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Quantifying ecosystem service trade-offs: The case of an urban floodplain in Vienna, Austria

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ABSTRACT

Wetland ecosystems provide multiple functions and services for the well-being of humans. In urban environments, planning and decision making about wetland restoration inevitably involves conflicting objectives, trade-offs, uncertainties and conflicting value judgments. This study applied trade-off and multi criteria decision analysis to analyze and quantify the explicit trade-offs between the stakeholder's objectives related to management options for the restoration of an urban floodplain, the Lobau, in Vienna, Austria. The Lobau has been disconnected from the main channel of the Danube River through flood protection schemes 130 years ago that have reduced the hydraulic exchange processes. Urban expansion has also changed the adjacent areas and led to increased numbers of visitors, which hampers the maximum potential for ecosystem development and exerts additional pressure on the sensitive habitats in the national park area. The study showed that increased hydraulic connectivity would benefit several stakeholders that preferred the ecological development of the floodplain habitats. However, multiple uses including fishery, agriculture and recreation, exploring the maximum potential in line with national park regulations, were also possible under the increased hydraulic connectivity options. The largest trade-offs were quantified to be at 0.50 score between the ecological condition of the aquatic habitats and the drinking water production and 0.49 score between the ecological condition of the terrestrial habitats and the drinking water production. At this point, the drinking water production was traded-off with 0.40 score, while the ecological condition of the aquatic habitats and the ecological condition of the terrestrial habitats were traded off with 0.30 and 0.23 score, respectively. The majority of the stakeholders involved preferred the management options that increased the hydraulic connectivity compared with the current situation which was not preferred by any stakeholders. These findings highlight the need for targeted restoration measures. By that, it is recommended that additional measures to ensure reliable drinking water production should be developed, if the higher connectivity options would be implemented. In the next step it is recommended to include cost and flood risk criteria in the decision matrix for more specific developed measures. The research showed that pair-wise trade-off figures provided a useful means to elaborate and quantify the real trade-offs. Finally, the research also showed that the use of multi criteria decision analyses should be based on a participatory approach, in which the process of arriving at the final ranking should be equal or more important than the outcome of the ranking itself.

1. Introduction

Riparian zones, floodplains and river-marginal wetlands are key landscapes of strategic importance to human society (Acreman et al., 2007; Amezaga et al., 2002; Mitsch and Gosselink, 2000; Thoms, 2003; Tockner and Standford, 2002). They provide important ecosystem services such as climate regulation, nutrient cycling, retention of flood waters, infiltration and stabilization of groundwater levels for drinking water abstraction and recreational

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services in urbanized areas (Hoehn et al., 2003; MEA, 2005; TEEB, 2010). It is estimated that more than half of the original wetlands in the world have been lost due to anthropogenic modifications (Fraser and Keddy, 2005; Mitch, 2005) such as drainage for agricultural production (e.g. Kanyarukiga and Ngarambe, 1998; Walter and Shrubsole, 2003), construction of dams for hydropower, urbanization and increased pollution loads in general (Revenga et al., 2000). In Europe, the loss of natural riverine wetlands is estimated to be about 95% (Tockner and Standford, 2002). The remaining riverine wetlands are also altered by straightening and dredging of river channels for navigation purposes (Hesselink, 2002) and confined (Jungwirth et al., 2002) by flood protection measures such as construction of levees and embankments (Henry et al., 2002; Hey and Philippi, 2006; Mauchamp et al., 2002). The reduced floodplain dynamics has turned many riverine wetlands into static, shallow and lake-like systems (Schiemer et al., 2006; Hohensinner et al., 2008), with a reduced integrity of floodplain ecosystem functions (Hale and Adam, 2007; Simenstad et al., 2006; Weigelhofer et al., 2011). The degradation of floodplain ecosystem functions is particularly far progressed in urban settings. Faulkner (2004) and Groffman et al. (2003) indicate that the majority of urban floodplains have already been settled or converted into other ecosystem types, urban settlements, industrialized areas or arable land. The remaining aquatic habitats are often disconnected from the river or are severely altered by intense human uses (Grayson et al., 1999; Hein et al., 2006; Zedler and Kercher, 2005). This often leads to unbalanced floodplain conditions such as increased sedimentation and siltation processes and enhanced eutrophication processes caused by local diffuse and point pollution sources (Henry et al., 2002; Shields et al., 2008). Today, urban floodplains are also increasingly used for recreational activities (Anderson, 1995) like hiking, fishing and swimming. Although these latter activities create additional pressure on the sensitive floodplain ecosystems, they also raise the demand for protection and conservation of nature (Hein et al., 2006; Schaich, 2009). Therefore, the future demands for socio-economic activities and other societal uses, but at the same time, the importance of protecting these valuable floodplain areas, emphasizes the need for new management strategies (Hein et al., 2006; Hopfensberger et al., 2006; Orr et al., 2007; Tong et al., 2006).

The development of such new management strategies can benefit from a multi criteria decision analysis (MCDA) approach due to the potential conflicts and trade-offs between different ecological, livelihood, water treatment and water supply functions. This approach is widely used to support the solution of multi objective decision making problems, where conflicts exist between different objectives (Tecle et al., 1998; Xevi and Khan, 2005). Multi criteria decision analysis aims at structuring the planning and decision making process (Mendoza and Martins, 2006). It provides a means to elaborate and quantify the explicit differences between the management objectives and hence can help in increasing the transparency of the decision-making process. Understanding the trade-off relationships between ecological, economic and social objectives is important in designing policies to manage or restore ecosystems (Cheung William and Sumaila, 2007; Reichert et al., 2005; Turner et al., 2000). Designing effective programs and policies to restore lost or degraded ecosystems also requires evaluation and prioritization of the management options (Prato, 2003). In addition, multi criteria decision analysis techniques allow the incorporation of stakeholders in decision making processes (Brown et al., 2001a; Linkov et al., 2004).

The main aim of the research was to investigate the potential role of multi criteria decision analysis in wetland management, more specifically in the quantification of trade-offs between objectives of key stakeholders involved in wetland management. The paper presents the results of an application of a multi criteria decision analysis to evaluate a set of management options for the Lobau floodplain, an urban floodplain along the Danube River in Vienna, Austria. For this purpose, a distance based algorithm was used to quantify and elaborate trade-offs between two conflicting objectives. The paper further explores what management options are the most preferred ones according to the preferences of stakeholders and, following that, also which option could theoretically offer the 'best' compromise between the group of stakeholders. The Mulino decision support tool called mDSS4 (Giupponi, 2007) was used to analyze the data.

2. Study area- the Lobau floodplain

The Lobau is a 23 km^2 floodplain formed by the discharge patterns of the Upper Danube River (Tritthart et al., 2011). The floodplain area is located on the left river bank of the Danube River at the eastern border of the Vienna City in Austria (Fig. 1). In its pristine condition, the Lobau area was one of the widest floodplains amongst the Austrian anabranching Danube River section, where braided river arms constituted the dominant floodplain habitats (Hohensinner et al., 2008). As part of improvements for navigation and flood protection, the Danube River was straightened and embanked substantially between 1870 and 1880, which changed the morphological character of this river section from an anabranching situation to a single channel system (Zornig et al., 2006). Since then, the former dynamic floodplain has been disconnected from the Danube River channel and changed floodplain development primarily due to altered geomorphological dynamics (Hohensinner et al., 2008). At present, the hydrodynamics of the Lobau is characterized as a groundwater-fed and back-flooded lake system with long periods of low to negligible flow (Janauer and Strausz, 2007). The reduced hydraulic connectivity has resulted in sediment accumulation and a reduction of water levels at the floodplain scale and subsequently enhanced the terrestrialization processes (Weigelhofer et al., 2011). Subsequently, the habitat distribution and vegetation cover has also changed (Hein et al., 2007) which together with prevailing sedimentation and eutrophication processes has resulted in a gradual decrease of size and quality of the aquatic habitats (Kirschner et al., 2001).

The recent urban expansion of Vienna into the north-eastern part of the Lobau has turned the upper part of the Lobau (Fig. 1) into a highly urbanized floodplain, contributed to the degradation of the natural floodplain (Hohensinner et al., 2004; Schiemer et al., 1999). Urban development has also led to an increase in the number of visitors to the Lobau, which adds further pressure on sensitive habitats and species in the floodplain. Nevertheless, the Lobau still contains a high aquatic, semi-aquatic and terrestrial biodiversity (Reckendorfer et al., 1998; Baart et al., 2010). In 1996, this floodplain area was designated as national park area and the ecosystem management target was to rehabilitate the hydrological connectivity approaching pre-regulation conditions again (Schiemer et al., 1999). Hohensinner et al. (2008) show that without sound management practices, most aquatic and semi-aquatic habitats of the Lobau floodplain are expected to change further and the floodplain will soon become a primarily terrestrial ecosystem with major implications for its rich aquatic and amphibic biodiversity (Hein et al., 2006). However, restoring the natural floodplain conditions by increasing the surface connectivity between the Lobau and the river channel, might impose adverse effects on the potential groundwater abstraction and limit other societal utilizations (Hein et al., 2008). Currently, the main uses of the Lobau area include recreation, groundwater abstraction for drinking water production, ecosystem development through