The effects of suburbanization, urban sprawl on the environmental change of suburbs in Central European middle-sized urban regions

Summary for final report on the research No. 128703

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1. Research objective, circumstances of the research

The urban sprawl around middle-size cities in Hungary and Central Europe, the rural change and suburbanization can be characterized by residential out-migration from cities and at the same time by immigration from the rural areas. These processes have intensified in the former socialist countries after the 2000's and a number of problems have not been addressed, which have become apparent during the eighties and nineties in Western countries. A fast urban sprawl took place with a low level of special control and planning but under the pressure of economic and financial development. The rate of spatial growth often exceeds the rate of population growth, it even occurs in the absence of population growth. In Central European countries, the main destination for migration is the capital cities and their suburbs, therefore suburbanisation studies focus on these areas. However, our aim is to focus on regional centres and their agglomerations, comparing them to capital cities and rural areas. The most dynamic and new urbanisation processes are taking place in urban agglomerations. The phenomena observed in these countries, especially in regional cities, have no historical precedent, but are a novelty from both a social and an economic point of view. Our research concentrates on the urbanisation tendencies of three post-socialist countries – Slovakia, Hungary, and Romania. The goal of the work is to reveal the environmental impacts affected by these processes. This issue is examined in all three countries that have gone through similar economic and political transitions, together with the differences caused by the diverse historical, geographical, and settlement hierarchy endowments at the time of the development and migration boom following the world economic crisis of 2008. The flow into cities seems to have accelerated, mainly in the case of capital city regions and the edges of regional centres. Besides population movements, the expansion of built-up areas is much faster, especially in less densely populated areas where the dynamism of these was outstandingly high between 2012 and 2018. This may have several negative consequences. In areas in the vicinity of urban zones of such high population density may emerge, which may lead to societal and environmental problems later.

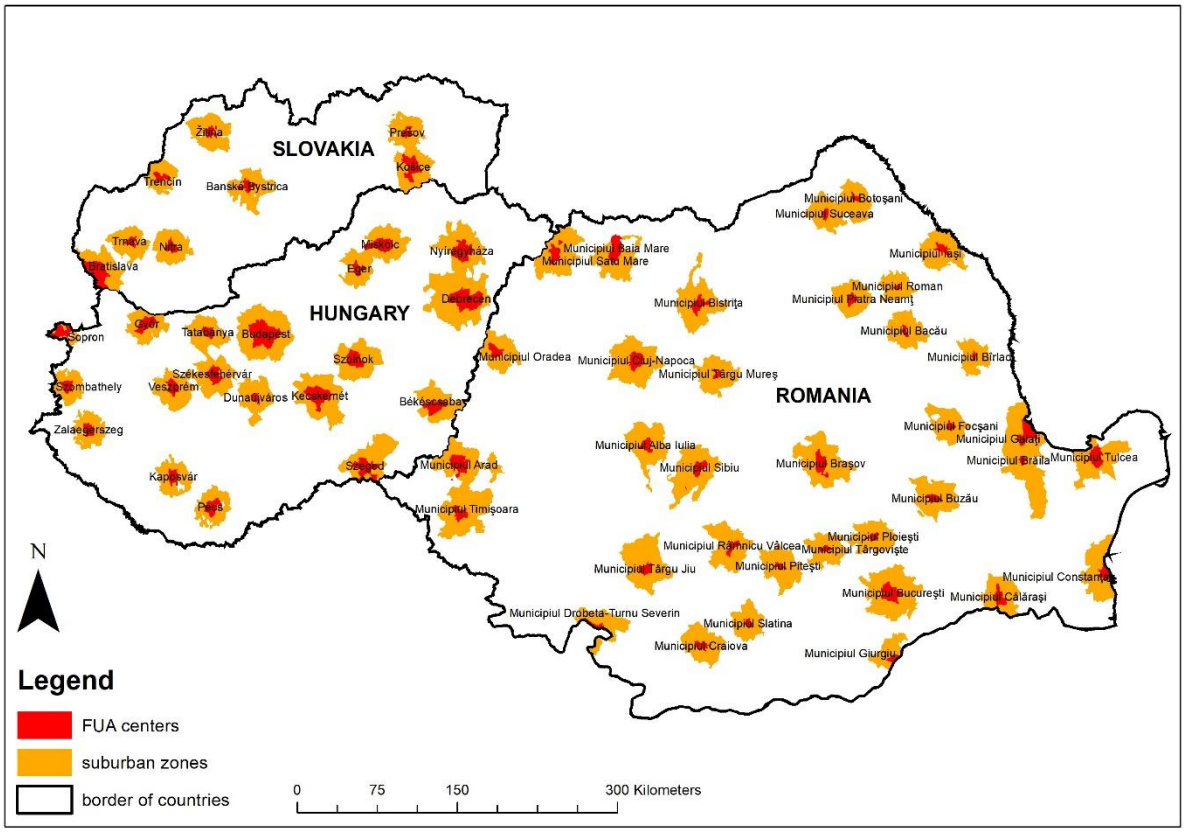
2. Preparation and analysis of the basic database

Our initial database was prepared at the municipal level for the three countries. An important element was the processing of the CORINE database, from which we extracted comparable data on the change in land cover for the three countries. In addition, we also took into account the population size and its changes. As a novelty, in addition to the CORINE land cover data, we started to analyse the impervious surfaces, characterising the built-up areas. We also used the Urban Audit database, which contains a wide range of data, but the delimitation of FUAs (Functional Urban Areas) differs substantially between countries, making them not comparable. To overcome this problem, we developed a zoning system in which we examined data by zones of 10, 20, 30 kilometres from the boundaries of the built-up areas of FUA centres in each country.

Our research area covers 62 regional centers and their suburbs in three post-socialist countries: Hungary, Romania, and Slovakia. The central cities were selected based on the Eurostat Urban Audit 2020 database (Figure 1). Their total population was 12,366,433 in 2019, based on Eurostat's GISCO Local Administrative Units 2019 database. The suburban zones around the cities were defined in the ArcGIS software, selecting those settlements whose built-up center is located within 10 km of the built-up boundary of the central city. Thus, a total of 1,629

settlements were included in our sample. The total population of these suburban settlements was 6,361,772 heads in 2019, meaning an average settlement population is around 3,900.

Fig. 1. Map of the study area



Data source: Eurostat GISCO, Local Administrative Units 2019 GIS dataset

Our study aims to examine urbanization and suburbanization from the perspective of land use and sustainability, so an essential characteristic of these settlements is the change in population, which is presented in Table 1 based on Eurostat data.

Table 1. Population and population change in the study area between 2001 and 2019

	Population 2001 (head)	Population 2019 (head)	Population change (head)	Population change (%)
FUA centers	12 182 877	12 366 433	183 556	1,51
Surrounding settlements	5 680 160	6 361 772	523 455	12,00
Total population	17 863 037	18 728 205	707 010	4,84

Data source: Eurostat-GISCO, Local Administrative Units 2019 GIS dataset, Eurostat historical population data 1961-2011

The population of city centers increased by more than 180,000 people (1.51%) between 2001 and 2019. Of the 62 central cities, 30 had an increase in population, with an average of 14,000 heads, while 32 had a decrease, with an average of 23,000 heads. The increase in the population of suburban settlements exceeded 520,000 people (12%) during the same period. Out of the

1,629 settlements, 1,025 showed an increase (an average increase of 830 people during the examined period), while 604 showed a decrease in population (an average of 294 people).

Materials

The land cover data used to analyze the years 2000 and 2018 came from the vector GIS files of the Corine Land Cover database (EU, 2021). During the GIS processing, we clipped Hungary, Romania, and Slovakia territory from the European-level database with ArcGIS software. We used Eurostat's GISCO Local Administrative Units 2019 database to prepare the extract, which contains LAU2 level administrative boundaries. During the analysis, each land cover category's area was calculated and later used to create indicators for the regional centers and their suburban zones.

Regarding the land cover, we also used the high resolution (10 m and 20 m) imperviousness data for the years 2006 and 2018 from Copernicus Land Monitoring Service.

The centers of the FUAs (Functional Urban Areas) were determined based on the Eurostat GISCO Urban Audit 2020 database in the three examined countries. The selection of suburban settlements connected to them was described in Section X.

Regarding the population data, we used the Eurostat GISCO Local Administrative Units database and the related Eurostat historical population data from 1961 to 2011.

Methods

During the analysis, we worked with various land cover indicators for the FUA centers and their suburban zones (merged from the LAU2 level units). All calculations were carried out for these two area types. Most of the applied indicators were defined by Gardi et al. (2010) to measure land use sustainability. The calculations were based on Corine Land Cover data except for the agricultural intensity indicator, which needed livestock data, which we did not have for the three countries. Because of this, we could not make a Land Use Sustainability Index assessment, so we only opted for the partial indicators for the years 2000 and 2018:

- urbanization indicator: ratio of artificial surfaces' area to the total area of a given territorial unit,
- industrialization indicator: ratio of the CLC 1.2.1 category's area (industrial and commercial zones) to the total area of a given territorial unit,
- agricultural indicator: ratio of agricultural surfaces' area (CLC Level 1 nomenclature's 2nd group) to the total area of a given territorial unit,
- naturalness indicator: ratio of natural, semi-natural, and wetland surfaces' area (CLC Level 1 nomenclature 3rd and 4th groups) to the total area of a given territorial unit,
- biodiversity indicator: number of different classes from the natural, semi-natural, wetland, and water bodies classes at the third level of CLC nomenclature.

In addition, relying on the surface coverage data, we also calculated the hemeroby level of the FUA centers and their suburban areas based on the methodology published by the European Environmental Agency (EEA, 2016). Each CLC Level 3 category has a hemeroby level number (from 1 to 7), and with the use of their area in hectares, we can calculate an average hemeroby level for a given region, in our case, for the territory of the FUA centers and their suburban zones. Finally, we reversed and rescaled (to between 0 and 1) these average values as the EEA methodology recommended and used them in our later assessments.

We used the imperviousness datasets to examine whether concentration or deconcentration of building density was decisive in a given FUA between 2006 and 2018. For example, if the average percentage of imperviousness increases, the various residential zone building density becomes higher, while if it decreases, the density decreases in parallel, which means urban sprawl. To achieve this goal, we classified the imperviousness datasets into five classes based on an analysis of the average imperviousness level of various residential categories of Corine LC. During the analysis, we used the top three classes: 3/ between 4 and 15 % of imperviousness, 4/ 16 to 50 % of imperviousness, and 5/ above 50 %. Then, we calculated their territorial share in the residential zones to see if building density increased or decreased.

As a final step, we tried to classify the data of the territorial units using SPSS software. This was used for cluster analysis and linear regression calculations to identify the main types. so specific and general conclusions could be drawn based on their characteristics.

Using the basic database, several publications and conference presentations have been produced, exploring the characteristics of each agglomeration and the three countries.

Publications:

1. Hoyk, Edit ; Hardi, Tamás ; Farkas, Jenő Zsolt Environmental impacts of urbanization processes on the examples of Kecskemét and Győr functional urban areas JOURNAL OF CENTRAL EUROPEAN GREEN INNOVATION 7 : 1 pp. 13-33. , 21 p. (2019)
2. Hardi, Tamás ; Hegyiné Bolla, Katalin A szuburbanizáció környezetátalakító szerepe a győri agglomerációban In: Berghauer, S; Dávid, L D; Dnyisztrjanszkij, M; Fodor, Gy; Gergely, L; Gönczy, S; Izsák, T; Mocá, A; Molnár, D I; Molnár, J; Nagy, T; Oláh, N; Papp, G; Sass, E; Scsuka, H; Tóth, A; Vince, T; Virván, O (szerk.) Társadalomföldrajzi folyamatok Kelet-Közép-Európában: problémák, tendenciák, irányzatok: Nemzetközi földrajzi konferencia Beregszász, 2020. március 26–27. Tanulmánykötet = Socìal′no-geografìčnì procesi v Shìdno-Central′nìj Èvropì: problemi, tendencìї, naprâmi : mìžnarodna naukova geografìčna konferencìâ Beregove, 26-27 bereznja 2020 roku. Zbìrnik naukovih robìt = Human geographical processes in East Central Europe: problems, tendencies and trends : International Geographical Conference Berehove, March 26–27, 2020. Selected papers Ungvár, Ukrajna : RIK-U Kiadó (2020) 356 p. pp. 667-674. , 8 p.
3. Hardi, Tamás ; Repaská, Gabriela ; Veselovský, Ján ; Vilinová, Katarína Environmental consequences of the urban sprawl in the suburban zone of Nitra: An analysis based on landcover data GEOGRAPHICA PANNONICA 24 : 3 pp. 205-220. , 16 p. (2020) DOI WoS Scopus (Q2)
4. Hardi, Tamás Differences and similarities in the expansion of suburban built-up areas around the different city regions of three Central European countries TÉR ÉS TÁRSADALOM 36 : 3 pp. 165-193. , 29 p. (2022) DOI WoS

Paper under peer review

- Hardi, T Szuburbanizáció és urban sprawl : Budapest, Bukarest, Pozsony összehasonlító elemzések. City.hu Várostudomány Szemle, 2022-3.

Elaborated manuscript

- Types of regional centers' urban sprawl and its impact on the environment in three Central European countries

Manuscripts under elaboration

- Long-term change in the land use in the agglomeration of Győr
- Types of urban sprawl patterns and their impact on the environment

3. Selection of sample settlements

Three sample settlements were selected in each of the four agglomerations (Győr, Kecskemét, Nitra, Cluj-Napoca), according to the urban-rural gradient principle. Statistical data (demographics, migration, construction, number of new dwellings), aerial photographs and field surveys were used for the selection. In each case, the three municipalities represented different levels of agglomeration and suburbanisation as follows:

1) An inner suburb, closely linked to the central city, which can be seen as a continuation of the central city, and which is significantly affected by suburbanisation, with the construction of condominiums in addition to detached houses.
2) A settlement located further away from the central city and significantly affected by suburbanisation. New housing in the settlement is mainly single-family houses, and there has been a significant change in the structure of the settlement: densification with the opening of new streets and the creation of new settlement area(s).
3) A more remote settlement, slightly affected by out-migration, with an increase in population but no change in the basic structure of the settlement. New residents and new houses have been incorporated into the traditional settlement structure as new houses or renovated old houses.

Sample settlements:

Győr agglomeration: 1) Győrújfalu; 2) Győrzámoly; 3) Börcs

Kecskemét agglomeration: 1) Ballószög; 2) Kerekegyháza; 3) Fülöpszállás

Nitra agglomeration: 1) Nitrianske Hrnčiarovce (Nyitragerencsér); 2) Malý Lapáš (Kislapás) 3) Jelšovce (Nyitraegerszeg)

Cluj Napoca agglomeration: 1) Baciu (Kisbács); 2) Chinteni (Kajántó); 3) Ajton (Ajtony)

4. Botanical surveys

The botanical survey basically meant the identification and statistical processing of woody plants. The survey covered the front gardens (the area between the fence and the roadway, typically managed by the owner of the plot) in the public domain. These front gardens are of considerable importance for the settlement landscape and also represent a significant amount of green space. An important aspect of our investigation is how different are the new streets/settlements built in the last 15 years from traditional village streets? For this reason, in each of the settlements studied, one traditional and one new street were selected and surveyed. Due to travel restrictions, this was only done in the sample settlements in Hungary.

We examined the number of species and individuals of woody vegetation in a total of 300 front gardens in settlements. Most often, one species or two individuals occurred in front gardens, but there were also front gardens with 8 or more species and 14 or more individuals in some cases.

Since we also saw several abandoned plots during our work, we also examined a part of a settlement on the outskirts of the Győr agglomeration that had been abandoned for decades. We were looking for answers to the question of what environmental consequences we can expect in a village that has been abandoned due to relocation.

The complete work and its processing and database will be completed in the summer of 2022. Previously, several publications and conference presentations have already resulted from the studies. We currently have an accepted paper in preparation (journal article, Tájökológiai Lapok / Journal Of Landscape Ecology) and a follow-up in preparation.

Publications

1. Hardi, Tamás ; Csontos, Péter ; Tamás, Júlia Environmental consequnces of the rural abandonment – A pilot survey of gardens in a Hungarian ghost village TÁJÖKOLÓGIAI LAPOK / JOURNAL OF LANDSCAPE ECOLOGY 17 : 1 pp. 121-129. , 9 p. (2019) REAL Scopus (Q4)
2. Csontos, Péter ; Tamás, Júlia ; Hardi, Tamás Egy felhagyott dunántúli település fás szárú növényzetének változása – túlélés, betelepülés, hasznosítás BOTANIKAI KÖZLEMÉNYEK 106 : 1 pp. 153-154. , 2 p. (2019) REAL-J Scopus (Q4 IF: 0,52)
3. Csontos, Péter ; Kalapos, Tibor ; Faradhimu, Tito ; Laborczi, Annamária ; Hardi, Tamás ; Tamás, Júlia Effects of tree size and park maintenance on soil seed bank of Gleditsia triacanthos, an exotic tree in urban green areas BIOLOGIA FUTURA 71 : 1-2 pp. 81-91. , 11 p. (2020) DOI WoS REAL Scopus (Q2 IF: 1,069)

Accepted paper under publication

- Tamás Júlia, Csontos Péter, Farkas Jenő Zsolt, Hoyk Edit, Hardi Tamás: Előkertek létesítéséhez választott fásszárú növények felmérése különböző mértékben szuburbanizálódott Kecskemét környéki falvakban. TÁJÖKOLÓGIAI LAPOK / JOURNAL OF LANDSCAPE ECOLOGY. (Q4)

Manuscript

- Tamás Júlia, Csontos Péter, Hardi Tamás: Előkertek létesítéséhez választott fásszárú növények felmérése különböző mértékben szuburbanizálódott Győr környéki falvakban. TÁJÖKOLÓGIAI LAPOK / JOURNAL OF LANDSCAPE ECOLOGY. (Q4)

5. Resident questionnaire and interviews

Botanical surveys could not be extended to areas owned by inhabitants. In the villages, a significant part of the green areas is owned (gardens) or managed (front gardens) by the population. These areas are of great ecological and environmental importance. However, families moving out of the city have different attitudes towards their management than the traditional village population. Orchards are disappearing, mown lawns and ornamental gardens are becoming more common, and more and more plots are being paved.

One of the key elements of the research project was a questionnaire to the population to investigate all this. In the 4*3 sample settlements, a total of 600 questionnaires were carried out.

A sample was drawn up per settlement. The method used was a spatial random sampling. This involved using recent aerial photographs of the given settlement to produce a grid structure, to do a list of households to be asked. In the case of an unsuccessful query, the interviewers had to ask the neighbouring household. This ensured that the respondents included both from new and old parts of a village.

Questions were asked about the respondent's motivations, the extent to which the landscape and settlement and the possibility of having their own green space played a role in their decision to move in the given settlement (in the case of a respondent moving in). In addition, we asked about the respondent's attitudes towards the public and their own green spaces and assessed the nature of the green space in the residential plot.

Unfortunately, the COVID epidemic greatly hampered the questionnaire's management. Mainly because of this, the duration of our survey had to be extended. Our original plan was to have students of sociology take the questionnaire. Online education made this difficult. In Hungary, we managed to do the survey with the help of students and under the guidance of a teacher, but in Nitra and Cluj-Napoca we had to contract a company to do the survey, as the latter city had online education until April 2022. Thus, after a considerable delay, we completed the survey in the summer of 2022 and then, during August and September, the cleaning of the database and the basic analyses. We now have the results, an excellent database, which is in the process of being published.

Manuscripts under elaboration:

- Hardi Tamás, Páthy Ádám, Nárai Márta: Attitudes of inhabitants on the management of green space in the suburbs
- Hardi Tamás, Csontos Péter: Change of villagescape in Central Europen suburbs

5. Modeling

Estimating the environmental impact of suburban traffic

Among many environmental impacts of the suburbanisation, the well-known increase in traffic stands out, which is accompanied not only by an increase in congestion and accidents, but also by a significant increase in pollutant emissions from transport in peri-urban areas. It is true that the scale of suburbanization in smaller agglomerations is significantly smaller than in metropolises, but it has more relied on individual modes of transport in the commuter traffic of the population. Our study uses COPERT (COmpERT Program to calculate Emissions from Road Transport) software developed in collaboration with the European Environment Agency (EEA), the Joint Research Center (JRC), the Aristotle University of Thessaloniki and EMISIA SA. to estimate the change in pollutant emissions in relation to a road connecting a group of Szigetköz settlements around Győr (the Dunaszeg – Győrújfalu section of road 1401) between 1995 and 2018. As a result, the composition and nature of air pollution from transport is changing rapidly near the city.

Modeling and forecasting of the suburban land use and the extension of urban built-up area

To perform the modeling task, we chose the Land Change Modeler v2.0 for ArcGIS software. The software framework, developed by Clark Labs and Conservation International, is suitable for analysing and predicting land cover change.

The structure of the software is organized around the major steps of LUC modeling, with separate submenus for analyzing change, determining change potentials, running the simulation, and setting design correction factors. In the software, the MLP (multi-layer perceptron) neural network was selected among the several available methodologies.

The model used in this research was developed based on the 2015 project "Forecasting the long-term social and economic development trajectory of Hungary". The results of the then forecast, which ran until 2030, were uploaded to the National Adaptation Geographic Information System (NATéR). In the current modeling process, changes have been made mainly in the parameterization of the model. The differences and similarities between the 2015 model and the model used in the present study are summarized below:

- the transformation submodels (30) on which the two models are based are identical in their entirety,
- the fundamental difference lies in the constraints and incentives of the model runs, on the one hand, because two versions of the new demographic and migration projections (Lennert, 2021) were used to refine the conversion of the artificial surfaces,
- on the other hand, the data from the Cordex CNRM45 projection, which mainly concerned agricultural and semi-natural surfaces, were used instead of the RegCM climate model previously incorporated,
- and an important difference is that in 2015 the model was run only up to 2030, whereas in the present case it was run up to 2050.

Based on the modeling of the two urban areas under study, it can be said that the landscape transformation associated with the suburbanisation process, i.e. the increase in built-up areas, may be significant up to 2050, but that the transformations affecting agriculture and forestry will exceed these, especially in the case of Kecskemét. In the Győr area, the increase in artificial surfaces could exceed 10 % by 2050, while in the Kecskemét urban area it will be 10 % or less, and in absolute terms this means the conversion of a much smaller area. It can also be pointed out that the area with its inherently mosaic land use is more likely to experience land use change in the coming decades, due to the fact that farmers are also more forced to adapt to climate change than in the Győr area.

Publications:

1. Hardi, Tamás ; Farkas, Orsolya ; Hegyiné Bolla, Katalin: A személygépjármű-forgalom növekedésének környezeti hatása egy Győr környéki szuburbán útszakaszon TERÜLETI STATISZTIKA 61 : 4 pp. 503-526. , 24 p. (2021) DOI Scopus (Q3)
2. Farkas, Orsolya ; Hardi, Tamás ; Hegyiné, Bolla Katalin: A személygépjármű-forgalom növekedésének környezeti hatása egy Győr környéki szuburbán útszakaszon In: Jóna, László; Nárai, Márta (szerk.) NYUTO 35 : Válogatott közlemények Győr, Magyarország : KRTK RKI Nyugat-magyarországi Tudományos Osztály (2022) 360 p. pp. 241-262. , 22 p. (ismételt kiadás)
3. Hoyk, Edit ; Farkas, Jenő Zsolt ; Hardi, Tamás: Kísérlet a magyarországi földhasználat fenntarthatósági szempontú értékelésére A FALU 37 : 1 pp. 5-16. , 12 p. (2022) REAL

Elaborated manuscript:

- Farkas Jenő, Hardi Tamás: Győr és Kecskemét várostérségek földhasználatváltozásának modellezése 2050-ig

6. Difficulties

The main difficulty of the research was the closures caused by COVID. As a consequence, the crossing of the state border was not possible or was limited at the time of the research. Access to the two cross-border study areas was therefore difficult. On the other hand, we were not able to conduct interviews under the epidemiological restrictions and domestic interviews were only possible after the withdrawal of some of these restrictions. Thirdly, we wanted to involve

university students in the survey work, but they were not present in the cities under study at the time of the online education.

This caused significant delays in the completion of the research activities. Finally, the work has been completed and the databases are available in good quality. A few of our publications are currently being published and peer-reviewed, and several manuscripts are in preparation. These will be published after the closure of the project.

7. Dissemination, popular publications

In addition to scientific publications, we have produced and are producing popular publications based on the research material.

The results of the research are also used in university teaching. The students of Sociology at the Széchenyi István University of Győr have been involved in practical activities such as the preparation of the research questionnaire and field interviewing. For the Hungarian and international students of the Master's programme in Regional and Environmental Economics and for the students of the Doctoral School of Regional Science, the results were integrated into the curriculum.

Publications:

1. Hardi, Tamás: A táj átalakulása: a városias területek rohamos növekedésének fenntarthatósági kérdései. KATEDRA: A SZLOVÁKIAI MAGYAR PEDAGÓGUSOK ÉS SZŰLŐK LAPJA (DUNAJSKA STREDA) 28 : 8 pp. 14-17. , 4 p. (2021)
2. Hoyk, Edit ; Farkas, Jenő Zsolt ; Hardi, Tamás: A földhasználat változásának hatása a fenntarthatóságra In: Koós, Bálint (szerk.) Területi riport 2021 Budapest, Magyarország : Közgazdaság- és Regionális Tudományi Kutatóközpont (2021) 190 p. pp. 126-138. , 43 p.
3. Hoyk, Edit ; Farkas, Jenő Zsolt ; Hardi, Tamás: A földhasználat változásának hatása a fenntarthatóságra Paper: 491800 (2021) PORTFOLIO.HU, KRTK blog, 2021.07.12., Megjelenés: Magyarország,

Manuscript under elaboration (accepted plan in pocket book series of ELKH-Libri kiadó):

- Hardi Tamás: Az urbanizáció környezeti hatásai

8. Conference attendance and organization

- Organization of the ”2th Urbanization Ecology Conference” Győr, 14-15. October 2021., Partners: CERS West-Hungarian Research Departement, Széchenyi István University, Centre for Ecological Research, Hungarian Ecological Society
- Organization of a parallel session: 61st ERSA Congress Disparities in a Digitalising (Post-Covid) world – Networks, Entrepreneurship and Regional Development 22 – 26 August 2022,, Pécs Title of the session: Suburbanization, urban sprawl, and their impact on the environment in Central Europe

Attendance

1. Hardi, T ; Csontos, P ; Tamás, J Environmental consequences of the rural abandonment – A pilot survey in a Hungarian ghost village In: Zapletalová, J; Vaishar, A; Stastná, M (szerk.) Eurorural '18: 6th Moravian Conference on Rural Research : European Countryside and its Perception Brno, Csehország : Mendel University in Brno (2018) 49 p. p. 18
2. Csontos, Péter ; Hardi, Tamás ; Tamás, Júlia Egy felhagyott település növényzetének alakulása - esettanulmány Zsörkön In: Csontos, Péter; Hanga, Zoltán; Hajdu, Tamás; Korsós, Zoltán; Kovács-Hostyánszki, Anikó; Mecsnóber, Melinda; Szurdoki, Erzsébet; Vitályos, Gábor Áron (szerk.) A Magyar Biológiai Társaság XXXI. Vándorgyűlése : összefoglalók Budapest, Magyarország : Fővárosi Állat- és Növénykert, Magyar Biológiai Társaság (2018) 40 p. p. 29
3. Hoyk, Edit ; Farkas, Jenő Zsolt ; Hardi, Tamás Environmental impacts of urbanization processes on the examples of Kecskemét and Győr Functional Urban Areas In: Kende, Zoltán; Bálint, Csaba; Kunos, Viola

(szerk.) 18th Alps-Adria Scientific Workshop : Alimentation and Agri-environment : Abstract book Gödöllő, Magyarország : Szent István Egyetem Egyetemi Kiadó (2019) 186 p. pp. 70-71. , 2 p.

4. Hardi, Tamás Az urban sprawl környezeti és tájképi hatásai néhány példán keresztül In: Fazekas, István; Lázár, István (szerk.) VIII. Magyar Tájökológiai Konferencia : Összefoglalók Kisvárda, Magyarország : MTA DTB Földtudományi Szakbizottság (2019) 101 p. pp. 42-42. , 1 p.
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