Assessment Matrix Based Evaluation of Ecosystem Services in Relation to Land Use Change Scenarios

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1. Introduction

The ecosystem services are natural assets and services, which are used by humans directly or indirectly over their respective lifetimes (MEA, 2005). Several authors and organizations describe these goods of nature in different ways. Some authors use ecological concepts as the basis for categorization (Norberg, 1999), others concentrate on different human needs (Wallace, 2007), however the most common categories are based on some functional distinction (MEA, 2005; de Groot, 2006; Hein et al., 2006). Authors representing this latter group usually mention the following classification: provisioning, regulating, supporting and cultural services. The provisioning services like water, wood or timber are used directly by people. The regulating services are climate regulation, water purification and other similar processes. The cultural services are for example education, recreation potential and spiritual inspiration. The supporting services ensure the clear functioning of the three groups, for example soil formation and photosynthesis (MEA, 2005).

The methodology of valuing ecosystem services is an effective decision support tool, because this highlights the natural, social and economic values of the goods and services of the living system for decision-making and planning. Despite the availability of a wide range of valuation methods (Chen et al., 2009; Kiss et al., 2012), there are still unresolved issues (de Groot et al., 2010). Its important elements are revealing the spatial characterization and the dynamics of the landscape and ecosystem services, for which there are effective methods among the dynamically developing GIS analysis tools. This usually does not create a comprehensive inventory of all the ecosystem services, but analysis several selected services in detail, primarily in context with the potentials and land use changes (Willemen et al., 2008). One of the most promising methods of ecosystem services valuation is the assessment matrix, a great advantage of the method is that it can be aggregated at the landscape-level (Burkhard et al., 2009).

The major account of the processing and analysis of the historical maps is that allows of understanding of the past human land use, the long-term landscape changes and the dynamics of the landscape. The knowledge of the past also contributes to the exploration of the main driving forces and use them to anticipate the future changes (Swetnam et al., 2011). Modeling of future land use change is proved to be a very efficient method among many types of landscape change analysis (Pontius et al., 2001; Goldstein et al., 2004; Kline et al., 2007), and a frequent tool in climate change analysis (IPCC, 2007), land use planning (Xiang & Clarke, 2003), conservation planning (Osvaldo et al., 2000) and recently it has been increasingly used in the assessment of the ecosystem services (MEA, 2005). The evaluation of the ecosystem services and the modeling of the future land use changes have an increasing role in regional politics. The consistency between these two topics would be a very important step forward (Estoque et al., 2012).

In this study we describe an assessment framework of ecosystem services analysis in a pilot area of Southwest-Hungary called Nagyberek, used to be the largest swampy bay of Lake Balaton. The method using GIS analysis of historic maps and recent land cover dataset explores the main land use types. It concentrates also on those driving forces which are directly influenced by the land use of the area. We plan three future land use scenarios based on the main driving forces, with the help of the CLUE-S (Verburg et al., 2002), the integrated land use modeling tool. We select and assess a certain part of the ecosystem services according to the Burkhard's study (2009), their trends, with the help of the assessment matrix.

2. Methods

2.1. Study area

The pilot area of Southwest-Hungary called Nagyberek is about 1200 km^2, it is situated on the South-western shore of Lake Balaton (Figure 1). This is one of the most transformed rural landscapes of Hungary with many contradictory characteristics. The landscape structure was very heterogeneous in the past with the zigzaggy brooks and lakes, marshes, rich fens, wetlands, sandbanks and dense, impenetrable reed. The area abounded in water, it provided livelihood for the inhabitants in several manners: they fished in the shallow water, reed was used as building material, they cultivated vineyards on the hillsides and the permanently wet meadow was waiting the cattle with a rich grass yield in the driest years as well. But the pilot area was regulated in the 19th and in the 20th century, and this wealth was eliminated by the draining works and the agricultural intensification. Besides the remaining and protected valuable wetlands, nowadays in most of the area is cultivated with intensive agriculture and hunting is also intensive, moreover there are many demographic problems, for example the high level of migration and negative birth rate.

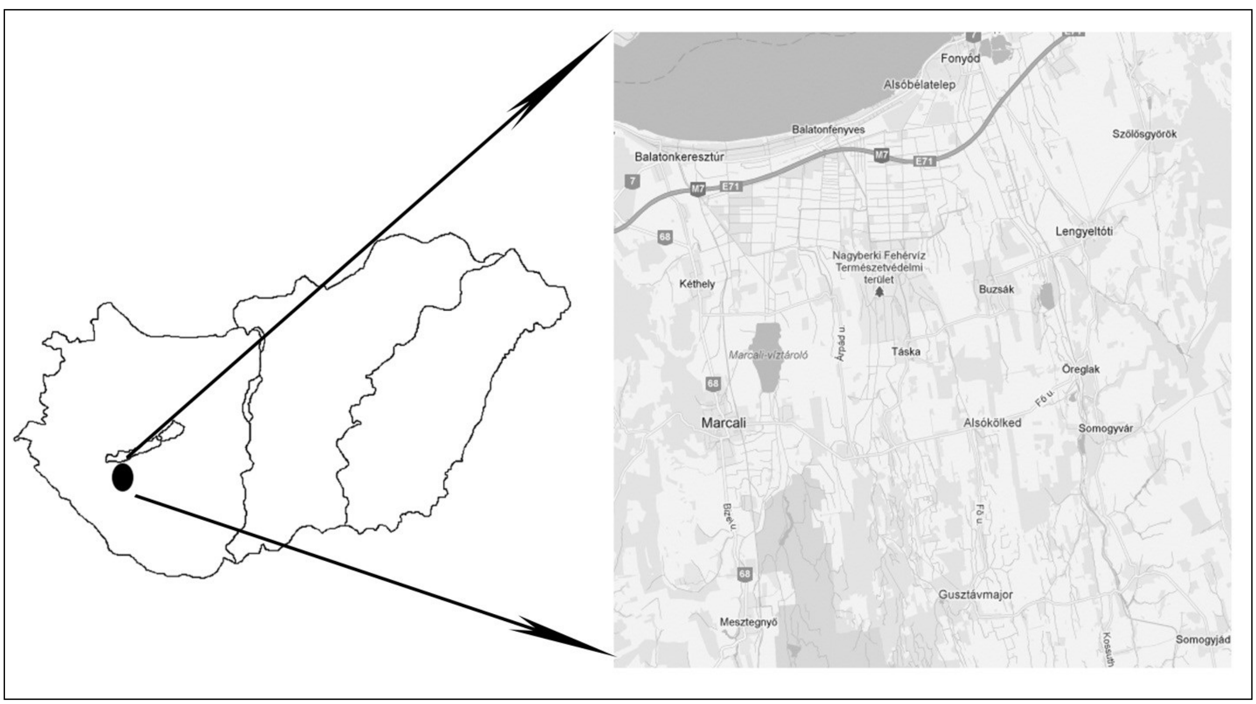

Figure 1. The location of Nagyberek in Hungary

2.2. Analysis of historic maps and recent land cover dataset

In the beginning of the processing of the maps we developed eight land use categories, which are different from the CORINE Land Cover categories, because of the analysis of the social aspect of biophysical land cover, also the new classification is called as „land cover with the land use aspects" (Table 1).

CLC CODE	CLC LEVEL 3	CLC LEVEL 2	Land use category
111	Continuous urban fabric	**Urban fabric**	**Built up area**
112	Discontinuous urban fabric		
121	Industrial or commercial units	**Industrial, commercial and transport units**	
122	Road and rail networks and associated land		
131	Mineral extraction sites	**Mine, dump and construction sites**	
132	Dump sites		
133	Construction sites		
141	Green urban areas	**Artificial non-agricultural vegetated areas**	
142	Sport and leisure facilities		
211	Non-irrigated arable land	**Arable land**	**Arable land**
213	Rice fields		
221	Vineyards	**Permanent crops**	**Vineyard and orchard**
222	Fruit trees and berry plantations		
231	Pastures	**Pastures**	**Pasture and meadow**
242	Complex cultivation	**Heterogeneous agricultural areas**	**Garden**
243	Land principally occupied by agriculture, with significant areas of natural vegetation		
311	Broad-leaved forest	**Forests**	**Forest**
312	Coniferous forest		
313	Mixed forest		
321	Natural grassland	**Shrub and/or herbaceous vegetation association**	
324	Transitional woodland shrub		
333	Sparsely vegetated areas	**Open spaces with little or no vegetation**	
411	Inland marshes	**Inland wetlands**	**Wetland**
412	Peat bogs		
511	Water courses	**Inland waters**	**Water surface**
512	Water bodies		

Table 1. The eight land use category with the corresponding CORINE Land Cover classes

The goal of the analysis and processing of the historical maps was to explore the main driving forces and determine the historical pattern of the land use, thus providing a base for the future landscape models' completion. The widely historical maps of Hungary are the military surveys, which provide quite detailed information. We analyzed the I. (1783-1784), the II. (1856-1860) and the III. (1880) military surveys, in addition, the present situation, 2012 was analyzed too. Due to the comparison, we fitted the historical maps in the same coordinate system (EOV). The digitalization and georeferencing of the military surveys were made by the ERDAS Imagine software package. The interpretation of the land use and the other informations of map were performed with screen digitizing with ArcGIS 9.3 software package, they were adapted to the above described eight land use categories. The smallest circumscribed patch was 0,01 km^2. The first created map was based on the land cover map of 2012, after the merging of the land use types to the abovementioned eight main categories. Thereafter the so-called „backspace method" was used to move backwards in time, than the next stop was the III. military survey. For it we fitted the previously created 2012 map, thereafter we transformed the boundaries of the patches. This was followed by the processing of the II. and I. military survey.

2.3. Modeling of the future land use

In the initial phase of the preparation process we set the policies and conversion rules from the story lines that influence land use transitions. Land use requirements are calculated at the aggregate level of the case study as a whole as part of a specific scenario. The land use requirements constrain the simulation by defining the totally required change in land use. The extrapolation of trends in land use change of the recent past into the near future is a common technique to calculate land use requirements. When necessary, these trends can be corrected for changes in population growth and/or diminishing land resources. Land use type specific conversion settings determine the temporal dynamics of the simulations. Two sets of parameters are needed to characterize the individual land use types: conversion elasticities and land use transition sequences. The second set of land use type characteristics that needs to be specified are the allowed land use transition sequences. Not all land use changes are possible – e.g., arable land cannot be converted into primary forest directly – and many land use conversions follow a certain sequence. During the simulation we evaluated the land use configurations of 25 years, from 2012 to 2037. In this study we have analyzed just the year of 2037. The "present tendencies going on" is the scenario of present tendencies going on, where the area of meadows, pastures and gardens are in decline, wetlands are stable and the demand for other land uses types is increasing. The "strong agricultural expansion" scenario, the area of arable lands increase strongly, the orchards, gardens and pastures expand moderately. The wetlands reduced moderately, while the forest and semi-natural areas more strongly. In the "increasing role of nature protection" scenario the nature protection activities are strong, hence the wetlands are increasing intensively. The water surfaces are also increasing, moreover, supposed that the arable land will be abandoned (following the natural succession) areas of pastures will be increasing.

2.4. Evaluation of ecosystem services: assessment matrix

For evaluating ecosystem services we tried to apply the assessment matrix developed by Burkhard and his colleagues (2009). The y-axis of this matrix contains the types of ecosystem services (ignoring the many controversial supporting services), while the x-axis of this matrix contains the abovementioned eight land use categories. In their crossroad is a value that expresses the category's potential to provide the service. The scale of possible values ranges from 0 to 5, 0 means that land cover class has no capacity to supply the service, and 5 means that land cover type has very high relevant capacity to provide it. This study compares the past, the current and the future land use using ecosystem assessment matrix developed by Burkhard et al. (2009) as a basis. These values are obviously weighted in proportion to the area, one area unit was 1000km$^{2.}$ We illustrated the exact steps of evaluation by the "arable land" land use category:

a) we selected the appropriate CORINE Land Cover classes from the Burkhard's assessment matrix (non-irrigated arable land; ricefields);

b) together the two CORINE Land Cover classes we calculated the scores for the three types of ecosystem services (provisioning services: 28, regulating services: 9, cultural services: 2);

c) we calculated the extent of the arable land use category for each maps

d) under the b) point calculated total values we weighted in proportion to the area, one area was 1000km^2, to give the final values (Figure 2).

a)- b)

		Provisioning services Σ	Crops	Livestock	Fodder	Capture Fisheries	Acquculture	Wild Foods	Timber	Wood fuel	Energy (Biomass)	Biochemicals/Medicine	Freshwater	Regulating services Σ	Local climate regulation	Global climate regulation	Flood protection	Groundwater rechage	Air Quality Regulation	Erosion Regulation	Nutrient regulation	Water purification	Pollination	Cultural sevicies Σ	Recreations and Aesthetic Values	Intrinsic Values of Biodiversity
Arable land	Non-irrigated arabie land	21	5	5	5	0	0	0	0	0	5	1	0	5	2	1	1	1	0	0	0	0	0	1	1	0
	Ricefields	7	5	0	2	0	0	0	0	0	0	0	0	4	2	0	0	2	0	0	0	0	0	1	1	0
	TOTAL	**28**												**9**										**2**		

c)- d)

	Land use category	Area (km^2)	Area unit (km^2)	Total value of provisioning services according to Burkhard et al. 2009	Provisioning services, weighted in proportion to the area	Total value of regulating services according to Burkhard et al. 2009	Regulating services, weighted in proportion to the area	Total value of cultural services according to Burkhard et al. 2009	Cultural services, weighted in proportion to the area	TOTAL VALUE
I. Military Survey (1783-1784)	Arable land	344,9673	1000	28	9,659085	9	3,104706	2	0,689935	13,45373
II. Military Survey (1856-1860)	Arable land	428,2487	1000	28	11,99096	9	3,854238	2	0,856497	16,7017
III. Military Survey (1880)	Arable land	438,8272	1000	28	12,28716	9	3,949445	2	0,877654	17,11426
CLC2012	Arable land	451,93	1000	28	12,65404	9	4,06737	2	0,90386	17,62527
Present tendencies going on	Arable land	473,21	1000	28	13,24988	9	4,25889	2	0,94642	18,45519
Strong agriculture expansion	Arable land	627,22	1000	28	17,56216	9	5,64498	2	1,25444	24,46158
Increasing role of nature protection	Arable land	52,57	1000	28	1,47196	9	0,47313	2	0,10514	2,05023

Figure 2. Example: Evaluation of ecosystem services by "arable land" use category (according Burkhard and his colleagues 2009).

3. Results

3.1. The results of the analysis of the historical maps and future land use scenarios

At the time of the I. military survey (1783-1784) the most typical land use types were forests (33%) and arable lands (28,9%), but wetlands (16,3%) and water surfaces (10,4%) were still present. During the years of the II. military survey (1856-1860) the land use was similar to the I. military survey, but the forest was reduced (22,8%) in parallel the arable land increased (35,9%). The effect of the drainage works is visible in the III. military survey (1880): the pasture and meadow (17%) took place the wetland, which reduced significantly (12,5%). Another difference is that, the forest reduced again (16,8%). Up to 2012, the wetlands almost disappeared (3,6%), the built-up areas (5,7%) and the forest (26,3%) increased significantly (Figure 3).

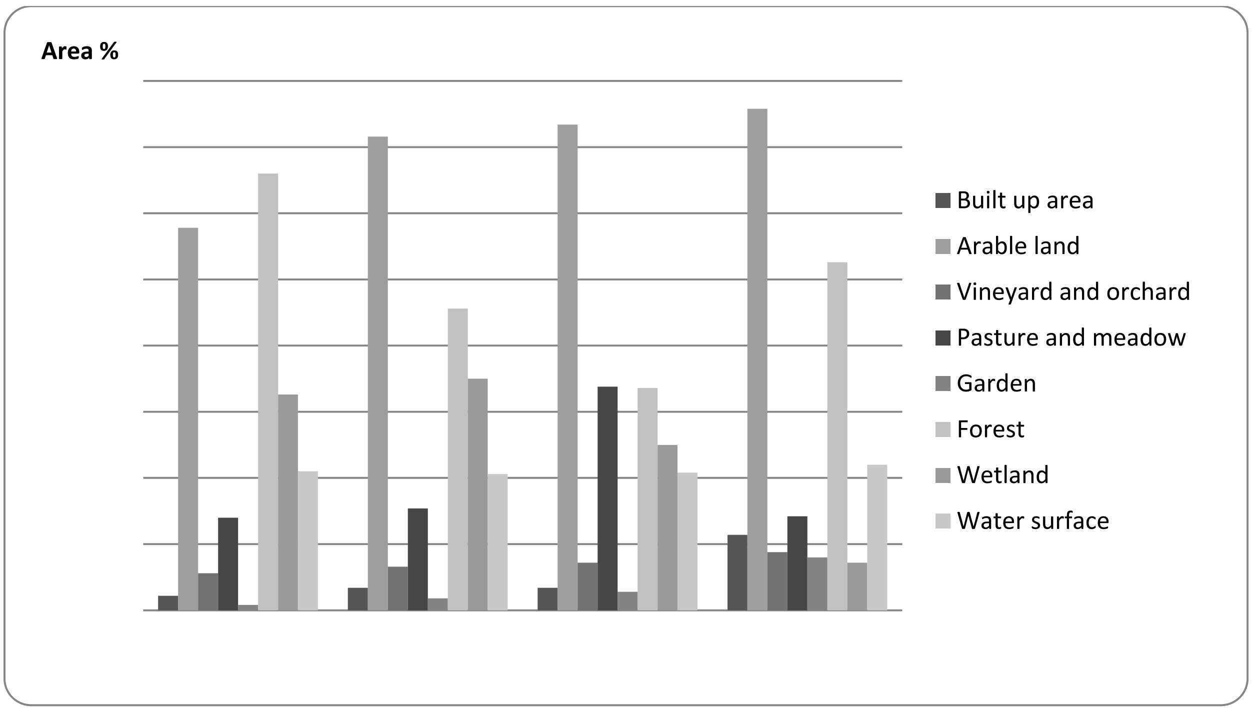

Figure 3. Land use change during the I. (1783-1784), the II. (1856-1860), the III. (1881) military surveys and in 2012

When we analyzed the states of 2037, the following statements can be made: The „present tendencies going on" scenario is similar to the 2012. In case of „strong agricultural expansion" scenario (the land use will change more intensively) the arable land will dramatically increase (52,5%) in contrast with forests (5,8%). In case of „increasing role of nature protection" scenario, the water surface (18,1%), the wetland (32,9%) and the forest (26,3%) will increase, but all of the other land use categories reduced (Figure 4).

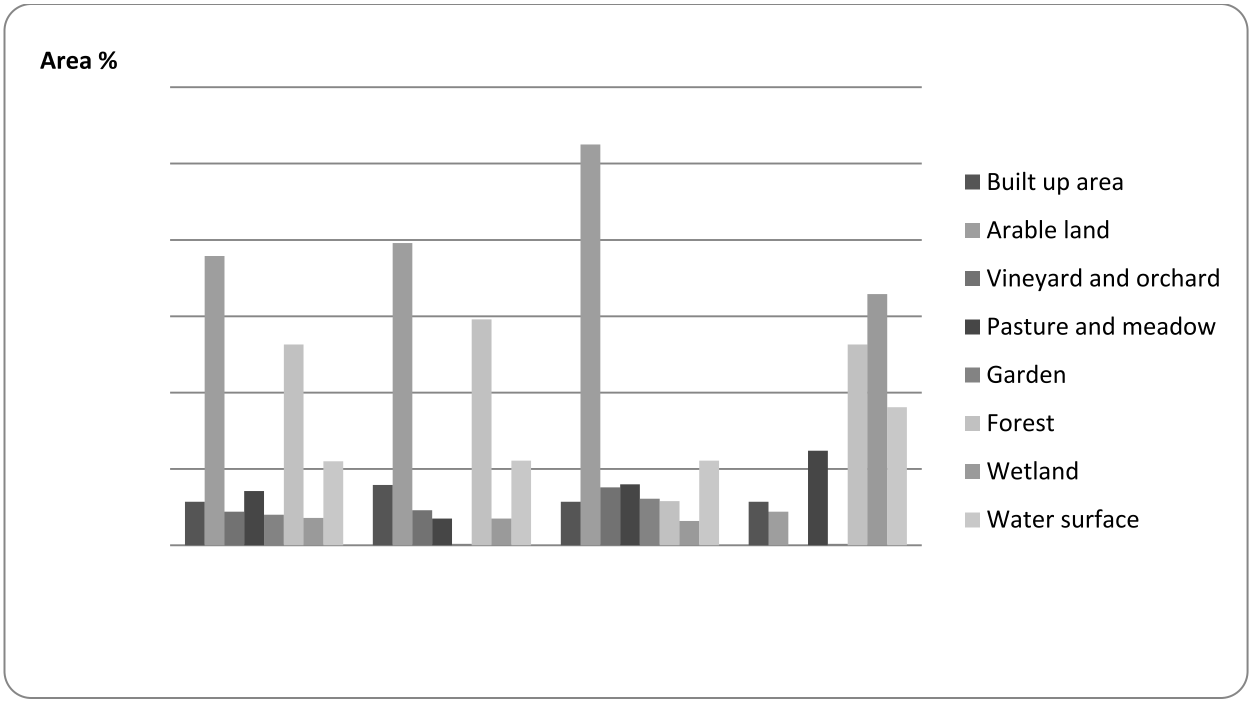

Figure 4. Land use change during in 2012 and in the three future land use scenarios in 2037

3.2. The change of the ecosystem sevices values

The growth of the arable land might be expected to increase the quantity of provisioning services, instead of this we observed a small and steady decrease still the III. military survey. The probable reason is the significant reduction of the forest which was overall contributed very significant to the provisioning services (wild food, timber, wood fuel, biochemical/medicine). We experienced that the values of the provisioning services increased again in 2012 because of the forest areas' re-growing. However the values reached just the measured values during the II. military survey. The values of regulating services' changes are similar to the values of provisioning services' changes, but here the values decreased very sharply, which were not recovered still 2012 (is similar to the values of provisioning services). In case of cultural services we found similar values along, there were no clear trend (Figure 5).

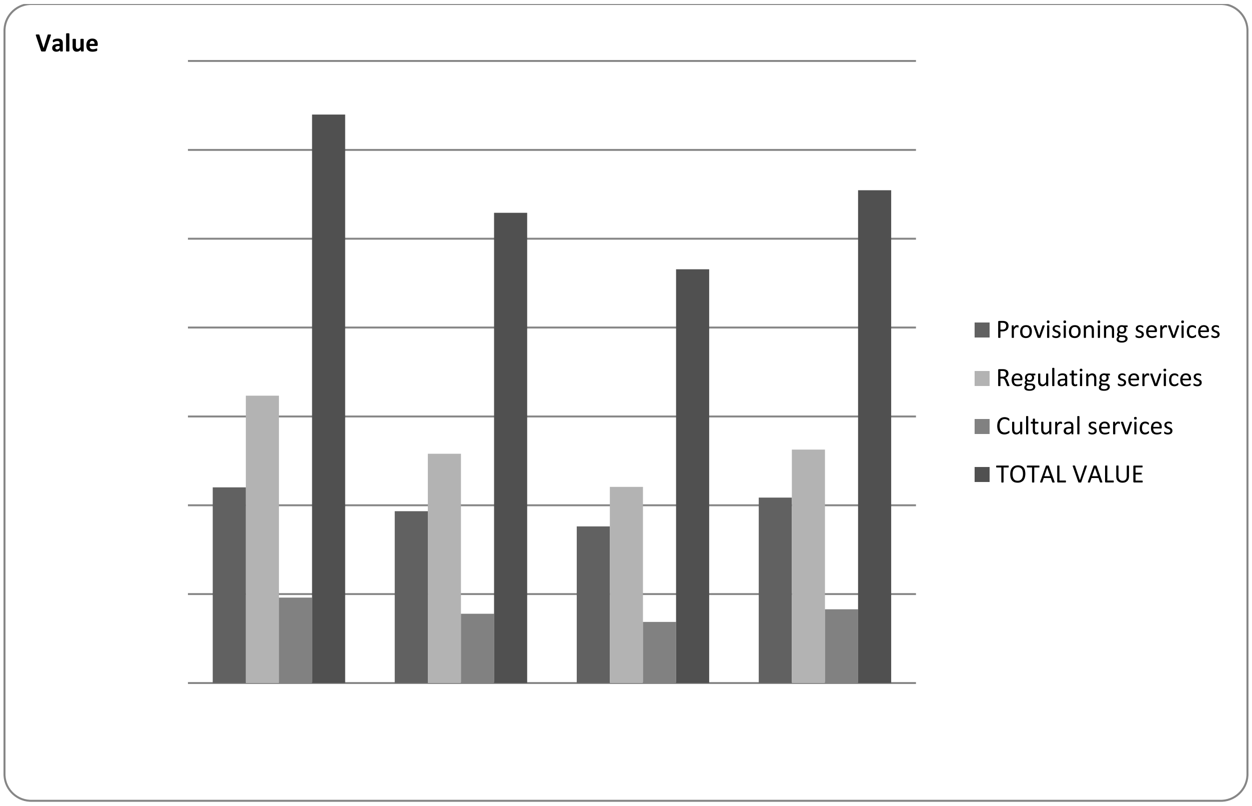

Figure 5. Changes of ecosystem services' values during the I. (1783-1784), the II. (1856-1860), the III. (1881) military surveys and in 2012

After the examination of future land use scenarios, it is obvious that the values of the "present tendencies going on" and the „increasing role of nature protection" scenarios are similar between the three types of ecosystem services and the total value as well. It is notable that there is no difference between these two 2037 scenarios and the one for 2012. In contrast we experienced that the values of the „strong agricultural expansion" scenario everywhere were about half of the measured values in 2037. If we compare with the 2012 state, the difference is not significant at the provisioning and the cultural services, however in case of the regulating services the value was halved, due to the high degree of the forest decrease.

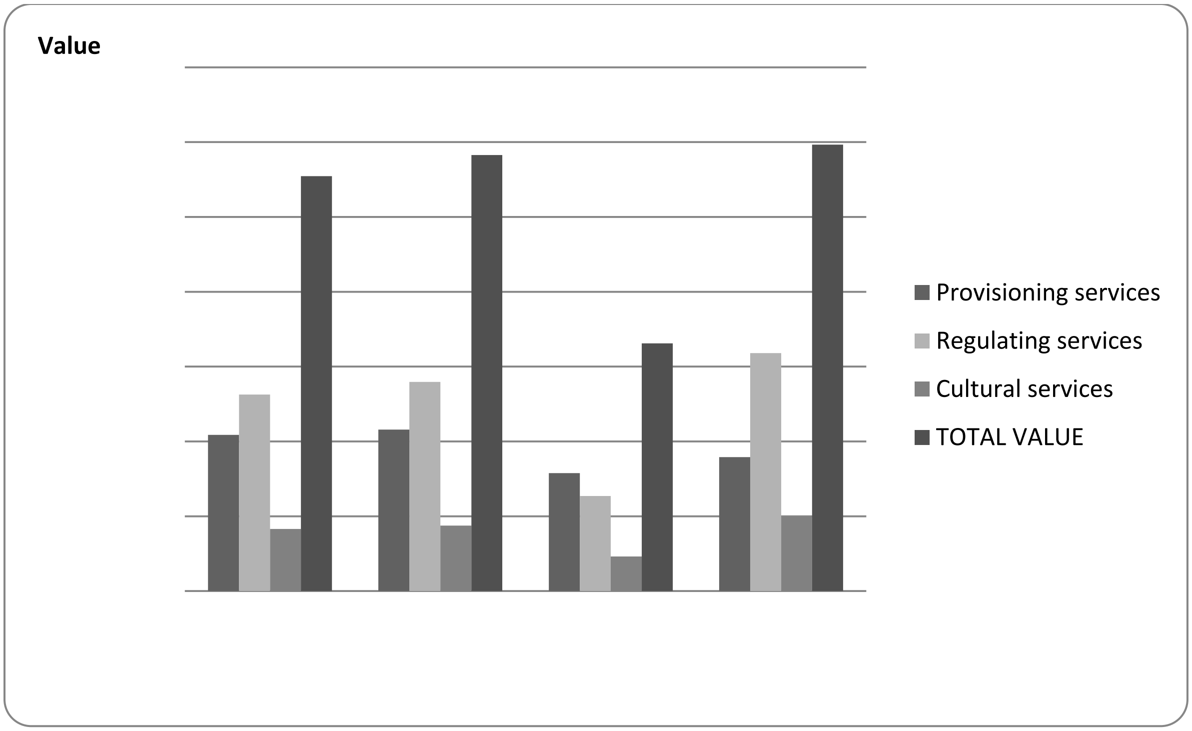

Figure 6. Changes of ecosystem services' values during in 2012 and in the three future land use scenarios in 2037

4. Discussion and conclusion

In the course of the analysis of the military surveys, the direction of land use change was obvious: the former semi-natural land use have been transformed into an intensive agriculture system. Despite the fact that on the I. military survey maps there were very large arable lands, at that time the agriculture system was extensive, nature-friendly. As time passed, the area of arable lands has increased because of the destroyed forest and drainage works, and the people gradually populated the region, significantly reducing the area of wetlands. Until the time of the III. military survey the forest decreased gradually, after the II. world war, thanks for the afforestation program, the forest area increased.

The important "index" of the ecosystems' condition and function is their measure of the ecosystem services, which is one of the most important factor is the land use change. The ecosystem services of the natural and semi-natural land use differ a slightly from each other. The intensive land use (especially in arable land areas) dramatically increased the rate of provisioning services, at the same time significantly decreased the rate of regulating services (Braat & ten Brink, 2008). These facts are supported in part by the analysis of the historical maps: the regulating services significantly decreased, however provisioning services – contrary to our expectations – did not increase but slightly decreased. The reason is clearly due to the loss of forests, which significant contribution to the provisioning services (see above). Despite the increase of the arable lands, the loss of forest influence negatively the provisioning services' values.

The important role of the forest is very obvious by the three future land use scenarios too. Where the forest cover large areas („present tendencies going on" and „increasing role of nature protection") the regulating services' values are very high, compared to the "strong agricultural expansion" scenarios where the forest areas are very low. All in all, forests have an important role not only in regulating but in provisioning services as well. This result is consistent with Costanza's matrix, in which the food production is examined, the cropland and the forest have similar importance (Costanza, 1997).

This method itself is strongly artificial, since the values of the individual services cannot be transposed to Hungarian habitats without changes, yet they provide approximate results. The following actions need to be taken as next steps: a) "translation" of the abovementioned eight land use categories to set up a typology better suited to the values of ecosystem services and habitat types b) taking into account the naturalness of the habitats c) creation of a matrix developed specially for the valuation of ecosystem services and completion of it by experts based on Hungarian case studies and investigations d) determination of additional steps in order to make the matrix more accurate.

5. Acknowledgement

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