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LAND USE CHANGES OF THE RIPARIAN LANDSCAPE IN HUNGARY BETWEEN 1990 AND 2018

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Abstract
The protection and the restoration of rivers is one of the most important challenges of our time, due to the impact of human activities. The aim of the research was to assess the land use changes in the Hungarian riparian landscape. Several landscape corridors of different (50-100-300-500 m) widths near rivers were analyzed since 1990, using the CORINE Land Cover database. Positive changes in the land use of riparian landscape can be seen: continuous increase in the case of forest areas; and slight decrease in the extent of agricultural land since 1990. Unfortunately, the extent of grasslands and other near-natural areas is reduced; and there has been a steady increase in built-up areas. Examining the changes in built-up areas in more detail, a big increase is shown by the extent of urban green areas. As a continuation of the research, an evaluation methodology is being developed to determine the restoration potential of urban rivers on study area level and on national level. The results presented in this paper on land use changes and land use conditions can be useful for the research about restoration potential at national level.

Keywords: CORINE Land Cover, change assessment, river, floodplain

1. Introduction

River protection and restoration is an important challenge in our days, due to the impact of human activities such as river regulation, increased of built-up areas, or the adverse effects of climate change (Stein et al. 2002, Nagy and Novák 2004, Bozó 2010). The condition of the rivers is also affected by the land use / land cover of the riparian areas, so the study of land uses can be used as an indicator of the condition of the riparian landscapes. Numerous studies have recognized that river ecosystems are strongly influenced by land use / land cover characteristics (Jovanovska et al. 2018). The effects of urban land use include, such as hydrological changes due to impervious surfaces, an increase in pollution by runoff, or a decrease in canal and habitat complexity. Agricultural land uses also have a number of negative effects on the state of rivers, including by increasing diffuse pollution or changing vegetation along the rivers (Guida-Johnson and Zuleta 2019).

The importance of analyzing riparian land uses is also underlined by the fact that it is used as an indicator in a number of studies that assess the condition or restoration potential of rivers. To assess the condition of rivers, for example, Meng et al. (2009) or Guida-Johnson and Zuleta (2019) considered land use as an indicator related to human activities to determine their effects. Saha et al. (2020) used land uses to assess the ecological quality of the riparian zone of a small river, while Hajdukiewicz et al. (2017) took land uses into account to assess the hydromorphological quality of rivers in the riparian zone or floodplain. The German River habitat assessment (Kamp et al. 2007) evaluates the differences between the current status and the reference status, including through land uses. There are a number of studies that, in addition to river condition assessment, aim to determine the restoration potential of rivers or to prioritize potential areas for restoration. Hein et al. (2016) examined land uses as an element to identify potential sites for floodplain restoration. Comín et al. (2018) took land uses into account in the ecosystem service-based assessment of identifying and prioritizing areas for ecological restoration, while Fan et al. (2018) in addition to the biological and physico-chemical status, used land uses for assessment as part of the SWAT model. As part of determining habitat restoration potential, land use was considered by Francis et al. (2008), among other indicators suitable for assessing the qualitative and spatial characteristics of habitats and factors influencing habitat development. To determine and prioritize restoration sites for riverine wetlands, O'Neill et al. (1997), Russell et al. (1997), White and Fennessy (2005) Zhang et al. (2015), also examined land uses.

There are several methods for examining land use and land cover. On a larger scale, the CORINE Land Cover (CLC) database is a frequently used tool. In Hungary, several researches have used this analysis, for example, Kertész et al. (2019) used the CORINE database on catchment scale to examine land use impacts on ecosystem services. Cegielska et al. (2018) used the CORINE database on a level of provinces/counties during the analysis and comparison of land use changes in a Hungarian and a Polish study area. On a national scale CORINE database was used for example by Waltner et al. (2020) to assess soil erosion potential. Szilassi (2015, 2017) analyzed the land use changes of the whole country.

There are several studies about riparian zone analyses with remote sensing techniques or open data repositories (Rusnák et al. 2022). A big challenge is to understand the functioning of riparian areas in an integrative way, which highlight the need to gather information about the characteristics of these areas (Dufour et al. 2018). The analyses of land cover and its changes can be used for example to detect the effects of flood events, to trace the coevolution of river channels and riparian forests, to detect the effects of floodplain embankment or to establish spatial priorities for conservation and restoration. CORINE database is one of the open data repositories and can be used in riparian zone assasment. Fiedler (2021) analyzed the impact of the land use on the river's water quality (nutrients and selected metals) with CLC data. Şandric et al (2019) customised an index to estimate water quality based on CORINE database to quantifying the potential of pollution. Jovanovska et al. (2018) assessed the integrity of streams in Bregalnica River Basin which was interpreted from available remotely sensed data sources, including CLC 2012. Clerici et al (2013) characterized the land-cover types of stream riparian zones based on Corine Land Cover 2000 data. Lieb and Sulzer (2019) also used the CORINE database to analyze the current land use and its changes in the Drava River Basin. They examined the land use changes in the light of the physical-geographical, historical background. They also covered the connections between land use change and environmental problems, nature conservation.

According to the National Landscape Strategy of Hungary (NLS, 2017) in the last two centuries, significant economic, social and geopolitical changes have taken place in

Hungary as well, which have greatly changed the utilization, functions and land cover of the areas (NLS, 2017). Among the nationwide processes, it can be emphasized that in the first third of the 20th century, uncultivated land (including urban areas) barely exceeded 6% of the country's territory, but from 1990 to the present it increased from 11% to 22%, mainly at the expense of grasslands, gardens, vineyards, fruit plantations and arable lands. Despite the steady decline in the population, the proportion of area set aside from cultivation is growing significantly. Settlements expanding toward rivers, houses within flood embankments impair flood drainage, and the protection of these parts of settlements during floods requires extraordinary effort, sometimes far exceeding the saved values (NLS, 2017).

In Hungary, the most significant changes in the riparian landscapes date back to the 18th and 19th centuries, with the completion of the main river regulation works. Subsequently, from the 19th century - but typically from the second half of the 20th century - water and waterside uses were also increasingly transformed. Water-independent land uses have emerged and the proportion of areas occupied by settlements or infrastructure in watercourse landscapes has increased (Báthoryné Nagy 2009). These unfavorably affect the flow, channel dynamics, flood levels, flood storage capacity, ecological functions, aquatic and riparian ecosystems, water quality and aesthetic value of watercourses (Kauffman et al. 1997, Nagy and Novák 2004, Bernhardt and Palmer 2007).

The aim of the present study was to examine the changes in land use and the main reasons for the changes in the Hungarian riparian landscape, and to compare them with the national trends.

2. Material and Methods

To explore the land use characteristics of riparian landscapes in Hungary, studies at national level were conducted. For the

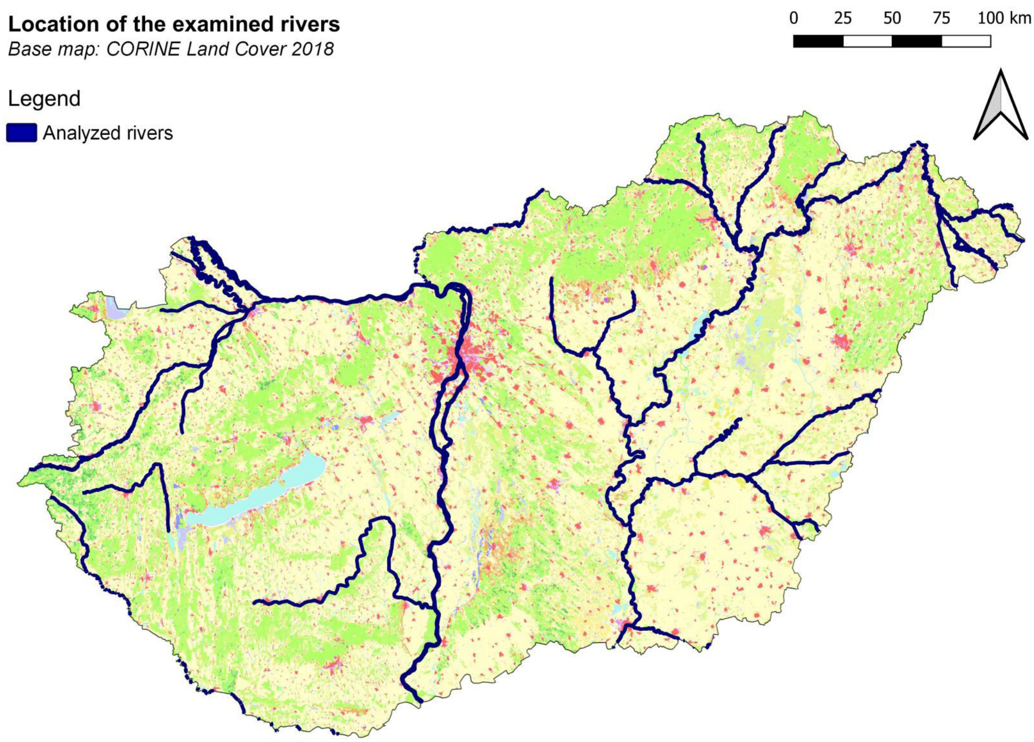

Fig. 1. Location of the examined rivers in Hungary

Table 1. Grouping of CORINE land cover categories examined during the research

Class	CORINE code	CORINE category
Built-up areas	111	Continuous urban fabric
	112	Discontinuous urban fabric
	121	Industrial or commercial units
	122	Road and rail networks and associated land
	123	Port areas
	141	Green urban areas
	142	Sport and leisure facilities
Disturbed surfaces	131	Mineral extraction sites
	132	Dump sites
	133	Construction sites
Agricultural and horticultural areas	211	Non-irrigated arable land
	213	Rice fields
	221	Vineyards
	222	Fruit trees and berry plantations
	242	Complex cultivation patterns
	243	Land principally occupied by agriculture, with significant areas of natural vegetation
Grasslands	231	Pastures
	321	Natural grassland
Forest areas	311	Broad-leaved forest
	312	Coniferous forest
	313	Mixed forest
	324	Transitional woodland/shrub
Other semi-natural areas	331	Beaches, dunes, sands
	411	Inland marshes
	412	Peatbogs
	511	Water courses*
	512	Water bodies

* Often riverside forest / grassland, waterlogged areas are included

studies, the CORINE land cover (CLC) database was used from the years 1990, /, 2006, 2012 and 2018. For the GIS map of rivers, we used the map of the waterbodies of the Hungarian watercourses provided by the General Directorate of Water Management as a base data, from which the rivers were manually selected (watercourses which has ‘river’ water management classification in the Danube River Basin Management Plan (2021), and watercourses which are classified as rivers in the Act CXCVI of 2011 on National Assets) (Dévai et al. 1998, Nagy 2013) - Figure 1. The width of the rivers was given by the data of the CORINE 2018 watercourse layer (in the case of large rivers) and the watercourse width data of the third Hungarian River Basin management plan (for small and medium rivers, as these do not appear on the CORINE watercourse layer or the floodplain is also included). Then the width of the watercourses was extracted from the CORINE layers and continued to work with the resulting layers.

The CORINE land cover categories of the landscape corridors along the Hungarian rivers were divided into the groups summarized in Table 1. The category of 'water courses' in the CORINE database did not completely overlap with the watercourse layer we used as a base data, as the CORINE water courses layer often includes areas that are river floodplains (most often mixed forest / grassland). For this reason, the areas of CORINE water courses that were outside the watercourse boundary were classified in the group of other semi-natural areas in our studies. Among the aggregated groups, the categories classified as built-up areas were examined in more detail in order to analyze which category's change in the proportion of built-up areas is most typical in Hungary along rivers.

The land cover changes were examined in landscape corridors of different widths, so differences can be seen in the processes of each landscape corridor. In the study 50 m, 100 m, 300 m and 500 m buffer areas (landscape corridors) were created with Quantum GIS 3.16.6. software and examined along rivers, the width of which was determined based on literature research (e.g. 50 m - Ahn and Kim (2017); 100 m - Kamp et al. (2007), 500 m - Saha (2020), supplemented by an intermediate-width 300 m corridor). The landscape corridors were intersected with the CORINE land cover categories. The analyses were performed also with the help of QGis 3.16.6. software, in which statistics by categories for each year and landscape corridor were compiled to examine changes in land use.

3. Results

The land use changes of the studied landscape corridors along the rivers are summarized in Table 2, based on the CORINE land cover database. The trend of changes between 1990 and 2018 is presented, and compared with the extent of changes in the whole country.

Based on the results, since 1990, there has been a steady increase in built-up areas along rivers (Fig. 2) in all studied landscape corridors. Between 1990 and 2018, the extent of built-up areas increased by almost 10% of all studied landscape corridors. This is less than the increase in built-up areas of the entire country, which was 14% between 1990 and 2018.

The extent of the disturbed surfaces is characterized by an almost continuous decrease, however, between 2012 and 2018 their extent increased minimally in all studied landscape corridors, mainly away from the rivers. The largest decrease occurred in the 50 m corridor of rivers, whereby 2018 the extent had become almost a quarter of the extent compared to 1990.

The extent of agricultural and horticultural areas is characterized by a slight but continuous decrease, although their extent was stagnated between 2012 and 2018 (change of less than 1%). Nationwide, approx. a decrease of 5% is typical, compared to which it can be considered positive that a slightly larger decrease can be seen near the rivers, approx. 7-8% in the 50 and 100 m landscape corridors. Further from the rivers, the decline is closer to the national average (6-7%).

Since 1990, there has also been a steady increase in forest areas, most of which are found in narrower landscape corridors along rivers, and their area proportion decreases more away from rivers (Fig. 3). The increase can be seen in all the studied landscape corridors, but their extent stagnates (increase of less than 1%) between 2012 and 2018. There has been an 11-12% increase since 1990 in each examined landscape corridor, which is broadly in line with the national trend (10% increase).

Grasslands and other semi-natural areas have a changing trend but overall, there has been a decline between 1990 and 2018.

Examining the riparian corridors, it can be seen that the proportion of grasslands is almost the same in all the studied landscape corridors, while the proportion of other semi-natural areas decreases significantly away from the rivers (Fig. 3). The extent of grasslands increased between 1990 and 2000, but has been declining since then, in all landscape corridors. Overall, since 1990, their area has declined by nearly 3-4%. This decrease is not observed nationwide, the area of grasslands increased by almost 2% in the whole country between 1990 and 2018. Overall, there is also a declining trend in the case of other semi-natural areas, with the difference that there was a slight increase in the 300 and 500 m landscape corridors between 2000 and 2006/2012, but has been declining again since then.

The characteristics of changes in built-up areas were examined in more detail since 1990, the results of which are shown in Table 3. Based on the results, it can be considered positive that although occupying a small area overall, the largest increase is shown by the extent of urban green areas among the land cover categories related to built-up areas in the 50, 100 and 300 m riparian corridors (Figs. 4 and 5). Their extent has increased by about 55-64% since 1990 in these landscape corridors. Their smaller but significant increase can be seen in the wider corridors of the rivers (30% in the 300 m band, 17% in the 500 m corridor), while nationally their extent has almost not changed between 1990 and 2018. These processes also show the potential and importance of rivers in the urban green space system.

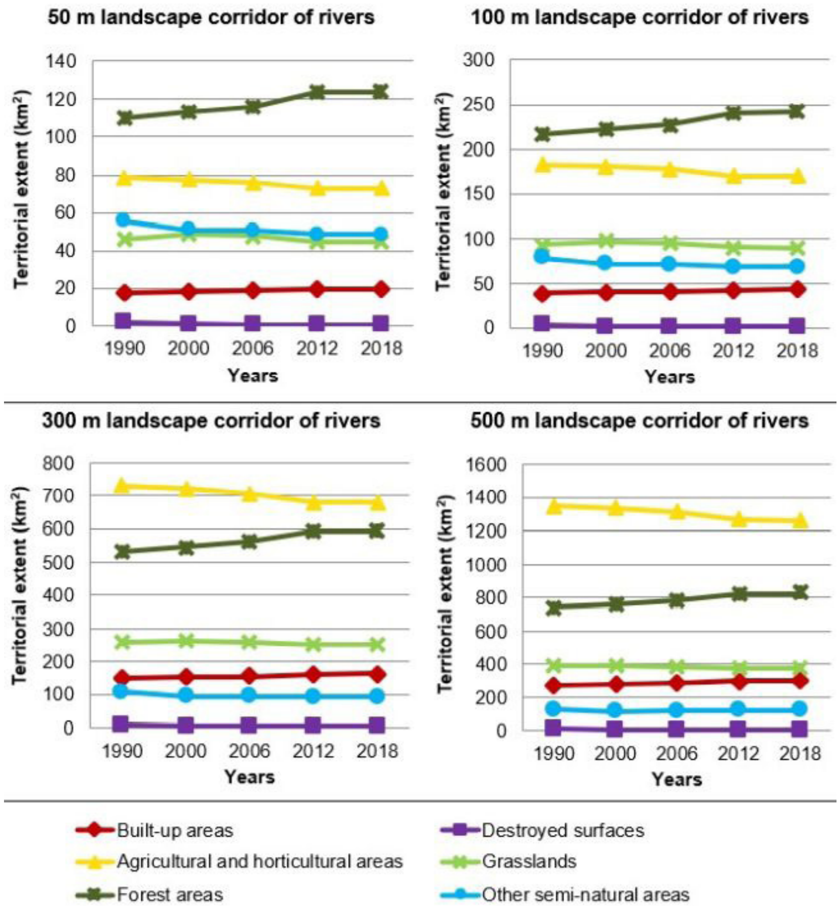

Fig. 2. Land cover change in 50-100-300-500 m landscape corridors along Hungarian rivers

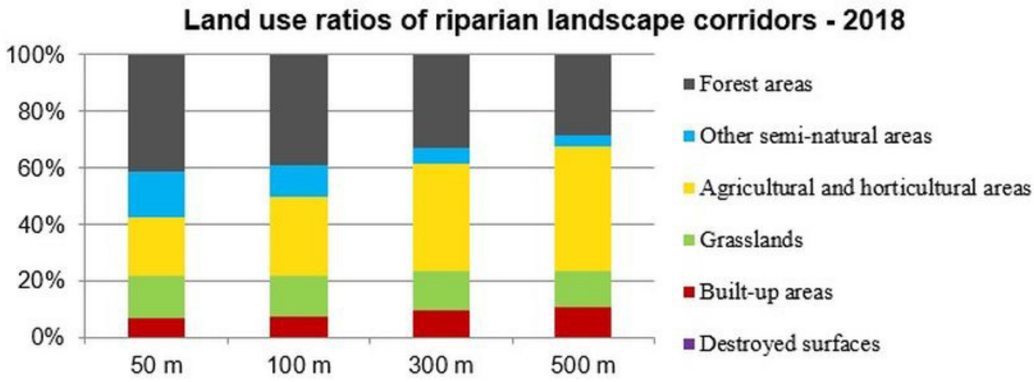

Fig. 3. Land use ratios of riparian landscape corridors based on CORINE database 2018

Sports, leisure and recreational areas occupy significant areas in narrower landscapes corridors along rivers (more away from the river, their area ratio decreases – Fig.5). In the 50 m corridor of the rivers, their area proportion is almost 20%, but even in the 100 m area they make up almost 19% of the area. Overall, their extent has shown an increase since 1990 (12-15%), which is similar to the national trends (about 13% increase). There was a small decrease between 2006 and 2012, but since then a small increase can be seen again.

Since 1990, there has been a steady increase in discontinuous urban areas, the proportion of which has been increasing in the wider landscape corridors (Fig. 5). These areas show slightly smaller growth in narrower landscape corridors than the national trend (6-7% in the 50-100 m corridor of rivers, while nationally 9%). Continuous urban areas are characterized by a decrease between 1990 and 2000, and since then they have shown an increasing trend, but they are still present in almost 24-33% less proportion in the riparian landscape corridors than in 1990.

There has also been an increase in the extent of industrial or commercial areas along rivers since 1990, although their extent has been more or less stagnant since 2012 (less than 1% decrease) in the narrower 50 m and 100 m landscape corridors. Growth in industrial or commercial areas is higher in the 300 and 500 m landscape corridors (18-20%), but even in these zones there is not as much growth as nationwide since 1990 (50%).

Road and rail networks, associated areas and ports have been declining between 1990 and 2006, and have been on an increasing trend since then. The increase of road and rail networks, associated areas are 15-18% in the 50 and 100 m river corridors, and 27-41% in the 300 and 500 m corridors. However, this

Table 2. Rate of land cover changes in Hungarian riparian corridors

Land use class	Rate of change 1990-2018 (%)				
	50 m corridor	100 m corridor	300 m corridor	500 m corridor	National average
Built-up areas	110	110	110	110	114
Disturbed surfaces	26	32	54	70	136
Agricultural, horticultural areas	93	93	93	94	94
Grasslands	97	97	97	96	102
Forest areas	112	112	111	111	113
Other semi-natural areas	88	87	86	94	96

* Meaning of colors: increase, decrease

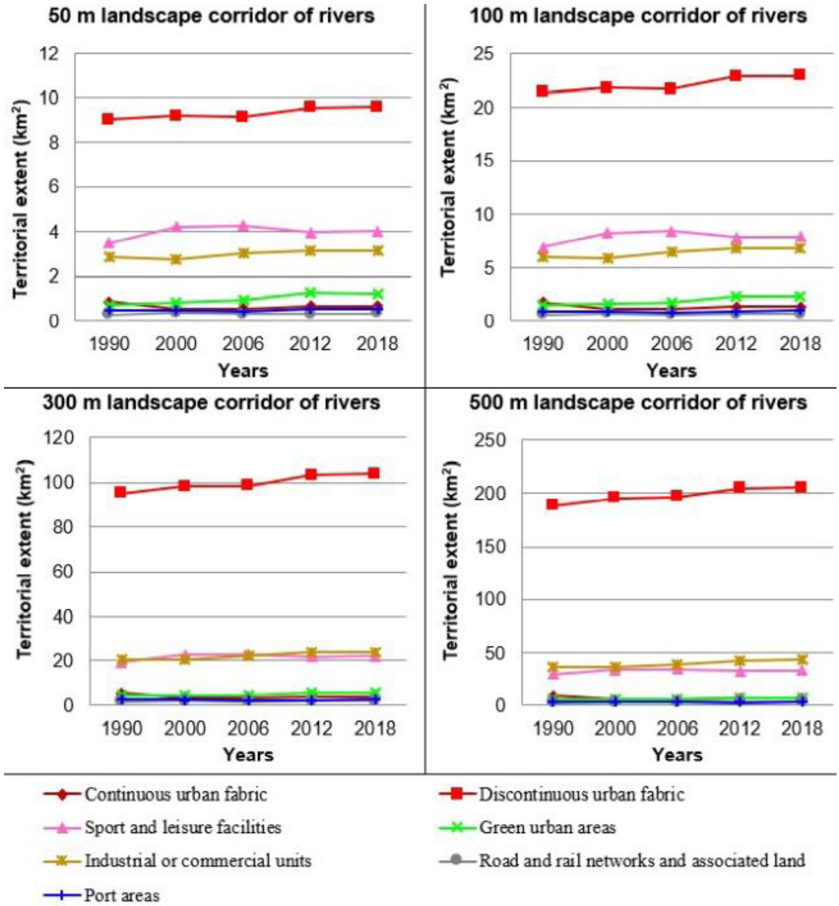

Fig. 4. Changes in built-up areas in 50-100-300-500 m landscape corridors along Hungarian

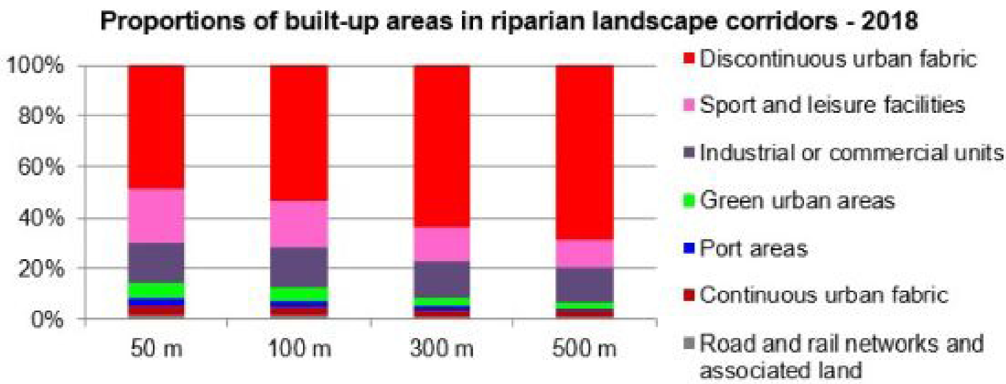

Fig. 5. Proportions of built-up areas in riparian landscape corridors based on CORINE database 2018

growth still lags behind the national average: between 1990 and 2018, the area covered by the road and rail network tripled.

Table 2. Rate of land cover changes in Hungarian riparian corridors

Land use class	Rate of change 1990 - 2018 (%)				
	50 m corridor	100 m corridor	300 m corridor	500 m corridor	National average
Continuous urban fabric	76	76	74	67	71
Discontinuous urban fabric	106	107	109	111	109
Sport and leisure facilities	115	115	114	104	112
Green urban areas	164	156	130	117	118
Industrial or commercial units	110	113	118	121	120
Road and rail networks and associated land	118	115	127	133	141
Port areas	114	111	102	88	92
Together	110	110	110	110	114

* Meaning of colors: increase, decrease

4. Discussion

Based on the results of the study, it became possible to present the differences in the land use of corridors with different widths along Hungarian rivers, as well as the changes in land use between 1990 and 2018. It can be concluded from the results that the extent of agricultural and horticultural areas in the Hungarian riparian landscape is characterized by a larger decline than the national rate, especially in narrower landscape corridors along rivers, which can be considered positive, taking into account the adverse effects of these areas on watercourses. For example, Fielder (2021) found that agricultural lands adjacent to rivers has a significant effect on sediment quality. Based on Lieb and Sulzer (2019) research, the Hungarian part of the Drava Basin represents intensive changes in the case of agricultural areas between 1990 and 2012, however the article did not address what kind of changes. According to them the changes can be a consequences of the agricultural transformation after the political changes in 1989. The reason of the decrease can be that due to the implementation of different investments nationally, approx. 50-70 km^2 areas are permanently set aside from agricultural cultivation, although there is a significant number of disused or under-used areas that may be suitable for development (NVS, 2012). Szilassi (2017) has also stated

Fig. 6. Transformation of agricultural area into a built-up area – River Lajta in Mosonmagyaróvár, Hungary

that the abandonment of agricultural land from cultivation represents a significant territorial proportion in the land use changes of the country. The abandonment of cultivation since the accession to the EU in 2004 has been influenced by external agricultural support systems and other economic processes. In the riparian landscape, on the basis of the GIS surveys, in addition to the built-up areas (Fig. 6.), forest areas were also established in place of agricultural and horticultural areas.

Another positive change in the last 30 years is the increase in forest areas, which is in line with national trends in riparian areas. Fuente et al. (2018) found that the riparian forests are an important part of the connections between Natura 2000 woodland habitats in Spain. The riparian forests in Hungary are the part of the National Ecological Network in almost all cases, therefore, they can be considered important connecting elements here as well. The increase of forest areas has been experienced in Hungary since the first half of the 20th century (NLS, 2017). Their growth in recent decades has been due to afforestation and the spontaneous afforestation (Fig. 7.) of unutilized agricultural land according to the National Forest Strategy of Hungary (NFS, 2016). These processes can also be observed in riparian landscapes. Szilassi (2017) analyzed the change of the land cover pattern of the landscape units in Hungary, and has found that in the case of some landscape units along flood plain areas, the mosaic of the landscape has decreased. On these areas the average size of the land cover patches increased, the the land cover patches have "merged", that may be related to the increase in the extent of forest areas.

Despite the growth of forest areas, the decline in grasslands and other near-natural areas is unfavorable in the examined landscape corridors. The decrease is not observed nationwide where a small increase can be seen. Various funds contribute to this, such as the Decree 10/2015 (13 March) FM of the Minister of Agriculture, which promotes, among other things, the support for the conservation of permanent grasslands, but funds can also be used in Natura 2000 areas. However, despite the fact that all areas have to be preserved in the case of naturally sensitive (Natura 2000) grasslands, and they can only be broken up with the permission of the nature conservation authority (NLS, 2017), the extent of grasslands in the riparian landscape has decreased. Examining the changes territorially, the most typical process is the transformation of grasslands into forest areas or their involvement in arable farming (Fig. 8.). Szilassi (2015) has also found that the most common change in the case of grasslands on national scale is to transform into forest areas.

In the case of disturbed surfaces, the largest decrease occurred in the 50 m corridor of rivers. The rate of decline is decreasing away from rivers, which may also be related to nature conservation areas along rivers. The previously disturbed surfaces are now partly overgrown with grassland and

Fig. 7. Spontaneous afforestation in the former agricultural area– River Sajó near Sajóhídvég, Hungary

Fig. 8. Transformation of grassland areas into agricultural areas – River Szamos near Fehérgyarmat, Hungary

wooded floodplain vegetation and just partly become built-up areas.

In contrast to the national trends, the built-up areas are characterized by a smaller increase in the examined landscape corridors along the rivers, however, their extent still increased by about 10% in the studied zones. The landscape corridors along the rivers are often part of the river floodplain, i.e. the area between the river bank line and the main flood defense line, which limits the opportunities for construction in these areas. In addition, a significant part of Hungarian watercourses, such as rivers, are protected natural areas of national importance and 71.5% of all wetlands are part of the Natura 2000 network (NVS, 2017), which are likely to contributes to the fact that built-up areas closer to rivers have increased at a lower rate, than the national average.

The changes in built-up areas were examined more detailed in the research. Discontinuous urban areas have a steady increase in the landscape corridors. While the lower growth rate near rivers is positive, these areas increase despite the fact that there is no quantitative housing problem in relation to the population, so instead of further expansion of settlements, it would be an opportunity to renew the existing buildings. This may be due to internal migration processes, which are characterized by the depopulation of rural areas and the influx of population into large cities and agglomerations, all of which cause an increase in built-up areas (NLS, 2017). The continuous urban areas decreased since 1990, but it does not indicate the decrease of the built-up areas, just the transformation of the built-up areas, e.g. into discontinuous urban areas.

The industrial or commercial areas have increased in the examined landscape corridors, but with a lower rate than nationwide. The greater growth nationwide is likely due to the establishment and growth of industrial parks with significant territorial needs. Road and rail networks also have been increasing since 2006, which is partly due to European Union funds (Mészáros, 2019).

Within built-up areas, the highest growth rates are in the case of urban green spaces, which may be partly due to the river restorations implemented in recent decades. The proportions of urban green areas occupy a larger area in the narrower 50 and 100 m landscape corridors along the rivers than in the wider landscape corridors. That fact and the significant increase in their proportion since 1990 also shows the importance and potential of rivers in the green area system of the settlements.

As a continuation of the research, an evaluation methodology is being developed to determine the restoration potential of urban rivers. The evaluation is planned on several scales, in addition to the study area level, it is also planned to continue the research on a national level. Research on the study area level can use remote sensing techniques, which can present more detailed results for a smaller area. As Rusnák et al. (2022) highlighted, these methods are widely used for several aspects in the case of riparian zones, such as physical channel properties, morphology, canopy detection or riparian vegetation, among others. The results presented in this paper on land use changes and current land use conditions can be a useful part of further research at the national level.

5. Conclusion

The aim of the research was to analyze the land use and land cover characteristic and changes of the landscape corridors along the Hungarian rivers. There are researches about the land use change of Hungary (Szilassi 2015, 2017; Waltner et al. 2020), but the present research specifically focuses on riparian areas. After examining several landscape corridors along the rivers, the main findings were, that there are some positive changes in the land use, such as the decline of agricultural and horticultural areas, increase if forest areas. However, some negative changes can be seen too, for example the decline of grasslands and other near-natural areas. The built-up areas are still increasing, thought the increase is smaller than nationwide. Urban green spaces have a small extant near rivers, but the rate of the growth is the highest in built-up areas, which confirms that riparian areas are important elements of the urban green infrastructure system.

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