

# Analysis of landscape change in the Nagyberek (Somogy, Hungary) with the DPSIR Framework

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MIÓKOVICS, E., BÓDIS, J. & MOLNÁR, ZS.: *Analysis of landscape change in the Nagyberek (Somogy, Hungary) with the DPSIR Framework.*

**Abstract:** We need complex thinking to manage habitats and conserve landscape values. We present the landscape changes between 1900 and 2013 of the Nagyberek, a huge, former marshy area along the south bank of Lake Balaton, with the help of the DPSIR Framework. We analysed the causal relations of *driving forces*, which induce landscape changes, and the change of habitat states from the nature conservation point of view. Our results show that the introduction of large-scale farming during the 1950-80s was the main *driving force*. The changes caused by the disruption of the natural water balance were too drastic and the ecosystem could not adapt to the new circumstances. The rapid changes also altered the self-identity of inhabitants and their relationship with the landscape. Landscape changes were analysed from the conservation biologist point of view. Accordingly the responses of the DPSIR Framework were selected from those laws and programmes which concern nationally and internationally important habitats. We argue that the DPSIR Framework can be used successfully to study the *impact of pressures* to analyse habitat and landscape changes in a complex way.

**Keywords:** land use, nature-agriculture interface, landscape history, wetlands.

## Introduction

According to the European Landscape Convention (2000) the landscape “means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors”. The study of past changes and processes is needed to understand the functioning of a landscape. The effects of land use on landscape changes should be studied from the point of view of nature and humans as well. This thinking is necessary to ensure the good practice for conservation (BIRÓ 2006, FOLKE 2004). The main factor of landscape changes is land use, which alters the landscape fundamentally. The transformation of traditional landscape management fundamentally changes the natural and the social environment. Several models can be used in landscape change studies to investigate the spatial changes in land use, such as GIS based models, e.g. CLUE (VELDKAMP & FRESKO 1996, VERBURG et al. 2002). Landscape change research shows increasing interest in the driving forces which induce the changes (BÜRGI et al. 2004). Comprehensive analyses, for example in landscape planning, seek real solutions to protect and maintain the landscape.

We used the DPSIR Framework to understand landscape changes. The model of Pressures – State – Response (PSR) was developed by the Organisation for Economic Co-operation and Development (OECD 1991) to help the understanding of environmental indicators for decision makers and a broad stratum of society. This model was expanded and further developed by the European Environment Agency (EEA 1991) nearly 20 years ago. The DPSIR Framework helps identify the forces which form and maintain landscapes and to realize the natural-economical-social environment, as the relations and interactions of the main landscape-changing factors. The Nagyberek is a broad area of habitats with relatively high naturalness. This landscape is one of the last representatives of the former extended marshes of the Carpathian Basin. This region has unique history and values. It is adjacent to the recreation area on the southern bank of Lake Balaton and it is characterized by degraded, drained habitats as well as a consequence of the management techniques used in the last 100 years. Because of the socio-economic changes the relationship of people with the landscape has altered fundamentally. This altered relationship has significant effects on wetland habitat complexes.

In our study we present the causes which have determined the development of the landscape structure and delineate the directions of future changes with the DPSIR Framework. We study the habitats of the Nagyberek from the nature conservation point of view: the changes of habitat and species diversity are the most important indicators. The causal relations of driving forces which induce landscape changes were investigated. The changes were studied with the DPSIR Framework through a given period of time (1900-2013). The actual state of landscape units (habitat complexes) was determined then compared with the reference state (1900). Interviews with the inhabitants and written sources and historical maps (TAKÁTS 1934, KANYAR 1985, HOSSZÚ 2009) were used for the analysis.

## Material and Methods

### *Study area*

The studied area is larger than 170 km<sup>2</sup> and physiographically represents an independent unit. The center coordinate of the area is N46°41'06", E17°30'53". The mean elevation of the area is 104-110 m above the sea level, the mean annual temperature is 10.1-10.3 °C, the mean annual precipitation is 670 mm from which 380-400 mm is in the vegetation period (DÖVÉNYI 2010). In our study we defined the Nagyberek as the area bordered by the following settlements: Balatonboglár – Ordacsehi – Fonyód – Balatonkeresztúr – Balatonújlak – Somogyszentpál – Táska – Buzsák – Lengyeltóti (Fig. 1). The population of the area is 45 000 (Hungarian Central Statistical Office), which is steadily decreasing.

Some literature (BORBÁS 1900, MÁGOCZY-DIETZ 1914, LÁSZLÓ & EMSZT 1915, SOÓ 1930, KOVÁCS 1955, KOVÁCS & PRISZTER 1957) documented the natural habitats of the landscape. The historical maps (I., II., III. Military Survey) and the book of BENEDEFY & V. NAGY (1969) provide data about the extent and water balance of these habitats.

Studies were carried out in the area within the framework of nationwide botanical surveys and habitat mappings (FLÓRA, MÉTA), as well as surveys required for the management of protected (ROZNER et al. 2011) and Natura 2000 areas (VIDÉKI & V. TÓTH 2006, 2007a, 2007b, 2007c). More than half of the Nagyberek is part of the Natura 2000 network (SPA: Balatoni-berkek - HUDD10012). The studies of LÁJER (2007, 2008) give summary about the actual vegetation of the area (especially about marshes and fens).



Fig. 1: The borders of Nagyberék (surrounded by green line)

Reed beds (*Phragmitetum communis* Soó 1927 em. Schmale 1939), tussock sedge communities and non-tussock beds of large sedges (*Magnocaricion elatae* Koch 1926) cover huge areas (40%), with patches of *Cladietum marisci* (Allorge 1922) Zobrist 1935) in the lower parts. *Urtica kioviensis*, *Thelypteris palustris*, *Lathyrus palustris*, *Ranunculus lingua* are typical species of the fens. Mesotrophic meadows dominated by *Deschampsia caespitosa* (*Deschampsion caespitosae* Horvatic 1931 em. Soó 1941) are significant as well. Wet grasslands cover 20% of the studied area, while dry grasslands 10%. The extent of *Salix cinerea* mires and alder swamp woodlands is negligible compared to the extent of plantations (*Robinia pseudoacacia*, *Populus x euramericana*, *Pinus nigra*, *P. sylvestris*) (LÁJER 2010). Actually the ratio of forests is 15%, however the presence of forests was never typical in this area. The ratio of arable land is 10%, while the ratio of other land-cover types (e.g. towns, villages, roads, waste places, mines, industrial sites) is 5%. The most dangerous invasive species are *Solidago* spp. and *Acer negundo*. These species threaten 30% of the studied area.

The landscape values of the area have been already inventorized with the support of a European project (Vital Landscapes Project) and a spatial landscape model about the changes of land use was made as well (JOMBACH et al. 2012, DURAY et al. 2013). The study of HOSSZÚ (2009) deals with this area in a complex way, it considers the area as natural unit of the landscape with special history. This study reconstructs the history of the landscape through the changes of land use. The Nagyberék is one of the largest marshy areas in Hungary. The marshes and fens remained untouched until the middle of the 19th century. We can find descriptions about the harmony of the natural environment and its inhabitants in the early 20th century in the study of TAKÁTS (1934). The “islands” (where grasslands were found) were mowed and grazed with buffalo and cattle. The area was rich in game and fish. The arable land and vineyards were on the higher parts of the area, on the edge of the Nagyberék (TAKÁTS 1934). Rapid changes have happened from 1950 in the period of socialism. The drainage of the whole area disrupted the natural

water supply, large areas were ploughed up (TAKÁTS 1986). The traditional land use disappeared in parallel with the nationalisation of the land and the spread of large-scale intensive farming. Although the Fehérvízi Protected Area was established in 1972, the effective protection and management of the habitats began only with the foundation of the National Parks (Duna-Dráva National Park 1996, Balaton Uplands National Park 1997). The migration and impoverishment of people became general after the collapse of the socialism (from 1990) with the ceasing of collective farms. Recently the state-owned land is hired by a foreign owned agro-industrial company. The company deals with game management, cattle breeding and crop production (corn, rape). Water management is under the control of several owners and a complex legislation system.

### Methods

In the last decades the study of driving forces become more and more important in landscape research (WOOD & HANDLY 2001, HERSPERGER & BÜRGI 2007, 2009, LONG et al. 2007, SCHNEEBERGER et al. 2007, HERSPERGER et al. 2010, SPULEROA et al. 2010). According to BÜRGI et al. (2004) there are three phases of the analysis of driving forces (1. system definition, 2. system analysis, 3. system synthesis). It happens through the following steps: definition of the study, the study period, the temporal resolution, and the landscape elements of interest, 2. analysis of the driving forces and directions of the changes 3. definition of causal relationships and driving forces in the studied landscape. The applicability of the DPSIR Framework for the analysis of landscape changes has been proved in the recent years by several studies (SVARSTADT et al. 2008, HERSPERGER et al. 2010, TSCHERNING et al 2012, BELL 2012). The DPSIR Framework is used widely in different studies (KRISTENSEN 2004, PIRONNE et al. 2005, LIN et al. 2007, HAJDU 2009, MAXIM et al. 2009, OMANN et al. 2009, SPANGENBERG et al. 2009, NESS et al. 2010).

The elements of the model are the following: (i) Drivers, (ii) Pressures, (iii) State, (iv) Impact and (v) Responses (Fig. 2). The Drivers can be divided into the following major types: political, economic, technical, cultural and natural (BÜRGI et al. 2004). The drivers-pressures-state-impact-responses are elements of a complex causal system, where the elements mutually influence each other. In the whole system the impacts can strengthen or weaken each other.

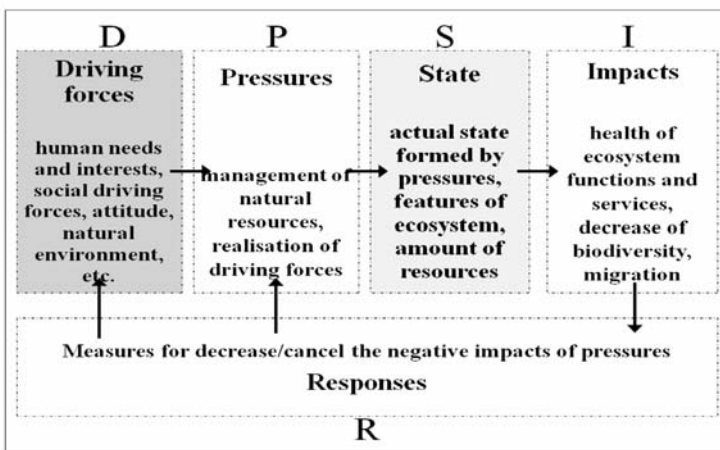


Fig. 2: Elements of the DPSIR Framework (based on EEA 1995)

The knowledge of landscape history is crucial to analyse landscape change and its impacts. Based on landscape history and the main changes of the state of the Nagyberek we identified the period before 1900 as a “benchmark”, a reference state, because the landscape has changed drastically from this period. The railway was built on the sand-bank between Lake Balaton and the Nagyberek. This bank functioned as a gate and the water of Balaton could stream in the area of the Nagyberek only after significant water-level rise and heavy storms. The drainage of the whole area had immediate and intensive effects, as all of the incoming waters were drained in artificial channels. With the help of the model we studied the reasons and effects of changes, the driving forces – which caused the changes between the reference state and the actual state-, the pressures and its impacts in a complex way, and we summarized the responses that were implemented in order to protect the habitats.

We studied the changes of the following categories (habitat complexes):

- I. *marshes: reed beds, tussock sedge communities and non-tussock beds of large sedges*
- II. *grasslands: meadows and pastures, mesotrophic meadows, rich fens*
- III. *forests: plantations and natural forests*
- IV. *arable land.*

## Results

### *Main characteristics of landscape changes*

The area of the Nagyberek has faced *pressures* for a long time. Land use started to be intensified ca. 60 years ago. Such *pressures* are the artificially changed water balance, the intensification of agriculture, the ploughing of marshes and the development of road and rail network. Prior to this development the building of the rail network was the most drastic intervention in the landscape as no way had crossed the marsh before. The M7 motorway fragmented the area of the Nagyberek. These *pressures* led to the actual *state*: spread of adventive species, habitat loss and fragmentation, disruption of water balance, water scarcity. As a result the most significant *effect* is the large area of threatened wetlands. The life of the inhabitants has changed fundamentally in the last 60 years (nationalisation, migration), therefore the connection between the inhabitants and the landscape has loosened, traditional land use has disappeared. *Impacts* threatening the balance of ecosystem are increasing. The spread of adventive species has the most damaging *impact* on the landscape. The area of degraded habitats is growing as a result of the lack of inherited ecological knowledge and the overuse of habitats or the lack of habitat management. Furthermore semi-natural areas disappear or become fragmented as a consequence of improper land use. The *responses* try to maintain and increase the naturalness of the habitats. The legal *responses* which protect the habitats of the Nagyberek are based on Act No. LIII. of 1996 on Nature Conservation in Hungary. The Nagyberek Fehérvíz Nature Conservation Area protects the most valuable habitats with management regulations (restriction of the use of arable land, water retention). Important regulations are the nature-friendly grassland management, suppression of invasive species and the prohibition of non-native woodland plantations. The required water level was regulated in 2013 in the management plan of the Nagyberek Fehérvíz Nature Conservation Area (Decree 9/2013. (II. 20. VM). In the case of Natura 2000 areas the following laws are important: Decree No. 275 of 2004 (X. 8.) of the Government on nature conservation areas of European Community importance, Decree No. 269 of 2007 (X.18) of the Government on the regulations of land use on NATURA 2000 grasslands, Decree No. 61

of 2009 (V. 14.) FVM of the Ministry of Agriculture and Rural Development laying down the conditions of support for agricultural environmental management from the European Agricultural Fund for Rural Development. The management of forests is based on the Act No. XXXVII of 2009 on forests, on the protection and management of forests (Forest Act). The rules of Act No. CXII. (2000) on the Regional Development Plan of the Lake Balaton Recreational District and Rules of the Lake Balaton Regional Development (Balaton Act) refer to the whole area of the Nagyberék.

*Driving forces* inducing environmental changes were induced by the establishment of agricultural cooperatives and their latter privatization. Migration and ageing of population are *driving forces* which influence the state of marshes and grasslands. The settlement development concepts and Leader programmes aim at solving these problems. Agricultural supports help to keep some families in the area. In parallel with this the appreciation of landscape values and the lack of traditional ecological knowledge of farmers became key *driving forces*. Natural *driving forces*, such as climate change, influence the local water balance, intensifying the problems of the artificial water system. Drought periods became more frequent, in turn sometimes extreme high precipitation events occur.

After the phylloxera epidemic in the 19th century vineyards were planted on the higher sandy areas around the lower centre areas. Soon after, tourism appeared as a *driving force* in the landscape, first near the lake, later on the whole area of the Nagyberék. Agricultural areas were parcelled out for holiday houses. As a *pressure* the number of farmers decreased further, the tourists who bought holiday houses have appeared in the last 30 years. The ratio of holiday houses reaches 30% in some settlements. The ratio of abandoned fields increased, which can be considered as an *impact* in the case of grasslands, because these abandoned areas facilitate the spread of adventive species.

### ***Detailed analysis of landscape changes***

#### ***I. marshes: reed beds, tussock sedge communities and non-tussock beds of large sedges***

The system of large estates has been present for centuries in the Nagyberék. Before the studied period the land use had adapted to the natural conditions for centuries. However, the drainage started in the 19th century, it had no significant *impact* on the stability and natural cycles of the ecological system as it affected only small areas. The *driving forces* have become strong enough in the last 100 years to change the social and ecological system of the Nagyberék fundamentally in the 1950. The concept of large-scale farming was the most determining *driving force*: in accordance with political and economic views the area of the Nagyberék was designated for intensive agriculture to ensure the self-sufficiency of Hungary. Technical development allowed the intensification of agriculture. At the same time the road and rail network was built and developed in the area. As a consequence serial *pressures* reached the area, e.g. the disruption of water balance: the whole area was drained, grasslands were meliorated. Peat was cut in huge areas. Marshy areas were divided into equal parcels and ploughed in. The heavy use of pesticides and intensive application of fertilizer has begun. In the actual *state* only the most low-lying areas are covered with water through the whole year, e.g. the fens between Somogyzentpál and Táska ("Martonosi-láp") and the *Salix cinerea* mires near Fehérvíz-pusztá. In the lower parts of the pits (peat, lime mud, loam) homogenous stands of *Phragmites australis* and *Cladium mariscus* can be found (e.g. areas near Fonyód and Ordacsehi). It is interesting to note that recently these secondary habitats in the abandoned pits provide refuge for the flora and vegetation of the once widespread marshes and fens. The Balaton Act influences the management of habitats with the tools of regional development. The act says that the actual land use may be changed only if it

serves the interest of nature conservation (25. §) and only extensive and environmentally friendly agricultural practices may be used. The Hungarian Ecological Network prohibits to designate the natural areas as built-up area. The above mentioned laws (responses) are valid in the case of other categories as well.

### *II. grasslands: meadows and pastures, mesotrophic meadows, rich fens*

In the case of wet grasslands and marshes the main *driving forces* are the same. Thus the conversion and overseeding of grasslands appear as *pressures* in the period of intensive agriculture. Further *driving forces* are: change of lifestyle, disappearance of rural lifestyle, development of mechanisation, economic transformation. *Pressures* are: disappearance of the pastoral grazing system and the small-scale livestock farming, reduction of mowing and grazing. As a consequence of unsettled ownership the secondary succession of former arable land and grasslands has begun. Grazing using electric or fixed fences can not suit to the natural cycles of grasslands and can not manage properly the different vegetation patches. Large mesotrophic meadows can be found in the "Pogányvölgyi rétek" Natura 2000 area (HUDD20035) and near Somogyzentpál. Adventive and invasive species, such as *Amorpha fruticosa*, *Fraxinus pennsylvanica*, *Acer negundo*, *Solidago* spp. are frequent in the area. These species spread as a consequence of the abandonment of arable fields and decrease the diversity and forage value of grasslands. This degradation affects 30-40% of the grasslands. Conservation legislation gives the responses. It specifies the followings: e.g. mowing or grazing is mandatory on Natura 2000 sites, invasive species should be suppressed, licence is needed to winter grazing, overgrazing of wet grasslands is prohibited. The system of agri-environmental supports incites extensive agriculture with higher payments.

### *III. forests: plantations and natural forests*

*Driving forces* began with large-scale farming: shelter forest belts were established between the parcels, *Populus x euramericana* plantations were established for variety trials. The sand banks and sand hills were forested with *Pinus sylvestris* and *Robinia pseudoacacia*. Those areas were forested which were unsuitable for agricultural utilization. In recent years *Fraxinus pennsylvanica*, *Amorpha fruticosa* *Acer negundo* have been planted in large areas for game management purposes. These plantations mean *pressures*: the spontaneous spread of *Acer negundo*, *Robinia pseudoacacia* and *Fraxinus pennsylvanica* degrade the habitats in the Nagyberek. The ratio of natural and semi-natural forests is negligible, the undergrowth is degraded. One important response is the clearcutting of the 30-40 year-old plantations. In accordance with regulations (Balaton Act, Natura 2000, Forest Act) these areas shall be replanted only with native species. Thus the species composition of forests is changing, however their extent must not decrease according to the Forest Act.

### *IV. arable land*

From the 1950s large-scale collective farming has dominated for decades in the Nagyberek. Thousands of hectares were converted to intensive farming, where inter alia, cotton was produced as well. After the end of communism it became important to manage the land economically, therefore arable lands have started to serve game management purposes. Recently game management is the significant *driving force* because many abandoned fields are maintained for small game breeding. The spread of weed species from these fields is considered as an *impact* on the landscape. First the annual crop weeds appear on the abandoned fields, then *Solidago* spp. infest them in 2-3 years. Without management (mowing or grazing) this state keeps steady and the vegetation can

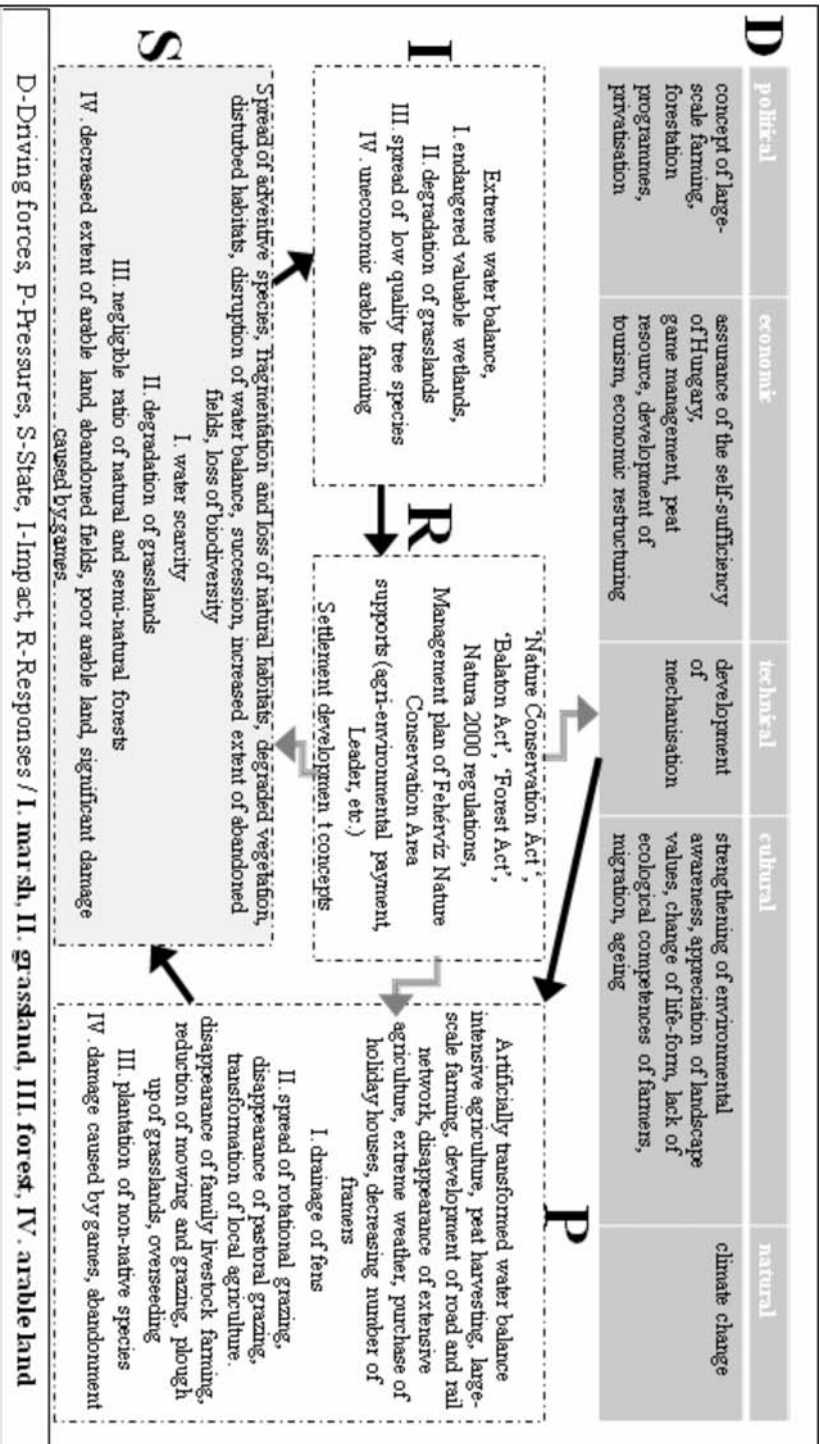


Fig. 3: Direct and indirect causes of landscape changes in Nagyberék in the DPSIR Framework and the applied responses (I. marsh, II. grassland, III. forest, IV. arable land)



not regenerate. Large areas are used as crop fields with game management purposes (feeding of games). Damage caused by games is significant in each habitat type. During the period of communism the most worthless areas has been ploughed as well, therefore the ratio of poor arable land is high in the inner part of the area. The extent of arable land decreased because of abandonment. Recently the main *impact* is that crop farming became uneconomic. The *responses* are agri-environmental supports and supports from the EU. These favour cattle breeding, so the area decrease of arable land will continue.

## Discussion

A significant part of the Nagyberek has been managed by large estates since the 18th century, similarly to Western Europe, but the natural vegetation remained mostly untouched, as technology did not allow the desiccation of the big marshes. Our results show that in the case of the four studied habitat complexes the main *driving force* was the transformation of agriculture to large-scale, intensive farming before but especially during the socialism. The study of HOSSZÚ (2009) concluded that the inhabitants of the Nagyberek had used the natural resources of this special landscape in the same way for decades before the 20th century.

Nature conservation management needs complex thinking. This thinking has just started to shape. Scientific research together with proper nature conservation management help the protection of these marshes and fens. FOLKE (2004) argues, that the landscape as a unit and as a system can only maintain its resilience when the relationship of inhabitants with the land is strong and stable (and land use is based on the local knowledge of generations), and the intervention and changes pay respect to the limits of healthy ecosystem functioning.

Landscapes are changing even if there is no significant driving force, as landscapes have their own dynamics and living beings (including humans) have to adapt to it (BÜRGI et al. 2004). For example in the case of the Nagyberek the extent of wetlands would also decrease without human intervention. Recently this process was accelerated with the artificial transformation of water balance. This accelerated change was too drastic for the ecosystem, which could not adapt to it. These rapid changes also altered the self-identity of inhabitants and their relationship with the landscape. Our study of landscape changes was based on the state-change of four habitat complexes. The *responses* in our area are laws and programmes which concern nationally and internationally important habitats. Owing to agri-environmental supports a stratum of farmers has formed in the last 10 years, which manages the grasslands with mowing and grazing and cultivate arable land in an environmentally friendly way.

We argue that the DPSIR Framework can be used effectively to study the interactions of complex factors that determine landscape change and we hope the framework will also help the proper management of our landscapes.

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