Optima Lobau: An interdisciplinary scientific approach evaluating future scenarios in an urban floodplain

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Keywords: restoration management, multi criteria decision aid, hydrological modelling, ecosystem modelling

Introduction

Due to many-fold ecological and socio-economic demands and constraints, the management of urban floodplains represents a challenging prospect for river engineers. The often limited understanding of the spatio-temporal dynamics and of the complex interactions between the main channel and its floodplain as well as the discrepancy between objectives to restore near-natural conditions and the restricted reversibility of certain ecosystems may lead to cost-intensive but ineffective measures on the local scale (Bujise et al. 2002). Various conflicting social demands and utilizations may place additional restrictions on ecological objectives. As a consequence, recent scientific studies emphasize the importance of an interdisciplinary approach for the revitalization of urban rivers and floodplains which should be based on the application of modern river ecosystem concepts that form the background of a conceptual framework for management decisions (e.g. Amoros & Bornette 2002; Nienhuis et al. 2002; Poole 2002). With respect to the reversibility of the system, restoration approaches have to be based on predictive geomorphological, hydrological and ecological models as well as on the comparison with reference conditions which give an insight into the complex interactions of the different compartments of the system. In addition, within urban areas, restoration concepts have to integrate the many-fold, often conflicting social and economic demands and involve local and regional stakeholders in a participatory process in order to raise public support for the proposed strategies (Hargrove et al. 2005).

However, the integration of the various ecological and socio-economic aspects of urban floodplain management often confronts managers and scientists with several problems. The incomparability of quantitative and qualitative data, the weak measurability of certain aspects, especially as regards social qualities (e.g. aesthetic values), together with contradicting objectives may hamper the comparison and evaluation of different management strategies. A restoration approach for urban floodplains, hence, needs an evaluation method which has the power to overcome these problems (Faucheux et al. 1998).

In this paper we present an interdisciplinary approach for future restoration measures in urban floodplains on the basis of a case study in the Lobau along the Danube River in Vienna. Because of the multi-objective nature of floodplain revitalisation, the recently started research project focuses on the development of a Decision Support System (DSS) to identify a best-compromise solution for a sustainable management of the Lobau. The approach links

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scientific research with management issues in a transparent and reproducible way through the application of a multi-criteria decision aid (MCDA) method. In order to cope with the complexity of the floodplain system, the approach is based on an interdisciplinary co-operation, involving ecology, socio-economy, fluid mechanics, landscape ecology, morphology, and operations research. Natural and social sciences contribute equally to the creation of predictive models with respect to large-scaled succession patterns in the course of potential hydraulic management alternatives.

Scientific approach

The pre-analytical vision behind this approach can be found in the school of Ecological Economics (Faucheux et al. 1998). The underlying assumption is that complexity is a vital part of our life and has to be taken into account in decision making processes. Complex systems like floodplain ecosystems cannot be captured adequately by a single type of representation or analytical perspective (O´Connor 1994). The conclusion of this theory is that there are multiple allocation possibilities instead of a unique optimal solution which require a ranking with regard to specified multiple criteria.

MCDA methods are widely used in private as well as public evaluation and decision support contexts nowadays, especially as regards river basin management (e.g. Munda 1995). In the current project, a best compromise solution will be identified out of a limited set of pre-defined alternatives with the help of the PROMETHEE outranking technique (Brans et al. 1986). This method allows us to take into account conflicting, multidimensional, incommensurable and uncertain effects of decisions and actions (Faucheux et al. 1998) and offers the possibility of simultaneously dealing with large numbers of data (including ordinal criteria evaluation), relations and objectives. The criteria evaluation needs a series of numerical models that describe the hydrological situation, ecological processes and socio-economic characteristics in the case of a given alternative.

Basically a discrete multi-criteria problem can be described in the following way:

$$\max\left\{f_1(x),\, f_2(x), \ldots\, f_j(x), \ldots\, f_k(x) \,\middle|\, x \in A\right\},$$

where A is a finite set of n alternatives and $\{fj(\cdot), j \quad 1, 2, \ldots k\}$ is the set of evaluation criteria considered relevant in the decision problem. In this way, the decision problem can be represented in a tabular or matrix form. Assuming the existence of n alternatives and m evaluation criteria, it is possible to build an $n*m$ matrix called the evaluation or impact matrix, whose elements represent the evaluation of an alternative by means of a certain criterion. This impact matrix may include quantitative as well as qualitative data. The ranking of the alternatives is then carried out by pair wise comparisons of the alternatives for each criterion based on the respective criteria scores and on the criteria weights defined by the stakeholders (Fig. 1). The alternative with the highest rank represents the best compromise solution.

Case study: the urban floodplain Lobau

The Lobau is situated along the left bank of the Danube at the eastern border of the city of Vienna. During the regulation of the Danube between 1830 and 1880, this former dynamic floodplain was disconnected from the main channel by the construction of a flood protection dam (Hein et al. in press). Lateral embankments along the main channel as well as the incision of the river bed led to a further decoupling of the floodplain from the Danube and resulted in heavy modifications of the geomorphological and hydrological dynamics. Nowadays, the Lobau represents a groundwater-fed and back-flooded lake system where sedimentation and terrestrialisation processes prevail.

River engineering has not only led to a reduction of most of the basic ecosystem functions, but also to a drastic shift in the structure and composition of habitat types and vegetation cover. The reduced hydrological dynamic favours the establishment of rare but atypical species of dry meadows. Despite these interventions the Lobau is still characterised by a complex mosaic of aquatic, semi-aquatic and terrestrial habitats, and features, therefore, an extraordinary high biodiversity. The floodplain has been designated as UNESCO Men and Biosphere Reserve, Ramsar site and Natura2000 area and constitutes a part of the Alluvial Zone National Park.

Because of its proximity to Vienna, the Lobau is also target of several societal demands, including flood protection, drinking water supply and recreation. Land-use issues like forestry, agriculture and sports fishery are currently regulated by the National Park Authority, but need to be considered in restoration policy.

The procedure

The MCDA approach in this project is based on the creation of scenarios which describe possible future conditions of the floodplain as hydrological responses to different hydraulic management measures (Fig.1). The scenarios, thus, mark corner stones of a *"possibility space of the system"* which represent potential images of the Lobau on the assumption of changed hydrological exchange conditions. In order to guarantee a clear and exact demarcation of the different scenarios, the alternatives cover a wide range of hydraulic measures, including different degrees of connectivity from a complete isolation of the floodplain to its re-integration into the flow regime of the main channel. The creation of the scenarios is based on analyses of the historical development of former side arms and backwaters and on hydrological and geomorphological models in consideration of the current flow and sediment regime of the main channel and the floodplain (e.g. lack of coarse bed load and fluvial dynamics, pronounced flood peaks).

In a next step, the main scenarios will be divided into sub-scenarios as to the effects of the maximum development of one dominating ecological or socio-economic demand (Fig.1). In a participative transdisciplinary process, the following driving forces have been identified for the Lobau: fishery, forestry, eco-farming, eco-tourism, drinking water supply, and the minimization or maximization of nature protection measures (rehabilitation of functional processes versus conservation of habitats). Restrictions due to laws and legal regulations as well as the ecological potential of the landscape for various utilizations determine the framework of the different sub-scenarios. For the assessment of the sub-scenarios, various ecological and socio-economic indicators or evaluation criteria will be determined by the linking of hydrological, ecological and socio-economic models.

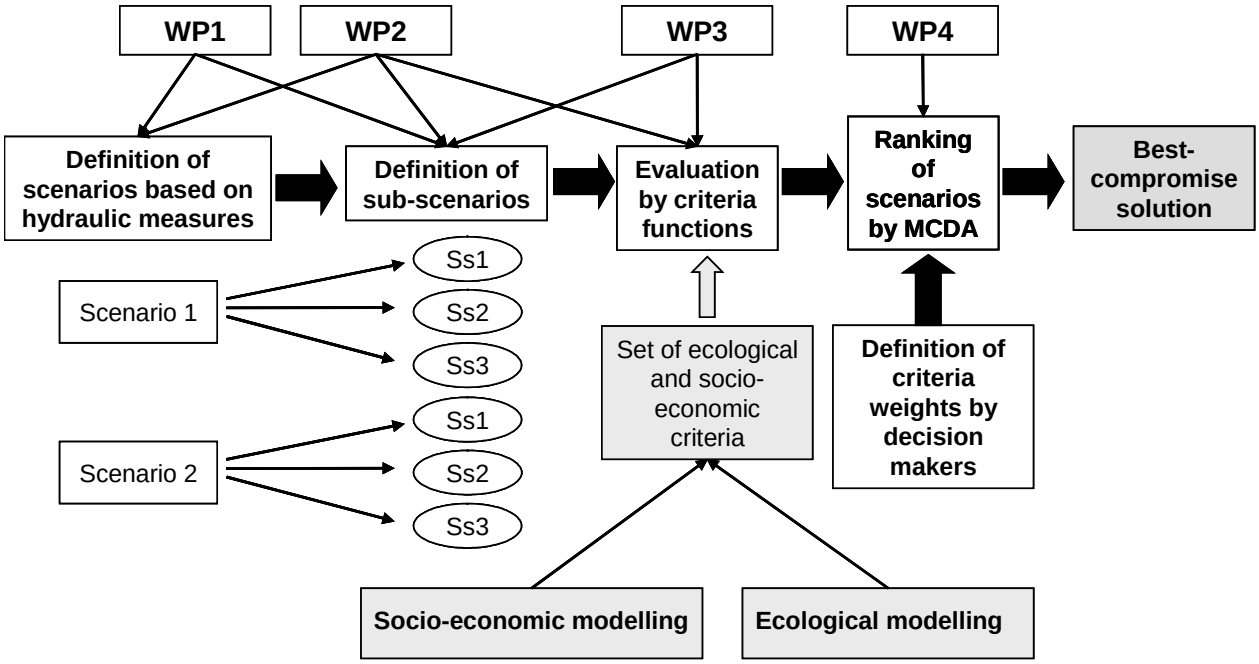

Fig. 1 Work flow diagram, showing the interdisciplinary co-operation within different work packages (WP). WP1 = Historical analyses, WP2 = Hydrology, WP3 = Ecology and socio-economy, WP4 = Development of MCDA; Ss 1-3 = Sub-scenarios 1-3.

The hydrological modelling involves the application and coupling of unsteady 2D surface and groundwater models and will provide time series of surface and subsurface water levels, surface water velocities and inundation patterns for characteristic water regimes. These data will be incorporated into the different ecological sub-models. On the level of functional floodplain processes, interactions among hydro-morphology, sedimentation, nutrient metabolism, and aquatic primary production will be analysed (Hein et al. in press). On the community level, a predictive vegetation model will relate vegetation types to soil maturity and the distance to the groundwater level and the next surface water body on the basis of analyses of aerial images, digital elevation models, and a stratified random sampling design. On the species level, the response of indicator species to different hydrological situations will be analysed. The indicator set for socio-economy is based on settlement policy and will cover issues such as flood protection, recreation, or drinking water production. Economic aspects in form of investment versus maintenance costs will be included on an ordinal scale.

The historical analyses will be used to describe the long-term development of human interventions in the Lobau and to quantify the potential degree of reversibility of the system (Gergel et al. 2002; Jungwirth et al. 2002). The compiled data on long-term hydro-morphological conditions prior to canalisation (1726 – 1832) provide a useful reference for the definition of river type-specific restoration goals. In combination with the knowledge about river engineering measures in the 19th and 20th centuries, the consequences of human interferences on habitat composition and turnover can be reconstructed. Together with data from the hydrological and ecological modelling, the analysis of former habitat conditions will help to assess the future hydro-morphological and ecological development of the Lobau on a profound basis. Once the potential management goals are defined, the reference data derived from the historical analyses will function as benchmarks against which the effects of proposed restoration measures can be evaluated and monitored (Hohensinner et al. 2005). Here, the

historical reference data will serve as additional criteria for the ranking of the management alternatives within the MCDA in order to support the selection of appropriate river/floodplain-type specific management concepts.

Summary

We present an interdisciplinary project for a sustainable management of the Lobau, a highly degraded floodplain of the Danube in Vienna. The approach focuses on the development of a Decision Support System (DSS) to find a best-compromise solution out of a set of pre-defined future scenarios. With the help of a multi-criteria decision aid method (MCDA) scientific research is linked with management issues, so that the various conflicting social and economic demands within this urban floodplain can be integrated into the approach.

Acknowledgements

This work is funded by the Austrian Ministry of Science (ProVision 133-113), the Federal Ministry of Agriculture, Forestry, Environment and Water Management, the Federal Ministry of Transport, Innovation and Technology, Municipal Authorities of Vienna, the provincial government of Lower Austria and the National park Authority.

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