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Economic valuation of ecosystem services, a case study for aquatic vegetation removal in the Nete catchment (Belgium)

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ABSTRACT

In the last decades, lowland rivers were forced to drain larger water quantities during ever shorter time periods. This is mainly caused by current and historic land-use changes (e.g. increase of built area) and increased intensification of agriculture practices (e.g. drainage). River flow, however, is hampered by human artefacts such as weirs and dams as well as by naturally occurring aquatic vegetation. To avoid flooding and water related problems, river managers opt to remove aquatic vegetation. According to the European Water Framework Directive (2000/60/EC), all costs of water management should be charged for (full cost recovery requirement). This study aims to assess whether or not this is achieved in case of aquatic vegetation removal. This method is illustrated through a case study of the Nete Catchment, Belgium. Results show that flood control benefits exceed costs by only a small amount in wet years, but costs exceed benefits in dry years. If decision makers account for even a few ecosystem services, the costs of vegetation removal exceed the benefits in both scenarios. Only local stakeholders in flood risk areas can benefit from aquatic vegetation removal during wet summer seasons.

1. Introduction

Since the EU Water Framework Directive (WFD, 2000/60/EC) was put into practice, integrated water management has become an important issue, meaning that all construction and management measures should contribute to the improvement and strengthening of a broad range of river functions. An important requirement for integrated water management is full cost recovery, meaning that all costs of water management should be charged for. For construction measures, the focus has already changed towards more integrated projects. In the Schelde estuary (Belgium), for example, the Sigmaplan project, originally developed to reduce flood risk, became a typical example of how integrated projects such as the creation of flood control areas with a controlled reduced tide (FCA-CRT Lippenbroek and Kruibeke–Bazel–Ruppelmonde) can contribute to both the reduction of flood risk and restoration of natural systems (Cox et al., 2006; Maris et al., 2007; White et al., 2011; Meire 2012). For the actualised version of the Sigmaplan, a cost-benefit analysis was performed to calculate the net benefits of the integrated management plan (Broekx et al., 2011). For management measures this integrated approach is however less established and a critical analysis by evaluating external effects is therefore at least advisable. Only few studies are found that evaluate integrated management measures (Currie et al., 2009; Blignaut et al., 2010; Wang et al., 2010). In this paper, aquatic vegetation removal is chosen as example to analyse the integrated effects of a management technique to society and the consequences regarding the full cost recovery standard. Macrophytes, i.e. different species of aquatic plants, are essential organisms in natural river ecosystems: they create a wide range of habitats for many fish species (Garner et al., 1996; Grenouillet et al., 2002) and macro-invertebrates (Malmqvist and Hoffsten, 2000; Harrison et al., 2004). Macrophytes also play an important role in oxygen production and nutrient uptake from the water (Cedergreen and Madsen, 2003; Bernot et al., 2006; Desmet et al., 2011). They also create spatial variation in stream velocity that leads to geomorphological changes of the river including changes in bathymetry (Schoelynck et al., 2012; Schoelynck et al., 2013). Macrophytes are therefore considered as functional hotspots in lowland river ecosystems (Bal et al., 2011; Schoelynck, 2011). Being so important in aquatic ecosystems, macrophytes are implemented in the WFD as one of the quality elements that are used as indicators of the ecological status (WFD, 2000/60/EC).

Current land-use changes and increased intensification of agriculture practices have changed the hydromorphological conditions of lowland rivers. In Flanders, built-up area has expanded rapidly from 14% in 1980 to 20% in 2010 (Statbel, 2012), resulting in the decreasing infiltration capacity and consequently increasing run-off and peak flows (Poelmans et al., 2011). Drainage, however, is hampered by human artefacts such as weirs and dams as well as

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by naturally occurring aquatic vegetation. Indeed macrophytes may sometimes cover a large part of the river, thereby strongly affecting the hydraulic resistance of the river (Manning coefficient), with higher water levels and slower drainage as a result (Bal and Meire, 2009; De Doncker et al., 2009a). During heavy rain events in summer this may lead to undesired floods and higher groundwater levels in the river valley. Aquatic vegetation removal is introduced as a management technique to control excessive growth, reducing water levels and hence flood risk and associated damage (Vereecken et al., 2006; Bal and Meire, 2009). In addition, it can also be a technique to remove nutrients from the system, stored in the macrophytes during growth, thereby improving water quality (Schoelynck, 2011). However, aquatic vegetation removal may cause ecological side effects on the short term e.g. macro-invertebrates drift (Gibbins et al., 2007) and mortality of species and on the long term frequent mowing leads to a species shift towards predominantly fast growing macrophytes (Riis et al., 2000), the loss of shelter for fish (Iversen et al., 1985, Katende 2004) and disturbance of the entire river ecology including primary production and nursery function. Furthermore, the reduction in hydraulic resistance and water levels will cause drought risk in dry summer seasons (decrease in water quantity) and a reduction in water purification due to a reduction in residence time. The removal of macrophytes will also increase erosion in the river (Ogunlela and Makanjuola, 2000). Mowing machines, used to remove aquatic vegetation, require a stretch of 5 m wide at both sides of managed lowland rivers, diminishing opportunities for agricultural benefits or natural riparian vegetation at the riversides.

The concept of ecosystem goods and services (ES) improves the understanding of socio-economic effects of environmental changes, hazards and environmental management techniques. In case of aquatic vegetation removal, many ES are affected, either in positive or in negative sense as described above and summarised in Table 1. The integration of the ES-concept in a societal cost-benefit analysis (SCBA) allows for many external effects, both negative and positive and direct and indirect to be included in decision making processes and in the evaluation of integrated management programmes (TEEB, 2010). One important advantage of the integrated ecosystem approach is that it becomes possible to incorporate social, economic and ecological aspects in the decision making process (TEEB, 2010). This helps to indicate synergies and conflicts and to support decision making in the direction of integrated management (Posthumus et al., 2010). To evaluate the societal benefits of management activities, many international studies recommend to estimate socio-economic costs and benefits by the monetary valuation of ecosystem services (Costanza et al., 1997; MEA, 2005; Daily et al., 2009; De Groot et al., 2010). Monetary valuation is a widely used approach to convey these impacts in the same units as many other costs and benefits. As such it is convenient to compare different impacts against each other, including social and ecological effects. Many studies (of which a few are cited hereafter) already showed the usefulness of monetary valuation of ES to inform policy makers and support decision making. This methodology indeed helps to decide if, for example, it is beneficial to restore an ecosystem or not and which management option is most favourable (Liekens et al., 2010; Posthumus et al., 2010; Westerberg et al., 2010). Another use is to value specific changes affecting ecosystems such as the influence of invasive alien species (Mwebaze et al., 2010) or losses from proposed land reclamation projects (Wang et al., 2010). Other studies also use ES valuation to evaluate specific management measures, but this is mostly from a strict economic point of view such as the effect of alien vegetation clearing on water yield and tourism (Currie et al., 2009), or restoring and managing natural capital towards fostering economic development (Blignaut et al., 2010).

Our study addresses the question whether the management measure achieves full cost recovery (objective 1) and whether an integrated evaluation by means of valuing ecosystem services could contribute to a better insight in the overall consequences of the management action and hence to an improved decision making (objective 2). The applied research method makes it possible to analyse the relevant socio-economic consequences and value them to balance some of the most important external costs and benefits. However, the net benefits do not include information on the distribution of costs and benefits among various stakeholders and an economic optimum does not necessarily match with a social optimum (Suzuki and Iwasa, 2009). Net benefits are therefore separately analysed for each stakeholder (objective 3). This will provide decision makers a better overview of the social consequences of the measure and expose adaptation possibilities where needed (e.g. compensation measures).

2. Study area

The study area is the Nete catchment (Fig. 1a,b), a sub-basin of the Schelde basin and mainly located in the province of Antwerp (the Northern part of Belgium). The catchment area is 167,330 ha and the main land uses in the catchment are farmland (49%, of which 47% cropland and 53% grazing land), residential area (18%), green area (11%), forestry (8%), industry (4%), others (10%). On average 650,000 residents live in the Nete catchment, this equals to ca. 300,000 households (Statbel. 2010a). The total length of all watercourses in the catchment is about 2400 km (Agiv, 2011). About 10% of the rivers are navigable waterways (width approx. 40 m), 6% non-navigable of category 1 (average width ca. 10 m), 32% non-navigable of category 2 (average width ca. 3 m), 33% non-navigable of category 3 (average width ca. 1 m), and 21% non-navigable and not-categorised watercourses (category 9). The rivers are only fed by seepage and rainwater. The total discharge amounts on average at a yearly basis 389 million m^3, with an average discharge of 6 m^3/s (CIW, 2009). The basic discharge is on average almost 30% of the peak flow. Water quality was moderate to very good according to the Flemish water quality standards in at least 90% of the 77 measuring points in the Nete catchment (De Cooman, 2007; Gevrey et al., 2010). A large biomass of aquatic vegetation is present in many parts of the rivers (Fig. 1c,d), with floating-leaved pondweed (*Potamogeton natans*), various-leaved water-starwort (*Callitriche platycarpa*), sago pondweed (*Potamogeton pectinatus*) and European bur-reed (*Sparganium emersum*) as most common species (Meire et al., 2007; Bal et al., 2009; CIW, 2009; De Doncker et al., 2009b; Desmet et al., 2011). Aquatic vegetation removal (Fig. 1e) is a standard technique in the catchment management plan (for category 1 and 2 rivers) that is performed every year independently of a wet or dry summer season. Only 10% of the removal activities is on demand if local problems with macrophytes are expected (Provant, 2010). In category 1 and 2 rivers (with a total length of 900 km), vegetation is removed yearly over a total length of 788 km, or on 85% of the rivers (NGI, 2007; Agiv, 2011; Provant, 2011). At most locations vegetation is removed once per summer season, but due to a fast regrowth (sometimes less than 6 weeks (Bal et al., 2006)) at one-third of the locations vegetation removal becomes necessary at least two times per year. In the analysis, an average removal frequency of 1.33 times per year is used. Also on category 3 rivers vegetation is removed, but this is left out of the analysis as it is too difficult to collect information from the 54 municipalities, responsible for the management of category 3 rivers, separately. Navigable waterways (category 0) are normally not managed for vegetation.

3. Method

The analysis aimed to assess whether or not aquatic vegetation removal in the study area gives full cost recovery. At first, the