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Innovations for biodiversity assessments in planning and industry – Integrating ecological models and ecosystem services

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Abstract

At the University of Giessen, a project team aims at developing a new innovative system to make scientific methods and results of ecological research applicable for urban and landscape planning. Assisted by user-friendly software modules the novel system will bring together ecological modeling and the quantification of ecosystem services to facilitate considerations of sustainable planning.
Healthy ecosystems formed by characteristic species, habitats and ecological processes provide essential ecosystem services that are the basis for human livelihoods, e.g. through the provision of resources and the regulation of environmental conditions. It is widely acknowledged that considering species, habitats and ecosystem functions is crucial for a sustainable regional development. Numerous rules and regulations exist concerning assessments of these issues in urban and landscape planning. Furthermore, an increasing number of companies is recognizing the economic significance of environmentally responsible behavior both for cost reduction and marketing purposes. However, existing procedures for assessing the impact of economic activities on ecosystems are costly, but they do not efficiently capture the complexity of interactions among humans, organisms and the abiotic environment. Currently, evaluations of species and habitats are mainly based on their conservation status and sectoral planning assesses possible impacts on landscape functioning such as hydrological processes or recreational value, but biotic, physiochemical and socio-economic aspects are not sufficiently integrated in a unified evaluation framework. Applying a more standardized approach to such integrated assessments would also improve their transparency and comparability, and it would aid communication among stakeholders and decision-makers.
Our novel system will facilitate higher quality results at lower costs by (1) applying spatially explicit models of species and habitat distribution based on collated existing data, (2) supporting discussions among stakeholders by providing easy-to-grasp information on the potential consequences of different land-management options and (3) providing coherent decision support by integrating biotic and abiotic aspects in the unifying concept of ecosystem services. Thus, we will develop comprehensive solutions for complex problems in a number of fields, e.g. landscape planning, agri-environmental policy or environmental protection in corporate operations.

Keywords
Biodiversity assessments, planning, innovation, ecological model, ecosystem services

Background

Healthy ecosystems are the basis of human livelihood and well-being. Since ecosystems are composed by characteristic species which form distinct communities considering wild species and the conditions of their habitat is crucial for a sustainable regional development. One important reason to maintain healthy ecosystems is that many ecosystem functions are beneficial to human well-being. Those ecosystem functions that provide benefits for people are also called "ecosystem services". These ecosystem services comprise a multitude of resources and processes. According to the Millenium Ecosystem Assessment (MEA 2005) a definition by the United Nations describes four categories of ecosystem services (Fig. 1):
Provisioning services are those ecosystem functions that provide resources indispensable for human livelihood such as clean water, food, fiber and timber.
Regulating services are ecosystem functions that help controlling natural hazards e.g. biological pest control, prevention of flooding or regulation of the climate.
Cultural services provide space for recreation and inspiration. Educational purposes are another aspect of cultural services.
Supporting services form the basis of all other ecosystem services since the supporting services make other functions possible to operate. Examples for such basis functions are nutrients cycles, soil formation or seed dispersal.

Given that all ecosystem services are free of charge compared to any technical solutions such as water preparation, ecosystems services hold enormous intrinsic and economic values.

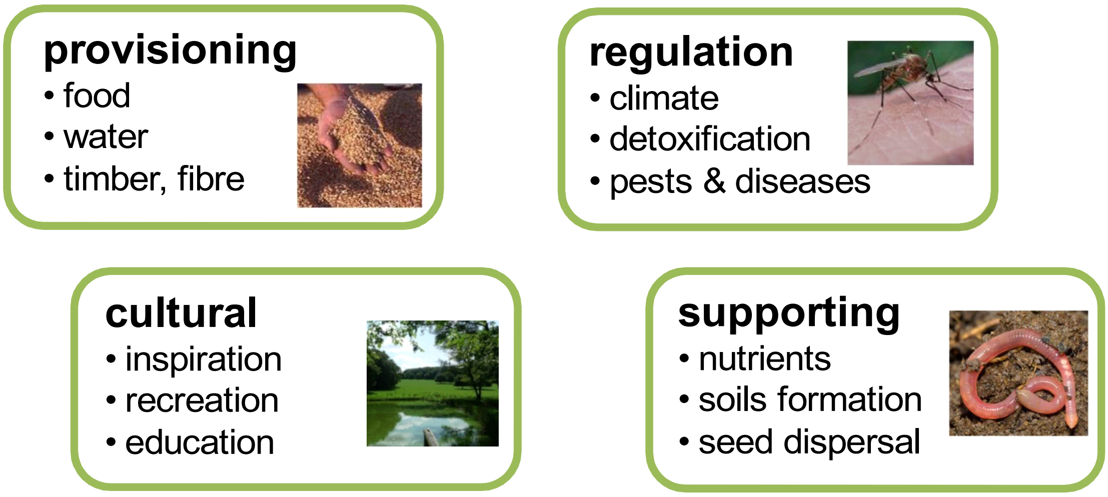

Figure 1: Categories of ecosystem services as defined by the Millennium Ecosystem Assessment (MEA2005).

Biodiversity assessments

Many national and EU-wide legislations require assessing the impact of economic activities on ecosystems. Among several EU directives are the Birds Directive (79/409/EEG 1979) and the Habitats Directive (92/43/EEG 1992) which form Natura2000, the extensive network of protected areas. Also, the EU Water Framework Directive and the Directive on the assessment of the effects of certain plans and programs on the environment (2003/35/EC 2003) demand biodiversity assessments from authorities and private companies. Moreover, at the national level regulations of environmental interventions exist. For example, the Nature Protection Law in Germany,

for example, calls for counterbalancing all encroachments upon nature (§15 Abs. 1-2 BNatSchG). Similarly, planning large projects, i.e. building projects are obliged to perform Environmental Impact Assessments (§2 Abs. 1 UVPG). Other regulations allow for a more active configuration in favor of nature conservation than preventing impacts on natural resources such as landscape planning, management plans for protected areas or strategies for remediating areas for restoration.
Besides these existing legislations the activities under the Convention of Biological Diversity and for the work of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) will increase the importance of environmental policies, presumably leading to more complex standards in considering the status of biodiversity (*SCBD 2010*).
Furthermore, assessing biodiversity in private companies shows enormous economic significance. In particular, lowering the ecological footprint holds growing potential for marketing purposes (*McKinsey & Company 2010)*. By now, calculating the ecological footprint and life cycle assessments rarely factor biodiversity.
However, although all these regulations and trends require an increasing implementation of biodiversity assessment, the main drawback is that existing procedures are time-consuming and costly, therefore impeding the inclusion of biodiversity in those procedures.

An innovative system for biodiversity assessments

The project "ÖkoService" aims at developing a new innovative system which will significantly lower the costs of biodiversity assessments while ensuring a high quality of results. These ambitious targets will be achieved by making scientific methods and results of ecological research applicable for urban and landscape planning. Assisted by user-friendly software modules the novel system will bring together ecological modeling and the quantification of ecosystem services to facilitate considerations of sustainable planning. The project "ÖkoService" is funded by the Federal Ministry of Research and Education (BMBF) in Germany within the funding program "VIP" which has targets at validating the potential for innovations of scientific findings.

Generally, biodiversity assessments comprise to the domains of surveying species, habitat and their ecosystem functions and evaluating them. Finally, the findings of biodiversity assessments feed into the balance of interest in the planning process. Balancing the interests include discussing different political opinions and the participation of the public and local people. Therefore, the novel system pursues the overall goal to provide an acceptable standard as a comprehensible basis for decision making.

Within the innovative system of ÖkoService five basic sub-procedures will cover the domains of surveying and evaluating biodiversity: (a) data integration, (b) landscape analysis, (c) modeling, (d) prediction and (e) valuation of ecosystem services.
Each step will be optimized and supported by effective software tools. In this way, the application of the system will ensure cost-efficiency and high quality results.

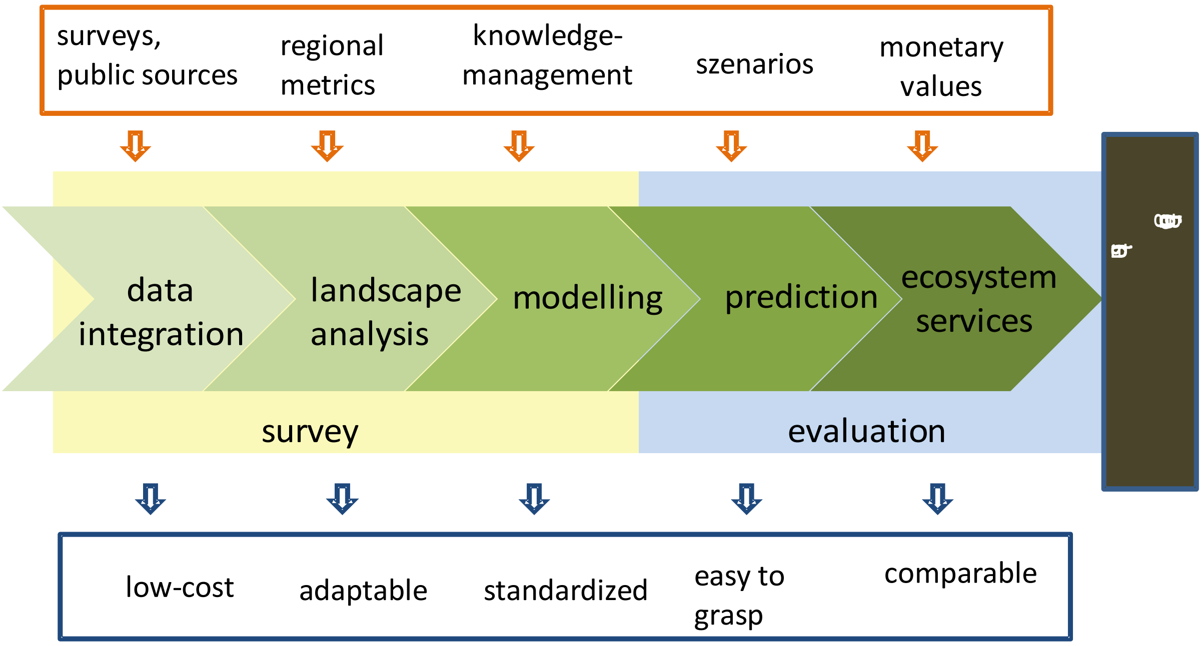

Figure 2: the concept of the innovative system to be developed by the project "ÖkoService". The workflow of sub-procedures covers the domains of surveying and evaluating species, habitats and functions in biodiversity assessments. Each procedure is optimized for an efficient application and supported by elaborated software tools.

In short, advantages of these steps are gained by the following principles (Fig. 2):

(a) Using existing data from public sources lowers the costs of data acquisition
(b) Landscape metrics allow for adapting the system to regional conditions
(c) Applying scientifically sound ecological models leads to a standardized approach in surveys of species and habitats
(d) Prediction maps visualize different scenarios in an understandable and intuitive way
(e) Valuation of ecosystem services, particularly in monetary terms leads to comparable units

Sub-procedures

In the following, the sub-procedures are described in more detail:

Data integration collates existing data from different sources, particularly publicly accessible data. Such data sources comprise data from public authorities and the World Wide Web, but also data from research institutes, national monitoring schemes and expert opinions. The main challenge is to ensure semantic, spatial and temporal consistency to allow for data mining in such heterogeneous data. The aim of the data integration procedure is to compile a common database for the following procedures, specifically for the ecological models. Naturally, the utilization of existing data lowers the costs for surveys in the field.

Landscape analyses then broaden the database created by the data integration. A set of landscape metrics capable to precisely describe the landscape's composition and configuration are calculated. Thereby, the regional context is taken into account. Parameterizing the ecological models with these metrics allow for adapting models to different regional conditions.

Constructing ecological models of species and habitats distributions form the core of the novel system. The modeling procedure will combine stochastic modeling approaches based on regression techniques (Gottschalk et al 2010), dynamic models of ecological processes and knowledge based models. Scientific knowledge bases hosted by a knowledge management system support the modeling procedure and allow for deriving core ecosystem functions. Ecological modeling provides a standardized approach for surveys of species and habitat.

Predictions are derived from the models and allow for projecting the distribution of species and habitats in a spatially explicit manner onto an extensive area of interest. As a result an extrapolation map provides the probability of species occurrence all over the area of interest. An example for the Yellowhammer is shown in Figure 3. Such extrapolated maps may help to more specifically and efficiently conduct field surveys. Equally, predictions can be applied on different scenarios which describe alternatives e.g. for a planning project. In this case prediction maps visualize prospective changes under each alternative. Such visualization are easy to grasp and understandable.

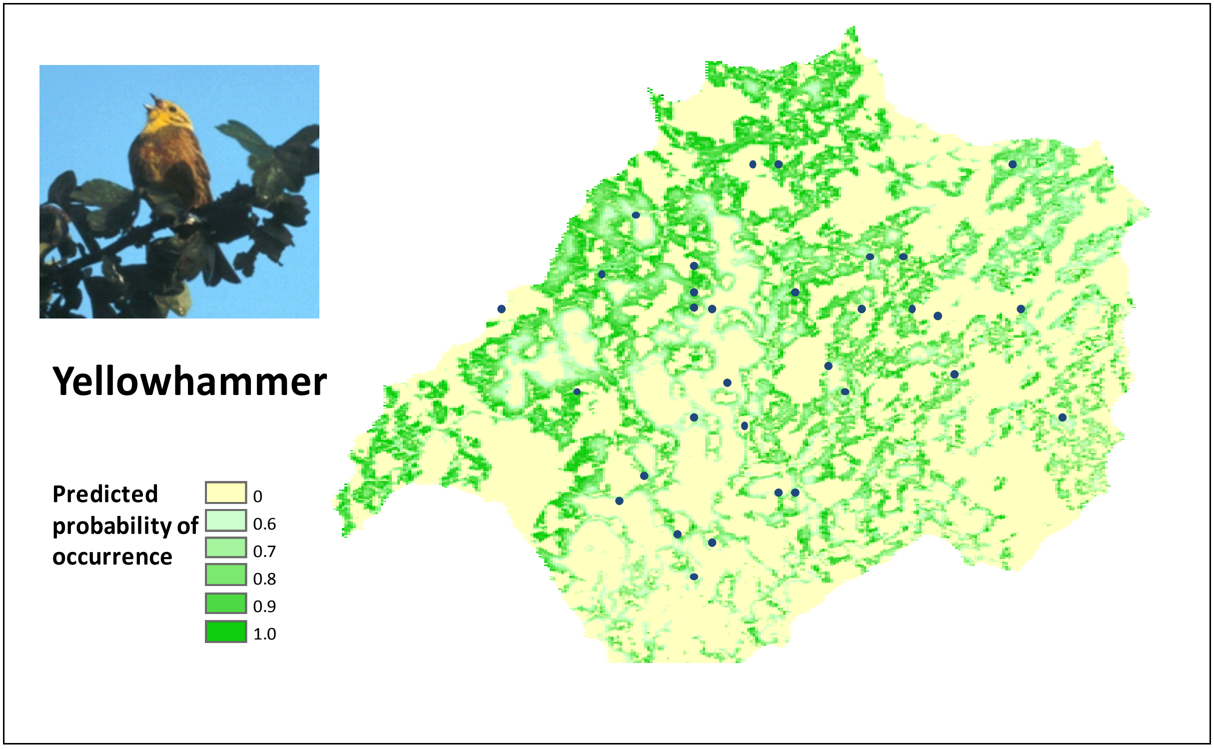

Figure 3: Modeling and predicting produces habitat suitability maps: The example for the Yellowhammer is taken from a previous project (Gottschalk et al 2010). The probability of occurrence is calculated with modeling techniques from several observed occurrences of the species and projected for the total area of the region.

Finally, valuating the ecosystem services determines the real value of a natural system and the accounts the gains and losses of different alternatives (*Nelson E et al 2009*). Valuation can be done in biophysical term, e.g. measuring the yield, the amount of carbon sequestration or deriving quantities of pollination. Also quantifying ecosystem services can be conducted in monetary terms, directly e.g. through market prices or indirectly by evaluating the willingness to pay. Generally, quantifying the ecosystem services provides comparable units in integrated assessments.

Software tools

Optimizing the sub-procedures for cost-efficiency and quality assurance will be gained by supporting all sub-procedures by effective software tools. These software tools allow for implementing the innovative system as a new reliable standard in biodiversity assessments. In particular, with the help of software tools it will be possible to create technical interfaces of the innovative system to existing enterprise resource planning systems, e.g. SAP or Oracle. In the current project, the vital functions of each step need to be elaborated and to be designed and implemented in a set of software modules (Fig. 4). These tools are modules, which are then embedded in common technical platform.

A Knowledge Management System is the main component in this concept. The Knowledge Management Systems hosts ontologies which help the Data Integrator to identify the matching data from different sources with a semantic search (*Jones et al 2006*). Further the Knowledge Managements provides knowledge bases on species characteristics and on applicable rules for deriving ecosystem services. Also the rules for monetary valuation are hosted by this system. The Modelling Engine is the workhorse of the technical platform which processes the data integrated from different sources. It calculates habitat suitability maps based on the current status and based on different scenarios of planning. Supported by the knowledge bases it also provides the quantities of ecosystem services and their economic balances. Prior to modeling the Data Integrator and the Landscape Analyzer facilitate building up the database from different sources. For applicability in practices a component responsible for presentation and reporting is crucial from which tables, figures and maps on the current status and predictions of species and habitats can be obtained and the current status and the predictions of ecosystem services can be visualized. These results then allow for a rigid analysis of the different scenarios in planning.

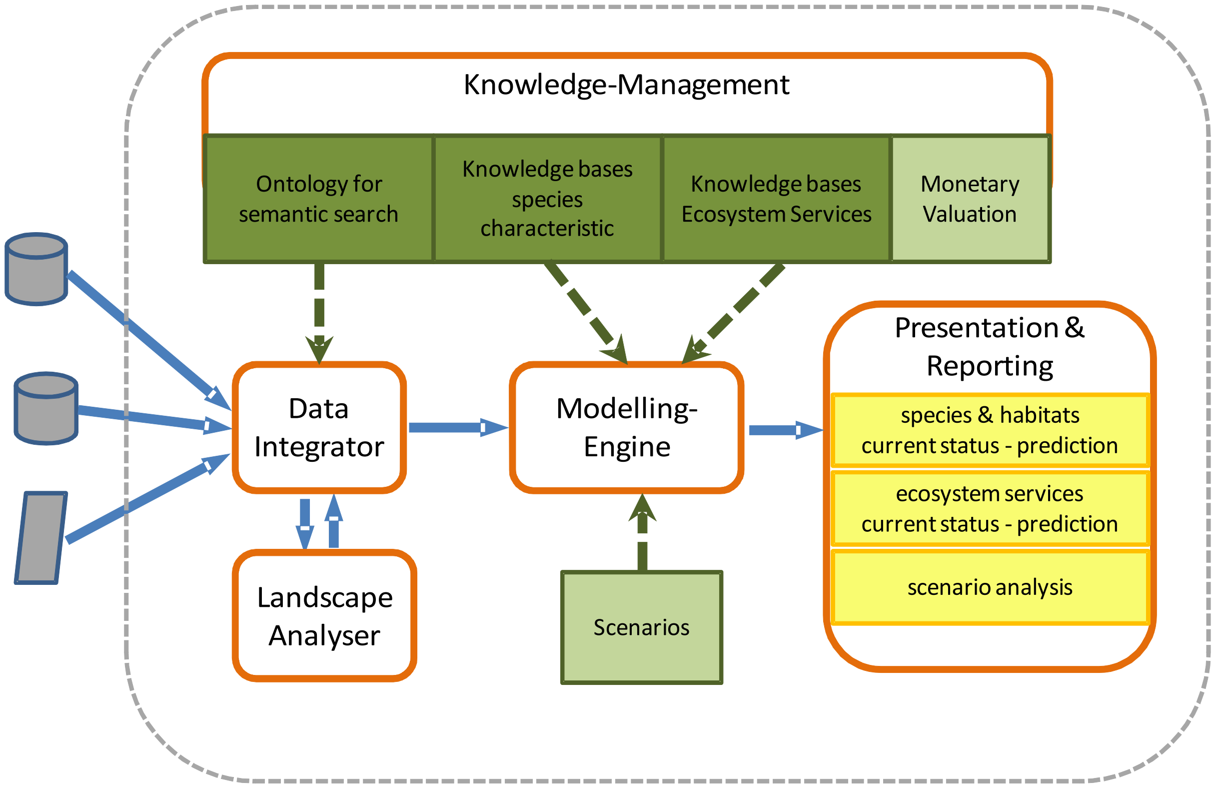

Figure 4: Technical platform of the innovative system with embedded components.

This way, the project ÖkoService will create an innovative, cost-efficient, standardized system for biodiversity assessments by integrating ecological models and the concept of ecosystem services and the use of sophisticated software tools.

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