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LANDSCAPE DYNIMICS EVALUATION –
Modelling relations of land use and regeneration potential
PhD Thesis

by

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1. INTRODUCTION

In these studies I was evaluated the effects of different economic and social activities, as well as examine the ecological drivers of land use changes. My primary purpose was to determine the most important factors that generate the land use changes, to analyze the interactions of key processes, and finally to understand the dynamics of land use changes and thus contributes to the sustainable methods of land-management. The research analyzes the complex process of land-use change and tries to integrate the social and economic spheres in the analysis. The method based on the interaction between landscape ecological, social, environmental and economic processes. At the integration of multidisciplinary knowledge the results of assess of land-use change and social, environmental and economic drivers provide the data to evaluate the effects of land-use change. The results of the model tested in the South-Plain region carried out in Kis-Sárrét study area where the geoecological mapping procedure has been used in other aspects of the reassessment.

1.1. Literature, Precedents

The landscape term are used by the literary sources as abstract and concrete sense as part of a place to determine the aesthetic quality of the traditional folk-culture. However it is also used to determine the ecological function of a mosaic structured landscape (landscape patches, corridors etc.) (Sauer 1963; Meinig 1979; Forman and Godron 1986; Cosgrove and Daniels 1988; Forman 1995). The common feature of these definitions integrates the land-use activities and the land cover. By Turner and Meyer (1994), we can describe the land use by the intention and instruments of cultivation of the people living on it. In this case, the land usually indicates that physical environment which the exposure, soil type, climatic conditions, the hydrological characteristics and vegetation type determined. The acceleration of the land-use change is associated with the increasing vulnerable elements (Tumer et al. 1990; Turner 1991; Krummer

and Tumer 1994; Turner and Meyer 1994), and the dynamic of the social and physical environment (Thomas 1956; Simmons 1988; Mather and Sdasyuk 1991; Munton et al. 1992; Krummer and Tumer 1994; Turner and Meyer 1994). The land-use change is not only important by itself but the role played at the society-environment-economy system too. Under land conversation Skole *et al.* (1994), means the changes in its function and structure, and under the transformation of it he means the effect of given surface cover on another place. The former case is more related to the land use change, the latter one is to the changes in land cover. The causes are working continuously, and they can be fully examined in socio-economic and environmental context (Turner and Meyer 1994). Overall, the land changes may carry the consequences in themselves. These may be positive for one party, group, community or social system, however, negative for the other part (Tress 2005; Bennett 1976). By some authors the Hungarian landscape ecologist researches are interpreted as the examination of land patches, landscape hierarchy and land functions like the oldest school of landscape ecology (Mezősi 2004). The results international and domestic landscape and land evaluation are summarized in the monograph of Lóczy D. (2002). The national land evaluation concerning the landscape potential is linked to Géczy (Géczy 1968). A plant production capacity of a landscape is measured by not only the soil attributes, but the geographic and climatic parameters as well. Besides the indication method, Géczy's other innovation were that he considered natural and human geographical factors too (distance to the market, transport facilities or the potential of labor). The new land evaluation system was quantifying the habitat by parameterized geographical attributes (Fórizs J.-né et al 1971).

The agroecological potential of Hungary was achieved by land evaluation using mathematical modeling (Láng I. et al. 1983). This method was innovative by the climate zonal system and the classification of fertility of soils.

The land evaluation as a part of a complex landscape research relies on a strong domestic literature. The most important milestones were the introduction the concept of landscape potential, and stressing the applied landscape research and spreading the complex landscape approach. (Ádám 1968). The agrogeological surveys of the sixties gradually developed into agroecological ones (Lóczy 2002), this developing processes' important results was to found the domestic theoretical ecogeography (Góczán 1972). The holistic approach from the 1980's led a monograph description of the landscape confirmed by numerical data (Marosi and Somogyi 1990). The tasks of the ecological approach landscape design and the theoretical issues of landscape ecology were mainly approached from the landscape architecture by Csemez, Csima and Mőcsényi (Csemez 1996; Csima 1993; Mőcsényi 1968). Basic scientific papers have been investigated in relation to the sensitivity of the landscape (Kerényi and Csima 1999). The complex examination of landscape carrying capacity was carried out by Mezősi and his colleagues on the University of Szeged (then Department of Physical Geography József Attila University), (Mezősi and Rakonczai 1997). They were further developing the German geoecological mapping procedures which was one of the most important works of the past decade in the research of land structure. In this work, major emphasis will be given to a new type of evaluation system of the landscape potential, which meant a integrated analysis of the biogen and abiogen components (Keveiné Bárány, 1997). Their theoretical and practical applications have a significant domestic history in the GIS landscape research (Kertész 1997; Zentai 2000; Detrekői and Szabó 1995). In recent years, there has been an increase in antropogen-centric landscape capacity evaluation methods (Csorba 1995, 1996, 1997). These process-orientated landscape analyses on small-scaled areas have an influence on measuring of landscape functions and effects of the human impacts. The species and habitat assessment are the most popular methods in the Hungarian ecological and natural evaluation. The species- and habitat-based ecological variables mainly used at the technique of evaluation habitat (Simon and Seregélyes 1999; Soó 1963). The biggest national habitat-evaluation project was the National Biodiversity Monitoring System (Fekete G. et al. 1997). Recent

years significant landscape research discipline was the regional approach functional landscape research with the optimal landscape potential assessment objective (Keveiné Bárány 2000; Marosi 1980).

1.2. Goals

The aim of this research, introduced in the dissertation, is to define the main relations between the social, environmental and economical processes in connection with the land use change, on the other hand to make more understandable the correlation between sustainable agricultural farming conservation activities. First I tested the applicability of the method in regional scale then I used the calibrated data at the Kis-Sárrét study area following it I made a proposal to an optimal land use techniques.

The used interdisciplinary method gives a possibility to determinate the present environment protection situations (in agricultural and environment protected areas as well) and also the nature conservation and cultivation activities have an effect on this type of landscape examination.

My goal is to define the most important social, environmental and economical factors, furthermore to estimate the effects of land use change and finally to analyze the effects of spatial planning policy on the nature protection function important habitats areas based on different scenarios.

My methodological objective was to test the applied and theoretical land use models in Hungarian landscape capabilities and to underline the Hungarian specialities of landscape dynamic.

The results of the research contribute to the excavation of the consequences and reasons of the land use changes on two study areas. The examination is integrating the pattern orientated method in macro level with micro level methods. South Great Plain region means the macro level where the spatial allocations of the land use change drivers are simulated by different land use scenarios. The Körös-Maros National Park Kis-Sárrét study area means the micro-scale level of the evaluation, where

the landscape continuously changes since river-regulation activities of the 18 century. The effects of land use and habitat changes in Kis-Sárrét and examines human-ecological consequences moreover define the regeneration potential of valuable semi nature areas.

2. METHODS

The method alloys the statistical models of the social-economical theory, and the results of the geographical landscape models. The work combines geographical approach based on widely used statistical models (Veldkamp and Fresco, 1997; Kok and Veldkamp, 2000; Serneels and Lambin, 2001; Nelson et al. 2001; Schneider and Pontius, 2001) working with socio-economic theories and municipality (Walker et al., 2000; Staal et al., 2002; Vance and Geoghegan, 2002). The method gives a more accurate statistical model from the currently popular ones, and provides access into the nature of generating processes, as well as an important tool for professionals working in landscape planning.

2.1. Land use model – the CLUE-s model

The CLUE-S model (Conversion of Land Use and its Effects) (Veldkamp and Fresco 1996; Verburg et al 1999) is a method for modeling the effects and transformation of land use which has already formed the basis for a number of landscape research. (Veldkamp et al. 2001, Verburg and Veldkamp 2004 Verburg *et al.* 2002, Verburg *et al.* 2004). The aim of this model is the simulation of the land use change with the help of the several empirically described factors of the land use and its drivers. The model can be used well to rate the spatial distribution and pattern of the land use change by analyzing the spatial and temporal dynamics of the change. Furthermore the CLUE-S is also used to analyze the fine-grained spatial scaled land use change. The model combines number of procedures dealing with land use system in spatial approach, and it is capable of a dynamic simulation between different the land uses. By bringing forward the spatial processes the model is suitable for displaying the future land use patterns on maps.

2.2. Statistical analysis

The dissertation is presenting a predictive statistical methodology with a multi-level model, which describes the changes approach in the landscape by integrating the time –and spatial processes. This kind of method is based on the more popular territorial approached and in time landscape models (Briassoulis, 2000; Veldkamp and Lambin, 2001), by uses different scenarios - using different scenarios – the analysis of the possible outcomes concerning the land use change reacts. If we are aware of the relationship between biodiversity and the landscape moreover the future land use change are mapable with the help of land use models. I determine the connection between the chosen variables and the land uses by the multinomial logistic regression analyze method.

2.3. Geoecological mapping

The processes at local level have allowed generating drivers to be more understandable with the help of the land use change of the study area. The method for examining optimal land use possibilities at local level is the geo-ecological mapping (GÖT, Mezősi G. és Rakonczai J 1997). The proposed method can determine the geo-ecological statement of an ecosystem, through the examination of biogen and abiogen components of the landscape. Also the process can asses the landscape with quantifying and weighting bio-physical parameters, for example, natural or ecological ones (Keveiné Bárány 1997).

3. RESULTS

In my research I wanted to prove four hypothesis (H1; H2.1; H2.2; H2.3) of which one is analyzed at regional level, and the other three are at local level.

3.1. Dynamics of land use change

The basic question is the land-use change, furthermore to understand the connection between the sustainable agricultural management activities, that how the land-use change process appear in the complex system of society, environment, economy, mainly at regional level.

The whole part of the Southern Great Plain is typically utilized agricultural area. We have to consider the land use demand according to the laws of land use and spatial planning and must take the environmental and nature conservation and the infrastructure needs into account as well. The land utilization in the Southern Great Plain is adopting to the natural conditions, primarily to the soil conditions, relatively homogeneous landscape boundaries. A most important dividing line is the River Tisza which shares its area for two markedly distinct major parts, considering the conditions of the landscape. The mosaic structured soil types and the climatic conditions give favorable terms for not only growing crops but growing several kinds of fruits and keeping animals. By their improving environmental impacts it may play a vital role to developing wooded patches area future.

3.1.1. Drivers of land use

a) A spatial location of a certain land use in those places most likely to be, where the "fit-factor of landscape is relatively high (H1.). Allocating the explanatory factors are chosen from spatial, demographic and economical statistical variables and the model simulation driven by the policy demands we can have the information in connection with the land use types.

At regional level, the demographic drivers are weaker explanatory than the soil features and the distance variables. Furthermore, either the area-specific land use method nor the occupation and the number of the inhabitants are crucial drivers on the landscape conversation.

The soil erosion attributes and the base saturation effect a certain land use mostly. On the soils with better buffer capacity it is more likely to be developed arable land than pasture land and forest. On the soils where the risk of soil erosion is remarkable, the chance to be an arable land is lower.

Where the proximity of water is determined, the importance of long-distance factors in the location of the pastures is the most picturesque. The agricultural lands mostly occur near the roads and waters and the arable lands are further from the towns but near to the roads. The forests and natural areas are spatially isolated.

The agrarian specific of a land is amplified by the fact that the agricultural employment rate for each type of landscape is displayed apart from the artificial landscape category. This rate is higher among pastures and arable lands and lower in forests and natural areas.

Towards west from the River Tisza, the occurrence of arable land patterns are limited, the probability of pastures are more likely to be in the Danube-Tisza Interfluve. Forest areas appear in the central and northern areas of Kiskunság in the model. However - if we look at the explanatory factors - the area loss of the riverside gallery forests are observed. The semi nature areas occur spreadly and not in every case show nature protection justification of the present land, these are not correlating with nature conservation policy.

There will appear a positive change in the pasture, the grass and forest areas based on the current land demand. The areas in north-west of Szeged and the South-Kiskunság, the pastures of Bácska sand ridge are dynamically changing.

By the prognostic scenario of the agriculture's appreciation there will not be expected any developing new arable lands because under conditions allowing the formation of the arable land.

As a result of the reduction of agricultural land, mainly in the Danube-Tisza Inter-sand ridge appear first natural and forested areas.

3.1.2. Landscape dynamic evaluation of Kis-Sárrét

With exploring the consequences and results of the habitat and land-use change, degree and extent of land-use change and socio-economic interactions were made possible.

b) The place of occurrence of a given habitat or biotope significantly affected by the biophysical parameters of soil and the distance from waters, and man-made objects (roads, settlements) (H2.1.).

By the distance parameters and on the basis of soil the occurrence of euhydrophy habitats is likely to be away from the settlements and near to the lakes. The reeds and marsh ecotypes can be found away from the settlements, but still within the protected area limits on the homogeneous land patches. We find the alkaline and wet meadow grass patches on the types of soils called solonetz which are close to the waters and settlements as well. The dry or semi-dry grasslands, are away from both the rivers and ponds. The occurrence of the forested areas shows strong ties to the fertility of soil.

The probability of occurring alkaline is very law, so the chance to create new wet ecotopes is little. The conditions developing any other non-woddy habitats are given almost everywhere. At other ecotopes these changes are balanced.

c) From the nature conservation point of view, the Kis-Sárrét is a valuable area where the land use and land cover are adjusting to the spatial pattern of the area's most valuable habitats. Furthermore, the spatial pattern of the characteristic land use mode of the study area is influenced by the type and location of the plant associations (H2.2.).

The euhydrophyte habitat is the most likely to be planted on the wetlands, while the reeds and marsh vegetations belong to the marsh surfaces. The woodland associations can be found in the leaved forest areas; however,

other treeless habitats are the ecotops of the complex agricultural areas. As a result of the mosaic structure of the area, the alkalines and the grass patches rarely fall into one site.

The distance from the settlements and the borders have an influence on the location of the arables. The existence of wet reliefs increase, while the distance from the roads and the woodland habitats reduce the chance of developing meadows and pasture lands. The complex cultivated structured areas can be found in the territory of the other non-wood habitats. The forest areas appear on the riverine and swamp woodlands, closed and open dry deciduous woodlands and other non-wood habitats. The areas of the semi nature grasslands and meadows are rich fens, and mesotrophic meadows and tall herb communities, the halophytic habitats and the dry and semi-dry closed grasslands and the shrublands are borders. The distance from the roads is increasing, while the distance from the national parks is increasing the possibility of the occurrence of grasslands. The inland marshes and the euhydrophyte habitats are located around the habitat types of reeds and marshes. The water lands are most identifiable around the rich fens, the halophytic habitats and meadow and also the lakes.

Overall, there is mowing and grazing on the alkalines, around the water management area there are euhydrophyte habitats, and also the forestation activities belong to the woody habitats. Near the roads we rather find pastures than marsh or euhydrophyte habitats.

Assuming the nature conservation perspective land use change – during the simulated 14 years - woodlands can be occured on the place where shrubs and herbaceous habitats are existing presently. In parallel with the process above mentioned, and the help of forestation, the expansion of the already existing forests is expecting. The area demand of pastures are increasing hence this kind of land use type will be appear on the places where the arable are disappearing.

The land use change on Kis-Sárrét clearly favors to the protection concerns and the nature of the landscape can be significantly improved in a short term. At the same time, keeping the biodiversity and the natural values of the Kis-Sárrét is primarily based on the various types of agricultural activities. This kind of conservation treatments are affected by the type of protected values.

d) The types, size of the ecotops and land use methods together are the explanatory factors of the regeneration potential of naturally valuable and sensitive habitats (H2.3.).

Ecologically more valuable associations can be found on the Lakes Ugrai, marshes and wet halophytic habitats. The euhydrophyte habitats have the highest nature conservation values it follows the grasslands, marshes, other non-woody habitats and finally the halophytic habitats and the woodlands. The habitat types with the highest nature conservation values appear near the watercourses and canals, and marshes and also reeds and marsh vegetation in the lakes. The artemisia salt steppes, the more valuable halophytic habitats, the large sedges and large sedges pastures have a slightly lower value. From a conservation aspect the less privileged areas are the good regenerating ability halophytic habitats and other woodlands and woody habitats. During a strict land-use planning activities, the halophytic habitats most likely to be receiving the highest conservation value. In addition, reeds and marshes, salt meadows of the border, the canal coast marsh vegetation, the wetlands and the artemisia salt steppes alone are expected to be the most sensitive areas.

e) Based on the above, the following optimal land use recommendations possible to be named:

The formation of halophytic habitats occur at the expense of other noon-wood habitats and marshes, all of them the noon-wood ecotops' space occupation is probably more likely to be. Therefore the land use which is for increasing the alkalines should be initiated on the latter vegetation types.

For increasing the forested areas, the most probable areas are the already existing forest patches. The further locations have unsuitable conditions concerning the forest.

Only on the arable are mostly possible to occur new meadows and pastures.

The extension of the protected zones (mainly toward eastern) could significantly increase the landscape and species diversity, as well as valuable new habitat types could be developed.

By the rationalization of the transport routes, and reducing their spatial occupation the regeneration potential of the valuable plant associations could be increased.

Preserving the wetlands and joining them to alkaline areas, could result more valuable ecotopes.

During the land use we must primary focus on the natural function of the area, which means a conscious land use. The degradation processes must be treated in particular, which in the long term significantly could reduce the land value of the current ecosystem.

The current practice of nature conservation is suggested to expand to the whole of the geoecosphere. The reservation of the land's natural functioning could be optimally possible with all the complex approach elements of the geoecosphere.

3.2. Methodological results

f) The dynamically evolving landscape patterns („hot-spots") selected by the Clue-S model, are possible to refine with the raster-based geological mapping. We can create a kind of application which is more accurately describing the changes of the dynamics and keeps the local circumstances in mind better.

g) The GEM method used at the examination of the habitats, allows an overall more homogeneous assessment of the plant associations. In contrast to this, the maturity and natural attributes of the Meta-evaluation focus on the habitat local characteristics, resulting more mosaic structures of the patches.

With combining the two models it will be possible to compare the national and local statistical and empirical data as well, on the other hand, it helps to understand better the land use processes between the two scale.

The use of empirical relations and conditions in statistical calculations, contributes significantly to the different interpretation of scientific theories which joins the social and ecological systems.

4. PUBLICATIONS RELATED THE DISSERTATION

Duray B., Hegedűs Z. 2004: Egy természetközeli agrogén táj szerkezeti és funkcionális vizsgálata – Biharugrai mintaterület. In: Táj, tér, tervezés. Geográfus Doktoranduszok VIII. Országos Konferenciája. Szeged, 2004. szeptember 4–5. Szerk.: Barton G., Dormány G.. Kovács F. Szeged: SZTE TTK Természeti Földrajzi és Geoinformatikai Tanszéke [18] p. CD-ROM http://www.geography.hu/cdrom/mfk2004/phd_keret.html

Duray, Balázs: Complex (functional and structural) landscape ecology research in the border area of the Dél-Alföld Region, Hungary, In. Planning, People and Practice. The Landscape Ecology of Sustainable Landscapes. Proceedings of the 13th Annual IALE(UK) Conference held at The University of Northampton. Ed: D. McCollin, J. I. Jackson. Northampton, 2005. 241–244. p.

Duray, B., Hegedűs, Z. 2005.: Geoecological mapping procedure in Kis-Sárrét study area. – Acta Climatologica et Chorologica, 38/39 kötet. 47–57. p.

Duray, B., Hegedűs Z. 2005: Komplex (funkcionális és szerkezeti) tájökológiai kutatások a Dél-Alföldi régió határmenti területein. Tájökológiai Lapok, 3(1): 133-153.

Hegedűs, Z., Duray, B., 2006.: Talajtani vizsgálatok szerepe a tájkutatásokban, talajelosztási rendszerünk korszerűsítései lehetőségeinek vizsgálata. In: Táj, környezet és társadalom. Ünnepi tanulmányok Keveiné Bárány Ilona professzor asszony tiszteletére. Szerk.: Kiss A., Mezősi G., Sümeghy Z. Szeged: SZTE Éghajlattani és Tájföldrajzi Tanszék, SZTE Természeti Földrajzi és Geoinformatikai Tanszék, 259–269. p.

Duray, B. 2008: Spatial conflicts of land-use changes on the rural areas of South Great Plain Region Warsaw Regional Forum EUROPA XXI. New functions of rural and industrial space in Central and Eastern (no 17, p. 97-108)

Duray B. 2008: A tájhasználat változásának vizsgálati módszerei;Kis-sárréti példa alapján. In: Tájkutatás-Tájökológia (Szerk.: Csorba P.-Fazekas I.) Meridián Alapítvány, Debrecen. pp.125-131.

Duray Balázs 2008: Tájváltozás modellezése a Dél-Alföldön. In: Tájökológiai kuttások. III. Magyar Tájökológiai Konferencia, 2008. május 8-10. Szerk. Csima P., Dublinszki-Boda B. Budapest Corvinus Egyetem,. 365-372. p.