ECOSYSTEM SERVICES AND DISTURBANCE REGIME AS LINKAGES BETWEEN ENVIRONMENT AND SOCIETY IN THE KISKUNSÁG REGION

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1. Introduction

The Kiskunság sand-ridge in the Danube-Tisza Interfluve represents a biome transition zone (ecotone) between temperate deciduous forests and continental steppes. The characteristic feature of the landscape is the hierarchic mosaic pattern of ecosystems, which appears in different levels *(Kovács-Láng et al. 1998).* This can be principally related to geomorphology and geological structure, to water-flow systems and to the history of human land-use. Underground water forms a complex water-flow system, which covers the whole area of the landscape *(Tóth 2001; Mádlné Szőnyi et al. 2009).* Levels of this water flow system (regional, intermediate and local) can be related to the levels of processes analyzed in this study. Precipitation recharges at higher elevations and starts gravitational water-flows towards the lower regions *(Mádlné Szőnyi et al. 2009).* Local and intermediate flow systems are based upon these ridge-level flows, and operate the subsystems between the dry and wet habitats. Landscape and habitat patterns formed this way show similar, fractal-like structure in different scales *(Biró et al. 2007).* Natural vegetation forms different communities, such as dry grasslands, sand forest-steppe mosaic to marshes, fens and alkali lakes. Human activity forms fine mosaics from the fragmented patches of the natural habitats through afforestation, agricultural production, settlements, roads and canals.

The climate of the Kiskunság sand-ridge is semiarid; the region regularly suffers from drought. The most common substrate is the coarse-grained, calcareous sand, which contributes to the drought sensitivity of the habitats not affected by underground water, due to its extreme moisture regime. The driest habitat is the open sand grassland, which is the richest in protected and endemic plant and animal species. Due to its low agricultural value, this is the most natural remaining habitat in the region.

The Institute of Ecology and Botany of Hungarian Academy of Science with the collaboration of several other institutions and universities joined the International Long-Term Ecological Network *(ILTER, http://www.ilternet.edu)* and founded the KISKUN Long-Term Ecological Research site (Kiskun LTER) in 1995. Research originally focused on the complex and long-term study of natural communities in many scales and taxonomic groups. Since then, reflecting upon the increase of human impacts (e.g.

climate change), the KISKUN LTER's research scope has expanded to include the analysis of mutual interaction between human activity and the surrounding ecological systems. The interdisciplinary work is built upon previous research about the interactions of natural and human modified ecosystems in the Great Plain led by IEB HAS (NKFP6/013/2005). This helped to form active cooperation between natural and social scientists in the thematic field of ecosystem services.

The purpose of this paper is dual: to work out a comprehensive framework that can sum up the historical, sociological and ecological research experiences in the sand ridge, and to identify the most important research directions for the near future. The elaboration of this framework is part of the cooperation initiated by the ILTER, which aims to compare different LTER research sites and identify critical social and ecological changes within them, as well as global patterns and trends of the changing ecological services.

2. Material and methods

2.1. The history of the analyzed landscape

By the end of the Turkish occupation (late 17th century), this region was nearly treeless and sparsely inhabited, where extensive grey cattle grazing maintained the sand surface constantly open. Strong winds combined with the effect of grazing kept sand surfaces mobile and caused catastrophic sand storms, which seriously affected the region's crop production. Immobilization of the sand became the central project of the Kiskunság region; the first afforestation started in the 18th century *(Biró and Molnár 1998; Biró 2003).* Meanwhile, as a consequence of local population growth and the growing demand for agricultural products on the European market, the proportion of cultivated land (arable fields, vineyards, orchards) increased, which was accompanied by the division of large pastures into small, fragmented plots. During the first part of the 19th century cattle grazing was gradually replaced by less intensive sheep pasturing, which caused the rapid encroachment of sand dunes. Parallel to the socio-economic changes in the second half of the 19th century, afforestation to immobilize sand continued and became more intensive based on regional decisions and on subsidies from the government *(Biró 2003)*. At first, mainly poplar and black locust were planted, but from the

20th century black pine and Scotch pine were planted as well. By this time, the effects of large-scale afforestation could be seen at the regional level (altered landscape pattern, climate, water resources, and alien propagule pressure). Intensive afforestation of large areas reduced the extent of the semi natural dry sand vegetation to 8%; 45% of the area covered earlier by the original vegetation became tree plantations *(Biró et al. 2009).*

A special small scale farming system (homesteads or "tanya" in Hungarian), adapted uniquely to the natural conditions was developed at end of 18th and blossomed at the end of the 19th. Its prosperity lasted until the first half of the 20th century. From the mid 19th century the ploughing of humic sand and chernozem soils accelerated and arable agriculture spread at the landscape level, causing the rapid destruction and fragmentation of the semi-natural areas. The cultivation gradually increased until the 1930s and eventually reaching the very unproductive drift-sand areas as well *(Biró 2003; Molnár 2008, 2009; Molnár and Biró 2011).*

The small-scale farming system disintegrated in several steps starting in the 1960s, and resulted in extensive land abandonment by the 1980s. Dominant processes within the dry sand area by the end of the 20th century were the emigration of the local population, the drastic decline of grazing and the regeneration of abandoned fields, the closure of bare sand areas due to succession, the spread of invasive species, and the dramatic decrease of the groundwater table *(Molnár et al. 2010).*

2.2. The „Integrative Science for Society and Environment" (ISSE) framework

The LTER sites participating in the project apply the "Integrative Science for Society and Environment" strategic initiative of US LTER (ISSE framework) in order to compare the flows of ecosystem services across different environmental and socio-economic contexts. The ISSE framework summarizes the status of the society, the disturbance regime, the status of the biophysical environment and the major ecosystem services, and finally the causal relations between them *(Collins et al. 2007; Robertson 2008).* The framework is based on a scheme, which shows the social and ecological subsystems as well as the causal relations between and within them (Figure 1).

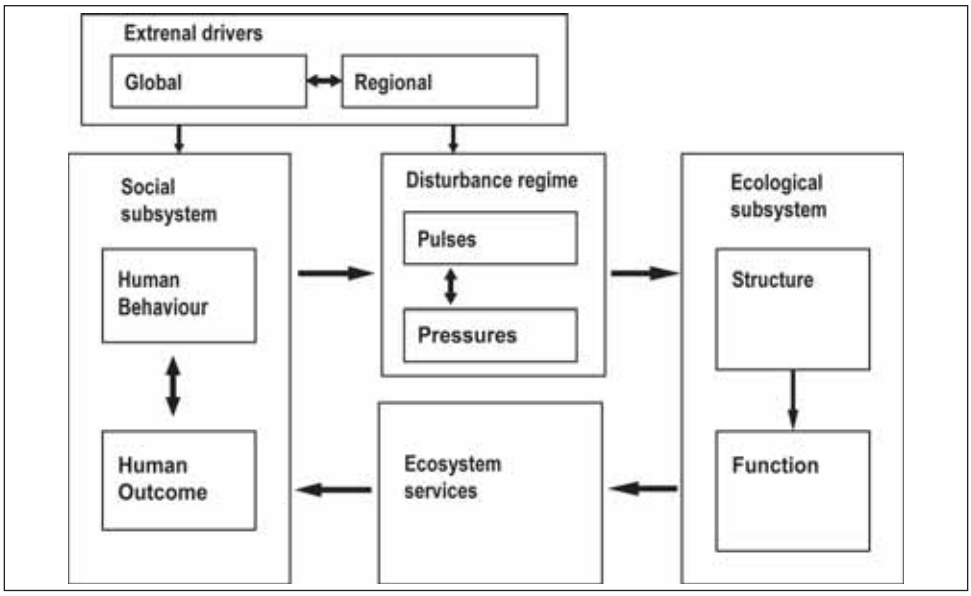

Figure 1: Basic structure of ISSE framework.

The basic subsystems are the social subsystem and the ecological subsystem, while the disturbance regime and ecosystem services connect these two. At a particular spatial scale, the causal relations between the subsystems are strictly directed. The social subsystem only affects the ecological subsystem through the disturbance regime, and the ecological subsystem only has an impact on the social subsystem through the ecosystem services. It supposes causal interactions between the subsystems and disturbance regime, but among the ecosystem services it does not. In the basic scheme, there is no shorting causal cycle at a particular scale. However, according to the examples of Collins et al. (2007) there can be shorting between the disturbance regime and the ecological structure, which corresponds to the ecological research practice.

Collins et al. (2007) recommends the use of the mentioned scheme in three spatial scales, e.g. local – landscape – regional or elementary catchment system – larger catchment system – regional level. However, each level has a subsystem, which displays external influences in the global and regional levels, compared to the particular scale, e.g. in the case of regional scheme at national level. The external factors have direct effect only on the social subsystem and the disturbance regime. In the examples of Collins et al. (2007) the shorting causal cycles are possible between the

regional external effects and the social subsystem as well as among the regional external effects and the disturbance regime.

As we tried to ensure the international comparability of the results of our analysis, in the case of ecosystem services we used the typology of the Millennium Ecosystem Assessment (2005).

Collins et al. (2007) propose the adopters to summarize the critical ecological, economic and social changes as well as the non-obvious relations between them. The "critical" change means here that it also affects other subsystems and levels, and it is difficult to reverse. The "non-obvious" means to determine relationships, which prevail between different subsystems and levels, e.g. effect of landscape level economic changes on the regional ecosystem. The scheme used here (Figure 3) differs from the first scheme (Figure 1 and 2) in that it separates the social structure into economic system and socio-cultural structure and it only represents the change of ecological structure in the ecological subsystem. It does not necessarily imply that all three kinds of critical changes happen in every level. At local level often only ecological, at a coarser level usually ecological and economic, finally on the coarsest level all three kinds of changes are realized.

The use of the ISSE framework is iterative. In an examined area first those levels that are relevant are determined, and then various basic schemes are interpreted based on the results of field research, statistical surveys and expert decisions. This iterative process generates further questions through completing the schemes and discussing the experienced uncertainties. In response to the emerging questions, further data collection and analysis, or a new research process is issued, and on the basis of the results the original schemes are revised. The basic requirement of the whole process is the close cooperation between ecologists and social scientists both in the questioning and the answering phase.

In the case of the Kiskunság sand-ridge we have completed the first phase of this iterative process. Based on our previous research results and experiences *(Kovács-Láng et al. 2008; Biró et al. 2007, 2008, 2009; Gómez-Baggethun and Kelemen 2008)*, we interpreted the schemes in three scales via expert decisions and asked research questions. Since that time (autumn 2008) questions have strongly influenced our current application and research activity as well.

3. Results and discussion

3.1. The applied scales (levels)

At the local scale we consider the fine mosaic structure of the Kiskunság sand-ridge, consisting of juniper-poplar thickets, open and closed sand grasslands, dry sand forest-steppe habitats, and of inter-dune mesophytic vegetation. We studied these habitats within the KISKUN LTER in several sites, such as Ágasegyháza, Bócsa, Bugac, Csévharaszt, Fülöpháza, Kéleshalom and Tatárszentgyörgy.

The landscape scale means the sand dune formations including shallow depressions in their vicinity. Beside the above mentioned habitats, it also contains forest-plantations on sand-dunes, small-scale farming areas (home gardens, orchards, vineyards and arable fields as well as the abandoned, spontaneously transforming areas) and large, shallow depressions, which used to be affected by groundwater (reed beds, fens, marshes, temporary alkali lakes and their current derivatives).

The regional level is the Kiskunság sand-ridge itself, the middle part of the Danube-Tisza Interfluve, which can be characterized with coarse-grained, calcareous sand and the interposed basins as well as the villages and farm systems settled there.

3.2. Local level disturbance regime and ecological subsystem

The two most important disturbances on the poplar-juniper steppe woodlands and on the open and closed sand grasslands are the decline of grazing pressure and sinking groundwater level. The latter is the local result of the regional level groundwater decrease *(Pálfai 1996)*. It does not affect directly the open sand grassland and the greater part of the poplar-juniper steppe woodland because those habitats are independent from the groundwater effect.

However, the *Salix rosmarinifolia* and the *Scirpoides holoschoenus*, which are characteristic to the close sand grassland and the deeper inter-dune depressions, gradually give way to a successional vegetation type consisting of common open sand grassland species and the locally invasive *Calamagrostis epigeios*. The *Salix repens sp. rosmarinifolia* survives, probably because the wetland is only necessary for its establishment, but

the *Scirpoides holoschoenus* gradually disappears, parallel with the decrease of the moisture *(Bagi 1997; Molnár 2003).*

The local result of a special, global level disturbance is the extinction of the rabbit *(Oryctolagus cuniculus) (Katona et al. 2004)*. Exactly how long this species had been a part of the juniper-poplar thickets remains debatable, but it surely had a role in shaping the current habitat structure *(Kertész et al. 1994).*

The aboveground biomass of the open grassland is increased by the decrease of the grazing and the disappearance of the rabbit, but this does not directly change the species diversity of the vegetation. Together with the decline of livestock grazing, fire hazard increases, threatening the juniper *(Ónodi et al. 2008)*. Landscape and regional level disturbance such as afforestation, especially the extensive black pine *(Pinus nigra)* plantations, further increases the fire hazard. Although the fire does not harm the herbaceous layer, it changes the structure of the landscape and reduces habitat diversity.

Overall, the local habitat structure becomes more homogeneous, the grass is closing, and the poplar-juniper steppe woodlands turn into poplar - open grassland mosaic due to its spontaneous spread and the frequent fires as well as the disappearance of water-affected habitats.

3.3. Local level ecosystem services and social subsystem

When we start the analysis of the social subsystem at local level – the poplar-juniper and the open sand grassland habitat complex – the question may arise if it makes sense at all to talk about changes in the social system at the finest scale, because humans are hardly present and are not acting directly at this scale. However, although socio-economic effects of changed ecosystem services are truly better felt at landscape level, we can also observe changing human behaviour at the local level, which can inform us about the subsystems' interactions at this level. As an example, we highlight the advancement of cultural ecosystem services (recreation, aesthetic values, education), which favours eco-tourism and environmental education in the poplar-juniper and dry sand dune vegetation of the Kiskunság region. This creates a new kind of subsistence opportunity and activity to some local people (e.g. mounted tour guiding).

The changes of human actions induced by the rise of eco-tourism are often accompanied by changes in attitudes and in the emotional connection with the particular area as our interviews have proved. Tourists and nature lovers visit the area and talk about it in the local community (e.g. to their host) as being highly valuable. These discussions foster gradual change of the local population's value system as they reinforce the idea that natural areas have greater value than those under intensive cultivation. This recognition poses the question whether the gradual change of the local community's value system and attitudes could help (and if they could, how) to mitigate the (negative) human impacts on the environment, and to encourage social adaptation to the environmental changes.

Changes in human activity and behaviour can also lead to long term changes in the disturbance regime. For example the sinking of the groundwater table, which is important at the local level, can partly be traced back to changes in human activity at landscape and regional level, such as increased water extraction (building illegal wells) and canalization *(Pálfai 1994, 1996)* (the 3.6. chapter has more details about this). However, we still need further research to investigate which human behaviours and actions contribute to the disturbance regime at local level and to what extent.

3.4. Landscape level disturbance regime and ecological subsystem

The two most important landscape-level related disturbance factors are afforestation with alien species *(Bagi 1997; Kovács, Farkas 2007; Molnár et al. 2010)* and the cycle of cultivation and abandonment, which is typical in the surroundings of sand dune areas *(Molnár 2003).*

Afforestation significantly reduces biodiversity by radically transforming the habitats of the sand dune area. In the interior patches of the black pine plantations, where afforestation failed or which were left clear for fire tracks, only a part of the original vegetation remains. A large black pine forest stand can preserve the elements of the original flora, and thus the regeneration potential of the area. To a lesser degree, the same is true for the plantation of alien poplar species. By contrast, the black locust *(Robinia pseudoacacia)* plantations remove the original vegetation and the black locust itself can spread spontaneously as an invasive plant. The understorey of the closed Robinia stands almost completely lack the elements of the original vegetation. The tree of heavens *(Ailanthus altissima),* which does not provide timber of commercial value, completely outcom-

petes natural grassland species. But the small patches, after upgrowth and self-thinning let some elements of natural forests colonise. In addition, as we mentioned in part 3.2, forests, especially pine stands, increase the fire hazard of natural and protected habitats.

The regional decrease of groundwater level is one of the most important drivers of the cycle of cultivation and abandonment *(Pálfai 1996)* as new areas become unsuitable for agricultural production. The cultivation first destroys the original vegetation; the tillage homogenizes the microrelief of the sand surface, followed by the abandonment and spontaneous succession. However, the post-abandonment succession often leads to a rapid establishment of invasive species in the natural communities. One of these invasive species is the milkweed *(Asclepias syriaca)*, which can interrupt recovery for long time periods. Its extended populations exert large propagule-pressure on habitats with natural vegetation. Another common invasive species is the common ragweed *(Ambrosia elatior)*, which does not spread in natural areas and disappears quickly during the succession. However, it is abundant in newly abandoned fields and because of the regular soil disturbance to control weeds, in fallows *(Csecserits et al. 2009).* Due to cultivation and abandonment of the former wetland areas, meadows have featureless vegetation. They still keep the previous rich flora at the regional scale, but they are species poor at the local scale *(Kertész and Ónodi 2008).*

Overall, the landscape, which used to be mainly natural with an extremely rich biota, has become dominated by tree plantations of alien tree species and species-poor, featureless secondary vegetation, typically with adventives including invasive species that threaten the remaining natural habitats.

3.5. Landscape level ecosystem services and social subsystem

It is easy to point out the connection between changes in flows of ecosystem services and changes in the social structure (especially in land use and ownership system and conservationist decisions) at the landscape level *(Gómez-Baggethun and Kelemen 2008)*. Due to the growing importance of regulating services (e.g. regulation of biodiversity) and the deteriorating productivity of provisioning services (especially food production and animal husbandry), land use favouring nature conservation has come to the front. This often leads to top-down changes in rules, norms and

conventions, determining local land use through the implementation of formal, top-down conservationist regulations. In the long run this may also alter the system of property rights (e.g. reduction of the proportion of private property and increase the proportion of state property as well as the proportion of leased agricultural land).

Changes at landscape-level ecosystem services can induce considerable changes in individual behaviour and actions. As provisioning services (especially food production and animal husbandry) become less profitable, possibilities for creating local livelihoods are narrowed, which leads to emigration of the more mobile (generally the wealthier, better-educated and younger) people, leaving the homesteads abandoned. Emigration contributes to the continuous growth of average age within communities, and to the disappearance of local/traditional ecological knowledge and traditional agricultural practices *(Kelemen et al. 2008)*. State subsidies and EU funds, which encouraged the establishment of small-scale black locust plantations also contributed to the change of landscape mosaic previously dominated by the peasant homesteads, because acacia was planted mostly in oldfields *(Biró 2011)*.

However, social reactions are not limited to emigration; they are also reflected by technological and economic innovations. For instance, recently in some protected parts of the sand-ridge, new livelihood forms (tourism) appeared and new technological solutions emerged to replace of some ecosystem services and adapted to the altered ecological conditions (i.e. water replacement, cultivation of drought tolerant plants). These changes affect the disturbance regime at landscape level (e.g. the cessation of grazing contributes to the spread of invasive species), but so far we have little knowledge regarding the background mechanisms. Therefore, the following could be important research questions in the future: which interactions result in the above mentioned changes of the social subsystem and in which ways do the social changes influence the disturbance regime at the landscape level.

3.6. Regional disturbance regime and ecological subsystem

The most important regional disturbance factor is the decline of groundwater level *(Pálfai 1996; Molnár et al. 2010)*. Reasons for this are complex but include: canalization to decrease the danger of inland inundation *(Lóczy and Szalai 1995)*, a series of droughts in the 1980s *(Liebe*

1993; Kertész and Mika 1999), water extraction *(Major and Neppel 1988)*, extended forest plantations *(Major et al. 1991)*, crude oil research *(Pálfai 1996)*, and also the long term shift in the balance of infiltration and evaporation due to recent climate change *(Lóczy and Szalai 1995; Kertész and Mika 1999)*. The relative importance of the above mentioned factors is heavily debated *(Lóczy and Szalai 1995; Szilágyi and Worosmarty 1997)*, but the severity of the phenomenon is beyond question *(Pálfai 1996)*. The debate over forest plantations is especially animated, because of the substantial changes they have caused; in the past two centuries more than 180 000 hectares of tree plantations were established compared to the 20000 hectares of forest existing in the 18th century.

The impacts of the decrease in groundwater table appear at each level of the analysis. The most important of these is the increased drought sensitivity, which primarily affects agriculture and leads to mass land abandonment *(Csatári and Kanalas 2007)*. Another regional consequence that greatly influences biodiversity is the disappearance of the alkali lakes and meadows from the sand ridge area, which not only leads to the homogenization of the soil and the vegetation, but also to the dramatic decline of bird diversity *(Boros and Bíró 1999)*.

As a result of the drainage of formerly wet habitats, some species, which originally lived in dry and sandy areas, spread over the dried-out habitats and abandoned agricultural areas. Abandoned croplands, gardens, vineyards and orchards established earlier on dry sand areas show fairly quick regeneration. This is due partly to the similarity in the species pool of the original and secondary sand habitats, and also to the rich and diverse propagule source provided by the fine-mosaic landscape structure. As a consequence, the dynamic connectedness of the original, the secondary, the natural and the disturbed ecosystems is greater here than in other parts of the country. The regeneration process, however, is slowed down by alien tree species coming from intensive forest plantations, abandoned homesteads and unmanaged tree lines. Until now, invasive herbaceous species have mainly spread over abandoned territories at the regional level, but the latest observations point out that they are more intensely occupying natural ecosystems.

The long term consequences of the regional sinking of groundwater level, so far, are not predictable. The main question is: to what extent can we reverse the unfavourable phenomena experienced so far, provided that the actions supposed to raise the groundwater level are accomplished in time?

3.7. Regional level ecosystem services and social subsystem

There are also changes in water balance, which create the biggest challenges for the social subsystem at the regional scale. Beside the global and regional drivers (EU subsidies, governmental decisions), changes in regulating and provisioning services have the most serious effects on social structure and human behaviour. This is well indicated by the fact, that from 1980-90 nearly 20 000 hectares of semi-natural habitats were converted to ploughland due to the low water table and the favourable agricultural subsidies *(Biró et al. 2008)*. This destruction primarily affected fens, which are influenced by subsurface waters. In order to adapt to the altered circumstances, nature conservation aimed to preserve wetlands and retain water. Making fens 'ex lege' protected helped halt the destruction of semi-natural habitats in the sand ridge. Regional development plans at the same time aimed to restore the former farming conditions by artificial water replacement.

Changing land use and economic structure, if not compensated by appropriate development policy, eventually leads to the regional realignment of the population by increasing the proportion of urban population compared to rural population. This can lead to increasing social disparity, infrastructural drawback, and the impoverishment and segregation of homestead dwellers. Emigration and segregation accelerate the process of agricultural land abandonment and intensive afforestation, which opens more space to invasive species and further decreases the groundwater table. To break this vicious cycle, region-specific regulations and development plans, which consider equally the natural and social-economic conditions of the Kiskunság are necessary,. However, this requires strengthening local decision-making processes empowering local communities, and transforming both the development and conservationist policy and the institutional system *(Mertens et al. 2009).*

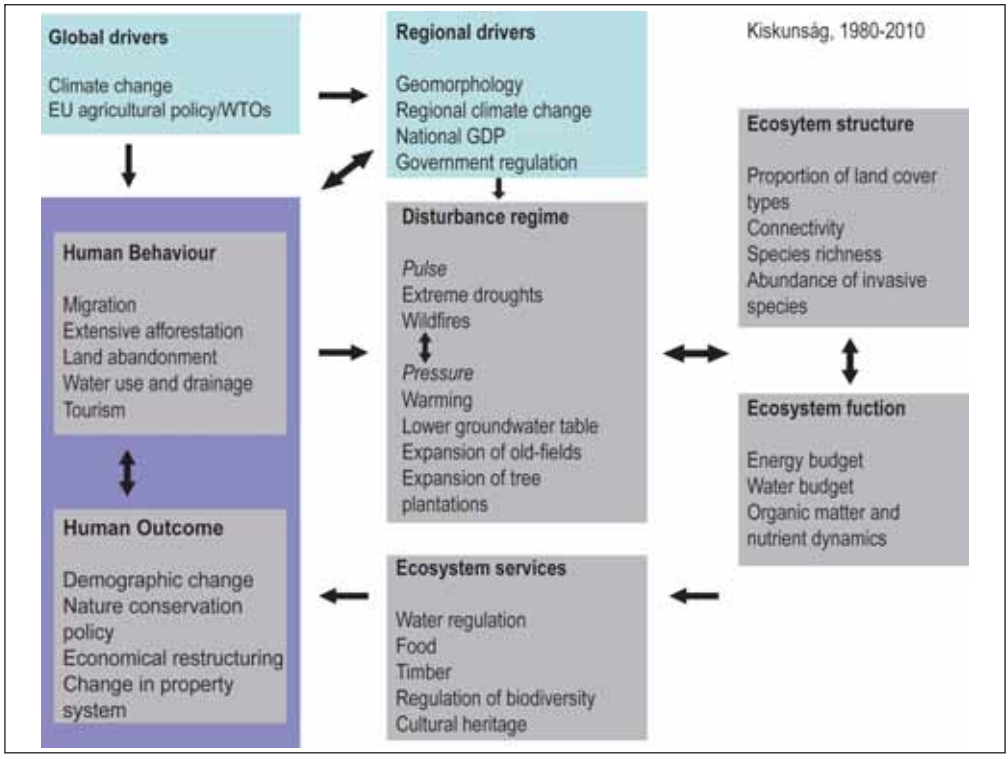

Figure 2: Regional scale ISSE framework for Kiskunság region.

3.8. Synthesis: critical changes and not evident relations

The ISSE framework points out not only how changes in ecosystem services affect society, but also shows how the social subsystem disturbs the ecological subsystem. It interprets interactions between the social and the ecological subsystems not solely as feedback loops within a closed system, but considers the external driving forces such as global and regional drivers.

Analysis of the local, landscape and regional levels shows that attitudes and values towards ecosystem services influence many processes. On one hand, they affect the socio-economic decisions, which determine the social structure (technological, institutional and economic measures balancing or adapting to the change); and on the other hand, they directly or indirectly define human behaviour. Thus, changes within the ecological system can initiate or modify processes between or within the elements of the social subsystem. They can influence for instance the access to natural resources by changing the regulatory system (property rights and nature conservationist rules); they can affect social stratification, demographic

situation, social exclusion and the structure and processes of decision-making, etc. These reactions, along with social responses fostered by external (global or regional) drivers, feed back to the ecological subsystem. Disturbances close the circular interactions between the two subsystems (within and beyond certain scales), irrespectively of whether the disturbance regime is the result of accidental social reactions to changes of ecosystem services or the conscious adaptation and intervention of society.

Since both the social and the ecological subsystems have delayed reactions to the changes affecting them, we need to apply a long-term research approach in order to analyze these interactions. Analyzing ecological changes and social transformations of the past, we can explain why humans alter the functioning of ecological system, and which adaptations were reactions to the ecological system. Understanding the co-evolution of ecological and social systems can help us interpret the present natural and social processes and thus propose more sustainable and socially just adaptation strategies.

The most important and most critical change going on in the flows of ecosystem services is the deterioration of the water regulation service, which we addressed at all scales and in each subsystem.

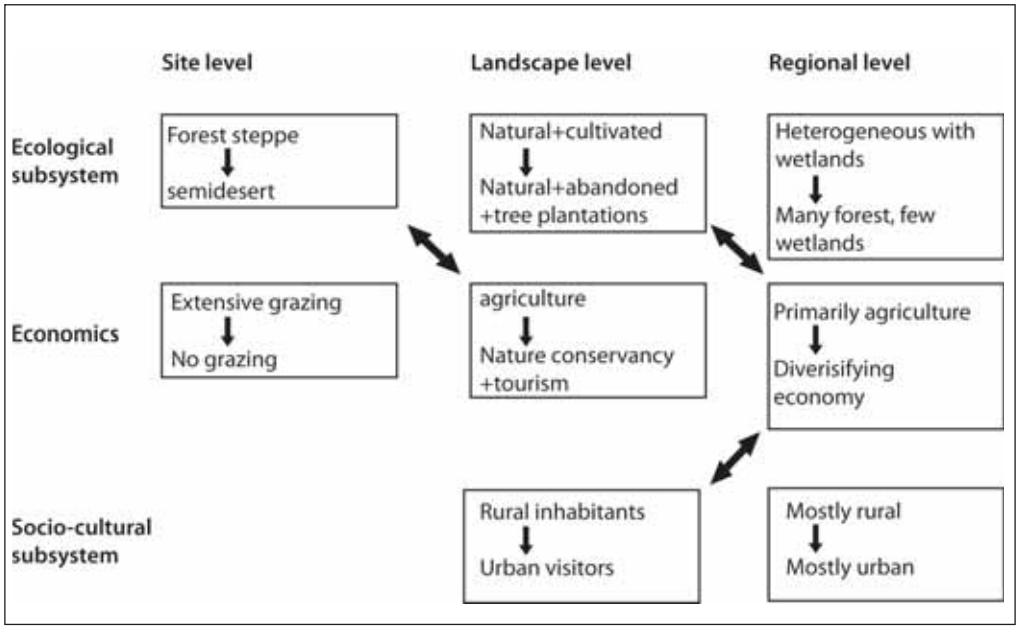

Figure 3: Critical changes and their major non-evident (i.e. cross-scale and cross-subsystem) interactions in the Kiskunság region.

In Figure 3, critical changes and the most important non-evident relations are shown. Now we will explain why these changes are said to be critical. Landscape and regional level ecological changes are critical because afforestation does not allow the regeneration of the original vegetation. Since forests are established for the long term, this effect is hardly reversible. This is further aggravated by the fact that after logging, according to the present regulations, it is mandatory to re-establish the forest plantation on the same area.

Change in the landscape level socio-cultural setup is critical because the traditional peasant lifestyle, well-adapted to the natural context and accommodating traditional ecological knowledge forms, disappears due to emigration and aging of the rural population (especially of homestead dwellers). This disappearance seems to be permanent. In order to halt aridification of the sand ridge, challenges of global climate change and the increasing water demand of the local population should be addressed, but this is a difficult task both for politicians and engineers.

Though the ISSE framework represents a given time period (in our case it is about the last 30 years), we would like to mention some longer-term non-evident relations, mainly related to afforestation. In the eighteenth century, this region was almost completely treeless and therefore the effect of wind was much more intense than it is today. At local level, this hindered the closure of sand grasslands. At landscape level it sustained the bare sand surface of pastures and arable fields in move and blew it to the settlements, agricultural areas and wetlands, and sometimes even caused big sandstorms. While the indirect impact of wind appeared locally by opening up the grassland and shifting the sandy soil, all these local effects generated landscape level and regional processes. The wind intensified the effects of trampling caused by overgrazing. With this, it limited the access to past local and landscape level ecological services (animal and human food, healthy air, etc), which was then addressed by the society with landscape level and regional arrangements (urban and state laws, tree-planting on sand etc). Because of tree plantations, the wind has virtually ceased to be a disturbance factor at all three scales. This change made the whole area more suitable for settlement and cultivation around the middle of the 20th century, and at the same time, exposed natural areas to human disturbance. Since then, the decrease of groundwater level has become the major disturbance factor.

3.9. General experiences of the ISSE framework application

The first and most important experience of the ISSE framework is the deepening of scale- and system-consciousness, although experts involved in the work had already been very scale-conscious in their own respective research fields (partly for methodological reasons). They had already interpreted cautiously their results obtained at a given scale but less consciously connected the studied phenomena to geographical scales than the ISSE framework required in this work. On the other hand, each phenomenon they had considered important had to be placed in the whole framework. This process generates many questions, and greatly helps researchers consistently consider those effects and consequences of their own work that are traditionally examined by other specialists, during both the planning of their future investigations and the interpretation of the results. At the same time, it is confirmed that complex questions could be effectively examined by an interdisciplinary team consisting ecologists, economists, and socio-cultural researchers.

The ISSE framework's first scheme (Figure 1 and 2) is similar to the Millennium Ecosystem Assessment's (2005) causal scheme, which is also scaled, and to the DPSIR scheme *(OECD 1993)*, used by the European Environment Agency. At the same time, we found that the causal network of the ISSE scheme is the easiest to apply. The application of the ISSE framework in the KISKUN LTER site is part of a program of international cooperation, initiated by the US LTER and pursued by the ILTER (see acknowledgements). In the context of the cooperation, 15 similar examinations are summarized. Compilation of the summary and an article are still in progress. According to the prior experiences, the ISSE framework is useful to compare the socio-ecological status of very different areas. KISKUN LTER is also involved in an ongoing European assessment of ecosystem services of LTER sites.

4. Acknowledgements

This work was supported by the ALTER-Net (A Long-term Biodiversity, Ecosystem and Awareness Research Network). The ALTER-Net (http://www.alter-net.info) is a Network of Excellence supported by the 6th Environment Action Programme of the EU. The work is part of the ILTER Eco-

system Services Assessment international project supported by the U.S. LTER (http://www.ilternet.edu/research/ecosystem-services-assessment). The work builds on the results of "Interaction between the natural and artificial ecosystems: estimation of the biodiversity, ecosystem functions and land-use in the Great Plain" NKFP6/013/2005 (2005-2008) project.

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