# THESES OF PHD DISSERTATION

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# Research of land use change modeling possibilities in Hungary, with the analysis of the national land use change processes and their regularities

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# 1. BACKGROUND, OBJECTIVES

The land around us is a complex and sensitive system in which the sub-systems of the environment, the economy and society are simultaneously present. The complex approach of the sustainable development principle, which takes the development needs of the environment, society, and the economy into account, aims to maintain this very system. It should be examined how land researchers and land designers address the topic of sustainability. In order to do so, one must understand what connection the three pillars of sustainability have with the land, and how they affect its operation through direct and indirect drivers with different intensities.

The basis of my research is a land model in which the elements of the land are represented by different land use categories the place and ratio of which is constantly changing due to socio-economic needs, the infrastructure system and changing environmental conditions. This land use change is a process which can be described by examining adequate data within certain timeframes. The driving force of change can be determined by the cause-and-effect relations between the pillars. By determining drivers that inflict the change and examining the magnitude of their impact, the land, that is, the land use change can be modelled.

The main goal of my research is to identify Hungarian territorial processes and drivers on a national scale that can be tied to the environmental, social, economic and infrastructural pillars. My additional goal is to develop a national land use change model based on the results of my research through which the synergetic effects present in the land can be understood better and can be used to support territorial engineering and nationwide decision-making.

In order to accomplish my main goal, I determined the following sub-goals:

1. Presenting the environmental models, including the land use change models that are applied in international practice, as well as collecting and evaluating the potential application of them.
2. Uncovering the main land use change processes documented in national and international literature and determining the leading driver of the processes.
3. Uncovering national land use change processes, evaluating directions of change.
4. Identifying the drivers of land use change.
5. Developing and validating a national land use change model.
6. Future modelling and evaluating the results of change processes based on the traceable land use change processes with the help of a trend scenario.
7. Drafting a sample future scenario based on the environment of the development policy influencing land use change and implementing them into the national land use change model, evaluating the results.
8. Drafting a proposal about the application of land use change models in a national planning environment based on the case studies of the application of the developed model.

## 2. MATERIALS AND METHODS

The basis for the methodology of my research is the research method originating from systems theory, which consists of three main steps: system definition, system analysis and system synthesis. By determining the land system and analysing the processes inside it, as well as synthesising the system, a national land use change model has been developed as part of my research. The fourth main step of my research was to model the operation of the developed system, to evaluate the modelled results and to identify new options to use the system.

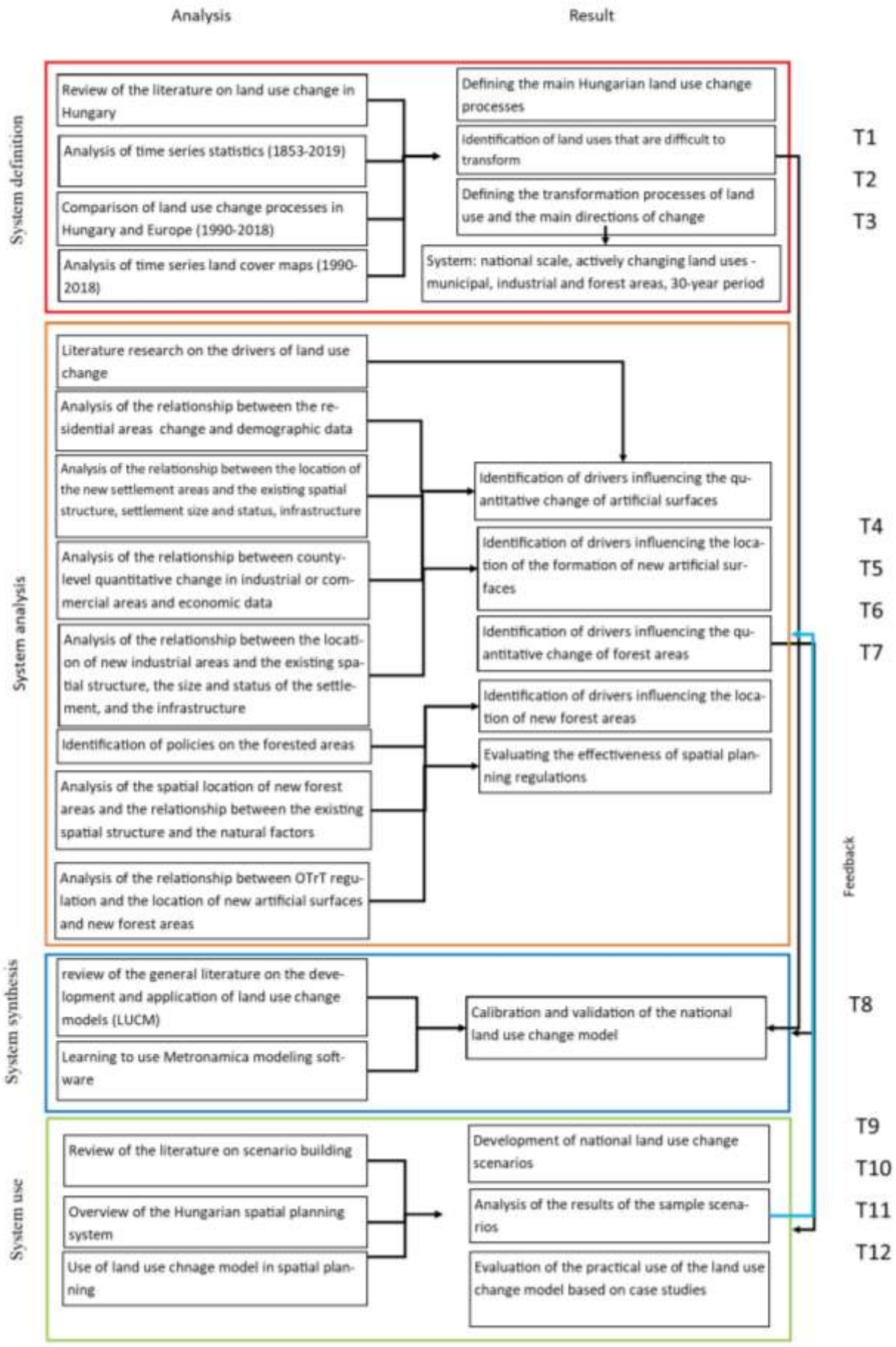
According to the developed system definition, a further subject of my research is a system in which:

- The land is represented by certain land use categories present in the CORINE database.
- The examined categories are artificial surfaces and forested areas, the growth of which is a consistently traceable landscape change process. Other types of area usage are altered passively, the transformation between agricultural areas and their leading drivers are not examined in this research.
- In the system applied in the present research, Hungary's land operation and change processes are controlled by the drivers of the development and location of primarily residential areas, industrial or commercial units and forested areas.

During the system analysis, I examined those drivers, the effects of which are traceable in our country through the changes of the three actively growing land use categories (residential areas, industrial or commercial units, forested areas), moreover, through the location of newly developing areas. In my research, while examining certain land use categories, I differentiated between the quantity of the given category and the drivers influencing the location of the new categories.

In my research, I developed a national land use change model, for the identified land use change processes and the system synthesis defined by the drivers. For the development of the model, I used the Metronamica software, a general modelling platform, which has been used successfully in several decision support systems on an international level. The national model developed by me can be seen as an integrated regional model, in which the spatial interactions component is a so-called regional model which simulates the way in which certain regions attract residents and the industry. The land use change component simulates the contest for free space of alternate sub-systems – environment-society-economy – under which national land use ratios and their location, that is, the spatial structure develops.

With the developed land use change model, I simulated the potential land use change processes until 2045 based on three scenarios. By analysing the obtained scenario results, I presented the expected effects of today's processes on the future spatial structure. The model also presented an opportunity to examine the long-term effects of the identified drivers, thus, it also provided feedback to determine the drivers.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## 3. THESES (NEW SCIENTIFIC RESULTS)

The formulation of the new scientific findings is based on the review of literature on the system approach and land use change modelling (Thesis 1), geospatial analysis of national land use change processes (Theses 2–3), identifying and evaluating the effects of drivers influencing national land use change (Theses 4–7), developing and applying the national land use change model (Theses 8–12), and examining the application of the model in national planning practice (Theses 13–14).

**Thesis 1**

**The land can be described by certain land usages, and its operation can be interpreted through a four-pillar model, where the drivers of the four pillars – society, economy, nature, and infrastructure –control the landscape change processes.**

The basis of system dynamics, based on the review of general literature on environmental models, including the development and application of land use change models (LUCM), the first step of research based on system theory is system definition. Accordingly, the land system used in my research is based on Tóth's 1981 description of a tetrahedron model, according to which, 'a settlement is a system of natural (environmental), social, economic, and infrastructural (technological) spheres in a dynamic interaction with each other. These are illustrated by a tetrahedron, along its edges, each sphere interacts with every other one.' Later Tóth interpreted the tetrahedron model for a geological space, in which a settlement is a densification of phenomenon in the geographical space. According to Tóth's (1981) model 'a change in one of the spheres necessarily generates changes in the other three as well'.

**Thesis 2**

**Due to their scale, the CORINE time series land cover maps and the change monitoring layers primarily reflect national or larger scale changes, therefore this serves as a basis for national land use change examination.**

The change processes show different attributes on different scales (e.g., national, regional, local), the available databases and data strings have various scales, so they are suitable for developing different scales of models. The main goal of my research was to examine the land use change processes that can be perceptible on a national scale. In order to do this, I took available data, their accuracy and temporal scope into account while determining the examined system. Based on the statistical time series data and the time series land cover maps, the land use change processes can be traced well.

**Thesis 3**

**The national land use change processes can be described by the following basic principles in Hungary:**

- **Artificial surfaces and forested areas are typically expanding, agricultural areas and semi-natural areas are shrinking.**
- **The residential area, extensive industrial or commercial units, forested areas and bodies of water are land usages that are hard to transform.**
- **It is common for the main directions of land use change that artificial surfaces and forested areas expand in the place of agricultural areas.**

In my research, I examined the analyses of national land use change available in relevant literature, analysed long time series (1853–1919) statistical data, compared national land use change processes with processes common in other European countries, and identified land use change processes from 1990–2018 by using the CORINE database. My analyses unequivocally confirmed that artificial surfaces and forested areas are typically expanding during national landscape change processes, the other land use categories transform passively. The other process identified and supported by other statistical data is that artificial surfaces, forested areas, and bodies of water are hardly transforming land usages, meaning that they did not transform at all, or only slightly in the examined 28 years. Based on the recorded processes, the basis of the system I applied is that the landscape operation and change processes of Hungary are controlled by drivers of the development and location of primarily residential areas, industrial or commercial units, and forested areas.

**Thesis 4**

**When looking at national land use change, the leading drivers can be categorised based on whether the given driver's effect impacts the quantity or the location of a land use category. The demand for quantity can be determined on a national level, however, it appears differentiated regionally. The spatial structure's localizing drivers determine the exact location of new land usages.**

In my research, I identified the main land use change processes, and the connection between the drivers attached to socio-economic-environmental and infrastructural pillars. The literature consulted separates five types of land use change influencing drivers: socio-economic, political, technological, natural, and cultural. In my research, I examined, in respect of the five types, those drivers, the effects of which are traceable in our country through the three actively expanding land use categories, moreover, through the location of newly developing areas. Based on the statistical and geospatial comparative analyses of the data, the effects of some drivers were perceptible during changes in quantity, while the effects of other drivers were perceptible in the examined categories' geospatial location.

**Thesis 5**

**The drivers influencing changes to the residential area can be interpreted according to the following:**

**Changes in the quantity of the residential area are influenced by a triple socio-economic driver, in which population change, urbanization process and cultural impact generating a larger living space are displayed.**

**The location of the residential area is influenced by regional policies mediating social and economic drivers, as well as the national transport infrastructure system.**

**The current spatial structure, that is, the location of current land usages, can be interpreted as a cultural driver, which impacts the location of the residential area. Among the technical drivers, the national transport network also impacts the location. The third political driver of the local appearance of new residential areas is the regulation of spatial planning, which aims to protect the natural (environmental) pillar (e.g., ecological networks, separate cropland areas).**

In my research, in order to evaluate the changes in population and the effects of consumers' demands, I examined the ratio between population changes and the expansion of residential areas on a national and county level. The demand for the expansion of residential areas differs in different parts of the country. There is a connection between population change and changes to the residential area: growing population typically results in expanding residential areas, however, changes to the residential area do not have a connection with shrinking population. Population change, the demand for settlement and the expansion of residential areas are defined by urbanization: new residential areas have been primarily formed next to settlements with an urban status in the last 28 years.

I examined the connection of the location of new residential areas with current spatial structures, the national transport network and the regulation of the spatial structure and zones of the national spatial plan with a geospatial analysis. New residential areas primarily formed inside inland areas and their vicinity. The effects of urbanization and the expansion of new residential areas near county seats can be clearly witnessed at the regional location, the intensive development of the metropolitan area of Budapest is outstanding. The regional location of new residential areas is heavily impacted by the national motorways and the main road network. The local formation of new settlements is impacted by the national road network: the further the roads of national significance are, the less residential areas are formed.

The spatial plan that can be considered as a political driver can also be interpreted as a mediator of natural drivers, since the primary objective of the regulation is the long-term preservation of our natural resources. Actual change processes only had a loose connection with the area usages suggested by the OTrT act, although, serious differences in magnitude were not found. In the examined time period, new built-in areas were formed in the area of restricted building zones, so the regulation of zones cannot be considered strong.

**Thesis 6**

**Drivers impacting changes in large scale industrial or commercial units can be interpreted according to the following:**

**Changes in the quantity of industrial or commercial units are primarily impacted by economic growth, including the demand for investments and the development of industrial or commercial employment.**

**The regional location of industrial or commercial units is determined by economic drivers and the national transport infrastructure system.**

**The location of industrial or commercial units is heavily impacted by the national transport network, within that the motorway network. Further drivers impacting exact location, similarly to the residential areas, are the current spatial structure and the spatial planning regulations that can be interpreted as cultural drivers.**

In order to examine the drivers impacting large scale industrial or commercial units, following the review of national statistical data, I classified the data about changes to the gross value added (GVA), and the data about raising employment in the industrial field as socio-economic drivers, that can be interpreted as economic drivers. I demonstrated the connection between indicator changes and the expansion of industrial or commercial units in both indexes.

In order to examine new industrial or commercial units' spatial location, I analysed the effects of the inland area and the national transport network with a geospatial method, which specify their formation in a traceable way. The analysis showed that 84% of new industrial or commercial units form 500 meters away from the inland area, and 90% of the units form in the 1000-meter radius buffer area. The metropolitan location of new industrial or commercial units is primarily determined by the motorway network and the main road network. 84% of the industrial and commercial units existing in 1990 were situated in the 5 km wide buffer strip of the examined roads. Local formation of new industrial or commercial units is also impacted by the national road network: new industrial or commercial units are developed closest to roads of national significance. Similarly to residential areas, the regulations of spatial planning are weak.

**Thesis 7**

**The drivers impacting changes to forested areas can be interpreted as the following:**

**The quantity demand of forested areas is primarily impacted by the political driver that communicates socio-economic expectations, that is, forest strategy.**

**On the one hand, regional location is determined by the spatial plan that records the decisions of forest strategy on the map; on the other hand, there is a demonstratable connection between the growing ratio of spontaneously afforesting areas and the shrinking of population, thus, the emptying of rural areas due to urbanization is an indirect driver.**

**The exact location of forested areas is impacted by the current spatial structure, more precisely, the current forested areas. A mild effect can be detected between**

**the location of the new forests and the development of natural drivers (terrain, soil).**

The strongest drivers controlling quantity changes to forested areas are the objectives recorded in forest strategy, which primarily support the expansion of forested areas. Next to conscious forestation, we can trace the afforestation process of abandoned agricultural areas. The counties most affected by the formation of spontaneous forests in the examined time period lost a considerable amount of their population, moreover, typically we can witness small village settlement structures in which the effects of urbanization apply even more, so that the emptying of rural areas and the abandonment of agricultural practices strengthens forestation processes.

I considered the current spatial structure (location of current forests) and the natural conditions as drivers impacting the regional location of forests. In order to examine the latter, I analysed at which lands and under what terrain and soil conditions do new forested areas form. The most forested areas formed at the 100–250-meter field level during the examined period, which can primarily be explained with the high rate of forest cover at the higher field levels even at the initial state. My research concerning types of soil confirmed that forestation happened in large volumes on soil with quicksand or sand during the examined period. This also means that during forestation, forests were not formed on areas with soil suitable for forests, but policies aiming to retain quicksand and sandy soils controlled the process.

The validity of the rule regarding the forestry region of the national spatial plan cannot be considered strong based on the changes to land cover data.

**Thesis 8**

**Land use and land change processes form an easy to describe system, which we can model by identifying and adequately determining the drivers. With the model, the change processes can be confirmed, moreover, future trends can be foreseen. During the development of the land use change model, the duration of the modellable future is determined by the duration of the examined processes. The objective of the application must be taken into consideration while developing the model. The formation of the model, that is, the calibration, happens with the quantification of previously recorded land use processes and drivers that can be observed in the area.**

Considering that the land can be interpreted as a system, a land use change model can be developed by applying a systematic approach, which is able to simulate future effects of examined landscape change processes according to different future scenarios. In my research, while developing and applying the land use change model, I kept in mind that the timeframe of processes examined in the past determine the timeframe of the modellable future, so based on the examined 28 years, I determined the timeframe of the modelling until 2045. I took into consideration that I would like to examine national-scale change processes with the model that are traceable during the examined period, while determining input data for the construction of the model.

I used the Metronamica software environment to create an integrated model which has two components: a dynamically changing land use change model working on a cellular basis and a regional model based on spatial interaction.

The basis for the calibration of the regional model component were statistical data showing a county's changes to population and industrial employment rate, and internal migration in the country. While calibrating the land use change model component, I designed an area eligibility map that depends on three factors. The first factor is the neighbourhood effect, which describes current spatial structure, the potential of land use transformations, and their magnetic effects on each other. I determined this factor while defining strengths and directions of conversions during the examination of land use change processes. The second factor of the area eligibility map is availability, with which I quantified the strength examined in the transport network's artificial surfaces. The third factor is the suitability to natural factors, the definition of which is based on the given natural factor's (terrain, type of soil) actual location.

**Thesis 9**

**Using the land use change model, the change processes discovered in the past can be projected to the future. This is facilitated by the development of a starting or trend scenario in which future changes in quantity can be determined by a trend function of changes that happened in the known past, and the spatial changes can be determined based on existing drivers. The evaluation of current drivers can be carried out by applying the starting scenario, and it can be determined which drivers' land use change effects could lead to land use conflicts.**

As part of my research, I created a starting scenario by integrating the known change processes and the identified drivers into the system to apply the land use change model developed. In this scenario, I described the changes in quantity of residential areas and industrial or commercial units with the identified trend functions of demographic and employment processes, determined the forest cover based on valid forest strategy and defined future expected quantities of other land uses with a developed trend function that is based on changes experienced in the examined period. I determined spatial changes by using the area eligibility map designed during the calibration, the expected road developments recorded in legislation and the regulations of the national spatial plan.

**Thesis 10**

**Known socio-economic trends, changes to cultural demands (e.g., consumer society), expected natural changes (e.g., climate change) and global changes must be acknowledged while creating alternative scenarios during the application of the model. These drivers must be quantified in a comprehensible – yet realistic – way for the model, and trends and strengths must be determined.**

For the application of the developed land use change model, I created sample scenarios and simulated regional political decision points and their possible trends. The created scenarios aim to compare the centrum principles with the balanced regional development principles in the research. The examined land use change processes and the current legislation regarding landscape development policies were considered while creating the scenarios.

**Thesis 11**

**According to the findings based on the national land use change model's trend scenario, in case the current land use change processes and spatial drivers remain in effect until 2045, the following changes can be foreseen:**

- **The size of the residential area expands on a national level, but considerable changes can be expected on the county level.**
- **A two-way process can be observed with regards to the development of artificial surfaces: an intensive expansion of urban areas and especially the metropolitan area around the capital, and the emptying of rural areas.**
- **It is expected that 42.000 hectares of residential area will lose functionality by 2045 due to the shrinking population in the modelled processes.**
- **National forest cover will reach 30% by 2045, due to policies and spontaneous forestation processes.**
- **One of the most important sustainability indicators regarding land use – the expansion of covered surfaces – can be expected following the internal displacement of artificial surfaces**
- **The protective categories of the national spatial plan do not set strong boundaries for incorporation. The fulfilment of social demand for built-in areas in the country's intensively developing regions despite the regulations can only be carried out in protected zones for the long-term protection of our resources.**
- **Agricultural practices will be discontinued on close to 10% of agricultural areas.**
- **The expansion of forested areas happens at an altering rate at different parts of the country, in some areas the scale of the expansion transforms the landscape's entire character, the land seals.**

Using the land use change model's trend scenario developed as part of this research, national spatial structure in the year 2045 can be simulated and expected change processes can be examined. The expansion of urban areas and the abandonment of rural areas is a two-way process well-recorded in relation to changes of artificial surfaces. Even though the model calculated with a shrinking population based on current population trends, new artificial areas formed in the central region of the country by modelling the migration between counties, however, due to the shrinking population, the model calculates with "disappearing" settlements, the area of which will reach 42 thousand hectares by 2045 based on the modelled processes. I called these "emptying" settlements during the examination since there are no examples or social theories regarding what will happen to abandoned settlements in the foreseeable future. Next to the internal displacement of residential areas the model simulated the expansion of

covered areas as well. The current national 5,7% ratio of covered surfaces will increase to 6,8% by 2045 based on the results of the trend scenario, which projects a 100 thousand hectare increase on a national level.

According to the trend scenario, agricultural areas will occupy 57% of the country in 2045 and the abandonment of agricultural practices will continue: agricultural practices will be discontinued on almost 10% of the country. However, based on experience, due to centuries of extensive land management, the natural resettlement following the abandonment of cultivation usually leads to the development of ecosystems with less species, for this reason in many cases practicing extensive agriculture with high natural value would be better from a habitat and species protection standpoint.

Different counties will have a different share in the 30% forest cover modelled for 2045. Forest cover expands more than the national average and current ratios in some counties, namely Pest, Bács-Kiskun, and Csongrád-Csanád. The expansion of forested areas in these counties significantly changes land use structure, thus the operation of the land and the status of environmental systems (e.g., water balance). The ratio of forested areas will increase in Nógrád county, which is already forested, the nearly 60% forest cover is expected to transform the landscape's image; valuable grassland habitats may disappear due to sealing forested areas. As a result of the effects of differentiated distribution, in other counties – namely, Fejér, Jász-Nagykun-Szolnok, Békés and Hajdú-Bihar – the expansion of forest cover does not follow the national rhythm.

The effects of the regulations of the national spatial plan are noticeable based on the modelled changes, but the rules do not apply in the case of strict regulations (e.g., core area or large waterbed area). This means that the fulfilment of social demand can be carried out based on other drivers (e.g., neighbourhood relations, infrastructural effects) in the given county and, despite the regulations, it can be carried out in the regulated area. This is a vital statement, since it raises awareness on the expected conflicts which can arise during the validation of the OTrT between the objectives of socio-economic demands-interests and the long-term conservation of resources.

**Thesis 12**

**Since the developed land use change model is based on known data, its application aids spatial planning. The recorded interventions and the conceptual links between their effects can be represented, and the complex effects appearing differently in time and space become perceptible. The modelling device can be used to assess the efficiency of the planned decisions and to evaluate whether the effect of the planned intervention actually fits the decision's objective. The volume and location of expected land use conflicts can be determined with the help of the modelled land use maps.**

Based on my practical case study related to the National Spatial Plan, the modelling device can be applied successfully during a strategic environmental impact assessment, especially to

anticipate the effects of the plan on the land – which is a requirement for such plans – as well as to evaluate the effects of the different plan variants.

The results of the other case study I conducted regarding flood control planning showed that the modelling device creates opportunity to present different planning alternatives which can substantiate policy decisions.

Land use conflicts expected in the future can be identified with the help of spatial structure maps simulated by the modelling device, when the spatial changes of the different pillars – economy, society, environment, infrastructure – obstruct the fulfilment of the requirements of sustainability. Conflict areas typically form where demands appearing in the regional sphere can only be satiated in the local sphere, that is, at the expense of protected areas. This way, the economic pillar strengthens at the expense of the environmental pillar. Identifying conflict areas can facilitate the creation of different spatial development alternatives that can be used to avoid future conflicts.

## 4. CONCLUSIONS AND RECOMMENDATIONS

In order to implement the land use change models into everyday spatial planning practice, the development of numerous sample projects and detailed methodology is required. However, the results and the case studies of the practical application of the land use change model developed by me showed, that a system like this can support spatial planning by being able to:

> Demonstrate the consequences of valid departmental policies concerning land use and regulations based on a comparison between current and future land use and evaluate its effects on the landscape.
>
> Evaluate alternative decisions and choose the one that ensures sustainability by comparing future land use maps modelled by scenarios that can be created based on different decision alternatives.

The everyday application of a national land use change model could aid the evaluation of the spatial effects of national and political strategies and to create a coherency between them. The land use change model would provide an opportunity right from the first phase of the planning phase to uncover expectable landscape change processes, display the area effects of planned strategic actions in scenarios and choose the version most suitable for the objectives after evaluating the effects.

The innovative decision preparing approach of the application of the land use change model combines the classic quantitative analysis methodology and the opportunities presented by modern geoinformatics, moreover, it takes every relevant variable with a spatial structure and every relation into account. If the model spreads and gets more refined, it could make the traditional decision preparation analyses, that only focus on single problematic areas, and draw regional conclusions originating from a special examination obsolete. Using these models supports decision-making by analysing ‘what happens if’-type processes. The model depicts complex effects and processes plainly by using a map, which can encourage and ease the socialization of the planning, social responsibility and dialogue.

The land use change model I have developed, was created primarily by uncovering the main drivers of land use change processes and by using existing national data.

The national land use change model could be developed further by carrying out the following research and supplementing further databases.

> Even though agricultural areas primarily offer space for the expansion of artificial surfaces and forested areas, transformation processes are still noticeable in these areas as well, which processes primarily mean an internal conversion between agricultural areas. These processes are controlled by the European Union’s agricultural support system, I did not examine these effects in my research. Refining the calibration of a developed model based on the results of examining the effects of the agricultural support system could present an opportunity to evaluate the results of the modelling regarding agricultural areas as well.
>
> It would be necessary to implement the climate change’s expectable changes and its effects on land use change into the developed model. For this, the implementation of national databases, that have a similar resolution to CORINE data regarding climate, is necessary during the refinement of calibration of the developed model.

The land use change model I have developed provides an opportunity to create further alternative future scenarios, to research the results and to support decision for the regional policies connected to these. The creation of further scenarios is suggested in the following topics:

Creating a climate change scenario by integrating regional or local climate maps created by climate change models, with which the effects on land use of given climate scenarios can be modelled and it could aid the formulation of national climate adaptation actions, furthermore, modelling the effects of possible alternative actions.

The European Commission published a communication titled The European Green Deal (COM(2019) 640 final), what's objective is handling climate and environmental challenges. The new European development policy is setting a new direction for many land use policies, so it is proposed to develop a scenario for the land use change model that could model the impact of the planned measures on land use by quantifying the objectives set out in the adopted policies.

## 5. THE AUTORS'S PUBLICATIONS RELATED TO THE TOPIC

### Journal articles

Vaszócsik, V., Vajdovich-Visy, E. (2017). Integrated land-use models for spatial planning support: country-specific solutions. *Deturope: The central european journal of regional development and tourism* 9(3) pp. 12-28. (ISSN 1821-2506)

Illyés Zs., Pádárné T. É., Nádasy L., Földi Zs., Vaszócsik V., Kató E. (2016): Tendencies and future urban sprawl in two study areas in the agglomeration of Budapest. *Landscape & Environment.* 10 (2) pp. 75-88. (ISSN 1789 – 4921)

Vaszócsik Vilja (2017): Meddig nőhetnek a városok? – A területhasználat-változási folyamatok modellezése *Területi Statisztika*, 57(2) pp. 205–223 (ISSN 0018-7828)

Vaszócsik Vilja, Göncz Annamária, Schneller Krisztián, Tóth Péter, Prokai Réka (2014): Magyarországi területi tervezést támogató térképes indikátor rendszer kialakításának lehetséges lépései a zöld infrastruktúra koncepció megvalósításáért *Tájökológiai Lapok* 12 (2) pp. 411-428. (ISSN: 1589-4673)

### Conference proceedings, full paper

Ganszky M., Vaszócsik V. (2017): Döntéstámogató rendszerek alkalmazása az adaptív tervezés támogatására. *In:* Blanka V., Ladányi Zs. (szerk.): *Interdiszciplináris tájkutatás a XXI. században. VII. Magyar Tájökológiai Konferencia tanulmányai*. U-GEO Alapítvány és Szegedi Tudományegyetem Földrajzi és Földtudományi Intézet. Szeged. 2017. május 25-27. pp. 176-183. (ISBN 978-963-306-542-6)

Vaszócsik V., Schneller K. (2017): Területi tervezést támogató térképes indikátor rendszer kialakítása két magyarországi kistérség területén. *In:* Blanka V., Ladányi Zs. (szerk.): *Interdiszciplináris tájkutatás a XXI. században. VII. Magyar Tájökológiai Konferencia tanulmányai.* U-GEO Alapítvány és Szegedi Tudományegyetem Földrajzi és Földtudományi Intézet. Szeged. 2017. május 25-27. pp. (628-636. ISBN 978-963-306-542-6)

Vaszócsik Vilja (2016): Hazai tájhasználat-változási folyamatok modellezése *In:* Horváth Gergely (szerk.) *Tájhasználat és tájvédelem kihívások és lehetőségek Budapesten* 2015. május 21-23. között megrendezett VI. Magyar Tájökológiai Konferencia előadásai 2016 Budapest pp. 190-197. (ISBN 978-963-284-778-8)

Krisztián Schneller, Erzsébet Vajdovich Visy, Vilja Vaszócsik (2016): Enhancement of the role of spatial planning in climate change adaptation by long term modelling of land use change in Hungary *In:* Jombach, S., Valánszki, I., Filep-Kovács, K., Fábos, J. Gy., Ryan , R.L., Lindhult, M.S., Kollányi, L. (Eds.) 2016: *Landscapes and Greenways of Resilience-Proceeding of 5th Fábos Conference on Landscape and Greenway Planning* (Budapest, 01 July, 2016) pp. 303-310 (ISBN: 978-963-269-548-8)

Vaszócsik Vilja (2013): Tájhasználat és tájszerkezet alakulásának hosszú távú modellezésének alkalmazása a területi tervezésben *In:* Dr. Koncz István – Szova Ilona (szerk.) *Együtt a biztosabb tudományos karrierért, a jövőtervezésért* című VII. Ph.D. -Konferencia előadásai. Budapest, 2013. október. 11. pp. 211-214 (ISBN 978-963-89915-0-8)

Vaszócsik Vilja, Göncz Annamária, Cserni Tímea, Hedwig van Delden (2012):: TICAD SDSS – Tájhasználat és tájszerkezet alakulásának hosszú távú modellezése *In:* Konkoly Gyúró Éva –

Tirászi Ágnes – Nagy Gabriella Mária (szerk.) *Tájtudomány – Tájtervezés* V. Magyar tájökológiai konferencia. 2013 Sopron pp. 37-41 (ISBN 978-963-334-102-5)

Hedwig van Delden - Annamária Göncz - Jelle Hurkens - Zsuzanna Nagy - Pavel Tacheci - Stanislav Vaněček - Roel Vanhout - Vilja Vaszocsik (2012): Integrating hydrology, land use and socio - economics in supporting spatial planning for the Tisza basin *In:* R. Seppelt, A.A. Voinov, S. Lange, D. Bankamp (Eds.): *International Environmental Modelling and Software Society (iEMSs) 2012 International Congress on Environmental Modelling and Software Managing Resources of a Limited Planet: Pathways and Visions under Uncertainty, Sixth Biennial Meeting,* Leipzig, Germany (ISBN: 978-88-9035-742-8)

**Conference proceedings, abstract**

Annamária Göncz - Vilja Vaszócsik - Krisztián Schneller (2016): Strengthening the climate change adaptation role of spatial planning by modelling future formation of land use *In:* Nadja Kabish, Jutta Stadler, Simon Duffield, Horst Korn, Aletta Bonn (Eds.) 2017 *Proceeding of European Conference „Nature-based Solutions to Climate Change in Urban Areas and their Rural surrundings"* (Bonn, 17-19 November 2015) (ISBN: 978-3-89624-193-1

Illyés Zs. – Pádárné Török É. – Kató E. – Nádasy L. Z. – Vaszócsik V. (2015): Expanding settlements. *In*: Fazakas Csaba – Benedek Klára (szerk.): *3. Erdélyi Kertész és Tájépítész Konferencia*. Absztrakt kötet. Sapientia EMTE, Műszaki és Humántudományok Kar, Marosvásárhely. pp. 57-58

Vaszócsik Vilja – Devecseri Anikó –Göncz Annamária – Horváth Balázs – Szekeres Orsolya – Tóth Ágnes – Schneller Krisztián (2015): Hol adunk teret a folyónak? *In*: Bardóczi Sándor (szerk.) 2015: *Tájodüsszeia a magyar tájépítész szakma 2010-2015 közötti legfontosabb munkáiból, alkotásaiból*. (ISBN: 978-963-12-4385-7)

Faragó Péter – Devecseri Anikó –Göncz Annamária – Faragóné Huszár Szilvia – Hamar József - Schneller Krisztián - Vaszócsik Vilja (2015) : Az ország területi jövőképe – OTrT *In:* Bardóczi Sándor (szerk.) 2015: *Tájodüsszeia a magyar tájépítész szakma 2010-2015 közötti legfontosabb munkáiból, alkotásaiból*. (ISBN: 978-963-12-4385-7)

**Part of Books**

Vaszócsik Vilja – Göncz Annamária (2018): A területhasználat-változási folyamatok modellezése *In:* Módosné Bugyi Ildikó – Földi Zsófia (szerk.) *Mit „akar" a táj? Tanulmánykötet dr. Csima Péter 70. születésnapjának tiszteletére* 2018. Budapest pp. 85-92. (ISBN 978-963-269-765-9)

Vaszócsik Vilja (2014): Hol adjunk „Teret a Folyónak"? – A területi tervezés szerepe az új szemléletű árvízi kockázatkezelés kialakításában *In:* Dr. Csemez Attila (szerk.) *Tájakadémia IV. – Időszerű tájrendezési feladatok* 2014. Budapest pp. 205-216.(ISBN 978-963-503-576-2)