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SPATIAL TRENDS OF GRASSLAND CHANGES BASED ON HUNGARIAN LOCAL STUDIES AFTER 1990 WITH A MACRO-REGIONAL PERSPECTIVE

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Abstract: Grasslands contribute to the ecological diversity of our cultural landscapes. In the last centuries, the most important trend was a constant loss of this valuable asset due to urbanization and the intensification of cultivation. Studies focusing on grasslands are not so abundant, and especially analyses on the spatial trends of grasslands in Eastern-Central Europe are scarce. Focusing on Hungarian local studies, we analyze our results from a macro-regional perspective, with a draft study of the V4 countries (Slovakia, the Czech Republic, Hungary and Poland). The authors employed GIS and statistical methods to analyze data to explore trends of changes of grasslands in V4 countries, Hungary, and in three micro-regions of different landscape character. These include an open landscape, partly intensively cultivated (micro-region of Csorna), and two more diverse landscapes with different proportion of forests (micro-regions of Gönc and Veszprém). Our results show that very complex, sometimes opposite processes influence the area of grasslands. In spite of the fact that an increase in the area of grasslands is witnessed at both the national and the international level in absolute values, recently, unfavorable processes have started, and there are certain landscapes where grasslands are threatened especially natural grassland by forestation and grasslands where soil conditions are suitable for crop production. Our results showed that despite the different landscape conditions, the majority of grassland has been turned into arable land and into shrubs and forest area. The loss of pastures due to urban sprawl is a dominant process just around the built-up area of city of Veszprém in the most urbanized study area.

Keywords: grassland changes, spatial analysis, Central and Eastern Europe, Hungary

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Összefoglaló: A gyepterületek tájaink fontos ökológiai, esztétikai stb. értékét képviselik. Az elmúlt évszázadok során nagy arányban tűntek el a rétek, legelők köszönhetően az urbanizációs folyamatoknak és a mezőgazdaság intenzifikációjának. Viszonylag kevés kutatás irányult különösen a kelet-közép-európai gyepek területi változásaira. Jelen kutatás magyar vizsgálati területek mélyebb elemzésére fókuszál, egy makro-regionális megközelítés mellett, amely a Visegrádi Négyek (Szlovákia, Csehország, Magyarország és Lengyelország) folyamataira is kitekintést nyújt. Térinformatikai és statisztikai módszerekkel vizsgáltuk a V4 országok, Magyarország és részletesebben különböző táji adottságú, magyar vizsgálati területek folyamatait. A magyar területek között van egy síkvidéki terület, részben évszázadok óta intenzív mezőgazdasági művelés alatt (Csornai járás), továbbá két változatos domborzatú, viszonylag magas erdősültségű térség (Gönci és Veszprémi járások). Kutatási eredményeink azt mutatják, hogy nagyon komplex, néha egymással ellentétes folyamatok határozzák meg a gyepterületeket jellemző változásokat. Annak ellenére, hogy összességében növekedtek a gyepterületek nemzetközi és országos szinten, kedvezőtlen irányú folyamatok is megindultak főleg az ökológiai szempontból legértékesebb gyepterületeket illetően. Leginkább a gyepeket szántóvá alakították vagy cserjésedésnek indultak és beerdősültek. Városi növekedés cask a legurbanizáltabb vizsgálati területen, Veszprém térségében emésztett fel gyepterületeket.

Kulcsszavak: gyepterületek területi változásai, területi elemzés, Kelet és Közép-Európa, V4 országok, Magyarország

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Highlights

- Intensive changes in the grasslands took place in the 1990s, while the situation later stabilized.
- Different processes cause grassland changes such as intensification of cultivation, farm abandonment, urbanization.

- Afforestation due to land abandonment especially in mountainous areas and backward regions is a great threat for grasslands.
- Suburbanization, urban sprawl, construction of roads, opening mining sites impacted on the stay of grasslands.
- The grasslands of high natural value are threatened and have a constant decreasing trend.

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1. Introduction

Grasslands cover 20% of the global land surface (approx. 3.2 billion ha), and they are important to maintain human livelihood and keep ecological balance (Yang et al. 2020; Villoslada Pecina et.al., 2019). They are characteristic elements of landscapes all over the world. Meadows and pastures are of diverse origin; they can either be the result of human activity, or they can have a natural character. All types can be valuable natural ecosystems, e.g., the former one might be maintained by grazing or mowing, with native species (Tälle et al. 2015; Zarzycki et al. 2013). Grasslands (mainly of semi-natural or natural type) are among the richest ecosystems in the world, especially in Europe (Lark et al. 2020; Dahlström et al. 2013). They provide many ecosystem services, such as regulating (e.g., water flow regulation; pollination; soil erosion protection), provisioning (e.g., bioenergy production; source of food and forage); habitat (e.g., gene pool protection), and cultural services (e.g., aesthetic and recreational values) (Sala et al. 1997; Hönigová et al. 2012). Several research had the outcome that permanent grasslands contribute to the multifunctionality of cultural landscape and have higher levels of biodiversity and cultural values compared to forests, especially considering the indicators of threatened species and aesthetic value (Schils et.al., 2022).

Despite their importance, for many decades, they did not enjoy high priority in European nature conservation programs (Sala et al. 1997). Moreover, the Common Agricultural Policy (CAP) of the European Union (EU) used to promote intensive farming practices (Emanuelsson et al. 2008) causing several environmental conflicts, reduction of biodiversity, loss and fragmentation of landscape elements (Šálek et.al., 2018). Nowadays, the EU agro-environmental policy gives support to the member states for proper management of their grasslands with conservation purposes (Valkó et al. 2012). However, the effectiveness of such subsidies is questionable, as highlighted by several authors (Whittingham et al. 2007; Török et al. 2018). In reality, grasslands are still among the most endangered ecosystems in Europe and also worldwide (Carbutt et al. 2017; Babai et al. 2015).

The Common Agricultural Policy for period 2014–2020 included the definition of permanent and temporary grassland by the EC Regulation 1307/2013 as Greening element of CAP, with a regional level criterion to maintain these grasslands and not to reduce their area more than by 5%. The Go-Grass project has shown that in 2006–2009 period, there was a clear reduction of permanent grassland in Europe but later, it more or less stabilized maybe due to the CAP policy. Current research showed that CAP measures failed in moving farms towards more biodiversity-friendly farming (Concepción, 2020), causing further loss of biodiversity. Specifically, grassland (mostly permanent) suffered a predominant decrease, turned into different land uses including woody and annual crops or forest trees. Bürgi et al. in 2017 highlighted the fact that woodlands are expanding over large formerly grazed grasslands (Bürgi et al., 2017). The positive effects of agri-environment schemes (AES), promoting the application of nature-friendly farming practices, are limited because they are voluntary measures applied at the farm level (Batáry et al., 2015). Pardo et.al. suggested that CAP may have been successful in conserving existing landscape elements and connectivity features through Good Agricultural and Environmental Condition measures (Pardo et.al., 2020). Concepción and Díaz suggested that based on landscape context conservation targets should be established on regional level (Concepción and Díaz, 2019). Extensive farming methods would answer several environmental problems, unfortunately CAP tools still do not compensate farmers properly.

In the last 9 years in Western-Europe data has shown a decrease while in Eastern-Europe, an increase of permanent grassland (Mosquera-Losada et.al., 2019). Eurostat national level data shows in V4 countries,

a more or less stable area of permanent grasslands with the exception of Hungary where there was a drop before 2010 (Eurostat, 2021).

Globally, half of grasslands have been degraded by human activity (Yang et al. 2020). Three different trends can be observed related to land cover / land use processes that reduce the area of grasslands: (i) intensification of agriculture; (ii) land abandonment (causing succession and forestation) and (iii) expansion of human settlements into agricultural land (i.e., the urbanization of rural areas) (Tokarczyk et al. 2018; Monteiro et al. 2011). These processes have led to the decline of many ecosystem services, resulting in soil degradation, biodiversity loss, desertification, floods, and encroachment of forests and shrubs (Yang et al. 2020; Monteiro et al. 2011). In its report, the European Environment Agency highlighted the loss of approx. 1% of pastures and mosaics in 27 countries (EEA 2017) between 1990 and 2012.

Several surveys have been carried out to explore land use and land cover changes. There are simple, descriptive studies based on historical maps and satellite views, which help to understand the ongoing processes and foresee the future spatial structure; and there have been studies using landscape metrics assessing e.g., the naturalness and anthropogenic alteration or the level of fragmentation of the landscape (Szilassi et al. 2012; Demény et al. 2016). Studying driving forces of landscape change has a long tradition in geography and landscape research (Hersperger et al. 2007; Demény 2018).

Considering changes of grasslands, most of the research studies focused on specific areas as the Alps, the Carpathians or the Mediterranean (Griffiths et al. 2013; Monteiro et al. 2011; Zarzycki et al. 2020), on the loss of grassland due to farmland abandonment (Bagella et al. 2016), on the effects of different management types on biodiversity (Tälleet al. 2015; Valkó 2012) or on the effects of agro-environmental schemes in the frames of CAP (Villoslada et al. 2019). Several studies present a local level analysis of the changes of ecosystem services in specific areas (Tälleet al. 2015; Monteiro et al. 2011). However, till now, there are no comprehensive studies analyzing the spatial trends of grasslands, especially in the V4 countries (Slovakia, the Czech Republic, Hungary and Poland). In our study, we try to give a short macro-regional outlook, highlighting the major trends in V4 countries based on the common historical processes (Griffiths et al. 2013; Cegielska et al. 2018), but the focus of the paper is to give a deep analysis about the trends, directions, rate furthermore the cause of grassland changes in three Hungarian pilot regions.

This resulted in nationalization and. The centrally planned economies (Griffiths et al. 2013) changed the former system of agricultural production drastically based on individual farms – with the exception of Poland – to a centrally planned system of large-scale agricultural production (Gresková Kusková 2013), which in Hungary, caused a significant loss of grasslands due to the intensification of agricultural production, changes of system of animal husbandry. Parallel to the conversion of agriculture, the intensive, centrally led industrialization took place and absorbed the workforce from agricultural production (Konkoly-Gyúró et al.2015).

In 1989 and 1990, CEE (Central and Eastern European) countries transited from the communist system into a market-oriented economy, which caused significant changes in the social, political, and economic environment (Bicik et al. 2001). The collapse of the communistic system stimulated the reform of the agricultural policies in many CEE countries, which meant privatization of land and restructuring the agricultural sectors (Kuemmerle et al. 2008). These processes led to substantial land use changes in the region, such as a reduced surface area of agricultural land (Cegielska et al. 2018); increased area of uncultivated land, including developed areas (Poławskiet al.2009); and expansion of forests into abandoned land (Bucała-Hrabia 2017). The accession of many former socialist countries to the EU in 2004 and 2007 had similarly significant effects on land uses and landscapes, mainly thanks to the CAP (Verburg 2006). Furthermore, there are many other common factors in CEE countries, which strongly influence the land use changes, such as the migration of young people to urban areas and to Western-Europe, as well as the retirement of elderly farmers (Cegielska et al. 2018; Bucała-Hrabia 2017).

General trends in Hungary

In Hungary, we can witness mostly all the general trends described for the V4 countries. To understand the recent processes, we have to take a glimpse on the trends of the past. For centuries, extensive animal production was prevalent, e.g., pastoralism reflecting constant human presence over herd movement and grazing intensity. From the 18–19th century, more intensive farming methods become dominant with different breeds, stable animal husbandry prevailed. Considering Hungarian land use changes, data is available since the end of the 18th century from the historical military maps and since 1895, from the Hungarian Statistical Office (Demény et al. 2016; Greslová Kusková 2013). Intensive and large-scale land use changes started in the 19th century due to river regulation projects, extensive drainage of former marshlands and wetlands, which were converted into grasslands and later arable lands. The most important motivations for economic development were the expansion of arable land and infrastructure building (Konkoly-Gyuró et al. 2015; Ihrig 1996; Csemez 1996; Illés 2008). The most intensive land use changes took place between the middle of the 19th and that of the 20th century: the ratio of cultivated land has grown from 47.5% in 1819–1869 to 61% in 1940–44, the proportion of forest dropped from 15.9% to 12.5% share of the country's territory; but most drastically, the ratio of grassland in agricultural area dropped: from 28.8% to 20% (all data is projected on the current area of Hungary) (Konkoly-Gyuró et al. 2015).

After the drastic changes, these trends continued, though with a slower rate during socialism and even after the transition (the proportion of grasslands in agricultural area dropped from 16% in the period between 1953–1959 to 12,8% of the country's territory in 1998–1999 calculated by (Konkoly-Gyúró et al. 2015). In the state socialist period (1959–1990), the rapid growth of urban population and the intensification of agricultural production were the main driving forces for land use changes (Lennert et al. 2020; Kohlheb et al. 2009). In case of grasslands, intensification of cultivation meant a general turn from extensive to intensive farming and breeding methods, wild grazing was replaced by cultivated pasture or crops for livestock.

The collapse of state socialism did not alter the general direction of land use changes; the extent of artificial surfaces increased due to the intensive suburbanization process (Lennert et al. 2020; Kovács et al. 2019) but had a significant influence on the changes of the system of agricultural production. After 1990, the shift from state ownership and collective farms towards private ownership destroyed all the existing production systems, and land abandonment became a strong process, which led to the growth of fellow land especially in the Eastern part of Hungary. This process was also fostered by investment/real estate developments. Several plots were no longer cultivated by the owners (Lennert et al. 2020; Kohlheb et al. 2009) waiting for development. In the mountains and hilly regions, some grasslands were converted into forests (Szilassi 2015).

In 2004, Hungary and other CEE countries became members of the European Union and witnessed more or less the same effects, including the introduction of CAP leading to an intensification of agricultural use. Moreover, the introduction of European agro-environmental measures had a positive effect on natural vegetation (Lennert et al. 2020).

Objectives

Landscape as a highly complex system is – as it is defined e.g., in European Landscape Convention – a "result of being acted upon by natural forces and human beings" (COE 2000). To explore the driving forces of changes, it is indispensable to analyze the parallel trends on macro-regional and local scales as well. As a macro-regional scale, we have chosen a block of countries with more or less similar past, i.e., the Visegrád Countries (V4) situated in Central-Europe: Poland, the Czech Republic, Slovakia and Hungary. As the local scale, we applied micro-regions (Local Administrative Unite – LAU1) (Eurostat) as an administrative unit, which is very close to landscape units, as these were delineated by social and economic relations influenced by landscape conditions. Despite the importance and values of grassland ecosystems, deeper analyses of them and their changes are still missing in V4 geographical context. However, in order to manage and protect these ecosystems efficiently, the knowledge, obtainable from

these analyses, would be essential. Thus, the aim of our paper is to analyze the trends of grassland changes in Hungary with an outlook in post-socialist V4 countries during the last 30 years. GIS and statistical methods were applied to analyze data for the V4 countries, and three Hungarian study areas. The research was guided by the hypothesis, that behind the general trends, different tendencies can be observed in different landscape conditions and very complex factors influence grassland changes. We set up the following research questions:

- What kind of tendencies can be observed in grasslands of post-socialist V4 countries after the political transformation?
- What are the tendencies of grassland changes on local level?
- How different or similar are the various changes in areas with different landscape features?

Considering terminology, as this analysis is based on the CORINE Land Cover data, we use terms corresponding to the land cover types of this database. Using this terminology, the focus of our research is the analysis of Pastures, meadows and other permanent grasslands under agricultural use (CLC 231) and natural grasslands (CLC 321). The term reflects more the land cover form not the management methods.

Based on the definitions of Copernicus Land Monitoring Service "Pastures, meadows and other permanent grasslands" (CLC 231) are characterized by agricultural use or strong human disturbance, typically used for grazing-pastures, or mechanical harvesting of grass–meadows.

CLC 321. „Natural grassland" stands for grasslands under no or moderate human influence, often in areas of rough, uneven ground, steep slopes. These are mostly low productivity grasslands close to natural or semi-natural botanical composition. Terms of CLC database do not comply with the European Union's definition of permanent grassland, as land used to grow grasses or other herbaceous forage that has not been included in the crop rotation of the holding for a duration of five years or longer. CLC 231 can stand for permanent grassland but also for abandoned arable land (after 3 years) as well, the form of CLC 321 reflect more stable, low intensity grasslands (EC, 2004). In our study, we use the CLC terminology, as this database gives the opportunity for analysis of changes in the last 30 years.

2. Materials and Methods

2.1 Study areas

We carried out our analysis on different regional scales: a broad scale analysis for V4 countries and Hungary, and a more focused analysis on the study areas – three Hungarian micro-regions (Figure 1). In order to have a general background and see the situation of Hungary in a more international framework, we analyzed the stability and trends of grasslands at the level of the European Union. Owing the close geographical location and similar historical backgrounds, we focused on the V4 region. In the 20th century, Poland, the Czech Republic, Slovakia and Hungary faced similar historical periods, with special drivers of land use changes that differ from those of Western European countries (Greslová Kusková 2013; Cegielska et al 2018).

We carried out a detailed analysis of trends of grassland changes in Hungary, at the national level, and focused the analysis on three micro-regions. Three rural Hungarian regions of different landscape character were chosen as study sites: the micro-regions of Csorna, Gönc and Veszprém. Micro-regions in Hungary represent the level of the Local Administrative Unit (LAU) level 1 in the statistical system of Eurostat. The LAUs are used for statistical reasons such as the availability of data and policy implementation capacity (Eurostat).

Tab 1. Major characteristics of the study areas (HCSO, Tirczka and Ferencsik 1998; Dövényi 2010; Valánszki et al. 2018a; Valánszki et al. 2018b)

Micro-region	**Csorna**	**Gönc**	**Veszprém**
Area	580 km^2	502 km^2	630 km^2
Population	32,642	16,277	81,475
Region	Small Plain, Western Hungary, along the Austrian border	North-Hungarian Mountain ranges, along the Slovakian border	Bakony Mountains in the Transdanubian Mountain region southern part of the micro-region belongs to the Lake Balaton Recreational Area
Landscape character	Intensive agricultural landscape, plain landscape. Wetlands, lakes of Hanság in the North, river Rába in the South	Diverse landscape composed of two major parts: the valley of the Hernád River, and the mountains of Zemplén	Varied hilly landscape, located in Veszprém Basin surrounded by the Balaton Uplands and the Bakony Mountains
Climate, geography, soil	Moderately warm-dry, flat landscape; typic meadow soils, humic alluvial soils	Moderately cool-dry; river valley and hilly landscape; brown forest soil with clay illuviation, forest soil	Moderately cool-dry; moderately warm; diverse geography, hilly, flat landscape; brown forest soil with clay illuviation
Agriculture	Dominant arable land, traditional meadow management ceased	Forestry and game management, arable land in river valley, and vine production in Southern part	Forestry, arable land, pastures
National level nature protection areas	Partly Fertő–Hanság National Park	Partly Zemplén Landscape protection area	
Largest city (Population number)	Csorna (10,042)	Abaújszántó (2986)	Veszprém (59,919)
Settlement network	Mostly small villages, 32 villages and the town	Mostly small villages, 30 settlements including 2 towns	More urbanized, with suburbanization trends

The micro-region of Csorna represents a plain landscape, a part of which has been cultivated intensively for centuries; while the micro-region of Veszprém has a varied geography in the Transdanubian Mountains, as it is located at the foot of the Bakony Mountains in the Transdanubian Mountains not far from Lake Balaton. The micro-region of Gönc in North-Eastern Hungary has a diverse landscape composed of two major parts, the valley of the Hernád River, and the mountains of Zemplén (Table 1).

In Hungary, the ratio of grasslands is 9.8% (pastures 7.4%, natural grassland 2.5%) in comparison to total country area. Out of the three study areas, Gönc and Csorna have values close to this average (Csorna pastures 6.6%, natural grassland 4%, total 10.5%; Gönc pastures 6.3%, natural grassland 0.2%, total 6.5%). Veszprém has the double value (pastures 10.1%, natural grassland 10.4%, total 20.5%) of the national average. The area of individual natural grasslands varies. In our study, grassland areas mostly follow a scattered pattern with the exception of Veszprém, where large patches of natural grassland can be found.

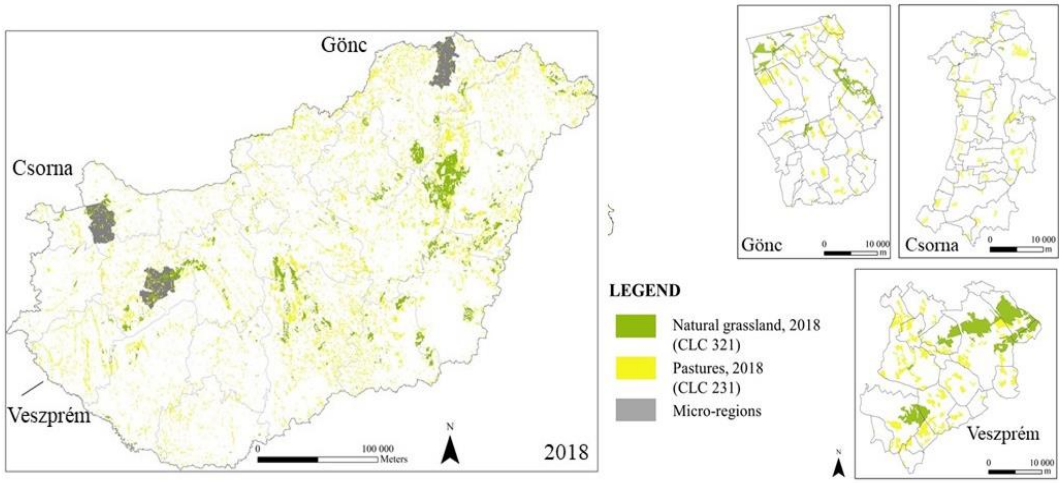


Fig 1. The analyzed micro-regions in Hungary. Pastures (Corine CLC code 231) and Natural grassland (Corine CLC code 321) are highlighted (MapChart). Source: own elaboration based on Corine Land Cover data

In Csorna, natural grasslands are in the wetland areas of Hanság and in the strictly protected Tóköz wetland area, while pastures are situated in a more scattered pattern. Considering grasslands of high ecological value in the Hanság Natura 2000 area (HUFH30005), alluvial meadows (6440) of river valleys dominate with a lower proportion of semi-natural dry grasslands and scrubland (6210), and Molinia meadows (6410) on calcareous, peaty or clayey-silt-laden soils occur from the grassland habitat types (TIR; EEA). In the Gönc micro-region, natural grasslands are underrepresented. These include the "Hernád-völgy és Sajóládi-erdő" (HUAN20004) (with habitats of Pannonic loess steppic grasslands (6250) and Alluvial meadows (6440) of river valleys) and "Központi-Zempléni-hegység" (HUBN20084) (with few grassland habitat types) Natura 2000 sites. In the Veszprém micro-region, larger patches of natural grassland can be found, partly owing to the closed military area, which provides a controlled, restricted use. In Papod and Miklád Natura 2000 site (HUBF20002) mostly Rupicolous pannonic grasslands (6190) and Sub-Pannonic steppic grasslands (6240) dominate with a lower rate of Semi-natural dry grasslands (6210) and Molinia meadows (6410) on calcareous, peaty or clayey-silt-laden soils (TIR; EEA).

Considering grassland as part of the historical landscape, we have to highlight micro-region of Csorna where pastoralism had a great tradition. Still in the middle of the 19th century, pastures and meadows made up 50% of the land use. Countless shadoof from the 18th and 19th century, military maps and folksongs prove the dominance of pastoralism in the region. From the mid-19th century, intensive drainage process started the marshland, wetlands were turned first into pastures later into arable land. In the 20th century, intensive farming and breeding methods became dominant, wild grazing were mostly replaced by cultivated pasture or crops for livestock. Since the political changes, animal husbandry is retreating, the number of livestock farms halved between 2000 and 2010 (from 4808 to 2104) and the agrocensus from 2020 show also a constant but less intensive decrease (14011) (HSO, 2000,2010, 2020).

In the eastern part of Gönc study area forestry, while in the central and western parts of it, agriculture have traditionally been the main source of livelihood. Throughout history, the area has been crossed by a north-south military and trade route, which allowed the rise of Košice to the north. The new state boundaries after 1920 cut off this link, which led to a decline in agricultural production in the study area, and a significant loss of population (it has almost halved in the last 100 years). All these have a significant impact on landscape change. In the western, forested parts, the original oak and beech forests has been preserved, while in the central slopes, a significant succession process is taking place in the areas formerly used for viticulture and fruit growing. The same applies to the former meadows in these areas causing a significant loss of the original vegetation. Similarly, to the other pilots, animal husbandry is retreating since 1990, the number of livestock farms is constantly decreasing (HSO, 2000,2010, 2020).

The micro-region of Veszprém represents a transitional area between Bakony Mountains and Lake Balaton. The dominant vegetation is dry oaks, they remained in patches in their basins, but rather arable

lands and on the uncultivated dolomite plateau steppes were formed. The high proportion of forests, and low proportion of grasslands and arable lands left in the vicinity of volcanic cones and plateaus remained, due to their endowments. The proportion of vineyards and orchards is low in the area (Dövényi 2010, pp. 550–556). In micro-region of Veszprém, the number of livestock farms after an intensive decrease stabilized after 2010 (HSO, 2000, 2010, 2020).

2.2 Data source and preparation

For the research, both statistical and GIS data were used. The use of GIS tools in studies make data processing easier, decreases analysis costs, and increases the accuracy of the results (Cegielska et al. 2018; Łowicki 2008). Since the analyzed period was 1990–2019, layers of the CORINE Land Cover from five different years were applied: 1990, 2000, 2006, 2012, 2018 (100, EEA, 1990–2018 retrieved from Copernicus Server). This database provides information on physical properties of the surface of the Earth (land cover) (Büttner et al. 2001), which contains 44 classes of land cover, grouped into three levels of detail. In accordance with our research objectives, we used the following categories from two different levels: artificial surfaces (level 1); pastures (level 3); natural grasslands (level 3); water bodies (level 1). Pastures and natural grasslands were involved in the international and national analyses, that is why these layers were clipped to the boundaries of European countries. During all steps of our work, we kept these two land cover types separately, because of the two different features of them (agricultural and natural/semi-natural). All four involved land cover layers were clipped to the boundaries of the three Hungarian study areas (micro-regions of Csorna, Gönc, and Veszprém). At this level of analysis, the study also employed vector data of the Hungarian National Ecological Network (Teir). This network contains the nationally and internationally protected areas; moreover, several other valuable and sensitive areas of the country (e.g., important bird areas, grasslands, valuable floodplains, forests) are also included. The digital version of this database is available in 1:50 000 scale. The vector administrative boundary layers of micro-regions were provided by the Department of Geodesy, Cartography, and Remote Sensing in Hungary.

Our micro-regional analysis involved the following types of statistical data, from the Hungarian Central Statistical Office: population, number of livestock and the area of Hungarian National Ecological Network. (HCSO). We applied Corine land cover data for statistical correlation analysis (Surface area of artificial surfaces, Surface area of pastures, Surface area of natural grasslands, Surface area of water bodies) from years: 1990, 2000, 2006, 2012, 2018.

2.3 Methodology

The research contains three main types of analyses: trend analysis (on four different spatial levels: Europe (1), V4 countries (Poland, the Czech Republic, Slovakia, Hungary) (2), Hungary (3), and the three Hungarian micro-regions (4)), principal component analysis (PCA) of the variables in the three study areas, and spatial analysis (at two different levels: Hungary; three micro-regions) were carried out. The paper employs statistical methods for the trend and PCA analyses; furthermore, ArcGIS tool was used in order to make spatial analysis.

For statistical analyses Microsoft Excel 365 and MATLAB programs were applied. The original data were normalized for each variable with zero as the mean value. A simple trend analysis was performed to visualize and compare the change trend of pastures and natural grasslands for each level of analysis.

The area of grasslands depends on complex issues e.g., livestock, water surfaces, protection, grants and population growth. Unfortunately, many of them were not available for the whole analyzed period based on the same methods. The chosen variables were statistically suitable for such analyses, because of availability and reliability. To identify the underlying relationship of input variables, PCA was carried out, using the datasets (artificial surfaces, pastures, natural grasslands, water bodies, population) that were available for all examined years (1990, 2000, 2006, 2012, 2018). For each study area, the percent variance explained by the principal components (PC) was expected to be above 95%, which required the use of 3 PCs in all cases. PC1 usually explained 65–70% of the total variability, and PC2 accounted for another

20–30%. Of the study areas, the micro-region of Csorna displayed significantly different behavior, as in its case PC2 and PC3 explained 18.9 and 16.2% of the variability, respectively, making PC3 just as important as the other two PCs.

Spatial analyses were processed using the ArcMAP software (ver. 10.2.2). After the preparation of vector layers (presented in Section 2.2.), further spatial analyses were proceeded. All layers of the involved land cover categories and the Hungarian National Ecological Network were intersected with administrative boundaries of the three micro-regions and Hungary (geoprocessing tools – Intersect). In order to prepare raw data for statistical analyses, the surface areas of the individual layers were calculated in different years (field calculator). For land cover types, changes over time were considered. A GIS tool was employed also for the visualization of results; graphic presentation styles were prepared for spatial distribution and changes of pastures and natural grasslands. This allowed us to find deeper explanations of the spatial processes related to grasslands during the last 30 years.

3. Results

3.1 Changes of grasslands at the international and the national level

As a starting point, we checked the general trends of changes of the area of pastures and natural grasslands at the macro-regional level (Figure 2). In the European Union, there was a dynamic increase of the area of pastures between 1990 and 2012, and after that there was a drastic drop. Furthermore, the trend of changes of the area of natural grasslands follows a similar line with a reversed trend around 2012, when after a drop, the area of natural grasslands has grown slightly. In total, the area of pastures (CLC 231) has grown from 319,900 km^2 to 405,720 km^2, and that of natural grasslands (CLC 321) from 186,120 km^2 to 228,536 km^2 at the EU level.

In the V4 countries not so intensive trends were going on with a reversed trend of natural grasslands (CLC 321). In total, the area of pastures (CLC 231) has grown from 40,250 km^2 to 44,367 km^2, but the area of natural grassland decreased (from 3438 km^2 to 3166 km^2). In Hungary, the area of pastures and natural grasslands seem to be stable, with a slight growth (pastures – from 6810 km^2 to 6850 km^2, natural grasslands from 2257 km^2 to 2282 km^2).

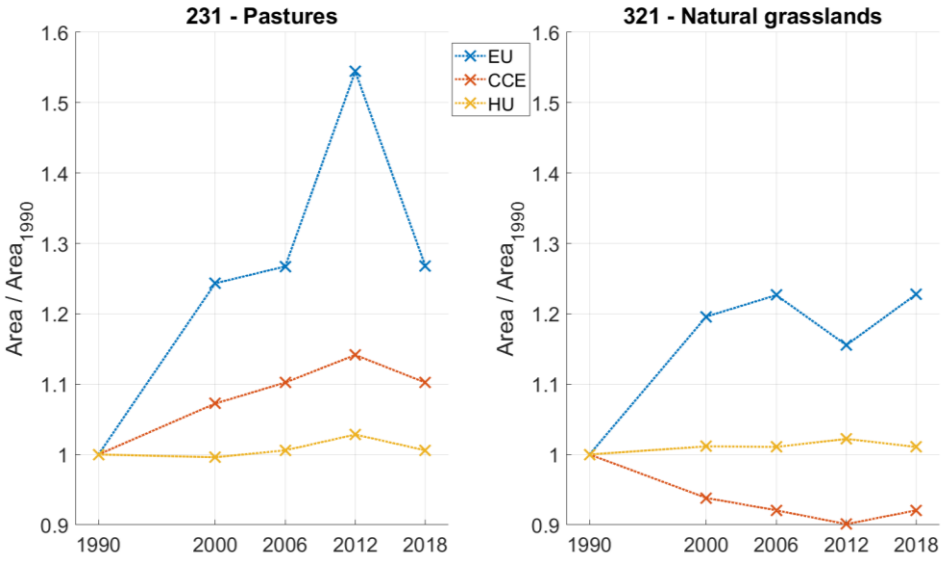


Fig 2. Change of Pastures (CLC 231) and Natural grassland (CLC 321) in the European Union, V4 countries and Hungary, compared to the basis year 1990. Source: own elaboration

Considering data of the national level, behind the more or less stable ratio of grasslands in Hungary compared to EU, there was a constant and intensive change, especially in the first decade after the political changes. Later, we can see a stabilizing process of land use changes (Figure 3).

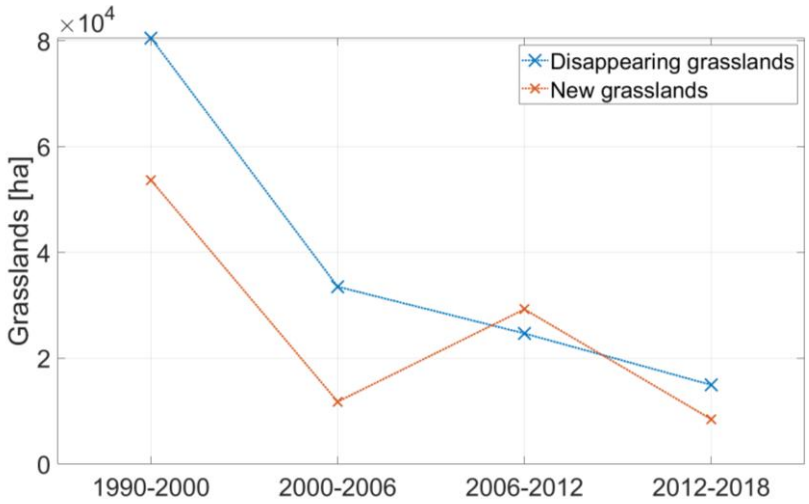


Fig 3. The trends of disappearing and grassland areas changed from oder CLC types (sum of CLC 231 and CLC 321) in Hungary. Source: own elaboration

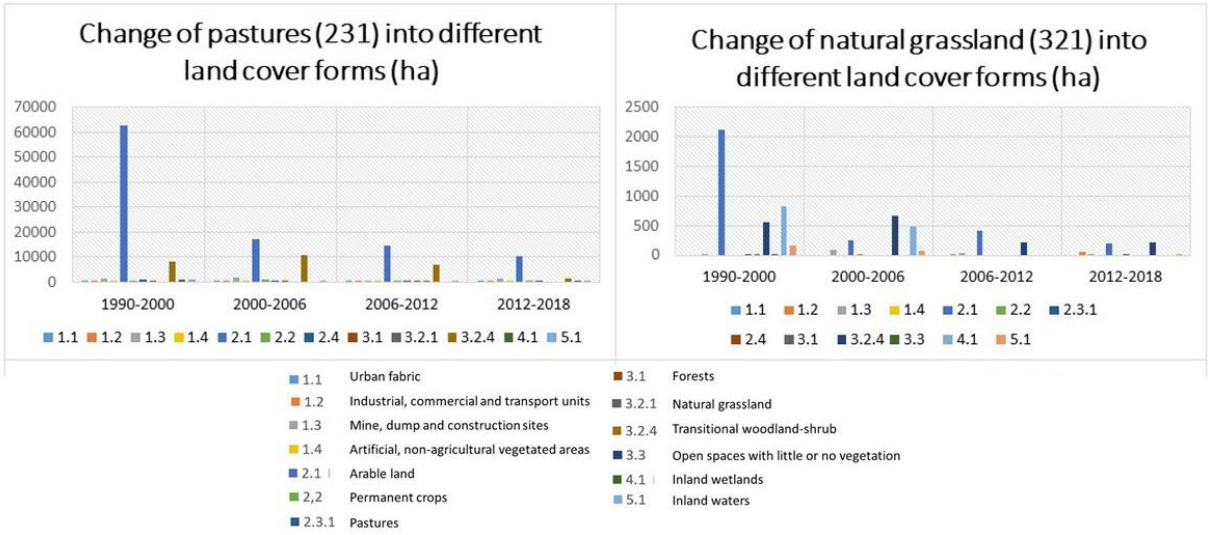


Fig 4. From database CLC-changes, change of pastures (CLC 231) and natural grassland (CLC 321) on national level (x axis shows the CLC categories in different periods, y axis the changes in ha). Source: own elaboration

Figure 4. shows which land cover forms changed parallel with the pastures and natural grassland. Pastures were turned into urban area (CLC 1.1), forest (CLC 3.1), wetland (CLC 4.1) but mostly in small proportion, but in both directions, we see high rate of arable land change (CLC 2.1), however in case of loss of arable land just in the first period (1990–2000). With the loss of natural grasslands, the area of transitional woodland/shrubs (CLC 3.2.4) has grown. In the birth of fallow land which was detected as grassland due to the abandonment of former gardens, vineyards (2.2) was probably a remarkable process.

3.2 Case studies / micro-regional scale results

Trends and directions in the study areas

Compared to the macro-regional and national scales, we can witness different processes in the study areas. In all study areas, the area of grassland decreased, as opposed to the larger/national scale. Figure 5 compares trends at the level of the study areas showing more or less fluctuating lines but generally decreasing area, with the exception of pastures in Veszprém.

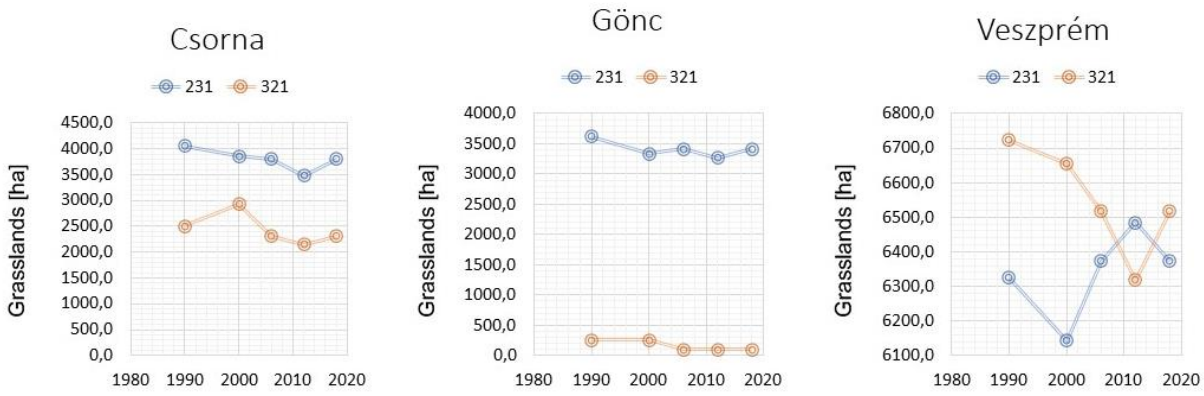


Fig 5. Change of pastures (CLC 231) and natural grassland (CLC 321) in the study areas. Source: own elaboration

Figure 5 shows that the area of pastures decreased in the Csorna micro-region (from 4054 ha to 3804 ha) and in Gönc (from 3624 ha to 3413 ha), but it was more or less stable in micro-region Veszprém (6324 ha in 1990 and 6373 ha in 2018). However, this stability on the long run hides intensive changes. In the case of natural grasslands, we can witness a drastic drop especially in the micro-region Gönc (from 252 ha, it dropped to 98 ha), but in all the other case, there is also a loss (in Csorna from 2508 ha to 2310 ha; in Veszprém from 6722 ha to 6517 ha). We highlighted the changes meaning the loss of grasslands (Table 2). In all micro-region, the abandonment of grasslands and afforestation and turning them into arable land is a present process. In Veszprém region, we can witness the growth of urban areas. In Csorna, 485 ha grassland was reflooded (4.1. Inland wetlands) as part of habitat restoration of the Fertő-Hanság National Park. Land cover changes in direction of new grasslands are of smaller scale, the CLC-change database explored transition of arable land in all cases (this was the only change in Csorna: 350ha, Veszprém: 1030 ha and in Gönc: 200 ha,) and turn of shrubs into grassland again (Gönc: 39 ha).

Tab 2. From the CLC-change database, the transition of pastures into different land cover forms in the case study areas. Source: own elaboration

Ch, lost 231 / Pastures turned to different land cover forms													
Ch into CLC:	**1.1**	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.4**	**3.1**	**3.2.4**	**3.3**	**4.1**	**5.1**	**Total (ha)**
Csorna			5,54		1121,3		13,9	21	101,257				1262,962
Gönc			0		663,32	17		8,8	185,087			11	885,436
Veszprém	14,99	74	72,7	1,7	1098,7				130,842				1392,605
Ch, lost 321 / Natural grassland turned into different land cover forms													
Ch into CLC	**1.1**	**1.2**	**1.3**	**1.4**	**2.1**	**2.2**	**2.4**	**3.1**	**3.2.4**	**3.3**	**4.1**		
Csorna			0		12,45		0	6,2	42,283		485,6		546,56
Gönc			0		0	0	0	0	22,949		0	0	22,949
Veszprém			18,6		39,131				153,6	6,4			217,678

1.1 Urban fabric	
1.2 Industrial, comercial and transport units	3.1 Forest
1.3 Mine, dump and construction sites	3.2.4 Transitonal woodland/shrub
1.4 Artificial, non-agricultural vegetated areas	3.3 Open spaces with little or no vegetation
2.1 Arable land	4.1 Inland wetlands
2.2 Permanent crops	5.1 Inland waters
2.4 Heterogeneous agricultural areas	

Spatial pattern of changes

In many cases, we can see all the disappearing grasslands and also most of the new grassland areas close to existing patches of pastures. Natural grassland areas are located within the National Ecological Network, but we can witness negative changes in the ecological network area as well (Figure 6). With

command “Intersect” in GIS software, we analyzed the overlapping areas of changes and the National Ecological Network. In the micro-region of Csorna, the disappearing pastures have a mosaic pattern and high proportion of them are located in NEN area (Lost 231: 1990–2000: 67,5%, 2000–2006: 61,7%, 2006–2012: 53%, 2012–2018: 86% on NEN area). The majority of them were transferred into arable land but in small proportion, forest and mining sites were established. Natural grasslands are generally parts of the nature conservation areas of Hanság and Tóköz. These remained mostly untouched with the exception of a large area of natural grassland in Hanság already mentioned before, which was flooded as part of the wetland restoration program (Lost 321: 1990–2000: 100%, 2000–2006: 100%, 2006–2012: 100% on NEN area). The new grassland areas are primarily in the territory of the National Park.

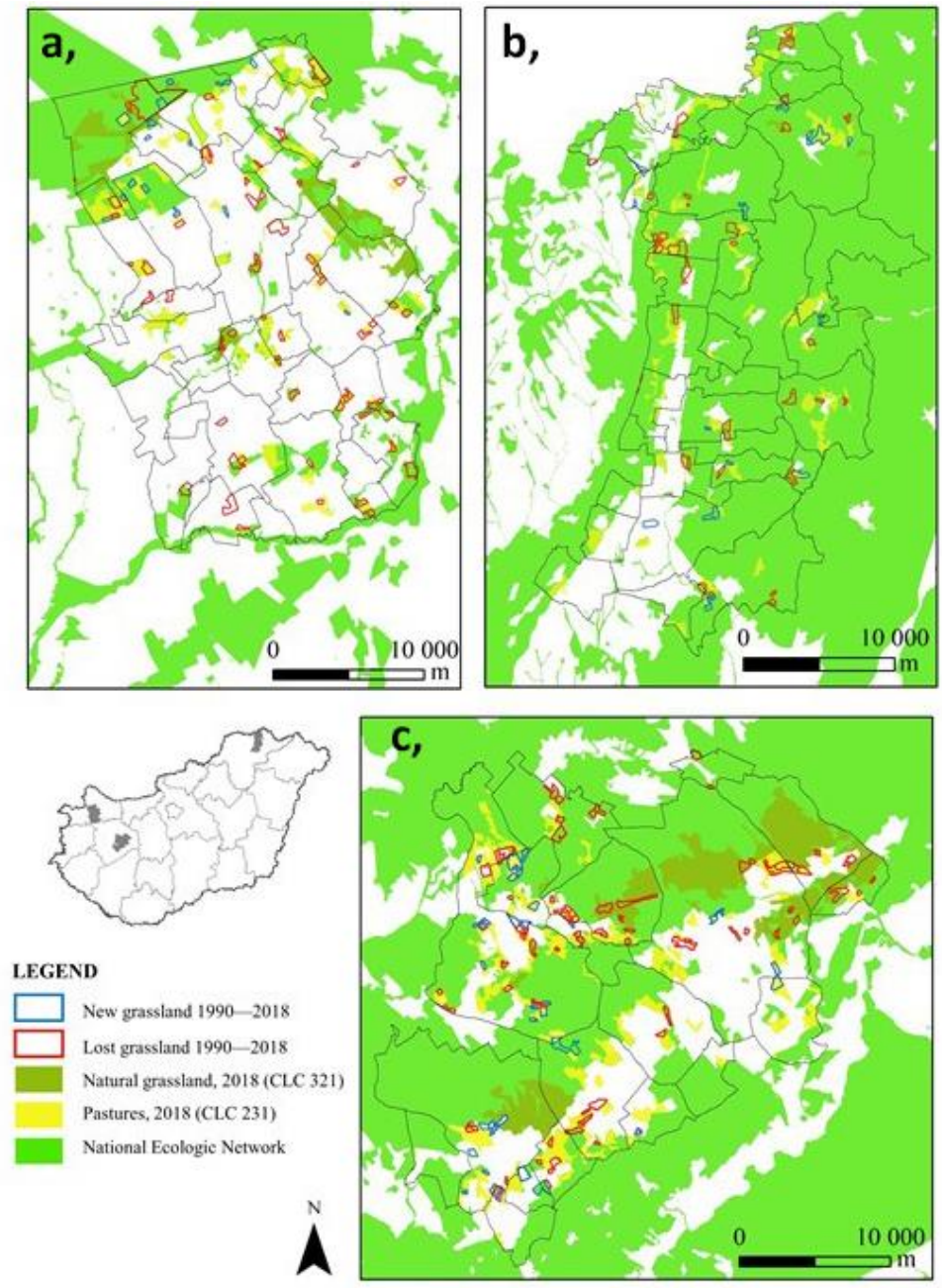


Fig 6. Changes of the National Ecological Network in the micro-regions: a) Gönc; b) Csorna; c) Veszprém. Source: own elaboration

In the micro-region of Veszprém, the majority of the area is part of the National Ecological Network. The majority of the disappearing grasslands (considering the natural grassland and pastures as well) are on the edges of larger grassland patches and at the peripheral area of the ecological network (Lost 231: 1990–2000: 63%, 2000–2006: 77%, 2006–2012: 53%, 2012–2018: 86% on NEN area). The natural

grassland area also shrunk, especially on the slopes of the Bakony Mountains (Lost 321: 1990–2000: 44,7%, 2012–2018: 100% on NEN area). In micro-region Veszprém as a more urbanized area under more significant suburbanization pressure between 2000 and 2006 a more than 22 ha former pasture became residential area but with remained NEN status. Furthermore, mining site, sport and leisure area were established on former NEN grasslands. A large scale afforestation program was started in the military area.

In the micro-region of Gönc, the pastures are much more frequent than natural grasslands. These pastures are mainly located in the Hernád Valley, along the river and also in the Zemplén Mountains, around the settlements (built-up areas). The vast majority of the grassland is part of the National Ecological Network. More precisely, in the mountains, they are situated within the Zemplén Landscape Protection Area, and in the valley within or close to the Natura 2000 areas. Similarly to the micro-region of Csorna, the disappearing grasslands have a mosaic pattern, but are mostly located in the mountain region (Lost 231: 1990–2000: 88,4%, 2000–2006: 94%, 2006–2012: 100%, on NEN area). However, during the last decades, we can witness disappearing grasslands also in the Hernád Valley, where they have a more concentrated pattern than in the Zemplén Mountains. In this study area, only a very small amount of new grassland appeared during the last 30 years (Only 22.9 ha between 2006–2012 100% on NEN area). In micro-region of Gönc between arable lands and forests, significant ratio of transitional woodland occurred in NEN areas on the disappearing grasslands. The elaboration of the National Ecological Network started in 1993 and in spite of the smaller spatial modifications, in the study areas, the mosaic pattern changes of land cover forms – as for example smaller lost pastures remained in the larger NEN blocks.

Principal component analysis of affecting factors of change

Figures 7–10 present the results of the PCA. In all figures, coefficients of the input variables (artificial surfaces, pastures, natural grasslands, water bodies, population) are plotted against the PCs. In summary, Figures 7–10 reflect important differences between the selected study areas; the only characteristic that can be identified is that population and artificial surfaces show an opposite behavior along all PCs (namely the decrease of population and the increase of urban fabric).

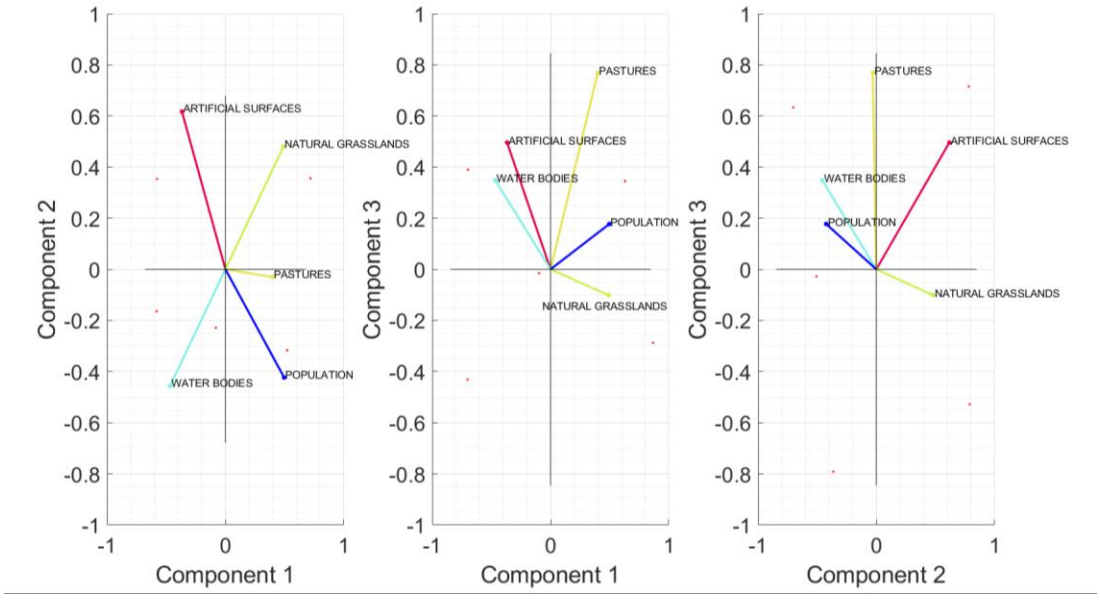


Fig 7. Biplot of PCA coefficients for the micro-region of Csorna. Source: own elaboration

The micro-region of Csorna shows that the behavior of the ratio of water bodies and natural grasslands is opposite, thanks to the large-scale wetland rehabilitation efforts of the National Park. The two types of grasslands show more or less similar behavior. Despite the presence of the Fertő–Hanság National Park area in the north, the majority of the micro-region is an intensively cultivated land; so agriculturally used grassland is dominant.

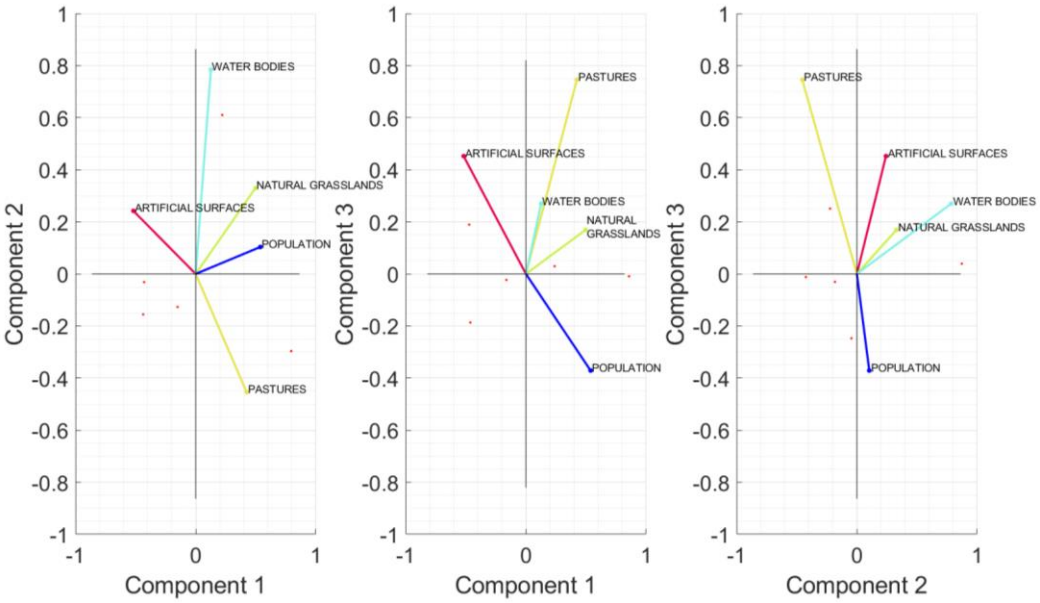
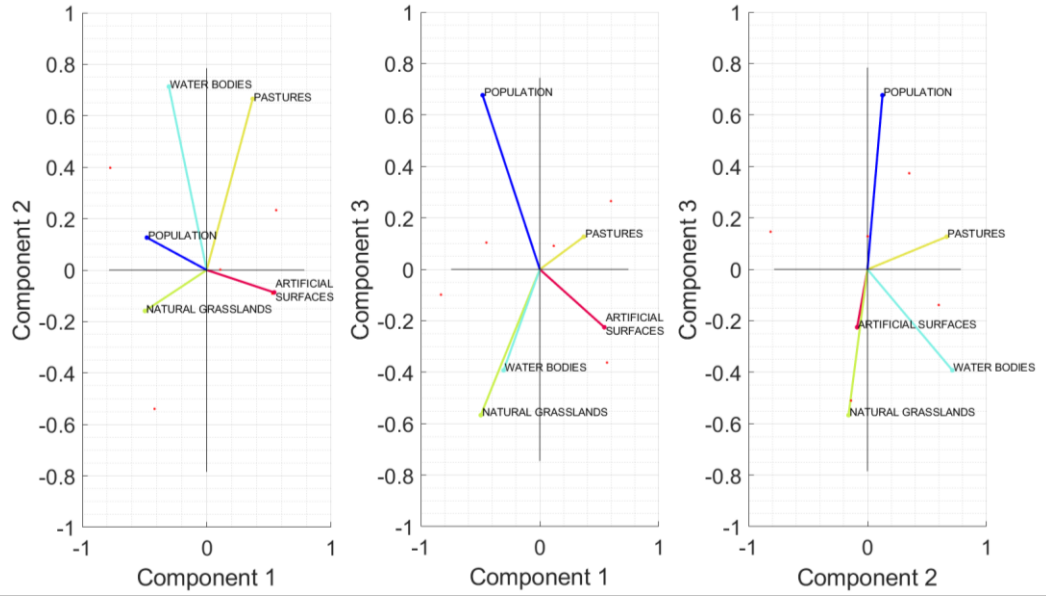


Fig 8. Biplot of PCA coefficients for the micro-region of Gönc. Source: own elaboration

In the micro-region of Gönc, we can witness a similar behavior between water bodies and natural grasslands. In this hilly landscape, the area of pastures is ten times bigger than natural grasslands. While the former one is mainly used for grazing and the pastures are scattered throughout the study area, the natural grasslands are concentrated along the river Hernád. As our analyses also proved, the water bodies (in this case the river Hernád) play an important role in the life of natural grasslands.



*

Fig 9. Biplot of PCA coefficients for the micro-region of Veszprém. Source: own elaboration

The micro-region of Veszprém shows again a similar correlation between water bodies and natural grasslands. Here, the ratio of both types of grasslands is stable due to the fact that large areas (mostly grasslands) are maintained by the military. This micro-region is the most urbanized one among the study areas, where urbanization process is the reason of some loss of pastures. The two types of grasslands have an opposite behavior.

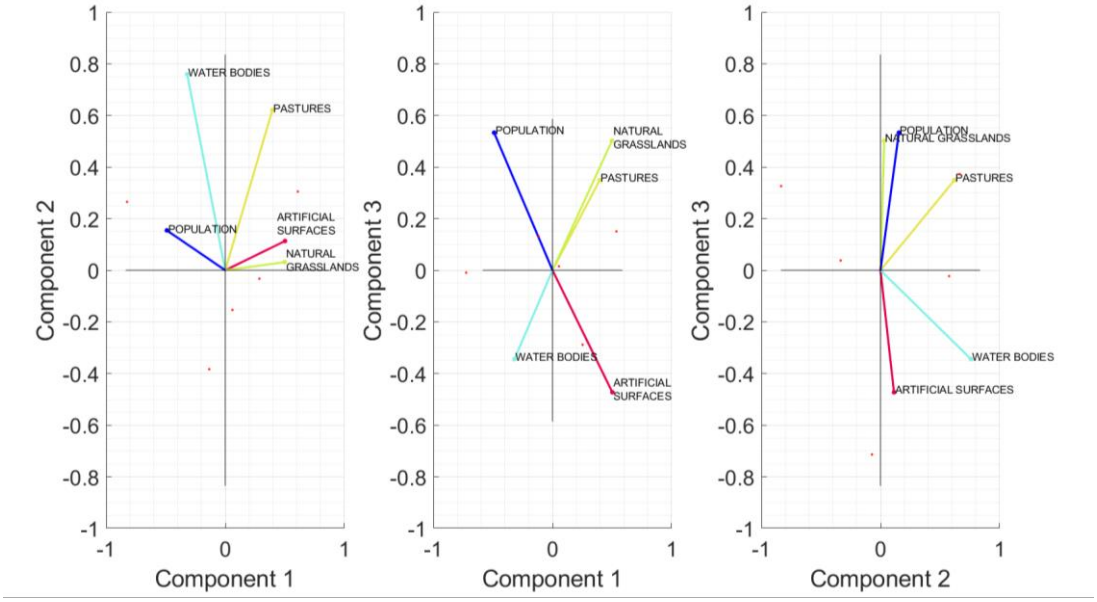


Fig 10. Biplot of PCA coefficients for Hungary. Source: own elaboration

To provide national benchmarking, PCA was also performed for country level data. The results show that artificial surfaces and water bodies have an opposite, while the two types of grasslands have a similar behavior. An important difference of the three study areas is the behavior of natural grasslands and pastures. Similarities include the opposite behavior of population and artificial surfaces.

4. Discussion

Our study presents an analysis of the changes of the area of grasslands focusing on the V4 countries in Central and Eastern Europe, with a special focus on Hungary and three Hungarian micro-regions. Compared to other former studies, it gives a deeper insight into the spatial trends of grassland changes in the V4 countries and in Hungary. Our results show that despite the common history, these trends are not the same in all parts of the analyzed post-socialist countries. With the help of the involved case studies, we discuss the explanations of these differences and similarities, as well as find possible relationships with historical milestones.

In the V4 countries different, in some cases, opposite trends and processes influence the area of grasslands. Meanwhile at the EU level, the Corine data showed growth of pastures and natural grasslands until 2018, several studies draw the attention on the constant decrease of permanent grassland (Schils, 2022). Our analysis based on Corine data revealed the shrinkage of natural grassland in the V4 countries, while the area of pastures increased. So, considering pastures, we see a similar trend between EU and the V4 countries. However, in the V4 countries, there is a more intensive growth after 1990, but looking at natural pastures, we can see an opposite process. This type of grassland is under greater threat. Meanwhile, in Hungary, after a slight decrease in the area of pastures and natural grasslands, their area started to grow, but behind these quite stable results, there were dynamic changes. A general trend is witnessed in the EU: land is converted into arable land, forest and urban areas. Urban sprawl is a strong process in the V4 countries as well. But causing an opposite process, another factor which is characteristic of the former socialist countries was the change of agricultural cultivation system after the political changes (1990), which led to land abandonment with a growth of grassland. But especially in mountain areas, abandonment of grassland, cessation of former mowing and grazing especially because of the drastic drop of animal husbandry, led to the conversion of grassland into forest (as we could witness in the case of Gönc micro-region study area).

The CAP had ambiguous effects by fostering intensification, but according to some studies, the agri-environmental program had positive effects on natural grasslands, improving their ecological value, several restoration projects started (Valkó et al. 2012; Török et al. 2018). Meanwhile, other studies

showed the limited effects of agri-environmental programs (Batáry et al., 2015; Pardo et.al., 2020). Our results showed also a few good examples in the study regions, in different landscape conditions, but more detailed, the overall effects of agri-environmental programs could be the subject of further research.

In spite of the slight growth of grassland areas at the national level, in all of our study areas (with the exception of Veszprém, but there also a rather stagnating state was also recorded), we see a loss. If we look behind the changes in the micro-regions, we can witness all the ongoing processes at the international and the national levels. However, when focusing on landscape and demographic conditions, we can see varying trend lines (Figure 5.). Among the study areas, the Veszprém micro-region is the most urbanized one with a population density of 124.8 inhabitants/km^2, which is double or triple of the other study areas (Csorna: 57 inhabitants/km^2; Gönc: 32.7 inhabitants/km^2). All these different processes (intensification of cultivation, farm abandonment, urbanization) and conditions are reflected in the differing results of correlation analysis in the micro-regions.

In all study areas, pasture-arable land conversion is a strong phenomenon as a back and forth process, but the loss of pastures is more dominant in all study areas. Here, the inaccuracy of data and limitations of Corine database (Diaz-Pachecoand Gutiérrez 2014; Mari 2010) can cause problems, but arable land abandonment especially in the Gönc micro-region is significant. The pasture-arable land conversion because of intensification of cultivation occurs also in all study areas, in Gönc micro-region especially in the Hernád Valley, where conditions for cultivation are better.

Abandonment of arable land is not such a dominant process in our study areas with the exception of Gönc micro-region as in the economically more backward regions or the eastern part of Hungary. The Csorna micro-region can be considered as an intensively cultivated land. Here, the shrinking of animal husbandry causes problems in the maintenance of grassland. The decrease of livestock and livestock farms (their number was halved between 2000 and 2010 (HCSO)) affected the decrease of grassland, which maybe the most important threat on the long run in these regions, where urban sprawl is not a dominant process.

Afforestation due to the abandonment of grassland is a dominant process in Gönc, especially in the mountain areas (1990–2000: 49 ha, 2000–2006: 90 ha, 2006–2012: 46 ha new stands/bushy area) next to existing forests. Also, opposite processes are detected (38 ha of young stands/bushy area became pasture) after 2012. In the Veszprém micro-region, afforestation seems to be more of a planned process (1990–2000: 61 ha, 2012–2018 pastures turned into woodland 130 ha, and natural grassland 92.3 ha in two large blocks at the edges of Bakony Mountain forests).

Former studies (Tokarczyk 2018) also highlight the threat of urban sprawl on pastures. In our micro-regions, the loss of pastures due to the growth of residential areas and the construction of industrial and commercial units is a dominant process around the built-up area of city of Veszprém; and even in its broader agglomeration zone. New industrial units are built, for example, a golf-course was opened, and thus pasture area was lost. This process was also reflected in the statistical analysis. In Gönc and Csorna, the growth of artificial areas did not affect grasslands, in spite of the fact, for example, that around Csorna after 2012, a large-scale motorway construction (M85) took place, but it mostly affected arable land.

Some specific changes also occurred; a large former pasture area (485 ha) was reflooded in the micro-region of Csorna, as a part of a wetland restoration project lead by the Fertő-Hanság National Park. This process was also detected in the statistical analysis. The program took place in areas of former marshland, which was drained after WWII. As an influence of the Tokaj vine region, a 17 ha area of pastures was turned into vineyards in Gönc. In the micro-region of Veszprém, large military areas maintained mostly as grassland by mowing help the preservation of natural grasslands.

Our results have shown that the protection of the National Ecological Network cannot prevent the loss of grasslands. The NEN category means just a building control reflected in the spatial plans, meanwhile, for example, Natura 2000 grasslands have a stricter regulation, these cannot be turned into arable land. In the spatial plans of the settlements, grassland and arable land occur under the same land use category of agricultural land. In the future, in order to have a better control over grasslands, the division or a more sophisticated control of this agricultural land use category would be advisable. The initiative of the EU

with the maintenance of permanent grasslands helps to preserve grasslands, unfortunately due to the lack of official data availability, we could not assess the trends.

Compared to the historical trends, we can see much more varied, diverse changes recently. Especially before the political changes, a few dominant drivers caused the usually intensively decreasing ratio of grasslands such as intensification of agricultural production by expanding areas of arable land and during the socialism next to the increase of output of agriculture, the rationalization of agricultural production were the most important drivers. After the political changes, the restructuring of agricultural production, the social economic circumstances, such as in the backward regions land abandonment is an intensive process, change of grassland into woodland but parallel to that intensification are drivers of opposite processes. But as other researches show the grasslands of high natural value are threatened and have a constant decreasing trend (Biró et al. 2011).

The first decade after the political changes brought drastic social-economical changes: it meant a transition period from a centralized, authority system without the right of owning land and a centrally managed agricultural production. The transition from this system brought also dynamic changes in the land use system, which is why we have seen more intensive changes of grasslands between 1990–2000 later we can witness a more stabilized trend. Even EU accession has not brought dramatic changes as it was a market based, smoother democratic transition with softer tools, incentives in the frames of EU CAP policy. In certain areas, CAP fostered intensive production which caused the loss of grasslands.

Summarizing the driving forces, we can state that afforestation firstly due to land abandonment especially in mountainous areas and backward regions is a great threat; from other side in Hungary, there is a very intense program for afforestation, which can also cause the loss of grassland especially because the number of animals decreased drastically through the last decades. Suburbanization, urban sprawl was a strong influence in micro-region Veszprém, but construction of roads, opening mining sites occurred in other study areas as well. Even a nature protection project caused grassland loss but this action restored a previous land use – wetland (micro-region Csorna).

Considering rural development in our opinion, it is really important, and has an added value to maintain divers, mosaic landscapes. In the intensively cultivated micro-region of Csorna, development of rural tourism would not be successful without grasslands representing ecological value in agrarian landscape. Micro-regions of Csorna and Gönc are more rural landscapes where important pillars of rural development are diverse local economy, local products. In Csorna, grazing has a really long and important tradition, the further decrease of grasslands would mean a loss of cultural, economical heritage. These regions could vision a Nature park-like development model where rural tourism, divers, more labor-intensive agriculture and food industry provide income for local residents. In case of micro-region of Veszprém where suburbanization is a more intensive process, in order to maintain the divers landscape of high ecological value, the maintenance of grasslands are crucial.

In the future, a more focused analysis would be necessary; also covering correlation analysis with other factors, for example, the compensations of EU CAP (Whittingham 2007; Török et al. 2018). Unfortunately, we still do not have datasets for covering the necessary period, due to the lack of spatial data about permanent grasslands hindered a more detailed analysis. However, in the light of our results, special, focused programs should be elaborated and launched in the sensitive landscapes to protect natural grasslands, since in spite of the general trends of growth, natural grasslands are threatened.

Reviewing the results, it is important to consider the limitations of the Corine database, such as errors due to scaling, the size of the smallest mapping unit, and the generalization rules (Diaz-Pacheco and Gutiérrez 2014; Mari 2010). Also, overlapping areas may occur in the database. There can also be errors in distinguishing arable land and grassland in the database, but also farmers from time to time turn their grassland into arable land, avoiding the category of permanent grassland. However, in our opinion, apart from the exact data of changes, the major trends are important, which sometimes differ in certain landscapes from the national trends.

5. Conclusions

Summarizing the major processes, the trends of changes in the pilot areas show more or less fluctuating lines but generally decreasing area of grassland, with the exception of pastures in Veszprém. The majority of grasslands disappeared due to intensification of agriculture, turned mostly into arable land, or as an opposite process due to abandonment of grass management afforestation process started. The abandonment of arable land caused the increase of fallow land detected by Corine database as growth of pastures. In most cases, the disappearing grasslands and also most of the new grassland areas close to existing patches of pastures. Unfortunately, even in the area of the National Ecological Network, we can witness negative changes as well. The loss of pastures due to urban sprawl was dominant just in the most urbanized study area, around the built-up area of city of Veszprém. On national level, in the birth of new grasslands, the abandonment of former gardens, vineyards was probably a remarkable process. Similar to other research results, our study reflects the significance of different landscape conditions, so a flexibility in agricultural and subsidy programs would be necessary and focused conservational programs should be elaborated.

Acknowledgments

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