PROCEEDINGS OF THE LATVIAN ACADEMY OF SCIENCES. Section B, Vol. 65 (2011), No. 5/6 (674/675), pp. 206–212.
DOI: 10.2478/v10046-011-0038-9

Science Life

PROJECT ON DEVELOPMENT OF A CONCEPTUAL INTEGRATED MODEL OF SOCIOECONOMIC BIODIVERSITY PRESSURES, DRIVERS AND IMPACTS FOR THE LONG-TERM SOCIOECOLOGICAL RESEARCH PLATFORM OF LATVIA

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INTRODUCTION

In 2002, the Conference of the Parties adopted a Strategic Plan, with the mission to achieve, by 2010, a significant reduction of the current rate of biodiversity loss at the global, regional and national levels. However, review performed by the group of biodiversity experts (Butchart *et al*., 2010) demonstrated decline in most biodiversity indicators and increase in indicators of pressures on biodiversity (including resource consumption, invasive alien species, nitrogen pollution, overexploitation, and climate change impacts). The third Global Biodiversity Outlook report (Anonymous, 2010) stated that loss of wildlife and habitats could harm food sources and industry, and exacerbate climate change through rising emissions.

The reason why the measures taken by man appear to have been ineffective in prevention of biodiversity decline is the lack of an integrative approach in the protection and management of the biodiversity. Until now, different aspects of human influence (e.g. air and water pollution, agricultural practices, landscape fragmentation etc.) on biodiversity have largely been studied separately. Nature conservation measures (e.g. development of protected territories, introduction of special legislation) have promoted local improvement of conditions for species populations and community structure. However, it is not clear whether these measures will have positive long-term effects. Effective policies to slow the rate of anthropogenic degradation of ecosystems and biodiversity loss should reduce integrated socioeconomic pressures on biodiversity, either directly or by modifying their underlying socioeconomic driving forces. The design of such policies is currently hampered by limited understanding of socioeconomic drivers and pressures on biodiversity, as well as insufficient data, indicators and models (Haberl *et al*., 2009).

IMPLEMENTING THE SOCIAL DIMENSION TO LONG-TERM ECOLOGICAL RESEARCH

The International Long-term Ecological Research network (ILTER) since its origin has been focused on long-term studies of ecosystem structure and function. It provides a vast array of different data sets concerning biodiversity and ecosystems. Human influence has been mostly considered as an external factor. During the ILTER meeting in Stara Lesna (Slovakia) in 2008, a new research strategy was set forward, which focused on threshold interaction between environmental and socioeconomic dynamics at multiple scales and possibly forecast of the effects of these interactions on biodiversity and ecological resilience. These objectives set a new challenge to the development of methodological approaches in studying complex landscape-level interactions between humans and ecosystems in different climate zones and under different economies. Each LTER country should have at least one Long-term Socioecological Research (LT(S)ER) platform to meet these new research demands. At present, the metadatabase of LTER Europe includes 21 sites as LT(S)ER platforms all around the EU.

At the workshop of LT(S)ER platform managers in Krusne Hory (Chech Republic), 2008, some guidelines to implement research programmes in the LT(S)ER platforms, in particular concerning the socio-ecological component, were discussed. A promising attempt was made by three LTER countries, Austria, Germany and Spain, in the development of biodiversity pressure and driver models for three LT(S)ER sites of Europe (Haberl *et al*., 2008). The aim of the model was to guide research aimed at improving our understanding of socioeconomic biodiversity pressures and drivers and to serve as a basis for the development of formal, quantitative models in that field.

LONG-TERM SOCIOECOLOGICAL RESEARCH PLATFORM OF LATVIA

Following the European initiative, LTER Latvia selected the drainage basin of Lake Engure as the LT(S)ER platform (Fig. 1). The region is one of the best investigated territories in Latvia in relation to ecosystems and biodiversity. The area of the region is about 644 km^2. Lake Engure is a remnant of the ancient Littorina Sea formed about 4000 years ago (Eberhards and Saltupe, 2000). Its depth does not ex-

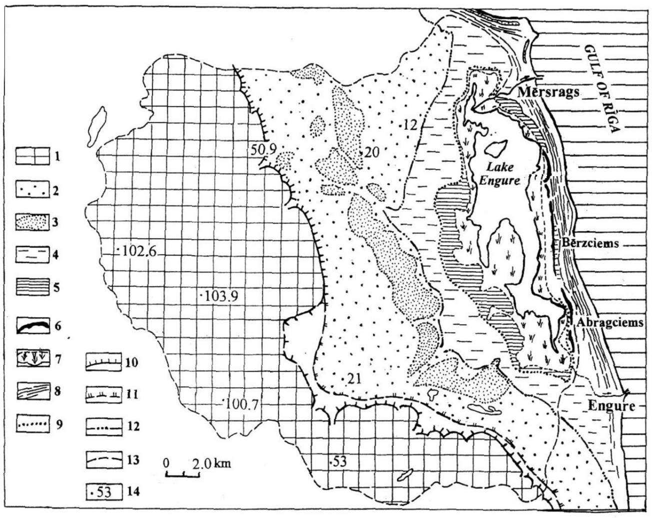

Fig. 1. Main zones of relief of the Engure region: 1 – hills of the North Kurzeme Upland; 2 – Baltic Ice Lake plain; 3 – inland dune belt; 4 – Littorina Sea plain; 5 – level plain of Lake Engure after digging of the Mersrags Canal; 6 – range of new dunes; 7 – belt of water-logged meadows, forest and reed-beds of Lake Engure; 8 – belt of parallel dunes of the Engure Spit; 9 – highest shoreline of Lake Engure; 10 – escarpment of the North Kurzeme Upland; 11 – shoreline of the Baltic Ice Lake; 12 – Litorina Sea coastline; 13 – boundary of the Lake Engure drainage basin; 14 – height, m a.s.l. (after Eberhards and Saltupe, 2000).

ceed 2 m, and the lake bottom is muddy and covered by charophytes. As a result of construction of a canal (in 1842), the lake water level has changed over the 20^{th} century and at present its area is about 41 km^2. Large islands and coastal habitats of the lake are particularly favourable for water-bird nesting. The avifauna of the territory includes 186 species, of which 44 are recognised as highly threatened (Vīksne, 1997). Most of the lake surroundings are covered with pine forests, but there are also large areas of marshlands, meadows, and deciduous forests rich in species. The flora of vascular plants includes 844 species (Gavrilova and Baroniņa, 2000). Part of the unique wetlands of Lake Engure is protected by state legislation and the Ramsar Convention.

Human activities have been shaping ecosystems and biodiversity of the region for centuries. However, big industries have never existed in the region and it has remained mostly as a rural landscape with small fisherman's and farmers villages. Therefore, selection of this region as a LT(S)ER platform provides a good background to study development of man–nature interactions in the future. At present, the new economical situation has radically changed the previous relative balance between man and nature in the region. Since the early 1990s, after land privatization and removing of socialistic state farms (kolkhozes), a number of private farms appeared to be non-profitable; therefore, large tracts of agricultural land were abandoned and overgrew with bushes and forest. Implementation of the LT(S)ER platform should contribute also to ecologically-based solution of the problems faced by the region.

Long data series of population data are available for birds of Lake Engure. Population dynamics and nesting success for several species of water birds have been studied since the early 1950s (Vīksne, 1997). Long-term research on some other biodiversity components started in 1995 in the framework of the national LTER project "Effects of climate change on the nature of Latvia". Studies under this project were focused on the effects of human impact and climate warming on lake and terrestrial communities and habitat structure (Melecis, 2000). Changes in landscape vegetation structure were investigated by remote sensing (Auniņš *et al.*, 2000). Twelve sampling sites representing the most typical ecosystems of lake surroundings were selected for long-term observation of plant and invertebrate communities. Hydrobiological data have been regularly collected from different parts of lake. Surveys of nesting water birds are performed regularly at several sites on lake islands.

NATIONAL LT(S)ER PROJECT

For implementation of the objectives set forward by the ILTER network community, the national LTER project „Development of conceptual integrated model of socioeconomic biodiversity pressures, drivers and impacts for the long-term socio-ecological research platform of Latvia" was initiated in 2010. To reach the objectives defined by the project, ecological data of the region are analysed in context with historical data on socioeconomical processes. The project uses ecological data collected in the region during long-term research, as well as data gathered from different sources (statistical data, archives, unpublished sources) on socioeconomic characteristics of the region.

The project is structured to form three work packages (WP) according to its sub-objectives (Fig. 2). In the framework of WP1, biodiversity research is to be carried out on landscape, community and population levels in terrestrial, marine and lake ecosystems. Particular attention is paid to indicators characterising long-term ecological changes in the past — analysis of lake sediments, dendrochronological studies, maps and aerial photographs made during the last century. One of the questions to be answered is the following: are the changes in historical land use structure of the region reflected in layers of sediments and its chemical composition. There are practically no data on community structure and population dynamics from the period before the 1950s. In parallel with collection of available ecological data from earlier periods, continuing long-term research on bird, plant and invertebrate communities is being carried out. Data on bird populations and community structure have accumulated since the 1950s. Studies of the aquatic ecosystem of the lake and terrestrial plant and invertebrate communities have been studied since 1995.

WP2 includes studies of the social component of the region. These studies also are organised to cover two major temporal components. The first is focused on collection of historical data, and the second, on study of recent socioeconomic processes within the region. Special attention is paid to in-

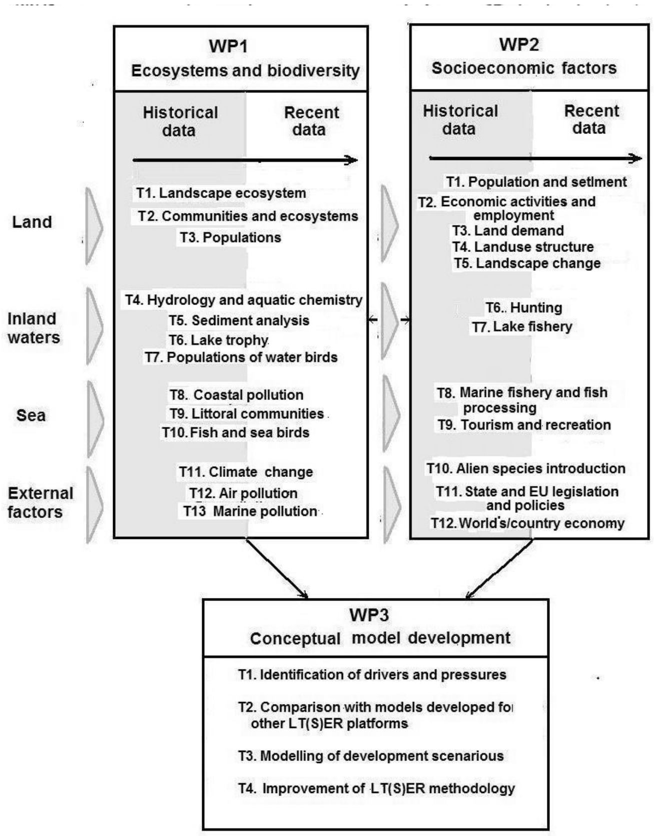

Fig. 2. Structure of the national cooperative project "Development of a conceptual integrated model of socioeconomic biodiversity pressures, drivers and impacts for the long-term socioecological research platform of Latvia". Work packages (WP) and project tasks.

vestigation of socioeconomic processes connected with the use and consumption of local ecosystem resources (agriculture, forestry, hunting, fishery and tourism), to improve our knowledge on the effects of man's integrated ecological pressure on natural communities.

WP3 will attempt to integrate ecological and socioeconomic data to determine whether it is possible to develop a preliminary list of indicators that describe the status of the system man–nature. These indicators could be included as obligatory variables in the long-term research of the system in the future. A conceptual model of the system is to be constructed, and behaviour of the system will be investigated by this model to determine the responses of ecosystems and biodiversity under different scenarios of socioeconomic development of the region.

MODEL SELECTION PROBLEMS

By investigating particular kinds of man's impact (industrial pollution, pesticide application a.o.) on the specific biodiversity components, simple models such as dose-reaction are commonly used. Social-ecological systems have complex structure and combine an extremely large number of elements. Development of the conceptual model of such a multidimensional stohastic system requires certain guidelines that can be elaborated by integration of knowledge provided by natural and social sciences on the basis of systems theory (Holling, 2001; Gunderson and Holling, 2002). According to Glaser *et al.* (2008), at least five important approaches can be identified among studies of social-ecological systems since the late 1990s:

- The evolutionary ecological orientation, focusing on adaptive renewal cycles in multi-scale, panarchical structures (Berkes *et al.*, 2003);
- Quantitative/formal approaches, which functionally analyse mutually embedded complementary systems and the conditions for the viability of systems and subsystems (Bossel, 2001);
- The "New Frankfurt School", which examines society-nature relations and identifies social-ecological patterns and dynamics that satisfy human needs (Becker and Jahn, 2006);
- Complexity theory, focusing on nonlinear dynamic systems and the transfer of system expertise to strategic planning and adaptive management (Ratter, 2001);
- Pattern and archetype approach based on an intermediate scale of abstraction focusing on reappearing building blocks of social-ecological dynamics (Eisenack *et al.*, 2006).

In addition, the DPSIR (drivers–pressures–state–impacts–responses) framework has been widely used since 1995 by the European Environment Agency and by EUROSTAT, for the organisation of environmental indicators and statistics (Thomas, 1995).

The evolutionary ecological orientation (Berkes *et al.*, 2003) is based on study of how humans, across a wide range of cultural settings, have adapted to ecosystem changes in ways that influence the resilience to external shocks of the social-ecological system.

The quantitative/formal approach (Bossel, 2001) represents a systems-based derivation of a comprehensive set of performance indicators, identification of subsystems within the hierarchical structure of the general system, defining structure of these subsystems and finding conditions for viable functional coexistence of subsystems providing sustainability of the general system.

The "New Frankfurt School" (Berghoefer *et al.*, 2010) considers nature as not just an entity that is somewhere out of human society to be either consumed or protected. Instead, it is constituted through a three-way relationship between the individual, society, and the physical world. The school understands nature not as a given, causal, objective entity, but as a sphere whose boundaries are dynamic and socially constructed.

Complexity theory (Berkes *et al.*, 2003) considers social-ecological systems as complex nonlinear open systems capable of self organisation. Reorganisation of such a system is possible at certain critical points of instability. Holling's adaptive renewal cycle (Holling, 2001) is an illustration of reorganisation that takes place within the cycles of growth and renewal.

The pattern and archetype approach (Eisenack *et al*., 2006) aims to identify the features of single-case studies to develop theories of social-ecological system management success factors, based on large samples of case studies. Archetypes are a suitable way of representing generalisable system features by reducing complex interaction to basic mechanisms. They are used as a pattern approach to this task. The general idea is that each problem class is structured by core interactions, allowing to describe them as typical patterns.

DIPSIR evolved as an interdisciplinary tool to provide and communicate knowledge on the state and causal factors regarding environmental issues (Fig. 3). It was developed as a framework for describing interactions between society and the environment (Svarstad *et al*., 2008). Under the term 'driving forces' is understood socio-economic and socio-cultural forces driving human activities, which increase or mitigate pressures on the environment. Under the term 'pressures' is understood stresses that human activities place on the environment. 'State' includes variables characterising environmental conditions e. g. pollutant concentration in air or water. 'Impacts' describe effects of environmental degradation e.g. biodiversity loss, decline of population numbers etc. By the term 'responses' is understood the reaction of society to the environmental situation e.g. introduction of cleaner technologies, environmental regulations a.o.

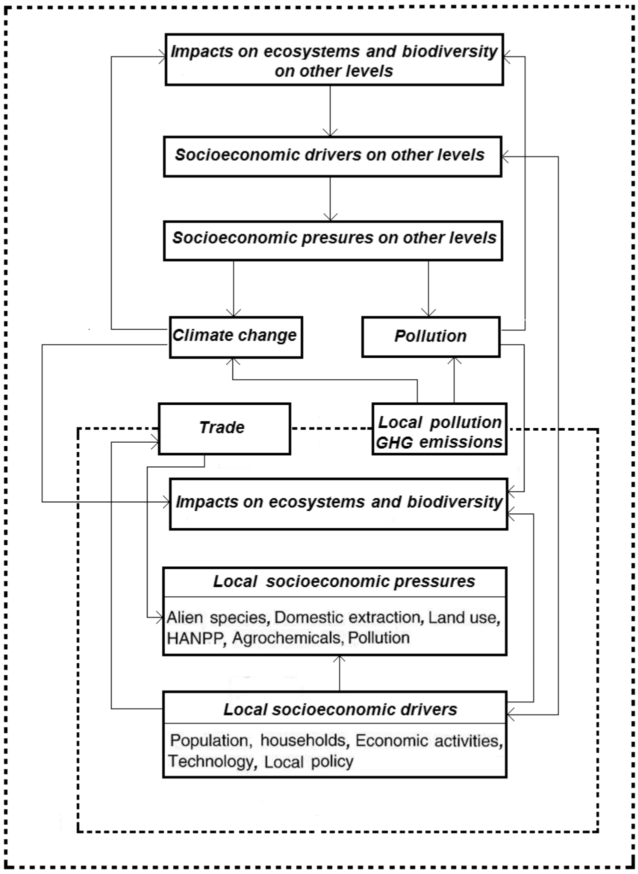

Fig. 3. The DPSIR (drivers–pressures–states–impacts–responses) framework applied to biodiversity of an LT(S)ER site (after Huberl *et al*., 2009). HANPP, human appropriation of net primary production.

It has been recognised that the strength of the DPSIR framework is that it captures, in a simple manner, the key relationships between factors in society and the environment, and therefore, can be used as a communication tool between researchers from different disciplines and between researchers, on the one hand, and policy makers and stakeholders, on the other (Svarstad *et al*., 2008). However, during recent years, much criticism has appeared concerning the DPSIR concept (Spangenberg *et al*., 2002; Gobin *et al*., 2004; Refsgaard *et al*., 2006; Maxim *et al*., 2009). It was concluded that for analytical purposes, the scheme is unsatisfactory. The simple causal relations assumed cannot capture the complexity of interdependencies in the real world. It is a relevant tool for structuring communication between scientists and end-users of environmental information, but it is inappropriate as an analytical tool (Maxim *et al*., 2009).

The approaches described above have so far been developed for the most part independently of each other and no comparisons have been made between them concerning their usefulness for modelling of LT(S)ER platforms. Until now, published results (Haberl *et al*., 2009) are available only on testing of the DPSIR approach in building the conceptual model of LT(S)ER sites. We used guidelines of the DPSIR approach in developing a conceptual model of the Engure LT(S)ER platform. Haberl *et al.* (2009) changed the DPSIR modelling guidelines by introducing a spatial dimension in defining drivers. The system was spatially demarcated and drivers were subdivided in two groups — external and local (Fig. 4). They considered an LT(S)ER region as a homoge-

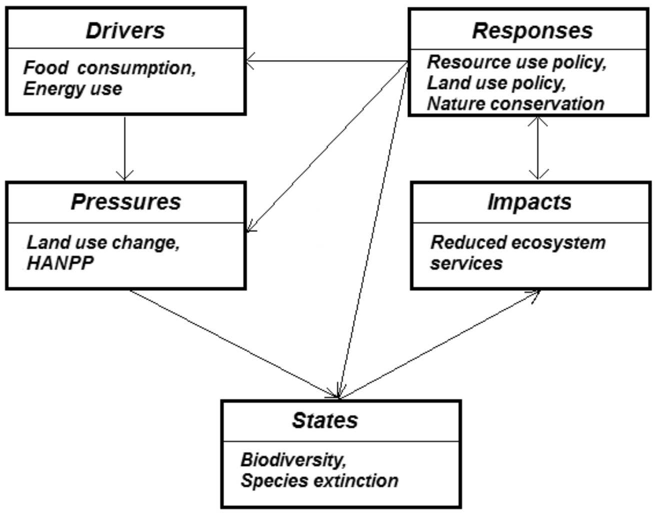

Fig. 4. Socioeconomic biodiversity pressures and drivers — flow-chart of a conceptual model of a LT(S)ER platform based on the DPSIR concept (after Huberl *et al*., 2009).

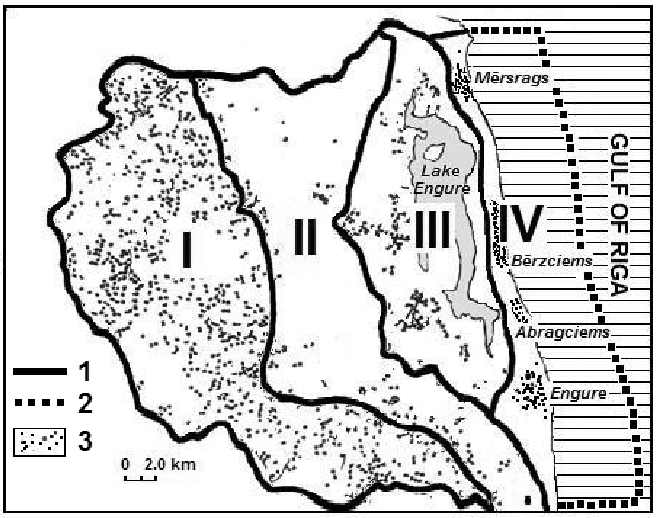

Fig. 5. Distribution of farms and settlements within subregions (marked by Roman numerals) of the Engure LT(S)ER platform: 1 – subregion borders, 2 – approximate sea border of the IVth subregion at the appr. distance 4 km from the coast – a zone mostly affected by coastal fishery and sea recreation, 3 – farms and settlements (after Eberhards and Saltupe, 2000).

nous territory in relation to ecological and socioeconomic factors. In fact this not always occurs. The Engure LT(S)ER site as a Lake drainage area can be subdivided in at least four different zones (Fig. 5) demarcated by natural geological an geographical barriers (Fig. 1). The largest part of the LT(S)ER region is occupied by hills of the North Kurzeme Upland. This territory is subdivided from the Baltic Ice Lake plain by the escarpment of North Kurzeme and shoreline of the Baltic Ice Lake. The North Kurzeme Upland is characterised by well drained soils that are mostly used in agriculture, while the Baltic Ice Lake plain is a lowland with sandy bedrock covered by peaty soils, wet pine forests and marshes. The Littorina Sea Plain has the most heterogeneous landscape. It includes Lake Engure and is subdivided from the Baltic Ice Lake plain by the coastline of the Littorina Sea. The narrow belt of parallel dunes of the Engure Spit with the coastal aquatory of the Riga Gulf forms a functionally separate part of the LT(S)ER region (Fig. 1). The mentioned parts of the region significantly differ in natural conditions such as soils, hydrology, and mesoclimate (Eberhards and Saltupe, 2000). These factors play important roles also in the distribution of human settlement and formation of the structure of land use (Fig. 5). It should be noted that the existing DPSIR model does not consider effects of natural environmental factors in explanation of social outcomes. The idea of dependence of the development of human society from geographical factors is old and was developed by the Huntington's school (Huntington, 1945) of geographic or environmental determinism at the turn of the 19th and 20th centuries. Due to certain exaggerations, later this theory was severely criticised and rejected (see e.g. Peet, 1985). Now, some believe this rejection has gone too far and that incorporating environmental factors into explanations of social outcomes is not only useful but necessary (Ballinger, 2011). This can be seen explicitly by analysing how the geological and soil properties of the natural landscape have affected the spatial distribution, land use structure and to a certain extent even employment of the local people of the LT(S)ER region (Fig. 5). The highest density of settlements is in the North Kurzeme Upland, while large territories of the Baltic Ice Lake plain have remained under-populated. Very few farms are located on the boggy shores of Lake Engure, but the coastal area of the sea is the most densely populated with three big fisherman's villages. The area has been inhabited from ancient times. The local coastal inhabitants were employed in fishery and fish processing, but the main type of employment of persons living inland was agriculture. Therefore, initial differences in the natural conditions have placed certain restrictions on the development of the social component of the system. The social component in its turn has reversible effect on the local ecosystems and species diversity. Thus, the conceptual model of the Engure region as a LT(S)ER platform cannot be described by a single block model. The system requires hierarchical structure, with submodels representing social-ecological systems of the subregions (Fig. 6). Geological and geographical factors need to be included as important external factors in the model. Each subregion has different structure of governing drivers and pressures.

However, introduction of subregions makes the model too cumbersome to capture in the form of simple flowcharts.

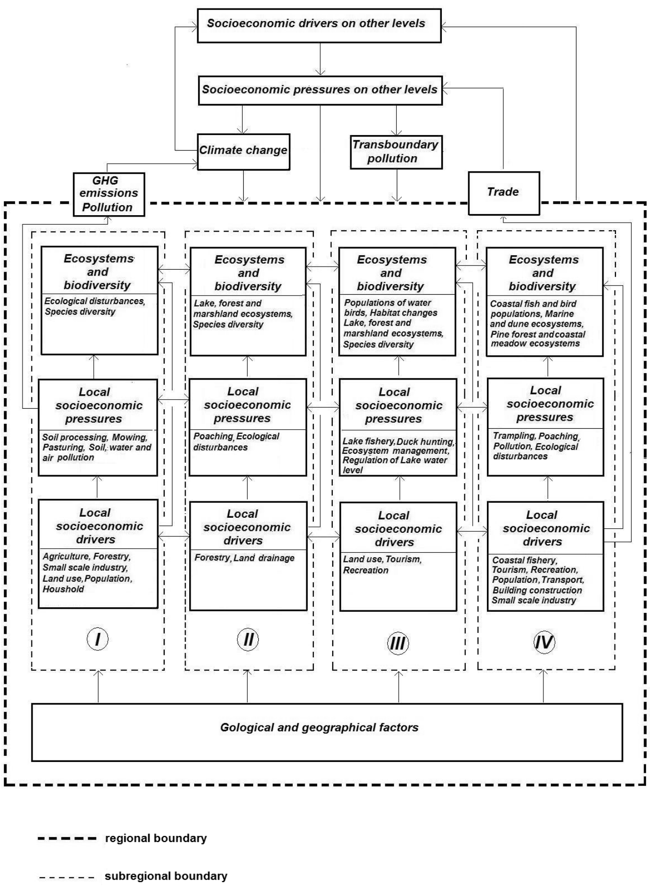

Fig. 6. Preliminary version of a conceptual model of the Engure LT(S)ER platform. The model is based on the DPSIR concept. The spatial subunits or subregions (marked by Roman numerals as on Fig. 5) are distinguished by landscape geological structures and geographical location.

	Socioeconomic pressures on other levels	Geology of the region	Climate change	Transboundary pollution	Land use SR I	Land use SR II	Land use SR III	Land use SR IV	Species diversity SR I	Species diversity SR II	Species diversity SR III	Species diversity SR IV	Lake ecosystem	Coastal marine ecosystem	...
Socioeconomic pressures on other levels		>	>	>	>	>	>	>	>	>	>	>	>	>	
Geology of the region					>	>	>	>	>	>	>	>	>	>	
Climate change					>	>	>	>	>	>	>	>	>	>	
Transboundary pollution									>	>	>	>	>	>	
Land use SR I						?	?	?	>>	>	>	>	>	?	
Land use SR II							?	?	>	>>	>	>	>	?	
Land use SR III								?	?	?	>>	?	>>	>	
Land use SR IV									?	?	?	>>	?	>>	
Species diversity SR I										?	?	?	?	>	
Species diversity SR II											?	?	>	?	
Species diversity SR III												<>	>>	<>	
Species diversity SR IV													>	<>	
Lake ecosystem														>	
Coastal marine ecosystem															
...															

SR - LT(S)ER subregion
> - influence
>> - strong influence
<> - interactions
? - relationship under question

Fig. 7. Example of eventual matrix structure for description of relationships between different components and factors of the Engure LT(S)ER platform. For designations of subregions see Fig. 5.

Therefore, we suggest use of a quadratic *k*-dimensional matrix (where *k* is the number of elements of the model) to describe multiple dependences of model elements and factors (Fig. 7). This form of representation allows grouping of objects and factors by characterising particular forms of relationships among them. By the first approximation of the structure of relationships, simple characteristics can be used (Fig. 7). To quantify these relationships different metrics or functions can be applied and depending on the matrix structure, different methods of multidimensional analysis can be applied.

CURRENT PROJECT ACTIVITIES

To meet the main objectives of the national LTER project, about 70 researchers representing different fields of science, including biologists, geographers, geologists, and sociologists are involved. Four largest research institutions of Latvia are Project partners: the Institute of Biology, the Faculty of Geography and Earth Sciences, and the Faculty of Biology of the University of Latvia, and the Latvian Institute of Aquatic Ecology. The studies performed in the framework of the project will improve our understanding of socioeconomic biodiversity pressures and drivers and will provide basis for the development of formal, quantitative models. However, it was concluded (Haberl *et al*., 2008) that the development of the mathematical model demands considerable investments in monitoring and reconstruction of past trajectories of ecological and socioeconomic parameters. There are still many unresolved questions regarding how to quantify the interrelation processes between society and ecosystems, since the conceptual model is not expected to be quantitative, except some hydrological sub-models, for example models of flows of substances in the lake drainage area. Large data sets are to be collected for the analysis. There are very few reliable biodiversity data concerning the period before the 1950s. Most of the data were accumulated during previous several successive LTER research projects (1995–2009) on ecosystems and biodiversity of the region. Some results of those projects were already published in a special issue of Proceedings of Latvian Academy of Sciences in 2000 (Melecis, 2000; see other articles of the same issue). Until now no special socioeconomic studies have been performed in the region. Currently the research focuses on gathering socioeconomic data and information scattered in different data bases, research reports, archival documents and papers. In the second phase of the project, local authorities and stakeholders will be involved in discussions of possible scenarios of regional development.

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Received 2 January 2012

KONCEPTUĀLĀ INTEGRĀLĀ MODEĻA IZSTRĀDĀŠANA SOCIOEKONOMISKO FAKTORU SLODŽU, VIRZOŠO SPĒKU UN IETEKMJU NOVĒRTĒŠANAI UZ BIODAUDZVEIDĪBU ILGTERMIŅA SOCIOEKOLOĢISKO PĒTĪJUMU MODEĻREĢIONĀ LATVIJĀ

EK pasludinātais mērķis līdz 2010. gadam apturēt bioloģiskās daudzveidības samazināšanos lokālā, nacionālā un reģionālā līmenī, diemžēl, nav sasniegts. To kavē nepietiekamās zināšanas par sociāli ekonomisko faktoru un slodžu ietekmi uz biodaudzveidību, attiecīgu modeļu un indikatoru trūkums. ILTER (*International Long Term Ecological Research network*) pētniecības tīkls kā vienu no prioritātēm definējis nepieciešamību sasaistīt ekosistēmās notiekošās ilgtermiņa izmaiņas ar sociāli ekonomiskajiem procesiem, šim nolūkam izveidojot katrā tīkla dalībvalstī LT(S)ER platformu jeb modeļreģionu šādiem pētījumiem. Latvijā LT(S)ER platformas statuss piešķirts Engures ezera sateces baseinam. 2010. gadā uzsākts sadarbības projekts „Konceptuālā modeļa izveidošana socioekonomisko faktoru spiediena novērtēšanai uz biodaudzveidību ilgtermiņa pētījumu modeļreģionā Latvijā", kura galvenais mērķis ir izstrādāt konceptuālu modeli sociāli ekonomisko faktoru, virzošo spēku un slodžu novērtēšanai uz ekosistēmām un biodaudzveidību. Rakstā apskatītas dažādu autoru līdz šim izstrādātās pieejas un koncepcijas sociāli ekoloģisko sistēmu analīzē. Sīkāk analizēta līdz šim LT(S)ER pētījumos izmantotā Eiropas Vides aģentūras izstrādātā DPSIR (*drivers – pressures - states – impacts – responses*) koncepcija un tās modifikācijas iespējas, izmantojot to kā pamatu Engures LT(S)ER platformas konceptuālā modeļa izstrādāšanai.