Coupling ecosystem valuation methods to the WAECO decision support system in the Zwalm Catchment (Belgium)

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Abstract: This paper discusses the need of coupling ecosystem valuation techniques and predictive models to support decision-making in the policy area of water management. It is shown that close linkages between ecological modelling and economic valuation are necessary, because the contemporary water management in Flanders, characterised by its regional orientation (whole Flanders), is based on too general information (mainly indexes) and does not account for the river system processes and its local particularities. Also the relations between the water uses and their effects on the water system are rather unclear, resulting in a lot of uncertainty about the management decisions that have to be made. To improve the reliability and efficiency of management actions in the future, Decision Support Systems working at different scales will therefore play an important role. A concept for a DSS at (sub)river basin scale is presented in this paper: the WAter ECOlogy Decision Support System (WAECO-DSS) in the Zwalm catchment (Flanders, Belgium). A major conclusion of this study is that the contemporary monitoring and assessment of water systems in Flanders only allow the allocation of major impacts and that more detailed and integrated monitoring, modelling and ecosystem valuation are required to obtain a sustainable restoration of the aquatic systems by using cost-benefit analyses.

Keywords: *Ecosystem models; Nature conservation; Restoration; Water management, Decision Support System and Economic Valuation*

1. INTRODUCTION

In this paper, an analysis will be made of the actual river monitoring, assessment and management methodologies applied at regional level (Flanders, Belgium) and at the level of river (sub)basins (Zwalm catchment in Flanders in particular). Although the ecological costs and benefits may be integrated into these analyses, the article shows that determining these costs and benefits at a regional level (whole Flanders) is distinct from the analysis at the level of river management. Linking ecological quality with economic values faces a number of barriers. The article discusses these difficulties and some recommendations for the further development of a Decision Support System (DSS) that aims to provide the necessary information for valuing environmental impacts to water systems at the level of a river basin, will be given. This system allows the prediction of aquatic organisms in the river stretches for different restoration scenarios. Several ecosystem valuation techniques can be applied to obtain a monetary output and cost-benefit analyses, allowing an integrated assessment of different management actions based on the output of model simulations.

2. WATER MANAGEMENT EVOLUTION IN FLANDERS: FROM A REGIONAL TOWARDS A RIVER BASIN APPROACH

In Belgium, different water policies are developed in the Flemish, Brussels and Walloon regions. Because parts of the major river basins (the Scheldt and the Meuse river basins) are situated in these three regions, the management is often conflicting between the different regions, resulting in ineffective and inefficient management of these water systems (e.g. many investments during the nineties did not result in a clear improvement of the ecosystem quality up to now). Particular examples are water quality management, flood control and restoration of the migration of fish, issues that need an integrated approach over all regions, because one particular region is not able to restore or control these aspects within the borders of its territory and related responsibility. On top of this, contemporary river management is scattered in different manners in Belgium, often resulting in specific targets for the responsible managers. The major divisions are based on river system sizes, system components (surface water, sediments, groundwater, aquatic ecosystems, …) and stakeholder (water uses) related issues.

The high need to come to a more integrated approach resulted in the very recent development of river basin committees, in which delegated managers of the different administrations interact to obtain the best integrated management solution for that water system. The different stakeholders take part in these debates (water quantity managers, land-use planners, wastewater collection and treatment managers, drinking water production companies, ecologists, …). However, a common denominator (such as economic value) can ease the discussion between all the involved managers and stresses the usefulness of ecological valuation methods in particular.

3. ECONOMIC VALUATION OF THE ECOLOGICAL QUALITY OF WATER SYSTEMS

3.1. Contemporary water (eco)system assessment in Flanders and the need for models combined with ecosystem valuation methods

A number of ecological/biological indexes are available that inform decision-makers in a condensed way about the potential changes in the ecological quality as a result of their decisions. A brief overview of the two major contemporary river quality assessment methods used to steer the water system management at a regional level (Flanders in particular) is given underneath (Goethals & De Pauw, 2001).

The Belgian Biotic Index (BBI) was developed as a policy tool to get insight in the biological condition of watercourses in Flanders (De Pauw & Vanhooren, 1983). The methodology was standardized to allow a convenient application of the methodology in whole Flanders. The BBI method uses macroinvertebrates as indicators for the level of pollution. The methodology is based on the theorem that increasing pollution will result in a loss of instream biodiversity and a progressive elimination of certain pollution-sensitive groups. The Fish Index or Index of Biotic Integrity (IBI) (Belpaire *et al*., 2000) is still under development for the Flemish watercourses. The index is based on a set of indices. Each index is based on three groups of variables: species composition, trophic composition and fish condition. The IBI integrates the characteristics of a fish population and the individual species in one number.

A major drawback to these indexes is that they only allow to gain insight into the quality of a particular system from a rather limited point of view, namely the ecosystem status. Therefore, they do not allow to allocate the causes of the water system condition. The use of models linking stakeholder activities to ecosystem status might be very useful to solve this type of questions. The development of ecosystem modelling needed for water management already has a fairly long history. Applications of ecosystem modelling in the field of water management show its practical relevancy to decision-makers. However, it also reveals some shortcomings. A striking shortcoming is the strict use of an ecological/biological dimension in presenting information to decision-makers. Policy studies on water management in the Netherlands show that decision-makers have difficulties in understanding this dimension and hence its importance to water management. Similar signals come from policy makers in other fields such as housing and infrastructure (Bouma, 1998). Indicating the economic value of the ecological quality would greatly facilitate the assessment made by decision-makers while evaluating the interventions in ecosystems. If this statement is accepted as a starting point, the related questions to overcome the shortcomings of the use of ecological modelling can be summarised as follows and are also the major goals to deal with in this article:

1. Which valuation methodologies can be used to measure the changes in the ecological quality in economic terms?
2. What are the implications of economic valuation for data collection and modelling approaches?

3.2. The concepts of economic value

From the perspective of welfare economics a useful common terminology regarding economic valuation is provided. This perspective regards values as the assessment of human preferences for a range of natural or non-natural ‘objects’, services and attributes (Turner *et al*., 2001). The Total Economic Value of a resource can be broken down into different categories (Turner *et al*., 2001):

Use values involve some interaction (actual use) with the resource, either directly or indirectly.

Indirect use value derives from services provided by the ecosystem (e.g. the prevention of downstream flooding). Direct use value involves interaction with the ecosystem itself rather than via the services it provides and can be consumptive or non-consumptive (recreational and educational activities,…).

Non-use values are associated with benefits derived simply from the knowledge that a resource is maintained. They suggest non-instrumental values which are in the real nature of the thing but unassociated with actual use, or even the option to use the thing (Turner *et al*., 1994). Existence values (derived from the satisfaction of knowing that some feature of the environment continues to exist), bequest values (associated with the knowledge that a resource will be passed on to descendants to maintain the opportunity for them to enjoy it in the future) and philanthropic values (associated with the satisfaction from ensuring resources are available to contemporaries of the current generation) are examples of non-use values.

Two other categories of values can be mentioned, not related to the initial distinction between use and non-use values. Option value refers to the fact that an individual derives benefit from ensuring that a resource will be available for use in the future, it reflects the value people place on a future ability to use the resource.

Quasi-option value is associated with the potential benefits of awaiting improved information before giving up the option to preserve a resource for future use.Some of these values can relatively easy be monetised, others however are less tangible. Table 1, presented by Turner et al. (2001), gives a general overview of different valuation methods that have been developed to estimate the value of resources.

The application of assumptions behind methods for monetarization show that not all effects can be monetised by each method. Therefore the inclusion of some effect into an assessment puts its limits on the choice of freedom regarding the selection of techniques to monetise the effects. Furthermore, one should proceed with caution when using the results of valuation studies that are based on different methods. The integration of the outcomes of valuation studies can be questioned when the concepts of value are based on different assumptions.

3.3. Applying economic valuation methods to aquatic ecosystems

Although economic values for biological resources are increasingly being incorporated in cost-benefit evaluations of projects and policies, values for biodiversity tend not to be (Pearce, 2001). Much of the literature on the economic valuation of ‘biodiversity’ considers the value of

Table 1. Valuation methodologies relating to ecosystem functions: e.g. wetlands

Valuation Method	Description	Direct Use Values	Indirect Use Values	Non-use Values
Market Analysis	use of market prices	x	x	
Public Pricing	public investment as a surrogate for market transactions	x	x	x
Hedonic Price Method	derive an implicit price for an environmental good from analysis of goods for which markets exist	x	x	
Travel Cost Method	costs incurred in reaching a recreation site as a proxy for the value of recreation	x	x	
Contingent Valuation Method	construction of a hypothetical market by direct surveying of a sample of individuals and aggregation to encompass the relevant population	x	x	x
Damage Costs Avoided	costs that would be incurred if an ecosystem function were not present		x	
Defensive Expenditure	costs incurred in mitigating the effects of reduced environmental quality		x	
Relocation Costs	expenditure involved in relocation of affected agents or facilities		x	
Replacement Costs	potential expenditures incurred in replacing the function that is lost	x	x	x
Restoration Costs	costs of returning a degraded ecosystem into its original state	x	x	x

biological resources and is linked only tenuously to the value of diversity. This is especially true of the studies that use stated preference techniques-questionnaire approaches which ask directly for willingness to pay for the resource (contingent valuation), or which elicit a value indirectly (conjoint analysis) (Pearce, 2001). Ecologists also draw attention to a wider insurance value of diversity in terms of its value in ecosystem integrity and functioning. The diversity of plants, animals and micro-organisms appears to have a role in helping ecosystems organise themselves to cope with shocks and stresses. Put another way, diversity would appear to be linked to resilience, the capacity of ecosystems to deal with externally imposed change (Pearce, 2001).

Imputing monetary values to the outcome of ecological indices is not straightforward. Suppose that under present conditions the Fish Index or Index of Biotic Integrity (IBI) would reveal a moderate river ecosystem quality, and one wants to value a quality improvement related to stricter nutrient emission controls. The results of such a study will depend on, amongst others, two important factors.

First of all, one has to take into account that valuing ecosystem integrity itself differs from trying to elicit the monetary value of ecosystem based on an ecological indicator such as the IBI. The value that people attach to the characteristics of fish communities that are embedded in an index, such as biodiversity, evenness, biomass, amount of invasive species, …, in the case of the IBI can be revealed by using, for example contingent valuation or, for certain characteristics, market prices. A different monetary value will be obtained when one does not only look at the characteristics themselves, but also at the underlying factors that have led to those characteristics. Modelling can provide a useful way to describe processes on different spatial and temporal scales. In particular the need for modelling parts of the water system on a small scale, such as a limited part of a river system located in a specific region, is requested to gain insight in the practical effects of restoration measures. In other words, both approaches (indices and models) measure different things. This will have implications for the choice of the valuation techniques (e.g. market analysis will not be sufficient in the second case) and the way in which they are applied (e.g. the questions asked to respondents in contingent valuation studies and the prior information they need to receive will differ).

A second important element is the type of stakeholder that is involved and his relation with ecological water system quality. Fishers e.g. will prefer a moderate (e.g. much white fish and big carps in a eutrophicated system) over a good river ecosystem quality (when expressed as an ecological fish index), because an improved quality would entail relocation costs to find another carp-abundant system. Consequently, the value they attach to improve the river quality further is negative. This will also be the case for farmers. Households that depend on the river for their drinking water supply will prefer the good quality, because this implies less investment in water purification plants. If a person is a multiple stakeholder, the valuation process will even be more complicated.

Within water management the decision-making context is often divided into decision making at a regional scale (Flanders, Brussels, Wallony) and the level of entire water systems (referred to as river basins), this latter approach is more and more aimed at in Flanders. In the next two sections we look more closely at the valuation of ecological quality of rivers at these two distinct levels of decision-making.

4. DIFFICULTIES TO RELATE ECOLOGICAL AND ECONOMIC INFORMATION AT A REGIONAL LEVEL

At a regional level (whole Flanders), contemporary river management is nearly merely steered on the basis of ecological indexes (Goethals & De Pauw, 2001). In this manner, the field data are filtered from the perspective of ecologists, aiming at restoring the system towards its natural condition. Therefore, theses indexes are very difficult to use for non-ecologists, e.g. fisherman, preferring the optimisation of only particular characteristics of fish communities.

For instance, fishermen prefer high biomasses (dense fish populations), a high percentage of large fish (narrow size distributions of fish communities), particular fish species (not too high biodiversity and often invasive species), … what is often in contrast with a high ecological quality of fish communities. Depending on the quality of the actual conditions, fisherman and ecologists (and other stakeholders) can have similar restoration goals, in particular when the quality of the systems is very low. Under these circumstances a lot of water system functions are threatened and most stakeholders have similar ideas about restoring the system. Once, the system improves, more and more stakeholders are satisfied and are not interested in further improving the ecological quality of systems, because also their own activities are now threatened (but from the other side) or it becomes much more expensive to allow this further ecological improvement.

The information from the indexes is therefore often too scarce and not straightforward enough to allow the development of an efficient and effective river restoration policy due to the unknown specific local conditions and needs. With this information, it is merely possible to find out what the sites are that need specific management programmes to restore the systems (sanitation of very bad sites) or protection (very good systems), but one is not able to select the most appropriate and optimal actions.

5. ECOLOGICAL AND ECONOMIC INFORMATION FOR THE MANAGEMENT OF A RIVER BASIN: A CASE-STUDY IN FLANDERS BASED ON COUPLING ECOSYSTEM VALUATION METHODS TO THE WAECO DECISION SUPPORT SYSTEM IN THE ZWALM CATCHMENT

Increasingly, water management is looked at from the perspective of a river basin (catchment) instead of the perspective of a region or country. Only then can the interrelationships between all the functions a river fulfils be fully acknowledged. For the river Scheldt the transboundary effects of river management are respected by establishing a policy plan which is formulated by both the Belgian and the Dutch government. Impacts in the river should be assessed on the basis of an integrated approach that takes the ecological, economic and social consequences of impacts on board regardless the country where they manifest themselves. The use of Cost Benefit Analyse is already prescribed to assess projects in the river basin. However, the methodical approach to identify and value all the ecological impacts of human interventions in this water system has not yet been defined. Because the information to do this at the level of the whole Scheldt river basin is not available, a case study was developed on the Zwalm subbasin that is part of the Scheldt river basin, because a lot of data and several models were already developed for the Zwalm river ecosystem (Goethals et al., 2001, D'heygere et al., 2002).

The Zwalm river basin has a total surface of 11650 ha and the Zwalm river has a length of 22 km. The water quality in the Zwalm river basin improved a lot recently, in particular due to investments in sewer systems and wastewater treatment plants during the last years. Nevertheless, most parts of the river are still polluted by untreated urban wastewater discharges and by diffuse pollution originating from agricultural activities. Also structural and morphological disturbances are numerous. Weirs for water quantity control obstruct fish migration and are one of the most important ecological problems within the river basin.

The complexity of decision making for systems such as the Zwalm catchment, suggests the need for computerised analytical tools that can integrate biological, physical, environmental, economic and social components of the knowledge base. Such tools integrate knowledge in the form of databases and/or rule-based (expert) systems into user-friendly software systems focused on analysing and optimising management strategies. In this context, models based on classification trees, artificial neural networks and fuzzy logic were developed and applied to predict the macro-invertebrate communities in the Zwalm river basin located in Flanders, Belgium (Goethals et al., 2001, D'heygere et al., 2002). Based on these models, the WAter ECOlogy Decision support system (WAECO-DSS) is developed, combining the computational strength of the individual models and allows the simulation of the impact of management activities that modify river characteristics, landscape features,… The complementarities of the different types of habitat suitability models enable the user to perform reliable simulations at different spatial and temporal scales. Decision trees extract simple rules from large quantities of data, while ANNs are able to establish patterns and characteristics in situations where rules are not known. Fuzzy logic on the other hand allows to process unreliability and inaccuracy of data and to incorporate external expert knowledge. To know when, how and in what sequences to use the models and data in combination to solve specific problems is an essential part of the WAECO-DSS. This involves knowledge of how to perform spatial modelling and how to use a set of tools in combination for particular analytical purposes.

The WAECO-DSS is therefore considered a valuable tool for assessing the economic and ecological impacts of alternative decisions on river restoration. The presented approach of the WAECO-DSS shows the benefits of applying this tool at the level of a river basin. Clearly, when the effects of human interventions in the river are only mapped for a specific local area crucial insights remain hidden. This can be prevented by following a river basin perspective in modelling the ecological consequences and the economic valuation process at different scales. Therefore it is necessary to use the information from the Zwalm DSS also at the Scheldt level (by simplification of and coupling of different subbasin systems) and exchange the output of the simulations between these different spatial levels to obtain sustainable management actions. The use of Cost-Benefit Analyses will be a good help for supporting the selection process, but for this it is also necessary that the data are collected in a convenient manner to set-up the models and provide the appropriate information for the valuation process. The interfacing between monitoring, modelling and ecosystem valuation is therefore probably the major bottleneck to develop and use Cost-Benefit Analyses in water management in Flanders and the rest of Belgium, because the data collection strategies will have to be drastically changed for this purpose. As a conclusion one can state that the water management will probably have to be adapted from a regional towards a water system approach (river basin) to be able to deal with the particularities of each water system and the involved social-economical activities even beyond the borders of Belgium.

6. CONCLUSIONS

Within the policy area of water management economic valuation can play an important role. The article shows that attaching a monetary value to the ecological quality asks for linking ecological data to the use of economic valuation methods. The level of decision-making (regional or river basin) might strongly influence the economic value attached to human interventions in water systems. Clearly, at the more general and regional level only a limited overview of the effects on the ecological quality might be identified. On top of this only part of the set of stakeholders who are confronted with the economic costs and benefits of the interventions might be involved in the valuation process. The use of a DSS, which explicitly maps the effects for the whole water system, prevents the calculation of only a limited part of the total economic value of the human intervention. The use of the WAECO-DSS for the management of Zwalm river for instance, might prevent sub-optimal decision making in the area of water management. Maximising the economic value of an intervention for only those stakeholders with a limited set of stakes could hinder the maximisation of the total economic value for all stakeholders with a stake in the total river basin. The use of models that allow a better allocation of the contribution of all stakeholders to the deterioration of the water system (water quality problems, floodings, ecosystem destruction, …) is an important step forward that delivers the needed data to allow an integrated economic valuation of the water system and can help to obtain a more sustainable use of one of the most critical natural resources for mankind.

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