2016 were obtained from the Land Register Portal of the Geodesy, Cartography and Cadastral Authority of the Slovak Republic, which contain the database of the Aggregated Areas of Land Types (known as "Úhrnné hodnoty druhov pozemkov", hereinafter as UHDP), representing summarization reports of ten land types acreage and the total area of all lots within the territorial units, including cadastral areas.

The changes of nine (the tenth land type – the hop fields do not occur in the study area) land type's acreage were analysed for each cadastral area from 2006 to 2010, 2010 to 2014, 2014 to 2016 and in summary from 2006 to 2016. The dynamics of landscape processes from 2006 to 2016 was assessed by using the following indexes: the index of landscape change (I_C), the index of dominant processes (I_{DP}) and the index of landscape-ecologically important processes (I_{LE}). The coefficient of ecological quality of spatial landscape structure (Ks) was evaluated in 2006, 2010, 2014 and 2016.

The index of total landscape change (I_C) pursuant to Bičík et al. (1996), Štepánek (1996), Bičík and Kupková (2003) and Riezner (2007) evaluates the total change in a land's structure over a certain period of time. The index indicates the share of the area of a territory where any change in land use occurred during the monitored period of time. If the index is zero, no change was observed in the land's structure. The index ranges from 0 to 100%. The index of total landscape change is presented in the form of the following formula (Štepánek 1996, Antrop 2004):

$$I_C = \sum_{i=1}^{n} |Pi_1 - Pi_2| / (P_1 + P_2) * 100$$

where: I_C – the index of total landscape change, Pi_1 – the acreage of individual land types at the beginning of the monitored period, Pi_2 – the acreage of individual land types at the end of the monitored period, P_1 – the acreage of cadastral area at the beginning of the period, and P_2 – the acreage of cadastral area at the end of the period.

Along with the typology of ongoing land processes, we applied the **index of dominant processes (I_{DP})** based on the differences in the area of the land types between two periods (2006 – 2016). Its share in the summary value of positive changes is calculated for the greatest positive value. If this share is greater than 75%, it is a strong dominant process, if it ranges between 50 and 74.9%, it is a medium process and if it ranges between 25 and 49.9%, it is a weak process in terms of the intensification of agriculture, grassing, forestation, expanding water bodies or urbanisation (Bičík and Kupková 2006, Blažík et al. 2011). In order to express the share of dominant processes, we created our own formula for the calculation of the index of dominant processes (I_{DP}):

$$I_{DP} = (Pi_2 - Pi_1) * 100 / \sum_{i=1}^{n} (Pi_2 - Pi_1), \text{ while } (Pi_2 - Pi_1) > 0$$

where: I_{DP} – the index of dominant processes (share in %), Pi_1 – the acreage of individual land types at the beginning of the monitored period, Pi_2 – the acreage of individual land types at the end of the monitored period, and *n* – the number of positive differences in acreages at the end and at the beginning of the monitored period (growth).

When evaluating changes in land types, we applied the **Index of landscape-ecologically significant processes (I_{LE})** based on differences in the area of ecologically significant land types (arable land, vineyards, gardens, orchards, permanent grasslands, forests, water bodies) between the two periods of time (2006 – 2016). For the sum of positive figures (growth area) of ecologically significant land types, their total share in the total value of positive change is calculated. If the proportion of landscape-significant processes > 75%, is a strong process, and if it is in the range from 50 to 74.9% it is the medium, and from 25 to 49.9% if the weak process in the direction of increasing the share of major ecologically significant land types. To reflect the proportion of landscape important process, we created the following formula (modified index of dominant processes):

$$I_{LE} = \sum_{i=1}^{n_{LE}} (Pi_{ES2} - Pi_{ES1}) * 100 / \sum_{i=1}^{n} (Pi_2 - Pi_1), \text{ while } (Pi_{ES2} - Pi_{ES1}) > 0 \text{ and } (Pi_2 - Pi_1) > 0$$

where: I_{LE} – the index of landscape-significant processes (share in %), Pi_{ES1} – the acreage of ecologically significant land types at the beginning of the monitored period, Pi_{ES2} – the acreage of ecologically significant land types at the end of the monitored period, Pi_1 – the acreage of individual land types at the beginning of the monitored period, Pi_2 – the acreage of individual land types at the end of the monitored period, and n_{LE} – the number of positive differences in acreage of ecologically significant land types at the end and at the beginning of the monitored period (growth), n – the number of positive differences in acreage at the end and at the beginning of the monitored period (growth).

The coefficient of ecological quality of landscape structure (Ks **–** thereinafter the coefficient of ecological quality**)** according to Izakovičová and Kartusek (1991) distinguishes the ecological acquisition of individual landscape elements by introducing the rate of landscape-ecological importance (kpi). The coefficient (Ks) was calculated for each cadastral area for 2006, 2010 and 2014 based on input data on land type's acreages to determine the extent to which the change at the level of the land types was projected in the ecological quality of the landscape structure. The following formula of Izakovičová and Kartusek (1991) was used:

$$Ks = \sum_{i=1}^{n} pi * kpi / P$$

where: Ks – the coefficient of ecological quality of landscape structure, pi – the acreage of individual land types in hectares, kpi – the rate of landscape-ecological importance of land types: arable land – 0.15, vineyards – 0.3, gardens – 0.5, orchards – 0.45, permanent grassland – 0.65, woodland areas – 1, water bodies – 0.8, built-up areas – 0, other areas – 0.15, P – the acreage of the cadastral area in hectares, n – the number of land types within the cadastral area.

The coefficient of ecological quality (Ks) acquires values in four categories (Ks up to 0.30 – the lowest quality; Ks in the interval from 0.31 to 0.60 – less quality; Ks in the interval from 0.61 to 0.80 – quality; Ks over 0.80 – the best quality).

The cadastral areas of Veľké and Malé Tŕnie which constitute the territory of the Vinosady municipality, were united for the purposes of the evaluation because a great mutual shift of lots occurred among them. The total area of the cadastral area of Veľké Tŕnie was extended by 28.82 ha at the expense of the Malé Tŕnie cadastral area.

Results and discussion

Based on the data of the land types in 28 evaluated cadastral areas, from 2006 to 2016, there was a change in approx. 2 % of the studied territory. The most significant decrease was recorded for the acreage of arable land (by 602.04 ha), and a less significant decrease was recorded for the area of orchards, permanent grasslands and water bodies. On the contrary, in the studied territory, there was an increase in the built-up areas (by the area of 161.36 ha), and the largest increase (by 460.95 ha) was recorded for the size of other areas (Fig. 3).

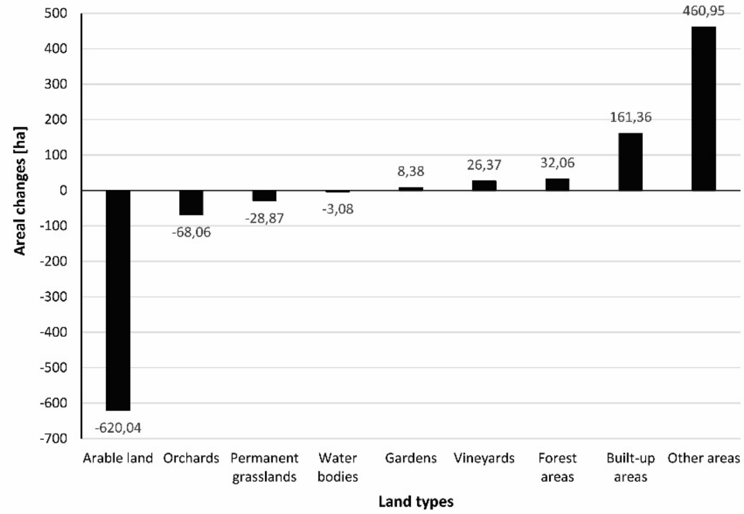

Fig. 3. *Areal changes of land types in 2006 – 2016; Source: Authors' calculations*

Changes of land types´ area

In spite of a different landscape character of the cadastral areas at the foothill of the Malé Karpaty Mts. (with a high share of woodland areas, vineyards and gardens) and the cadastral areas of the municipalities in the Trnavská pahorkatina upland (with a high share of arable land), there were some changes in land types at the expense of arable land in the majority of the study area. In ten cadastral areas, the decrease in the area of arable land was higher than 1 ha; in sixteen cadastral areas, the decrease was smaller than 1 ha, and just in two cadastral areas a slight increase occurred (Fig. 4a).

On the other hand, in the majority of municipalities, a slight increase in the size of the built-up areas was observed, and in four cadastral areas, this increase is more than by 1 ha (Fig. 4b).

The built-up areas of municipalities are situated mainly along the hydric biocorridors of the Stoličný potok and Gidra streams with their tributaries (Vištucký potok, Trniansky potok, Ronava streams), and the extension of built-up areas may influence their functionality. In the evaluated territory, the size of other areas increased substantially as well. The other areas include various unproductive and unused areas of natural and anthropogenic origins. In the future, a change of the other areas into built-up areas can be expected. This type of development took place in 2010 – 2014 in the cadastral areas of Voderady, Veľké Šenkvice, Blatné, Sládkovičovo a Pusté Úľany (Ružičková et al. 2015).

Regarding other agricultural land, the size of orchards and permanent grassland (meadows and pastures) areas in the studied territory was reduced in general, though it is not a uniform trend. The size of orchards was reduced in six cadastral areas (in total by 71 ha) of which a major reduction (> 1 ha) was recorded in Modra, Vištuk and Sládkovičovo. On the contrary, orchards were added (in total by 2.5 ha) in Budmerice, Blatné, Častá and Voderady (Fig. 4c). The area of permanent grassland was reduced in ten cadastral areas, while its size increased in seven cadastral areas (Fig. 4d).

The land types where the total size decreased also include water bodies, even though the total decrease in their size is small (3.08 ha). A decline in water bodies is observed in thirteen cadastral areas (46%), in four of which the decline in the size was somewhat higher than by 1 ha (1.1 – 1.9 ha). By contrast, the size of water bodies increased slightly (Fig. 4e) in fourteen cadastral areas (50%).

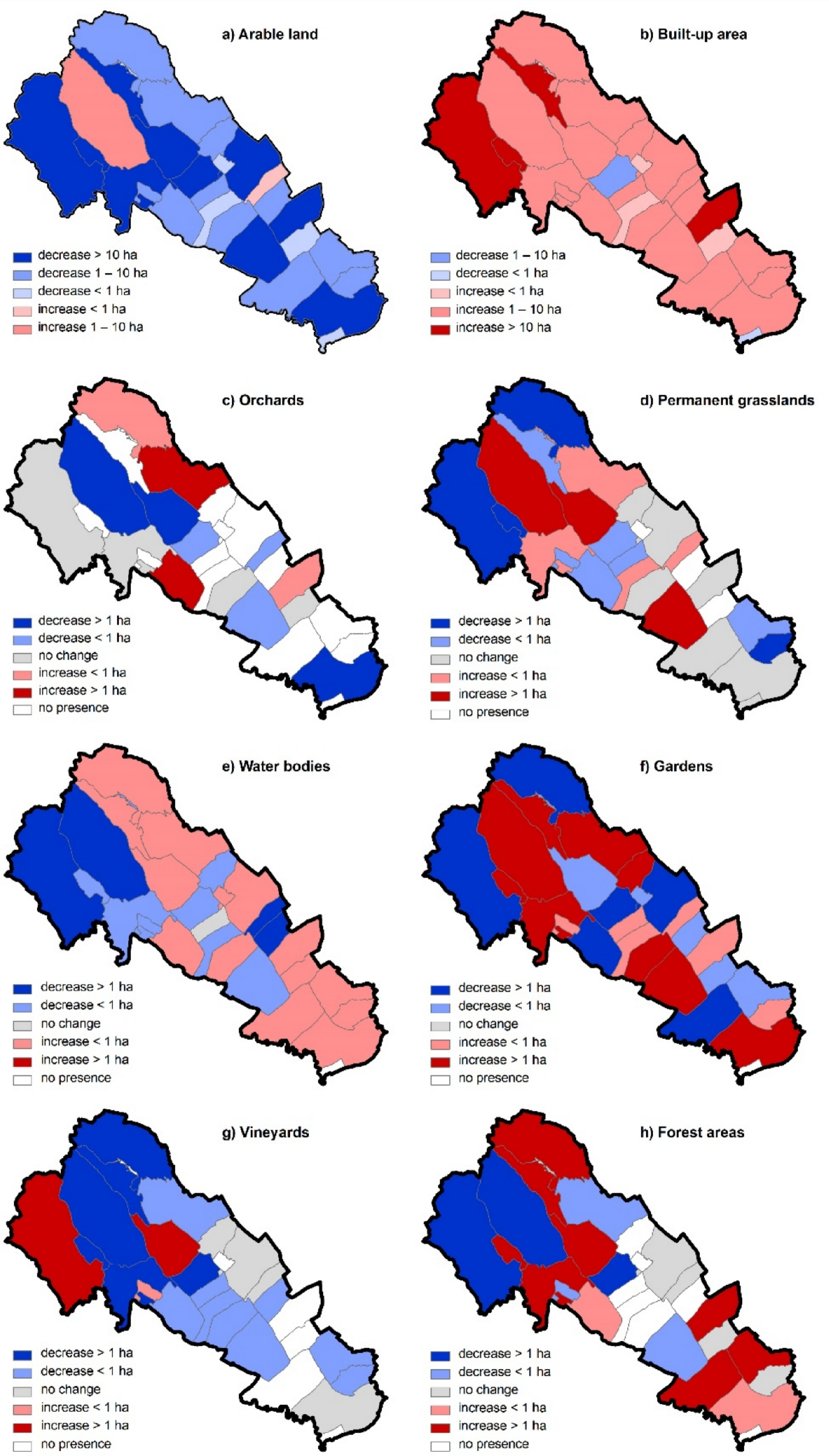

***Fig. 4**. Illustration of land types changes within the cadastral areas in 2006 – 2016; Source: Authors' calculations and elaboration*

Regarding agricultural land, the total area of gardens (by 8.38 ha) and vineyards (by 26.37 ha) increased. In the region of the Malé Karpaty Mts., as well as in Trnavská pahorkatina upland, gardens were added. In ten cadastral areas, the area increased by more than 1 ha, in six others, the area of gardens increased only slightly (in total by 20 ha), while in twelve cadastral areas the acreage of gardens declined (in total by 12 ha) (Fig. 4f).

In the case of vineyards, it is possible to observe on one hand, an increase in vineyards (in total by 111 ha) in three cadastral areas (11%) in the Wine Region of Malé Karpaty (Pezinok, Malé Šenkvice, Vištuk), and on the other, a decrease in vineyards (in total by 84 ha) in sixteen cadastral areas (57%), including major wine-growing municipalities (Modra, Vinosady, Dubová, Častá and Budmerice). In four cadastral areas, the acreage of vineyards remained without changes (Fig. 4g).

The forest areas increased by 32.06 ha in total, and woods were added in ten cadastral areas in the Malé Karpaty Mts., as well as in the Trnavská pahorkatina upland. The largest increase was recorded in Častá, Dubová, Vištuk and Veľké Šenkvice. By contrast, a major decrease (>1 ha) was recorded in Modra, Pezinok and Báhoň (Fig. 4h).

A summary of the increase and decrease in particular types of land is given in the graphs (Fig. 5). The size of the other areas was increased by 52%, of built-up areas by 18%. On the contrary, the area of arable land was reduced by 66%.

Changes in land types in the period of 1980 – 2010 for four selected districts of Slovakia (Dunajská Streda, Levice, Prievidza and Stará Ľubovňa) were evaluated by Blažík et al. (2011). Pursuant to Blažík et al. (2011), there was an increase in the size of built-up areas by 0.95 – 104.46% in each of the four districts and a decrease in the area of arable land by 0.57 – 24.37%. In the district of Dunajská Streda, which is the closest to the study area, the size of built-up areas increased by 88%, water bodies by 15.3% and gardens by 1%. On the other hand, the area of arable land was reduced by 0.6%, and there was also a decrease in other areas by 27%. Along the monitored hydric biocorridors in the study area, the size of other areas, however, substantially increased (Fig. 5).

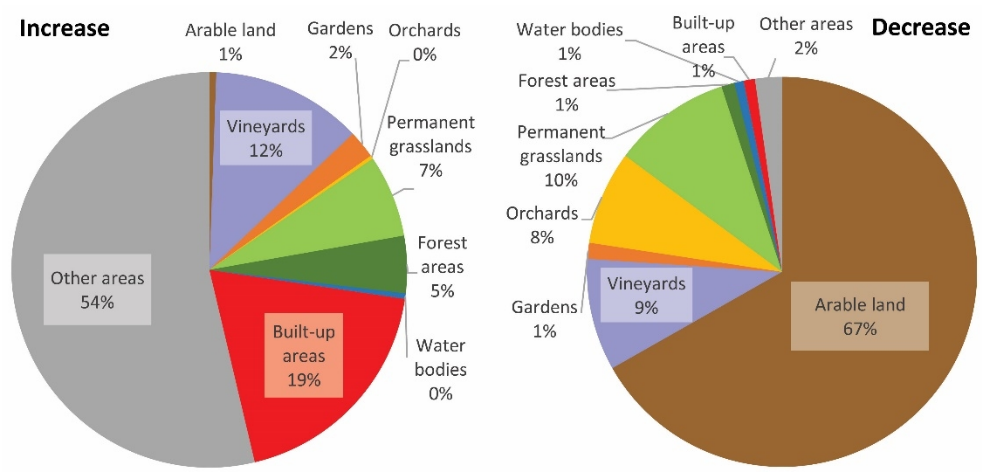

***Fig. 5**. Summary of the land types increase and decrease in 2006 – 2016; Source: Authors' calculations*

Evaluation of total landscape change

In 28 cadastral areas along Stoličný potok and Gidra, the **index of total landscape change** (I_C – thereinafter also as the index of change) in the period of 2006 – 2016 ranged between 0 and 15.02%, of which in 15 cadastral areas (54%), it was below 1% and in 8 cadastral areas ranged between 1 and 5%. The largest changes (over 5%) were observed in four cadastral areas – Vinosady (15.02%), Voderady (10.02%), Vištuk (8.04%) and Veľký Grob (5.12%) (Fig. 6).

When the index of landscape change is compared with the extent of the total change in hectares, the order of cadastral areas is different. The largest areal changes took place in Vištuk (161.2 ha), Voderady (141.8 ha), Veľký Grob (120.8 ha), Pezinok (80.7 ha) and Vinosady (77.6 ha).

Regarding the territory along Stoličný potok stream, compared to the territory along Gidra, a much more substantial areal extent of changes is obvious. In seven cadastral areas, in the territory of Stoličný potok, there were changes in the size of area ranging between 40 ha and 160 ha, while in a prevailing majority of cadastral areas along Gidra, the changes concerned a smaller area (up to 20 ha) only. The cadastral area of Voderady, with a total change of 140 ha, was the only exception within the basin of Gidra. With regard to other indicators, the average total landscape change index for the biocorridor Stoličný potok achieved the value of 2.41%, while in the case of Gidra, the value is lower, amounting to 1.25%.

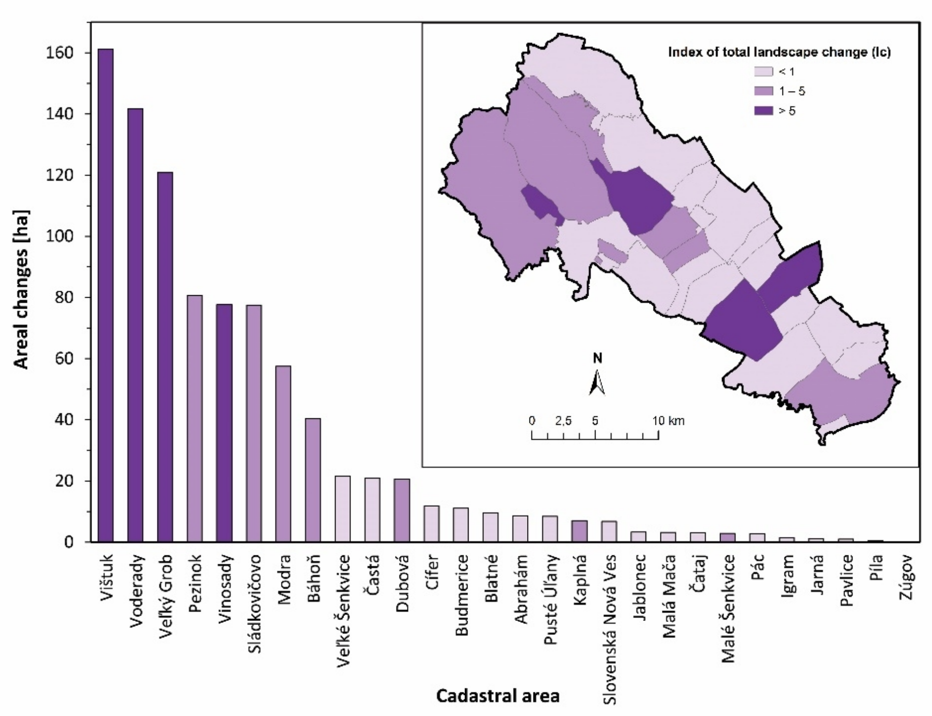

***Fig. 6**. The values of the index of total landscape change in 2006 – 2016, presented on the map and areal changes in 2006 – 2016, presented on the graph. The colours of the columns in the graph correspond to the map legend; Source: Authors' calculations and elaboration*

The values of the index of landscape change in particular time periods indicate differences and a gradual appearance of major changes. In Voderady, the greatest changes occurred in the period of 2006 – 2010 (Ic = 9.41%). In Vištuk, the greatest changes took place in the period of 2010 – 2014 (Ic = 6.65%). A well-balanced, long-term process of changes in the course of ten years is observed in Vinosady, even though the area between 23 and 31 ha is concerned. A beginning of major changes in land types is indicated by a higher value of the index for the period of 2010 – 2014 in Báhoň (Ic = 3.6%).

The values of the index of landscape change (I_C) vary depending on the length of the evaluated period and the dynamics of the changes. Moravčíková (2008) evaluated the index of landscape change (I_C) for cadastral area Budmerice. The index amounted to 6.44%, while the average annual change index was 0.15%. In 2006 – 2016, no major changes in land types in Budmerice took place, and the total index of landscape change was low (0.37%), to which the average change index of 0.04% corresponds.

Within the functional urban region of Bratislava, Šveda (2010) evaluated the landscape change index for 2000 – 2008 in a comparable manner based on the analysis of data from the UHDP database. The author expressed the values of the index of landscape change graphically in four intervals. Based on the results of Šveda (2010), the index of change achieved higher values in the 3rd interval (5.01 – 10.00) in Dubová and Veľký Grob, while the values of the index were within the range of the 2nd interval (1.01 – 5.00) in Modra, Pezinok, Šenkvice, Vinosady and Vištuk. In other cadastral areas from the study area, the author evaluated the index of change in the first interval (0.00 – 1.00).

Comparing the data of Šveda (2010) with the values of the index of total landscape change in the study area in the period of 2006 – 2010 (Fig. 7), the differences are recorded for Dubová, Vinosady and Vištuk. In Dubová lower value of the index of change was calculated there, which indicates a certain attenuation of changes in given territory. On the contrary, in Vinosady and Vištuk the index of change increased to 3rd interval (5.01 – 10.00).

Within the functional urban region of Trnava (which is part of the study area), the intensity of change in the period 2000 – 2008 was quite low (Šveda and Vigašová 2010). Only in Voderady did the values of change index range in the second interval, while the authors evaluated the others (Cífer, Pavlice, Abrahám, Malá Mača) in the first interval. Comparing the data of Šveda and Vigašová (2010) with the values of the index of change in the study area in the period of 2006 – 2010 (Fig. 7), the differences are recorded for Voderady, where the value of the index of landscape changes increased (I_C = 10.02%).

Vavrouchová and Lepková (2013) evaluated the same index of landscape changes for 27 cadastral areas of the city of Brno and for 94 towns and municipalities within the territory of the city of Brno between 2001 and 2011, in the context of sub-urbanization processes. The index of change achieved a value between 0.1 and 10.3%, whereby only 30% of the cadastral areas achieved an index higher than 1%. Only five towns achieved a value higher than 5%, and just one of them slightly exceeds a value of 10%. Pursuant to the authors, the results of the analysis show that the recorded changes are not of any major intensity and that there is a slowdown in the sub-urbanization trend within the hinterland of Brno.

In the studied territory along Stoličný potok and Gidra, the index of change achieved low values, below 1% in sixteen cadastral areas of municipalities and towns (57%), and larger changes (over 5%) were observed in four cadastral areas, of which in two cases (Vinosady, Voderady) the value was higher than 10%.

When evaluating the index of landscape change, the acreage of cadastral areas and the extent of the change need to be taken into account as well, as also smaller area changes can result in a major share in the total change in smaller cadastral areas. One example is a small area of Vinosady, which based on the comparison of the values of the index of change in particular cadastral areas in 2006 – 2010 ranked third, and in terms of the areal extent of changes (in ha), ranked even seventh (Fig. 7).

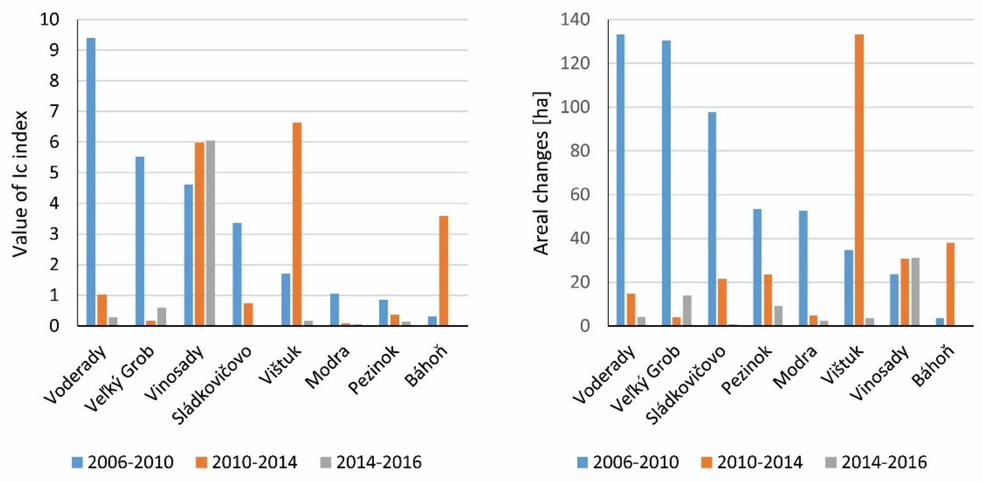

Fig. *7. The values of the index of total landscape change (left) in comparison with areal changes (right) in three time periods. Source; Authors' calculations*

Dominant processes

In terms of the impact of changes in land use on the functionality of biocorridors, the determination of dominant processes within the territory is crucial.

Based on the **index of dominant processes** (Fig. 8), the urbanization process takes place in twelve cadastral areas (43%), of which the most intensive is in Blatné (I_{DP} = 81.55%) and Slovenská Nová Ves (I_{DP} = 80.5%).

The process of forestation of medium intensity was recorded for Častá (I_{DP} = 54.8%) and Veľké Šenkvice (I_{DP} = 50.1%). The process of agricultural development of medium intensity was demonstrated in Vištuk (I_{DP} = 61.40%) in connection with a substantial increase in the area of vineyards, and in Jablonec (I_{DP} = 63.09%) in connection with an increase in the area of gardens by 1.7 ha.

The dominant share of other areas in the changes indicates unspecified dynamic processes in ten cadastral areas (36%), and it is the most intense in Báhoň (I_{DP} = 100%) and Sládkovičovo (I_{DP} = 90.5%).

In the case of dominance of other areas, or dominant processes of medium up to weak intensity, it is advisable to determine the second dominant process (I_{DP2}) as well for greater objectivity within the given territory. A well-balanced share of the process of urbanization including agricultural development were shown for example, in Čataj, where the size of built-up areas increased by 1.6 ha (I_{DP} = 54%) and gardens by 1.4 ha (I_{DP2} = 46%). In Veľké Šenkvice, a relatively balanced process of forestation (11 ha, I_{DP} = 51%) and urbanization (9.4 ha, I_{DP2} = 44%) is in progress. The urbanization and the growth of the size of other areas comprise two most important processes in ten cadastral areas (36%). In the case of evaluation of the index of dominant processes, in order to express the highest percentage share of changes in positive changes in land types, it is necessary to consider the areal extent of changes as well, similarly to the index of total landscape change (I_C).

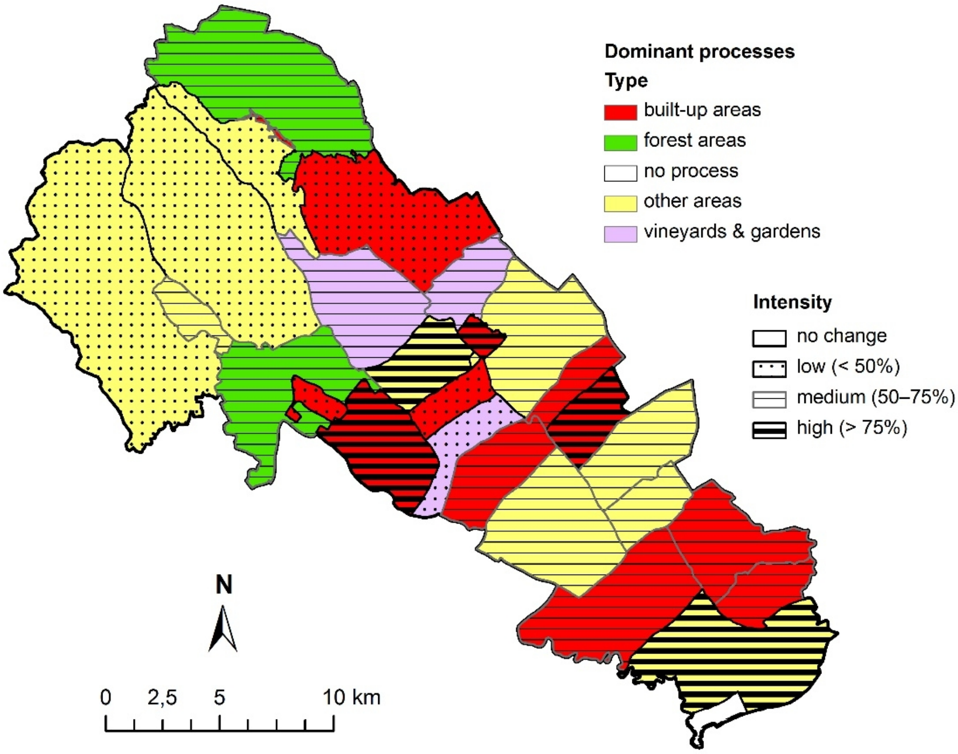

Fig. 8. *Dominant processes and their intensity within the cadastral areas in 2006 – 2016; Source: Authors' calculations and elaboration*

Landscape-ecologically significant processes

Given the focus of this paper, we also established the **index of landscape-ecologically significant processes (I_{LE}),** whereby the index expresses a share of ecologically important land types in the total land types growth in given cadastral areas in given period.

The landscape-ecologically significant processes were of a medium intensity (I_{LE} = 50 – 74.9%), in conformity with the dominant processes of forestation and agricultural development in four cadastral areas (Fig. 9). The lower share (I_{LE} = 25 – 49.9%) of landscape-ecologically significant processes was shown in ten cadastral areas, including the territories where the urbanization process is dominant.

In connection with the localization of nature protected areas, the medium share of landscape-ecologically significant processes in the changes of land types in Častá and Modra (PLA Malé Karpaty), Veľké Šenkvice (SKUEV0089 Martinský les) and Budmerice (SKUEV0174 Lindava) is positive. The extension of the area of meadows and pastures (permanent grasslands), and notable values of the index (25 – 49.9%) were demonstrated in the territory (Veľký Grob, Pác, Igram, Čataj, Abrahám and Malá Mača) to which the wetlands of SKCHVU023 Úľanská mokraď stretch.

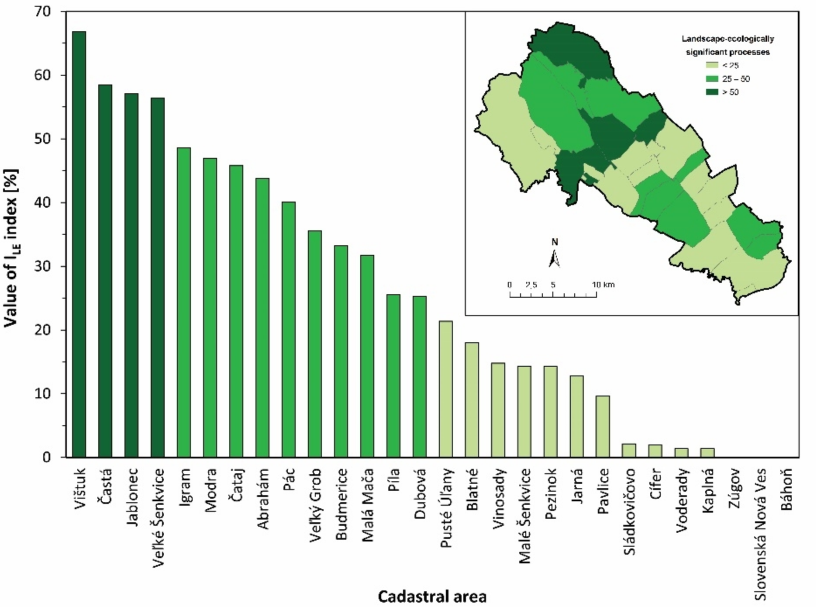

Fig. 9. *The values of the index of landscape-ecologically significant processes (I_{LE}) in 2006 – 2016, presented on the graph and the map. The colours of the columns in the graph correspond to the map legend; Source: Authors' calculations and elaboration*

Ecological quality of landscape

Changes in the land types in a majority of cadastral areas are reflected in the values of the **coefficient of ecological quality (Ks)** for the years 2006, 2010 and 2016 to a minimum extent only. Therefore, average values of the coefficient (Ks) are mentioned here. In 28 evaluated cadastral areas, Ks for the years of 2006, 2010, 2014 and 2016 achieved average values ranging from 0.15 (spatial structure of land of the lowest quality) to 0.81 (spatial structure of land of the highest quality). A slight increase in the values of Ks was recorded for cadastral areas where land types with a higher rate of landscape-ecological importance (kpi) extended to a larger area. In Častá, the size of forest areas increased (11.5 ha), and in Dubová, forest areas (1.9 ha) as well as gardens (2.8 ha) were added.

The studied territory is substantially differentiated by the values of the average Ks (Fig. 10). The highest value of Ks (0.81) is calculated for Častá at the foothill of the Malé Karpaty Mts., where the woodland areas with a high rate of landscape-ecological importance (kpi = 1) account for 74.7% of the cadastral area. Three cadastral areas at the foothill of the Malé Karpaty Mts. (Dubová, Pezinok, Modra,) with a larger share of forest areas and other ecologically important areas (such as permanent grasslands, vineyards, orchards, gardens and water bodies) show a medium spatial quality (Ks = 0.61 – 0.80) of the land structure.

The values of Ks indicate the spatial structure of landscape of lower quality (Ks = 0.31 – 0.60) in four cadastral areas in the transitional area between the Malé Karpaty Mts. and Trnavská pahorkatina upland. The spatial structure of landscape of the lowest quality (Ks < 0.30) was determined for 20 cadastral areas in Trnavská pahorkatina upland, also due to a high share of arable land (kpi = 0.15). After 2006, the ecological quality of landscape slightly improves only in Vištuk and Jablonec, while deterioration is recorded for eight cadastral areas (29%). In the other eighteen cadastral areas (68%), the values of Ks are well-balanced or they vary slightly.

In several cadastral areas, a substantial change in the land types occurred in favour of other areas, which have a low rate of landscape-ecological importance (kpi = 0.15). It probably concerns an average value, as these include areas of zero, low and high landscape-ecological importance.

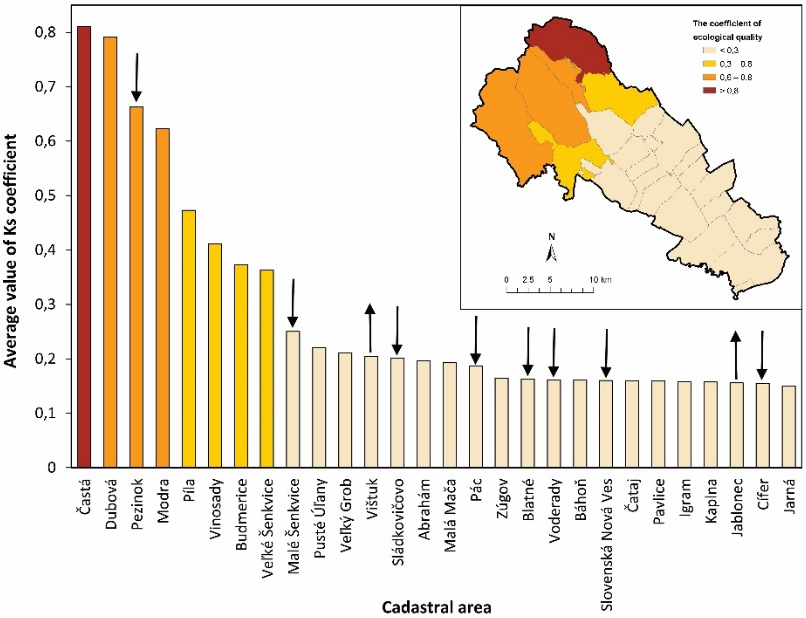

***Fig. 10**. The average coefficient of landscape-ecological quality (Ks) for the years 2006, 2010, 2014 and 2016, presented on the graph and the map (arrows indicate the trend of increase/decrease of the coefficient values). The colours of the columns in the graph correspond to the map legend; Source: Authors' calculations and elaboration*

In accordance with the Decree of the Geodesy, Cartography and Cadastral Authority of the Slovak Republic (ÚGKK SR) No 79/1996 Coll., and the implementation of the Act of the National Council of the Slovak Republic regarding the real estate cadastre and entering of ownership and other rights related to real estate (the Cadastral Act), the other areas also include mixed areas. The other areas comprise areas of a low landscape-ecological importance, such as storing and workshop premises, heaps at mines, silage pits, paved pens for poultry, stock, pigs etc.

On the other hand, the other areas also include landscape-ecologically more important areas such as nature reserves or other areas protected under relevant regulations; areas of cultural monuments provided that no agricultural activities are carried out there or they are not classified as woodland areas; parks; public, private decorative gardens; peat-lands, gravel pits, clay pits, quarries, devastated land and cemeteries; land that cannot be agriculturally used such as gorges, ravines, high balks with shrubs or rocks, protection levees, berms of regulated watercourses, and land that cannot be permanently used for any other reasons, such as areas overgrown with shrubs, or washed-on with gravel or rocks, or moorlands, i.e. areas wet or overgrown with peat moss.

Change of landscape in the study area did not cause any significant improvement of the landscape ecological quality because changes were reflected mainly in a decrease of the area of arable land and an increase in other areas, namely land types with the same rate of landscape-ecological importance (kpi = 0.15), which enters into the calculation of the coefficient of ecological quality (Ks). A slight downward trend in the value of Ks was reflected in seven villages and towns with a low-quality landscape, and in one cadastral area of Pezinok with a medium quality of landscape.

The coefficient of ecological quality was used by Miklós and Špinerová (2011) to evaluate the ecological quality in the river basin of Ilijský potok, where the coefficient achieved values ranging between 0.06 and 0.98, which is even a bigger dispersion than in the case of the study area of the basins of Stoličný potok and Gidra.

Urbanisation and territorial planning

The results of the analyses along the hydric biocorridors Stoličný potok and Gidra streams, with inflows in the wider hinterland of the cities Bratislava and Trnava, suggest a trend of development and urbanization. An increase in built-up areas by a total of 161 ha more or less was felt throughout the area; urbanization process is dominant in twelve cadastral areas, which make up 28% of the territory. Intensive trend of urbanization is most pronounced in the attractive area of the foothills of the Malé Karpaty Mts. (Pezinok and Vinosady) and in villages in the Trnavská pahorkatina upland (e.g. Voderady) near the highway D1, or in the north-eastern development direction of Bratislava, which is in harmony with the results of Šveda and Vigašová (2010). The values of the index of changes indicate significant changes (over 1%) in eleven cadastral areas, which make up 51% of the area of interest. In terms of acreage, the greater changes have taken place in the municipalities along the Stoličný potok stream, thus closer to Bratislava. In the future, we can expect the continuation of the trend, as shown by the significant growth of the other areas (about 461 ha).

According to Tóth and Šveda (2014), the period 2007 – 2012 brought an unprecedented boom of suburbanization in the hinterland of Bratislava, not only adjacent to Bratislava, but also in more distant locations and its intense manifestations extend up to 30 – 35 km from Bratislava. According to Ouředníček (2003), suburbanization cannot be seen only as population growth in the hinterland of cities, as well as changes in land use, architecture and infrastructure, but also as a significant change in the social structure of the population.

The trend of expanding built-up areas in the assessed area was largely reflected close to hydric biocorridors; construction of houses, industrial buildings and recreation complex in many cases were carried out and planned in close proximity to water courses. According to territorial planning documentation (and related amendments and supplements) of municipalities through which the Stoličný potok and Gidra streams and their tributaries flow, this trend will continue in the future (Ružičková et al. 2015). What's more important is the protection and restoration of the network of biocorridors and biocenters in order to maintain or restore their functionality and continuity.

Several obligatory regulations have been proposed in territorial plans of municipalities with the aim to improve the quality of waterside undergrowth and the ecological quality of the landscape in the vicinity of hydric biocorridors. For example, in the city plan of Sládkovičovo (Žalman et al. 2010), it is mandatory for regional biocorridors to have a minimum width of 40 – 50 m. In the territorial plan of Budmerice (Dudášová et al. 2014), width parameters were determined for the regional biocorridor RBk Gidra – 20 m on each side of the axis of the stream i.e. 40 m. In the obligatory part of the territorial plan of Šenkvice (Dudášová et al. 2008), several principles and conditions are formulated in relation to the hydric biocorridors to protect them from barrier elements, fencing, and building projects near the streams. Given regulations can be assessed as positive in order to maintain the functionality of biocorridors, but should be applied in practice.

Based on the analyses of existing territorial planning documentation, in order to maintain the continuity and functionality of hydric biocorridors, a proposal for hydric biocorridors and biocenters was developed (Ružičková et al. 2015). The most valuable natural elements and line communities, selected biocenters and biocorridors should be protected in the form of protected landscape elements, or protected areas.

Conclusions

The trend of landscape changes in 28 cadastral areas of municipalities along the Stoličný potok and Gidra streams with their tributaries was investigated. For the analyses of lots development in the period 2006 – 2016, data from the database of Aggregate Areas of Land Types (UHDP) were used. The dynamics of landscape processes were evaluated using the following indexes: the index of total landscape change (I_C), the index of dominant processes (I_{DP}), and the coefficient of ecological quality (K_S). We also applied the new index of landscape-ecologically significant processes (I_{LE}). The most significant decrease was recorded for the area of arable land (decrease of 602 ha); a less significant decrease occurred in the area of orchards, permanent grasslands and water bodies. On the other hand, a substantial increase in built-up areas (about 161.4 ha) and other areas (about 461 ha) was found. The index of total landscape change in the period of 2006 – 2016 ranged between 0 and 15%. Changes over 5% were observed in four cadastral areas. Based on the index of dominant processes, the urbanization process takes place in twelve cadastral areas (43%). The landscape-ecologically significant processes were of a medium intensity in four cadastral areas, in conformity with the dominant processes of forestation and agricultural development.

A noticeable increase in the acreage of the landscape-ecologically significant areas in the north-western part of the study area within the reach of PLA Malé Karpaty and SKUEV0089 Martinský les forest was recorded; but also in some municipalities dominated the urbanization process (Igram, Čataj), which can be considered as a positive trend.

The study area is sharply differentiated by the values of the coefficient of ecological quality of the landscape. In the Malé Karpaty Mts. and their foothills, the coefficient Ks is of medium and high ecological quality and in the Trnavská pahorkatina upland, low quality of landscape structure was found.

The analyses suggest a trend of urbanization and suburbanisation, which is more significant in the cadastral areas along Stoličný potok stream. The trend of expansion of built-up areas in the assessed territory was largely reflected just near watercourses, which may affect the functionality and continuity of hydric biocorridors. Therefore, it is necessary to respect obligatory regulations, formulated in the territorial plans within the area of interest related to biocorridors and elements of territorial systems of ecological stability (ecological network). The most valuable sections of hydric biocorridors and biocenters should be granted in the form of legislative protection of protected landscape elements or protected areas.

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